THE AUSTROADS/AAPA PMB SPRAYED SEAL FIELD TRIALS – ONE YEAR ON

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ABSTRACT

The current Austroads PMB specification framework AGPT/T190 has revised PMB classifications and includes banded properties. It also includes a new PMB grade which has not previously been produced or field validated.

In 2011/12 Austroads arranged and laid a sprayed seal PMB field trial program at two locations: Coober Pedy SA; and north of Cooma NSW. The objective of these trials is to validate and rank the performance of the current generation of Australian PMB sprayed seal binders. In a cooperative arrangement with AAPA, several proprietary PMB products selected by the industry were laid at the trial sites adjacent to the Austroads binders.

The performance of PMBs is to be investigated in both the field and in the laboratory by 1) as a crack inhibitor – determined by crack growth measurement; 2) as a seal – including examination and adjustment of the PMB factor – determined by sand patch depth testing and visual assessment of the height of the binder up the stone, over time; and 3) by laboratory binder characterisation tests PMBs sampled at the point of manufacture and delivery, and after one and two years' service on the road.

This paper describes the information gained after one year.

INTRODUCTION

Background

The total usage of bituminous binders in Australia is approximately 750 000 tonnes per year (BREE 2012), of which around half is used in sprayed seals. While the proportion of polymer modified binders (PMBs) in this total is not easily identified, it is reported that in some jurisdictions up to 40% of reseals include PMBs, and this use is rapidly increasing as periodic maintenance funding becomes more difficult to obtain. Funding restraints have led to increased intervals of reseal applications during which time existing surface conditions more often require PMB seals to address cracking and other pavement distress. PMBs are also more often being used in reseals in lieu of pavement rehabilitations and reconstruction.

The latest Austroads PMB specification framework AGPT/T190 (Austroads 2010) has revised PMB classifications and includes the introduction of a new grade that had not previously been produced and field validated.

Field validation of the performance of these current generation PMBs by means of these trials will ensure appropriate binder selection enabling longer seal life and reduced maintenance costs.

Additionally, several proprietary PMB products selected by AAPA members were laid at the trial sites adjacent to the Austroads binders.

This paper provides details of the trials' location and layout, judgement of the trial seals performance after one year, and laboratory testing results for the binders.

Objectives

The objective of these trials was to validate and rank the performance of PMB sprayed seal binders.

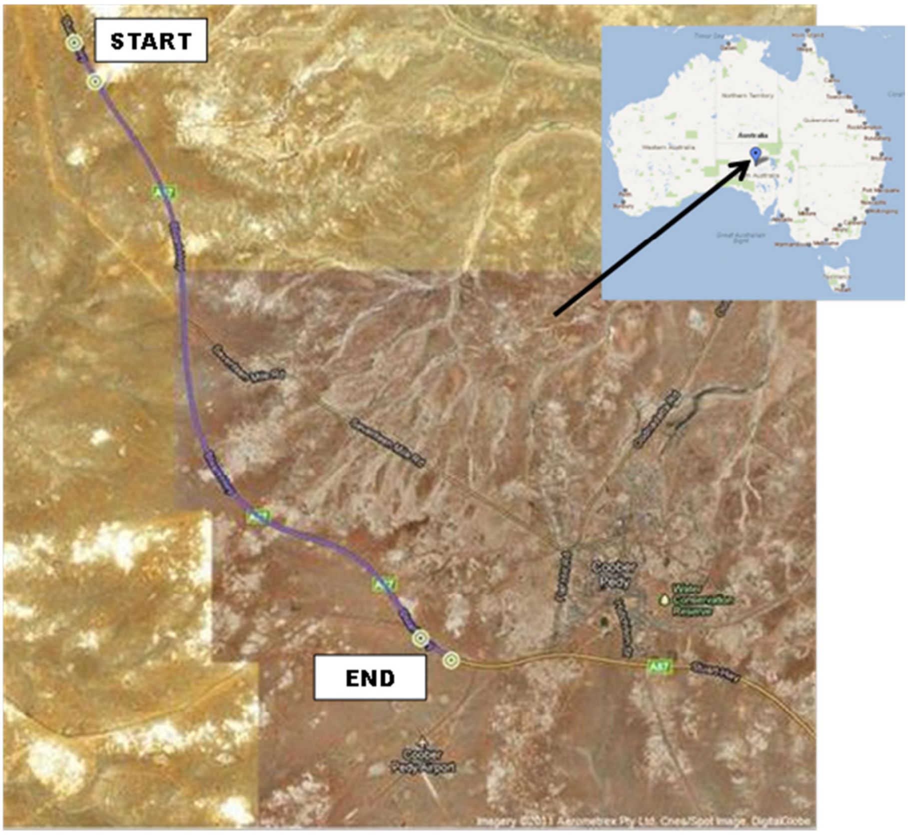
The performance of PMBs is to be investigated at two levels:

- as a crack inhibitor – determined by crack growth measurement
- as a seal (including PMB factor) determined by sand patch depth and visual assessment of height of binder up the stone, over time.

