Contract Report

Spray seal stripping in the Wide Bay District, 2007

by Kym Neaylon

for Queensland Department of Main Roads

QEAHDMR- 11/2007
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Summary

On 28 June 2007 the Queensland Department of Main Roads requested ARRB Group to undertake an independent investigation into spray seal stripping in the Bundaberg Region.

'Stripping' in the spray seal sense is where the crushed rock particles that are normally stuck to a road surface with bitumen, become separated (stripped) from the road surface by traffic.

Stripping had occurred with initial seals on the Bruce Highway (Road 10B) overtaking lanes at Curra, Durramboi, Tiaro and Owanyilla (also known as Glenorchy). Reseals had also stripped on the Isis Highway (Road 19A), Goodwood Road (Road 171), Bargara Road (Road 174) and Port Road (Road 175).

All the seals and reseals affected were 12 mm aggregate, S2S polymer modified binder (PMB), variable binder application rate seals.

A number of possible causes of stripping were considered, examined and are discussed in this report.

It is concluded that stripping occurred because of variations in the properties of the bituminous binder, resulting in variable adhesion between the binder and aggregate. With the combination of rain and record low temperatures that were experienced the binder became increasingly brittle and traffic action stripped the particles from the surface.

Although the binder supplied met the specification requirements, it had such a large variation in properties that it overlapped higher modified specification classes. This more highly modified behaviour led to stripping in some locations. A higher level of modification is a disadvantage where it is not required or intended and in particular if field crews are unaware of the change in characteristics. More highly modified binders are usually only specified in special cases such as in strain alleviating interlayers which will be immediately covered by asphalt.

There are a number of specification properties that relate to this behaviour. The most recent changes to both the Austroads and QDMR specifications now place upper and lower boundaries on the Consistency property in particular. On this project it was the Consistency property that showed greatest variability.

It is the opinion of the author that the more highly modified SBS binders, as they are currently used in sprayed sealing across Australia, are variable products and that applying these binders for hot sealing applications is challenging. Asset managers need to carefully assess the balance between application risk and in-service performance on all projects.

For the overtaking lane sites, the sprayed seal design produced the same binder application rate for all lanes. There was a need to apply a slightly higher rate of binder application for the overtaking (fast) lane. While this, by itself, may not have led to stripping behaviour, in combination with the variable binder properties, it was likely to have contributed.

It is the opinion of the author that process improvements may also reduce the performance risks when SBS modified binders are used. These processes include increased cutting and increased aggregate rolling.

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The report includes four recommendations. These recommendations relate specifically to:

- influencing the national specification for polymer modified binders
- reviewing Main Roads specifications for *Sprayed Bituminous Surfacing* in the areas of cutting practice, aggregate application and rolling practices
- consideration of the use of crumb rubber as a practical alternative binder
- undertaking training of spray seal design personnel and review the spray seal design system tools
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1 Background

On 28 June 2007 the Queensland Department of Main Roads requested ARRB Group to undertake an independent investigation into spray seal stripping in the Bundaberg Region.

‘Stripping’ in the spray seal sense is where the crushed rock particles that are normally stuck to a road surface with bitumen, become separated (stripped) from the road surface by traffic.

1.1 Brief

On 2 July 2007 the author attended a briefing at Pavements and Materials Branch in Herston.

The author was tasked to conduct an external, independent review into the cause of stripping of some 16 km of recently sprayed seal in the Wide Bay District.

1.2 Stripping

Stripping had occurred with initial seals on the Bruce Highway (Road 10B) overtaking lanes at Curra, Durrambal, Tiaro and Owanyilla (also known as Glenorchy). Reseals had also stripped on the Isis Highway (Road 19A), Goodwood Road (Road 171), Bargara Road (Road 174) and Port Road (Road 175).

All the seals and reseals affected were 12 mm aggregate, S2S binder (a polymer modified binder described in Queensland Department of Main Roads 2006a), variable binder application rate seals.

1.3 Detail

The author was advised of the following details.

Seals and reseals were designed by the QDMR Wide Bay District staff. All were sprayed and laid by Roadtek (Toowoomba).

The aggregate sources were from three frequently used local quarries.

The District requested that the findings of this report compare the tested data to both the Queensland Department of Main Roads (1999b) and Queensland Department of Main Roads (2006a) polymer modified binder specifications. These specifications are equivalent to the Austroads Class S20E polymer modified binder specifications of their respective times.

The S2S was ordered through supplier A who subcontracted much of the supply to supplier B under the 1999b specification, the specification applying at the time.

The areas of interest were sprayed between 13 March 2007 and 1 May 2007. Major stripping was noticed from approximately 28 May to 21 June 2007.
2 Data collection

This section details only the available data and the source from which they were obtained. All interpretation and discussion of this data is contained in section 3.

Following the initial briefing at Herston, discussions were held with Pavements and Materials branch staff, regarding the present and future laboratory testing of the binder and precoat materials involved.

The Bruce Highway overtaking lane sites and Goodwood Road sites were inspected during the author’s drive from Brisbane to Bundaberg.

At Bundaberg, Wide Bay District staff were interviewed and a joint inspection of Port Road and Bargara Road was carried out, followed by further discussion at the District office. Data compiled in spreadsheet format by the Wide Bay District office was provided. This spreadsheet included detailed data on locations and extent of stripping, estimate of shade, and other district comments. The traceability of binder manufacturer’s docket number to site locations was checked using field daily record sheets, and errors found on the spreadsheet were corrected.

Isis Highway and Goodwood Road were then inspected with Wide Bay District field staff followed by detailed discussions.

Staff from Roadtek (Toowoomba), were also interviewed. Questions were answered and additional information offered. Copies of all field daily record sheets which are the original source of much vital data, such as temperatures, parts of cutter, binder delivery dockets, and locations sprayed were supplied.

The available Bureau of Meteorology (BoM) weather recording sites which would best represent the local conditions, were discussed with District staff. The weather data were downloaded directly from the appropriate BoM internet site.

All laboratory binder testing on retained field samples was undertaken by QDMR Materials Services laboratories in Herston.
2.1 Site inspections

All sites had received a remedial treatment of C170 bitumen at 0.5 L/m² and 7 mm aggregate, to lock in the 12 mm aggregate that had not stripped and provide surface texture to the stripped areas, before this site inspection occurred. This treatment was successful in preventing any further 12 mm aggregate stripping.

2.1.1 Curra overtaking lanes

The road alignment was in general straight and flat, such that traffic would not be applying magnified stresses on the new seal. Stripping did not appear to be related to wheel path locations, and was relatively constant across the lane widths (Fig 1). There were some examples where stripping may have commenced in the shady areas first, and was more severe there (Fig 2). The stripped sealing aggregate on the shoulders was recognisable as it had a different geological appearance. It appeared dusty, and most particles had no binder adhering to it, although there were stains where the binder had been (Fig 3). There were only a few loose particles that did have some binder adhering to them. It was then some 11 weeks after spraying, and yet some of the binder from the more severely stripped sites remained dimpled, similar to a golf ball surface (Fig 4). There was also some evidence of ‘tramlining’, a phenomenon where the layer of sprayed bituminous binder resembles sheets of corrugated iron, with longitudinal peaks and troughs along its depth (Fig 5).

Fig 1: Stripping (as longitudinal stripes) relatively constant across lane widths
Fig 2: Stripping may have commenced in shade first
Fig 3: Slight stains where binder has been, but no binder adhered
Fig 4: Eleven week old binder remains dimpled
2.1.2 Durramboi overtaking lane

Again the road alignment was in general straight and flat. The stripped aggregate appeared dusty (Fig 6) and most particles had no binder adhering, although they had stains where the binder had been. It was still possible to smell traces of precoat on the particles. There were only a few loose particles that did have some binder adhering.

Stripping here, though, was different to Curra in that for the two-lane, one-way direction, there was stripping mainly between the wheelpaths in the heavy vehicle lane, but widespread stripping throughout the light vehicle lane. In the one-lane one-way direction where both heavy vehicles and light vehicles were combined, there was minimal stripping (Fig 7).
### 2.1.3 Tiaro overtaking lane

Again the road alignment was generally straight and flat. Stripping was variable in the transverse section, meaning that it was sometimes related to wheelpaths or lanes, but sometimes not (Fig 8). In some locations, in the two-lane one-way direction there was only a little stripping in the heavy vehicle lane and widespread stripping in the light vehicle lane. In the one-lane one-way direction where both heavy vehicles and light vehicles were combined, there was severe stripping (Fig 9).

The ‘tramlining’ phenomena was far more evident here, with aggregate typically plucked off first in the binder troughs (lowest binder depth) and last to go on the binder crests (deepest binder depth) (Fig 10 & 11).
2.1.4 Owanyilla (also known as Glenorchy) overtaking lane

Stripping was less severe than the other overtaking lane sites.

2.1.5 Goodwood Road

The road alignment in general had numerous short, steep hills and some tight curves. Near the Childers end, Ch 0 – 4 km, stripping was mild and fairly uniform along the transverse cross section (Fig 12). Between chainage 7 to 10 km there was widespread stripping, ranging from shade only failures to full width failures (Fig 13). The aggregate appeared very clean and of good shape, but again there was no binder adhering to the stripped aggregate, only faint blemishes where the binder once was.

District field staff advised that Goodwood Road first started showing signs of some minor stripping in the shade, but then started stripping severely after a bout of cold, wet weather. The same applied to all of the other stripped reseals.

Goodwood Road was interesting because there were sections that behaved normally, and sections that stripped badly, despite all sections using the same binder specification; aggregate; spraying contractor; designer; and traffic.

Based on the author’s previous experience, where stripping is variable along a length of road and other conditions are constant, and polymer modified binders (PMBs) are used, the binder properties should be investigated further.

This further investigation included particles of aggregate being levered from the seal (at a pavement temperature of around 30°C) at sites where the aggregate had stripped, and again at sites where aggregate had not stripped. The resulting observations were very different, and are discussed in Section 3.
2.1.6 Isis Highway

The road alignment in general had numerous short, steep hills and some tight curves. There was no binder adhering to the stripped aggregate, only faint traces where the binder once was. One bad section of stripping traversed a spray run match line, indicating that stripping at the start of a run was the same as stripping at the end of a run (Fig 14 & 15).

![Fig 14: Severe stripping](image1)
![Fig 15: Spray run match line](image2)

There were some sections that had stripped badly, and, surprisingly, a T junction (such that traffic would be applying magnified stresses on the new seal) that did not strip. Again, this was interesting, as all sections used the same binder specification; aggregate; spraying contractor; and designer.

To further investigate the aspect of binder variability, particles of aggregate were again levered from the seal (at a pavement temperature of around 30°C) at sites where the aggregate had stripped, and again at sites where aggregate had not stripped. The resulting observations were quite different for the two situations, but the observations were the same as for Goodwood Road. They are discussed in Section 3.

2.1.7 Port Road and Bargara Road

The road alignment was straight and flat. Bargara Road had evidence of ‘tramlining’. Bargara Road was sprayed discontinuously, in a chronological sense. There were sections that behaved normally, and sections that stripped. All sections used the same binder specification; aggregate; spraying contractor; designer and had similar traffic.
2.2 Treatment selection

The treatment used throughout was a 12mm S2S single-single seal (meaning a single application of binder and a single application of aggregate).

2.3 Seal design

The seal design method used was the current Austroads method (Austroads 2006b).

The QDMR published traffic data applicable to this design investigation is found in Queensland Department of Main Roads (2006b). Relevant data from this source has been extracted to form the following table.

<table>
<thead>
<tr>
<th>Location (OTL = Overtaking Lane)</th>
<th>Traffic count chainage (km)</th>
<th>Traffic count AADT (vpd)</th>
<th>Light vehicle (%)</th>
<th>Truck or bus (%)</th>
<th>Articulated vehicle (%)</th>
<th>Road train (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10B Bruce Hwy Curra OTL, Durrangoi OTL</td>
<td>14.0 – 27.4</td>
<td>8,250</td>
<td>82</td>
<td>6</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Tiaro OTL</td>
<td>60.3 – 67.2</td>
<td>8,572</td>
<td>79</td>
<td>11</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Owanyilla OTL</td>
<td>67.2 – 76.6</td>
<td>8,718</td>
<td>82</td>
<td>7</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>19A Isis Hwy</td>
<td>5.5 – 12.8</td>
<td>10,782</td>
<td>91</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>12.8 – 18.2</td>
<td>4,783</td>
<td>86</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>171 Goodwood Rd</td>
<td>0.0 – 1.8</td>
<td>1,689</td>
<td>93</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1.8 – 9.1</td>
<td>2,312</td>
<td>90</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>17.8 – 39.3</td>
<td>2,058</td>
<td>89</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>174 Bargara Rd</td>
<td>8.2 – 9.8</td>
<td>7,240</td>
<td>95</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>9.8 – 11.9</td>
<td>6,916</td>
<td>96</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>11.9 – 13.2</td>
<td>8,012</td>
<td>96</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>175 Port Rd</td>
<td>10.0 – 15.2</td>
<td>3,768</td>
<td>88</td>
<td>7</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>15.2 – 19.7</td>
<td>1,150</td>
<td>79</td>
<td>6</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

One local variation to the published design method is that this District undertakes variable application rate designs. This is where one binder application rate is designed for the trafficked wheelpaths, and another binder application rate is designed for outside-of-wheelpaths, as illustrated in Fig 16.
The District favours this method because it does not exacerbate any bleeding-wheelpath issues, yet sprays enough binder to hold the same aggregate outside-of-wheelpaths. This method has been successfully used by the District for a number of years.

The seal designs are calculated initially for wheelpath conditions, using AADT (Average Annual Daily Traffic) that is proportioned into vehicles per lane per day, as for any design. The untrafficked areas are then designed separately for a traffic estimate of 10% of AADT.

### 2.4 Aggregate

Records indicate that the aggregates used were from:

- quarry at Isis (for Goodwood Road)
- quarry at Biggenden (for the Bruce Highway overtaking lanes)
- quarry at Inness Park (for the Isis Hwy 19A, Bargara Road, and Port Road).

The aggregate for the Bruce Highway overtaking lanes appeared to be a little dusty, whereas the aggregate for the other jobs was quite clean.

The shape of all aggregate used looked to be very good, almost textbook. The aggregate was quite cubical, with little elongation, flakiness or flats apparent.

#### 2.4.1 Plate stripping test

Modified Plate Stripping (aggregate to binder adhesion) test results for these aggregates were not available.

#### 2.4.2 Precoat

Samples of the precoat in use at the time of these works were not available.

### 2.5 Binder

#### 2.5.1 General

The MRS11.18 Dec 06 specification (Queensland Department of Main Roads 2006a) for S2S binder is identical to the Austroads AP-T41/06 specification (Austroads 2006a) for S20E, and both contain upper and lower boundaries for consistency.
The MRS11.18 Dec 99 specification (Queensland Department of Main Roads 1999b) for S2S binder, was based on the Austroads specification at that time and does not specify an upper boundary on consistency values.

The district has requested that the findings of this report compare the tested data to both the Queensland Department of Main Roads (1999b) and Queensland Department of Main Roads (2006a) specification versions.

2.5.2 Field sampling

Roadtek advised, and District field staff confirmed, that all binder samples were taken half-way through unloading the tanker/bulker on the site, and that no binder samples were taken from the sprayer. Even so, there were still samples received that were contaminated with cutter, and their test results could not be used.

All samples were taken by Roadtek and stored at Toowoomba.

In addition to laboratory binder testing, particles of aggregate were levered from the binder on the road (at a pavement temperature of around 30°C) as described in Section 2.1, and the in situ binder behaviour noted.

2.5.3 Laboratory testing

S2S binder samples were sent to QDMR Material Services Branch at Herston by Roadtek and tested. These samples relate to all of the sites covered in the investigation. Sample numbers B07:206 (Curra), 266 (Goodwood Rd), 269 (Bargara) and 273 (Port Rd) were later found to be contaminated with cutter, and were excluded from the data set.

The S2S binder samples were tested for softening point, torsional recovery, viscosity and consistency in accordance with specified test methods (Queensland Department of Main Roads 1999b and 2006a).

2.6 Specification and work methods

2.6.1 Aggregate precoating

Aggregate for all jobs was precoated at the quarries. Roadtek advised that the precoating used at all three quarries was Boral Precoat APT2 at 8L/m$^3$. Boral APT2 is a precoat approved for use by the Materials Services Branch of Queensland Department of Main Roads.

2.6.2 Aggregate stockpiling

Roadtek advised, and District field staff confirmed, that precoated aggregate was delivered to the stockpile sites and was stored there for up to three weeks before spraying in accordance with the specification.

2.6.3 Pavement temperatures at spraying

MRS11.11 (Queensland Department of Main Roads 1999b) specifies a minimum surface pavement temperature of 25°C for at least one hour before spraying commences for polymer modified binders. Actual pavement temperatures at time of spraying were obtained from the daily record sheets.
2.6.4 Cutter

The MRS11.11 (Queensland Department of Main Roads 1999a) specification provides cutting practice for Class 170 bitumen. RoadTek advised that BP cutter was used. The quantities used were obtained from the daily record sheets.

2.6.5 Spraying

A Main Roads certified ‘Variable Sprayer’ was specified and used on this project. (This sprayer has two calibrated spray bars, where the basic wheelpath binder application rate is sprayed full width, with the second application of binder applied between the wheel paths by the second spraybar during the same pass as the first).

2.6.6 Time to cover

A maximum time between hot binder spraying and aggregate cover is not included in MRS11.11 (Queensland Department of Main Roads 1999a). RoadTek advised, and the District field staff confirmed, that three aggregate spreading trucks were used. They also advised that the time to cover was prompt.

2.6.7 Rolling

Queensland Department of Main Roads (1999a) specifies that there shall be a minimum of two rubber-tyred rollers on site, and that there shall also be sufficient rollers on site, and in use, to complete the specified minimum amount of rolling as a continuous operation with successive spray runs.

RoadTek advised (and District field staff confirmed) that two 13 t multi-wheeled, rubber tyred rollers were used on site.

2.6.8 Contract timing

This PMB contract finished spraying on 1 May 2007

2.6.9 Workmanship

No evidence was found on site to suggest poor workmanship, and no evidence that anything different had occurred on site to what had been stated to the author.

2.7 Weather

Weather data for Gympie and Bundaberg was extracted from the Bureau of Meteorology web site.
3 Results and discussion

3.1 Treatment selection

The treatment selection throughout was a 12 mm S2S single-single seal (meaning a single application of binder and a single application of aggregate).

12 mm aggregate is not a commonly used size for sprayed sealing purposes. The Average Least Dimension (a critical factor in seal design and in the resulting bitumen film thickness) of the local 10 mm aggregate however is very low (4.6 – 4.7 mm), so local 12 mm aggregate is used instead. This has an ALD of 7.2 – 7.4 mm, which is what would typically be expected of a 10 mm aggregate.

The Queensland MRS11.18, March 07, specification for S2S binder is identical to the Austroads AP-T41/06 specification for S20E. This is a polymer modified binder (PMB) that uses styrene-butadiene-styrene (SBS) as the modifying polymer.

The District chose S2S binder because of:

- its superior aggregate retention properties under increasingly heavy traffic
- its improved waterproofing characteristics for old and fatigued seals.

The Austroads Guide to the Selection and Use of Polymer Modified Binders and Multigrade Bitumens (Austroads 2006c) does not include S20E (S2S) as a suggested binder for aggregate retention. It does, however, include S20E (S2S) as a suggested binder for waterproofing over cracked pavements. The older Pavement Worktip No. 6, Polymer Modified Binders, (Austroads & AAPA 1998) also recommends S20E (S2S) as a strain alleviating membrane over ‘rapid activity’ pavement cracking.

The author notes that a double-double seal treatment was not considered for this project (a double application of binder and a double application of aggregate). These are more expensive, but reduce the consequences of possible binder adhesion problems. They also have the advantage of providing an added mechanical interlock between particles to aid in holding the layers of aggregate in place. These are not commonly used by Main Roads but could be considered in the future as a risk minimisation strategy.

It can be concluded that the treatment as selected had a small element of considered risk, but nonetheless the author believes that the option chosen was reasonable.

3.2 Seal design

3.2.1 Traffic

The seal design method used was the current Austroads method (Austroads 2006b). This method included, for the first time, a design concept called Equivalent Heavy Vehicles (EHV), which will be discussed in detail below.

The QDMR published traffic data applicable to this investigation is found in Queensland Department of Main Roads (2006b). The data was four-bin data which was adequate for this design method (meaning that the traffic data are split into four categories, in this case: 1) short and light vehicles; 2) trucks and buses; 3) articulated vehicles; and 4) road trains). These data have been extracted and tabulated in Table 2.
The current Austroads vehicle classification system is a 12 class system, as shown in Appendix A3.

The author has assumed the following (Table 2) correlation between the QDMR four-bin data and the Austroads 12 class system.

Table 2: Equivalent heavy vehicles

<table>
<thead>
<tr>
<th>Location (OTL = Overtaking lane)</th>
<th>Traffic count chainage (km)</th>
<th>Light vehicle Class 1 (%)</th>
<th>Truck or bus Class 2, 3, 4, 5 (%)</th>
<th>Artic’d vehicle Class 6, 7, 8, 9 (%)</th>
<th>Road train Class 10, 11, 12 (%)</th>
<th>EHV used (%)</th>
<th>EHV check (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10B Bruce Hwy</td>
<td>14.0 – 27.4</td>
<td>82</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Curra OTL, Durranboi OTL</td>
<td>60.3 – 67.2</td>
<td>79</td>
<td>11</td>
<td>8</td>
<td>2</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Tiaro OTL</td>
<td>67.2 – 76.6</td>
<td>82</td>
<td>7</td>
<td>8</td>
<td>3</td>
<td>43</td>
<td>27</td>
</tr>
<tr>
<td>Owanyilla OTL</td>
<td>5.5 – 12.8</td>
<td>91</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>19A Isis Hwy</td>
<td>12.8 – 18.2</td>
<td>86</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>171 Goodwood Rd</td>
<td>0.0 – 1.8</td>
<td>93</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>1.8 – 9.1</td>
<td>90</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>17.8 – 39.3</td>
<td>89</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>20</td>
<td>11</td>
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<td>95</td>
<td>5</td>
<td>0</td>
<td>0</td>
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<td>5</td>
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<td></td>
<td>9.8 – 11.9</td>
<td>96</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>11.9 – 13.2</td>
<td>96</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>4</td>
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<td>10.0 – 15.2</td>
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<td>1</td>
<td>4</td>
<td>19</td>
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<td>15.2 – 19.7</td>
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</table>

A brief explanation of the Austroads treatment of Equivalent Heavy Vehicles follows:

Austroads (2006b) defines Equivalent Heavy Vehicles (EHV) % as being Heavy Vehicles (HV) %, plus three times the Large Heavy Vehicles (LHV) %, or

$$ EHV(\%) = HV(\%) + 3 \times LHV(\%) $$

where LHV includes B-doubles and other heavy truck/trailer combinations with seven or more axles (i.e. LHV are Austroads vehicles class 10 and above).

For the QDMR data above, this calculation would be

$$ EHV(\%) = HV(\%) + 3 \times \text{road train}(\%) $$

The calculation adopted in the District design spreadsheet is

$$ EHV (\%) = \text{HV}(\%) + \text{truck or bus}(\%) + 2 \times (\text{artic’d vehicle}(\%) + \text{road train}(\%)) $$
An EHV check calculation, and the EHV calculation used in design, are tabulated in Table 2. It can be seen that EHV% has been overestimated in the designs for most locations, resulting in a small reduction in basic voids factor leading to a small reduction in binder application rate (BAR). However EHV is not a precise number and the design method utilises them within four general bands. (Austroads 2006b, table 2.2). The highest amount of EHV in either calculation method appears on the Bruce Highway overtaking lanes. At these locations, the effect was to shift the design traffic into a different design band, which reduced the design voids factor by 0.01 L/m²/mm.

For the ALD used (7.4 mm) this has caused the BAR to be under-designed by 0.07 L/m².

Generally, a reduction of 0.1 L/m² in binder application rate could be tolerated in the field; however, there are further complexities to be considered. These are discussed in Section 3.2.2 Design method.

It is worth noting that the correct design application rates were used on Goodwood Road and Bargara Road which suffered stripping. This suggests that other factors were dominating.

The recent inclusion of EHV% has raised the seal design method for heavily trafficked roads (particularly National Highways) to the next level of design complexity. It is the author's opinion that the seal designer was adequately experienced and perhaps additional training to highlight the new changes would be of benefit to other less experienced QDMR spray seal designers.

3.2.2 Design method

The seal design method used was the current Austroads method (Austroads 2006b). District staff had created an Excel spreadsheet to undertake the calculations described in Austroads (2006b). The detail of this spreadsheet was not originally checked as part of this report, as for simple roads it gives answers that appear to be within the normal range.

3.2.2.1 Overtaking lanes

The nature of the stripping that was observed at Durramboi and Tiaro overtaking lanes was that adjacent traffic lanes stripped to different degrees. Because of this, a spot check of overtaking lane design was undertaken. This found that although equivalent heavy vehicles may have been calculated within reasonable accuracy, the average annual daily traffic (AADT) had been incorrectly split for the three differently trafficked but adjacent lanes. The 60/40 traffic split at the bifurcating lane was applied to 100% of AADT, whereas it should have been applied to 50% of AADT. This resulted in a design binder application rate that was 10% to 14% too light in the carriageway that split into two-lanes one way. This resulting design binder application rate was applied also to all the overtaking lane designs.

A reduction of 10% or less in binder application rate would not have a noticeable effect in the field. A reduction of 10% to 14% in binder application rate may just start to have noticeable performance effects, but when the EHV related reduction in binder application rate is added, the total design application rate reduces by 16% to 20%. This places the seal performance into a high risk situation. Binder characteristics dealt with in Section 3.5, have exacerbated this high risk situation.

A further complication is that when designing a polymer modified binder spray seal, a PMB factor is applied, such that the binder application rate is increased above that for an unmodified binder. This is to ensure there is adequate binder available to hold the aggregate particles in
place for the early life of a seal. For an S20E (equivalent to an S2S), this PMB factor is 1.3, or a 30% increase. The author has confirmed that this factor was applied in the design. For more highly modified binders this factor will increase (for example, the next grade of Austroads binder, S25E would require an increase to 1.6 or 60%). Test results show the binder delivered to site very often even exceeded the specification for S25E binder. This suggests a PMB factor of higher than 1.6 would be required.

In practice most of the binder delivered to site meant that the seal design application rate was then an additional 30 – 40% light, meaning stripping would be inevitable.

3.2.2.2 Other sections of roads

The issues of traffic calculation as described for the overtaking lanes in section 3.2.2.1 do not apply to the other sections of roads investigated.

However the issues relating to an appropriate PMB factor as described in section 3.2.2.1 do apply to the other sections of roads investigated.

3.2.3 Site observations relating to design

Most stripped aggregate particles examined on site had no bitumen adhering. This suggests that stripping occurred primarily because of reduced binder adhesion capability and not due to any reduction in design binder application rate. Had the seal stripped solely because the binder application rate was too low, there should still be small amounts of binder adhered to the ‘soles’ of the aggregate’s ‘feet’.

Fig 17: A photograph of the road shoulder. Note bottom right of coin: no binder adhering to stone, only faint mark where it once had been. Other stripped stones are similar.

In some locations, dimples remained in the binder after the aggregate stripped, suggesting that at these particular locations there was enough binder to work up around the sides of the aggregate particles as per design, but not of sufficiently low viscosity to ensure adequate aggregate wetting that would lead to adequate adhesion. This aggregate would most likely not have stripped if proper adhesion had been obtained.
3.3 Aggregate

The sealing aggregate found on the shoulders at the Bruce Highway overtaking lanes appeared a little dusty, whereas the aggregate for the other jobs was quite clean. The District field staff commented that this apparent dustiness was not unusual, and that past experience had not raised this as a problem.

Precoat is commonly used to assist adhesion of aggregate to the binder. Traces of precoat were still evident (by sight, touch and smell) some 11 weeks after spraying. It is considered there would have been enough precoat to easily overcome any dust present.

As stated earlier, modified plate stripping (i.e. aggregate to binder adhesion) test results for these aggregates are not currently available. The District advises it has had a long history of successful use of these aggregates across a range of binders.

3.4 Precoat

Boral APT2 is a Main Roads approved precoat in popular use around Queensland, and is not known to have any adverse performance issues. In particular, this District has had no adverse performance history with either this precoat or the locally available aggregates.

Samples of the precoat in use at the time of these works were not available. Samples of the precoat now at the quarries could be tested for amine content, (amines being a measure of the active ingredient in precoats which assist with adhesion where water and dust are present), and compared with the amine content of the precoat samples as submitted for approval-for-use by the QDMR Materials Branch. However this would only tell if current batches meet specification, and has not been pursued further.

3.5 Binder

3.5.1 Background

The Queensland MRS11.18 (Queensland Department of Main Roads 2006a) specification for S2S binder is identical to the Austroads AP-T41/06 specification for S20E. Therefore this is a standard, Australian ‘off-the-shelf’ specification. This binder is a bitumen that has been modified by the addition of the synthetic styrene-butadiene-styrene (SBS) polymer.

The specifications for polymer modified binders only require either a maximum or minimum limit for specified properties. However, for the property ‘consistency’, for certain grades of binder, there is a footnoted ‘target’ and ‘range’ (See details in section 3.5.4 Binder laboratory test results; general discussion). For torsional recovery and softening point, only minimum limits are

1 It is understood the QDMR modified plate stripping test compares variously conditioned aggregates with class 170 bitumen, as do all Australian plate stripping tests. It would be most interesting to test these aggregates against S2S, but as this is not a standard test there is no library of historical test results to compare against observed field performance. For example, even when using the reference C170 binder, 50% stripping in the plate stripping test does not equate to 50% stripping on the road, and the specified limits for plate stripping tests are usually historically obtained from correlations between field experience and test results. Therefore, based on reported past successes of these aggregates, and the fact that S2S is not a reference binder for the test, plate stripping tests have not been pursued.
specified, leaving the maximum limits open ended. Similarly, viscosity and stiffness only have maximum limits specified. It is also worth noting that specified values within all documents apply to as-manufactured properties.

The Austroads spray seal binder specification nomenclature is such that lightly modified binders (say 3% by mass SBS in the binder) are S10E, medium modified binders (say 4% by mass SBS in the binder) are S20E, and the most heavily modified binders (say 6% by mass SBS in the binder) are S25E. Commonly accepted field experience has shown that the more heavily modified binders require more cutter (Austroads & AAPA 2001, and Maccarrone, Neaylon, Clark, Gnanaseelan 1997) to assist with spraying and aggregate wetting and adhesion.

Where SBS concentration is in the range of 3% by mass to around 4.5% by mass, the polymer undergoes a transition from being partially networked within the binder, to fully networked. In this zone, a small change of polymer concentration can produce a large change in the measured properties of the polymer modified binder as shown in Fig 18. Thus the properties of an SBS binder delivered to site can vary considerably depending on the exact polymer concentration and resulting degree of networking present after storage and transportation.

For any PMB specification without upper bounds, a more highly modified binder can be delivered (for example an S10E (3% concentration for example) can be ordered, and a product meeting S25E (6% concentration for example) can be delivered). However, the characteristics of the more highly modified binder can be very different and can require substantial changes to the design application rate and the field procedures including the cutting rate.
The question of upper and lower bands on PMB specification properties has been debated nationally for many years. However, it was more firmly placed on the Austroads Bituminous Surfacings Research Reference Group (BSRRG) agenda in late 2005, when the QDMR representative described a process of developing a banded specification for PMBs and identified several areas in need of resolution. DTEI SA at that time had been reporting on 11km of stripped S15E reseal, believed to be caused by excessively modified binder (three grades higher than that ordered, yet permissible under the national specification) sprayed late in the sealing season (i.e. approaching the cooler months) with not enough cutter used.

Banded specification negotiations between PMB manufacturers and state road authority users have been difficult and prolonged. Agreement in principle for banding of torsional recovery and softening point properties for PMBs was finally reached in February 2007; however the detail of what those numbers should be was made the subject of further negotiation.

At the July 2007 BSRRG meeting, PMB manufacturers presented data supporting their position on where the upper and lower bands should be. This data showed a very large variation in the properties of S20E (S2S) produced around Australia. This variation was unacceptable to state road authority users, who were united in recommending that S20E (S2S) be now deleted from the national specification. This recommendation from the Users Group, with other recommendations, was circulated for comment on 30 July 2007.

It is also worthy of note that in the RTA (NSW) northern regions sprayed sealing is already mainly focused on two PMBs, being S45R (crumb rubber modified binder) and S35E. RTA northern region has little interest in SBS modified binders (S10E, S20E (S2S)), due to past experience.

VicRoads tends to use very little S20E (S2S), and is focused more on crumb rubber binders.

DIER Tas. has little interest in SBS modified binders (S10E, S20E (S2S)), due to past experience.

DTEI SA is also using less SBS modified binders due to past experience and is now using more crumb rubber binders.

3.5.2 On-site observations

Binder to aggregate adhesion

As mentioned earlier, it was the author’s experience that where seal performance is variable along a length of road and other conditions - such as specification, workmanship, aggregate, seal design and weather - are constant, and where polymer modified binders are used, the binder should be investigated.

As part of this investigation, particles of aggregate were levered from the seal (at a pavement temperature of around 30°C) at sites where the aggregate had stripped, and again at sites where aggregate had not stripped.

At sites where stripping had not occurred, the binder adhered to the aggregate extremely well, stretched into long strands, and was almost ‘too’ elastic for a typical S2S (S20E). When the aggregate to binder bond was stretched to failure, the binder broke at the centre of the binder elongation, leaving ample binder adhering to the aggregate sample.

At sites where stripping had occurred, when a stone was levered out, the binder peeled off the aggregate surface and sprang back towards the pavement, without leaving a trace of binder on the aggregate. It behaved similarly to the glue used to attach a plastic credit card to a paper
letter, where the glue is extremely elastic and when stretched, unpeels itself completely from the plastic card and springs back to the paper.

At one site on Goodwood Road where the seal had not stripped but remedial treatment was applied anyway, the binder behaved identically to that at the stripped sites, suggesting that this site too would have stripped had the remedial treatment not been applied when it was.

**Binder viscosity – dimples**

The fact that in places the binder has remained dimpled (Fig 19) for such a length of time, is noteworthy.

![Fig 19: 11 weeks after spraying, binder remains dimpled similar to a golf ball surface](image)

This suggests a very high in-service viscosity, that not only impedes proper aggregate wetting and thus bonding of the binder to the aggregate, but also it impedes the aggregate reorientation that is necessary in the early few weeks of a seal. It is during this time that the traffic kneads the individual aggregate particles into a tighter, flatter mosaic. The seal design philosophy assumes that aggregate particles are worked down to a flat orientation and that binder at the same time works its way upwards, such that the binder becomes half to two-thirds the way up the depth of the aggregate particles. This then secures the aggregate in place – both with adhesive bonds discussed earlier, and also with physical interlock and restraint – such that the sprayed seal remains stable.

It appears likely that the aggregate particles were never sufficiently wetted, but were held in place only by very weak adhesive bonds and by physical restraint of the solid binder around them.
Binder viscosity – tramlines.

The issue of 'tramlining' (Fig 20) is another important phenomenon to consider.

![Image of tramlining](image)

*Fig 20: ‘Tramlining’ of binder identified on the Bruce Highway north of Tiaro indicating viscosity too high at time of spraying*

In order to achieve a uniform film thickness of binder onto the pavement surface, spraybars are designed such that each point on the pavement is covered by the overlapping fans of a number of spray nozzles, as in Figure 21.

![Diagram of spraybar](image)

*Fig 21: Overlapping jets of a spraybar*

For the correct fan widths to be attained, the spray bar needs to be at the correct height above ground, and the binder being sprayed needs to be of the correct viscosity. In practice, it is not common for the spraybar to be set at an incorrect height, as this can be seen immediately. This leaves viscosity as the most likely cause of the observed tram lining.

If the binder is of too high a viscosity, the bitumen fan leaving the jets will not be properly established, with the binder spray more highly concentrated under each individual jet. This creates a layer of sprayed bituminous binder resembling sheets of corrugated iron, with longitudinal peaks and troughs along its depth (as described earlier).
Tramlining is detrimental to seal performance. Aggregate is typically plucked off first in the binder troughs, because there is insufficient binder to work up around the sides of the aggregate and hold it in place. Once the aggregate in the troughs has gone, the integrity of the aggregate mosaic is compromised. The mosaic starts fretting away at the exposed edges, until eventually even the aggregate at the deeper binder depths can no longer stand alone and unsupported.

3.5.3 Adhesion agent added to binder

Daily record sheets show that for all jobs there was 0.6 parts adhesion agent per 100 parts of binder ordered, in accordance with specified practice. (Queensland Department of Main Roads 2007)

3.5.4 Binder laboratory test results

In the analysis below, the Queensland Department of Main Roads (2006a) specification is used, and for S2S and S4.5S this specification is identical to the Austroads national specification (Austroads 2006a) for S20E and S25E respectively.

The specifications require only minimum values of softening point (°C) and torsional recovery (%) be attained. These minimum values for Austroads S20E (identical to QDMR S2S) and S25E (a more highly modified binder) are shown on Figures 22 -24. Consistency is the only value that has a footnoted target and upper and lower range - as shown in Fig 25.

S4.5S (S25E) limits are shown to give an indication of how much of the S2S (S20E) binder delivered actually met or exceeded the specification requirements for the next higher grade of polymer modification, being S4.5S (S25E).

Laboratory binder test result data is tabled in Appendix A1. The actual site location that relates to each of these samples can be found in Appendix A2. The results of the laboratory binder tests are graphed and discussed below:
Softening point

Figure 22: Binder softening point results

Softening Point (Fig 22) is a test originally developed for monitoring waxes but for conventional bitumens has been an acceptable measure of a temperature at which a particular level of viscosity is reached. Softening point is sometimes described as an equi-viscous temperature.

When applied to visco-elastic binders (S2S/S20E), the simple operation of the test is potentially masked by the presence of a polymer network. The softening point (SP) for S2S (S20E) is not an equi-viscous temperature and therefore should not be given implied performance links.

The presence of the network normally increases the temperature at which the ball passes through the ring (the operation of the softening point test).

A higher softening point in a class of PMB for a given manufacturer normally implies increased levels of modification.

Where the performance of same class binders from two manufacturers is compared in terms of softening point, it is likely that the higher softening point group (supplier B) are more highly modified than the supplier A group as shown in Figure 22.

It can also be concluded that since many of the supplier B binders exceed the SP limit for S4.5S (S25E) (the highest modification sealing grade), significantly higher levels of modification may be found in these samples.

Other factors that can influence the observed data are:

a) Small levels of cutter oil contamination can significantly reduce the softening point of a given binder. Some measurable levels of cutter were found in three samples taken from bulk tankers on site. These samples were excluded from any analysis.
b) Since S2S (S20E) is a PMB placed close to the critical polymer levels that describe the property S-curve (a region where properties are highly sensitive to polymer concentration, Fig 18), small changes in effective polymer concentration through laboratory handling of the samples at elevated temperatures may contribute to some of the reported property differences. Again, looking at the aggregated results should minimise this source of error.

**Torsional recovery**

![Torsional recovery graph](image)

**Figure 23: Binder torsional recovery results**

Caution should be exercised when interpreting TR data (Fig 23). This property is influenced by two fundamental binder properties. A high elastic modulus (high SBS modification resulting in a stable network) increases TR. A high viscosity in the binder decreases TR. A high elastic modulus and low underlying viscosity results in a high to very high TR. Clearly TR is a complex property.

Torsional Recovery (TR) follows a similar pattern to softening point with supplier A binders (Figure 23) close to the limit for S2S while a majority of supplier B binders exceed both the S2S min and the S4.5S min.

If supplier B uses a combining or compatibilising oil in their PMBs, the underlying viscosity will reduce and thus the TR will increase. It is not reasonable to conclude, based on TR data only, that the supplier B binders are more highly modified than supplier A binders.
Viscosity at 165°C as shown in Figure 24, suggests that supplier A binders are generally softer (less viscous) than supplier B binders. Contamination can influence this property but since the temperature is very high, elasticity is not a key factor. It is reasonable to conclude from this data that the supplier A binders are less modified than the supplier B binders. All binders meet the specification limit.
Binder consistency (Fig 25) is, in particular, worthy of discussion. Consistency at 60°C is a property sensitive to the formation of a full network (Fig 18). Most recent specifications, (Queensland Department of Main Roads 2006a and Austroads 2006a) have a footnoted target value of 3,200 Pa.s, and an upper and lower range of 2,000 Pa.s to 5,000 Pa.s. All supplier A binders meet this requirement, and only 12% of the supplier B binders meet this requirement. Most of the supplier B binders exceed 8,000 Pa.s and more than half exceed 10,000 Pa.s.

The largest proportion of the binder delivered is typical of a fully networked binder, well above the partially networked binder expected. This fully networked binder may not be adequately cut by any amount of kerosene and will retain a very strong elastic response at the cost of a viscous response. In practice this means that it is difficult for aggregate wetting and adhesion to occur in the first instance, and then is unlikely to ever develop further even with warmth, traffic and time. Use of such a binder should only be attempted when the absolute best of conditions apply, and a crew are prepared for it.
General discussion of binder laboratory test results

While consistency continues to be the subject of debate, the only part of current specifications that attempts to limit over-modification in sealing grade binders (and S2S (S20E) in particular), is the limit placed on consistency at 60°C for sealing grade binders. Currently, AP-T41 Note 4 to Table 1. Properties of Polymer Modified Binders for Sprayed Sealing Applications requires the manufacturer to target a consistency at 60°C of 3200 Pa.s and be within the range 2,000 Pa.s to 5,000 Pa.s. Only the supplier A binders achieve this goal. When taking the other properties into account, the supplier A samples appear to achieve the aims of the specification and can be considered to be band limited products.

Extract from AP-T41

| Note 4 | Manufacturers shall aim for a target consistency of 3200 Pa.s at 60°C for S20E within the range 2000-5000 Pa.s |
| Note 5 | Manufacturers shall aim for a target consistency of 450 Pa.s at 60°C for S10E within the range 400-600 Pa.s |

Relationship of laboratory test results to field stripping

Estimates of the degree of field stripping are given in the district spreadsheet (Appendix A2.)

There is a qualification on the precision of this data, as in some locations it may be generalised and averaged over long lengths, and also the definition for 10% stripped or 80% stripped is not clearly understood.

For example, 80% stripped could mean there was 80% stripping over the complete area, or that there was complete stripping over 80% of the area. 10% stripping could mean that the wheelpaths stripped severely but between the wheelpaths did not, but the average was 10%.

In general engineering terms, if the amount of stripping appeared not too large, and just at the tolerable limit, it would probably score 10%. However, in the literal sense, if 10% meant that for every 100 stones in place 10 stones had become unstuck, the actual appearance of the stripping would be severe, and would be ranked as such. The person who made these estimates is no longer available for any clarification. The author’s own observations were that the locations and extent of stripping did vary, but the detail of the supplied location data was not cross checked.

Another qualification is that the District, quite correctly, intervened in the stripping process, and remedial treatments were applied. As stated elsewhere, it was observed that at some sites where the seal had not stripped but remedial treatment was applied anyway, the binder behaved identically to that at the stripped sites. This suggests that these sites too would have stripped, had a remedial treatment not been applied when it was.

Consistency is probably the most important indicator of properties which can affect stripping.

Consistency is compared to the stripping as noted in the District records, and a resulting relationship is illustrated in Fig 26. The Bruce Highway and overtaking lanes sites have been removed because of the influence of compounding design flaws, as discussed in section 3.2.
Figure 26: Consistency and extent of stripping

There are many possible causes of stripping, and many of these can interact. It is rarely possible to accurately quantify the contribution of each, so the key task becomes to identify the most influential causes.

What can be concluded with confidence from this laboratory data, is that the risk of stripping is greatly increased when consistency increases beyond the specified range. Conversely, the risk of stripping when consistency is low, is minimal.

3.6 Cutter

The function of cutter is to temporarily reduce the viscosity (similar to ‘thickness’ of a liquid) of the binder at time of spraying. Not only does this then enable the liquid binder to fan out correctly from the spray nozzles and result in a binder coating on the road surface that is uniform in thickness, it also assists in the binder’s ‘wetting’ of the aggregate. This aggregate wetting is critical in building up adhesive bonds between the binder and aggregate. A lower viscosity also enables reorientation of aggregate particles to occur sooner, to form the aggregate mosaic as mentioned above.

The MRS11.11 specification provides cutting practice for C170 bitumen. For Polymer Modified Binders, the field practitioner would then either apply the specified practice given for C170, or use Austroads and AAPA published guidelines.

Appropriate publications are Austroads & AAPA (2001), and Austroads (2006c).

The daily record sheets show that typically two or three parts cutter were used as a minimum, increasing to six or seven parts from time to time.

Both Austroads & AAPA (2001) and Austroads (2006c) recommend minimum cutting of three parts for S20E (S2S), no matter how high the pavement temperature may get, rising to six to eight parts when lower pavement temperatures are expected at the end of the day or overnight.
The contractor cut either at or just below the published cutting requirements. It is not unreasonable to suggest this contract could have benefited with more cutter being specified/used, particularly at the higher temperature ranges encountered. The problem remains, however, that in many cases the properties of the binder as delivered would have required far more cutter even than that recommended in publications, because the binder consistency was higher than expected for the class of PMB specified.

3.7 Pavement temperatures at spraying

The specified minimum pavement temperature was 20°C for the overtaking lane contracts. For the reseal work, District field staff advised that standard practice applied, in that MRS11.11 specifies for polymer modified binders the minimum surface pavement temperature be 25°C for at least one hour before spraying commences.

The daily record sheets supplied show that for both the overtaking lanes and the reseals the pavement temperatures ranged from 26°C to 59°C, with pavement temperatures most commonly in the 30s and 40s.

The lowest morning temperature in the reseal sections (Goodwood, Bargara, Port Roads and Isis Hwy) was 26°C on 28 April and rose 7°C in the first hour. The lowest pavement temperature for a last run of the day was 30°C on 27 April. It is also understood that further ad hoc pavement temperatures were taken around sunrise during mid to late April. A pavement temperature of 17°C was recorded at 5:45 am on 21 April.

Pavement temperature at time of spraying is not regarded as a contributor to any of the stripping issues being investigated, although pavement temperatures and the time of year is discussed further in section 3.9 Contract timing and size.

3.8 Aggregate rolling

Queensland Department of Main Roads (1999a) specifies that there shall be a minimum of two rubber-tyred rollers on site, and that there shall also be sufficient rollers on site, and in use, to complete the specified minimum amount of rolling as a continuous operation with successive spray runs. The specification makes no differentiation between PMBs or C170 binders (at least for dry aggregate), but leaves Clause 6.3 of Annexure MRS11.11.1 available for differences if needed.

The contractor advised (and the District field staff confirmed) that two 13 t multi-wheeled, rubber tyred rollers were used on site. Because of traffic volumes and the fact that a variable sprayer was used, the jobs were sprayed half width (i.e. in lane widths). Reported practice is that both rollers were present at the start of each lane width run, so that the full width sprayed was rolled in one pass. Once this was done one roller continued to roll the new run while the other roller returned and back-rolled previous runs.

Austroads (2006c), in section 4.6.3 Field Procedures for PMB sprayed seals, also recommends there be sufficient rollers to cover the full run width in one pass, and additional rollers may be required as compared to conventional bitumen work.

Notwithstanding, it is considered that specifying more rollers on PMB work, as practised in some other areas of Australia, would be worthy of further investigation, especially with PMB contracts extending towards the end of the spray sealing season.
3.9 Contract timing and size

For weather/temperature reasons, Wide Bay District staff would like to have all sealing/resealing work finished before the end of April. This PMB contract finished spraying on 1 May 2007.

Anzac Day is a common date used in the southern parts of Australia as the cut-off for C170 sealing works, with preferably much earlier for PMB seals. This particular date may or may not be applicable to coastal Queensland, however the underlying concept of ceasing to spray hot binders after a certain cut-off date, could be applicable.

It was suggested that there would be benefit in calling two smaller concurrent contracts rather than one longer continuous contract. The District’s response was that they generally call three contracts: a summer C170 contract; an S2S spring contract; and an S2S autumn contract.

Avoiding S2S and using C170 in summer is chosen so that the risk of seal failures due to wet season rain and storms is reduced. It is not uncommon to lose two to three weeks of the resealing program due to wet weather during this period.

S2S seals in autumn are undertaken in the cane growing areas to reduce the possibility of surface contamination as a result of cane trash and soil from the cane fields, both of which are deposited on the road surface by haulage plant. Sugar sap and processed sugar contamination can also occur during this time in haulage operations.

The District also favours variable sprayers as they are able to focus on reducing wheelpath bleeding, but there is currently not sufficient equipment available in Queensland to split the one autumn variable-sprayer contract into two smaller but concurrent variable-sprayer contracts.

3.10 Weather

All people interviewed at Bundaberg commented that the seals in this sealing program generally held together and performed their function until a cold wet southerly change came through around 7 June 2007.

A regional newspaper, The Gympie Times, stated in its 23 June 2007 editorial that ‘Gympie managed to set another record this week with a record lowest maximum on Wednesday’ (20 June), ‘followed by a freezing Thursday, eclipsing all records for June, going back about 130 years.’

The following Figures show weather data extracted from the Bureau of Meteorology for Gympie and Bundaberg.

It is likely that these recordings were taken inside a Stevenson screen. The Stevenson screen is a special shelter that prevents direct heating by the sun’s rays, while permitting air to flow through. It consists of a white wooden slatted box that is fixed 1.2 m above ground.

As the recorded overnight minimum temperatures are thus probably from a sheltered position 1.2 m above ground, one could expect that actual minimum pavement-level temperatures at the aggregate/binder interface were somewhat lower than these records show.
### Gympie weather and Bruce Hwy overtaking lane events

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<td>April</td>
<td>Max temp (°C)</td>
</tr>
<tr>
<td>May</td>
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<tr>
<td>June 16-19 April 07</td>
<td>overtaking lanes sprayed</td>
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<tr>
<td>June 9</td>
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<tr>
<td>June 21</td>
<td>major stripping, Curra &amp; Durramboi</td>
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### Bundaberg weather and Isis Hwy events

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<td>April 30 - May 1</td>
<td>Isis Hwy 15A sprayed</td>
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<td>June 7</td>
<td>Isis Hwy 15B stripping started</td>
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**Figure 27:** Gympie weather and Bruce Hwy overtaking lane events

**Figure 28:** Bundaberg weather and Isis Hwy events
Figure 29: Bundaberg weather and Goodwood Rd events

Figure 30: Bundaberg weather and Port Rd events
There is no doubt that the combination of very cold weather and high rainfall was the trigger for the stripping event.

However, it is likely that many aggregate particles were never sufficiently wetted by the binder to begin with, and were held in place only by a very weak adhesive bond and by physical restraint of the solid binder around them.

The unusually cold weather (including the coldest June day in 130 years of record keeping) would have further weakened the adhesive bonding, and rainfall would then have been sufficient to break the adhesive film, and lubricate loose aggregate particles.

These low temperatures would have also reduced water evaporation, thus leaving the water present for a longer period of time. (It is known in the asphalt community that water induced stripping occurs when water is retained in a mix for a significant period of time.)

4 Conclusions

A large number of possible causes of stripping were considered, examined and discussed in this report.

It is concluded that stripping occurred because of variations in the properties of the bituminous binder, resulting in variable adhesion between the binder and aggregate. The binder was unable to wet the aggregate sufficiently to enable the formation of a strong adhesive bond. The aggregate remained in place until the binder became increasingly brittle at low temperatures, and traffic action stripped the particles from the surface. Water action also assisted the detachment of the weakly adhering binder film. The combination of record low temperatures and rainfall acted as the trigger for the stripping event.
Although the binder supplied met the specification requirements, it had such a large variation in properties that it overlapped higher modified specification classes. This more highly modified behaviour led to stripping in some locations. A higher level of modification is a disadvantage where it is not required or intended, and in particular if field crews are unaware of the change in characteristics. More highly modified binders are usually only specified in special cases such as in strain alleviating interlayers which will be immediately covered by asphalt.

There are a number of specification properties that relate to this behaviour. The most recent changes to both the Austroads and QDMR specifications now place upper and lower boundaries on the Consistency property in particular. On this project it was the Consistency property that showed greatest variability.

It is the opinion of the author that the more highly modified SBS binders, as they are currently used in sprayed sealing across Australia, are variable products and that applying these binders for hot sealing applications is challenging. Asset managers need to carefully assess the balance between application risk and in-service performance on all projects.

For the overtaking lane sites, the sprayed seal design produced the same binder application rate for all lanes. There was a need to apply a slightly higher rate of binder application for the overtaking (fast) lane. While this, by itself, may not have led to stripping behaviour, in combination with the variable binder properties, it was likely to have contributed.

It is the opinion of the author that process improvements may also reduce the performance risks when SBS modified binders are used. These processes include increased cutting and increased aggregate rolling.

5 Recommendations

1. The QDMR representative on the Austroads Bituminous Surfacings Research Reference Group (BSRRG) be strongly supported in attempts to develop a banded specification for PMBs.

2. The use of crumb rubber as a practical alternative binder be investigated by QDMR.

3. Main Roads Standard Specification, Sprayed Bituminous Surfacing (Excluding Emulsion), MRS11.11 12/99, be reviewed in the areas of cutting practice, time before cover by aggregate, and rolling practice, for PMBs.

4. Updated training be offered for all QDMR spray seal design personnel. All spray seal design macros then be checked and corrected if necessary, for Equivalent Heavy Vehicle calculation formulae, and for correct management of traffic splits at lane bifurcations.
References

Austroads 2006a, *Specification Framework for Polymer Modified Binders and Multigrade Bitumens*, AP-T41/06, Austroads, Sydney, NSW

Austroads 2006b, *Update of the Austroads Sprayed Seal Design Method*, AP-T68/06, Austroads, Sydney, NSW

Austroads 2006c, *Guide to the selection and use of Polymer Modified Binders and Multigrade Bitumens*, AP-T42/06 Austroads, Sydney, NSW


Queensland Department of Main Roads 1999a, Main Roads Standard Specification, *Sprayed Bituminous Surfacing (Excluding Emulsion)*, MRS11.11 12/99

Queensland Department of Main Roads 1999b, Main Roads Standard Specification, *Polymer Modified Binder*, MRS11.18 December 99

Queensland Department of Main Roads 2004, Approved Product Listing, *Precoating Agent*, APA/04, 2 September 2004

Queensland Department of Main Roads 2006a, Main Roads Standard Specification, *Polymer Modified Binder*, MRS11.18 December 06


Queensland Department of Main Roads 2007, Memorandum, *Standing Offer Arrangement No 50/06 for the Supply and Delivery of Bitumen Anti-Stripping Agent*, Principal Advisor (Materials Testing), 11 April 2007
### Sample Results Table

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### Notes on Testing
- **Consistency - Underlying Viscosity**: Consistency = Underlying Viscosity * 10
- **Elastomer Recovery @ 60°C**: Calculated from Consistency - Underlying Viscosity / 10
- **Elastomer Recovery @ 60°C**: Apparently negative underlying viscosity yet to be quantified.
- **Elastomer Recovery @ 60°C**: Sample previously heated to 180°C before cutter content tested
- **Elastomer Recovery @ 60°C**: Sample has a distinct burnt odour when smelt
Spray seal stripping in the Wide Bay District, 2007
QEAHDMR- 11/2007

A2 Spreadsheet of District Data

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<th>HV</th>
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Stone source: Boral
Bark: 12
Appox: 1.7
Ham: 1.4

www.arrb.com.au
## Spray seal stripping in the Wide Bay District, 2007

**QEAHMDR - 11/2007**

### 10 mm BIT

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### Stone source Biggenden

*Flakiness 28*

**Owanyilla OTL**

*Flakiness 39*

**Bruce Hwy**

*Ch. runs from Gympie to Maryborough*
### Isis Hwy: Ch. runs from Bundaberg to Childers

#### Treatment: 12 mm S2S

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**Stone source**: Boral

**Flakiness**: 12

**ALD**: 8.2
Spray seal stripping in the Wide Bay District, 2007
QEAHDMR- 11/2007

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**Note:**
- One patch at 1.4 km is in near full shade and has fully let go.
- Shade seems to have little effect on where stripping occurs.
- Stone source: Paverock
- Pavement Type: Softness
- ALD: 8.4

www.arrb.com.au
### Spray seal stripping in the Wide Bay District, 2007

**QEAHDMR- 11/2007**

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**Port Rd : Ch. Runs from Bundaberg to Bundaberg Port**

**Treatment: 12 mm S2S**

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**Stone source**

Boral

**Bitumen**

13

**AAD**

77
### A3 Austroads Vehicle Classification Table

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A4 Site Locations

- Bargara Rd
- Bundaberg
- Isis Hwy
- Port Rd
- Goodwood Rd
- Childers
- Owanyilla OTL
- Tiaro OTL
- Curra & Durrambol OTLs
- Gympie

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