LOCATION OF TRIALS

Coober Pedy

The trial site of 4 km length is on a two-lane two-way section of the Stuart Highway approximately 4 km from Coober Pedy, South Australia (Figure 1). The trial seals were laid in this location on 1 and 2 November 2011.



Source: © 2012 Google, Aerometrex Pty Ltd, Cnes/Spot Image, DigitalGlobe, GeoEye.

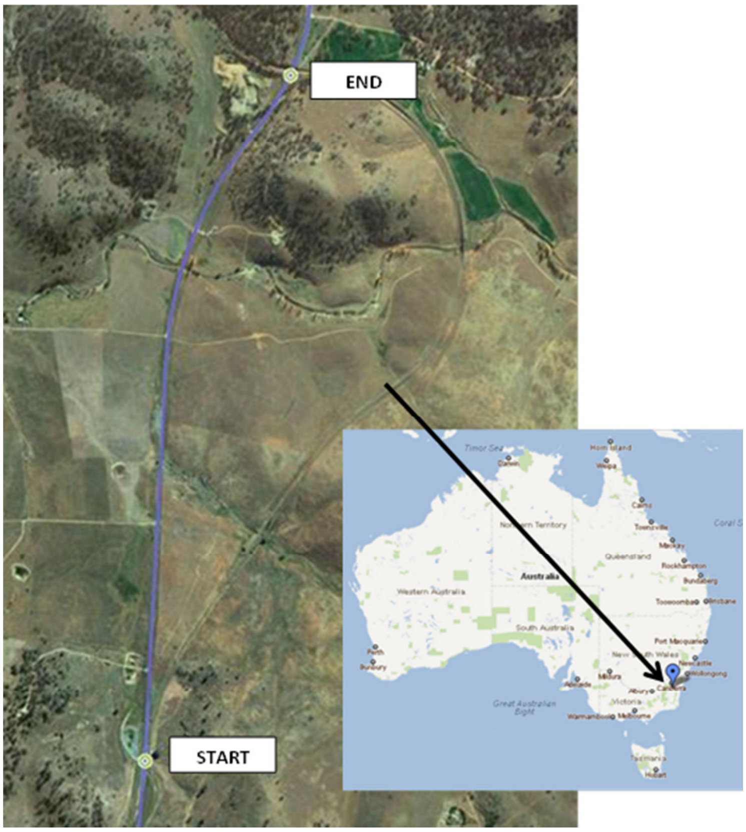
Figure 1: Location of of Coober Pedy test site

The Coober Pedy site was chosen for its uniformly heavily cracked surface, fit for SAM treatment, and its generally hot/dry climatic conditions. There is significant cracking observed over much of the section with at least low-level cracking along the whole length, in both lanes, excluding a few very short sections that remain uncracked. There are only small variations in both grade and horizontal curvature along the length. These factors make the site a suitable choice for the PMB trials.

A traffic count of 330 annual average daily traffic (AADT), with 19% commercial vehicles and 35% equivalent heavy vehicles (EHV) (Austroads 2006b), was reported by the Department of Planning, Transport and Infrastructure South Australia (DPTI) for seal design purposes.

Cooma

The trial site of 3.1 km length is on the Monaro Highway, 50 km north of Cooma, New South Wales, and 65 km south of Canberra, Australian Capital Territory (Figure 2). The trial seals were laid in this location on 31 January 2012 and 1 February 2012.



Source: © 2012 Google, Cnes/Spot Image, DigitalGlobe, GeoEye, TerraMetrics.

Figure 2: Location of Cooma trial site

The Cooma site was chosen for its cooler/wetter climatic conditions and the cracking along cracking along the length of the northbound carriageway, making it a suitable candidate for these trials. There is only small variation in the horizontal curvature, but a significant grade is encountered in the middle of the section.

A traffic count of 4100 vehicles/day (AADT) with 10.5% heavy vehicles was reported by Roads and Maritime Services New South Wales (RMS) for seal design purposes.

TRIAL CONSTRUCTION

Binders

The bitumen and PMB binders C170, S10E, S15E, S35E, S20E, S45R (Coober Pedy) and S15RF (Cooma) were used, as defined in the Australian standard (AS 2008-1997) and the Austroads PMB specification framework AGPT/T190 (Austroads 2010).

The resealing contractors chose the source for these products through their normal procurement process.

AAPA manufacturing members were also given an opportunity to provide additional binders of their own selection to be included in the trials. At Coober Pedy the additional industry proprietary products were SAMI S20E SS and Shell S5E. At Cooma the additional products were Fulton Hogan Surfix 70X emulsion and SAMI Samiflex and Polyseal emulsions.

Site layout

A summary of the test sections included at the Coober Pedy site is in Table 1.

All seal designs were completed using the *Update of the Austroads Sprayed Seal Design Method*, AP-T68/06 (Austroads 2006b). The designs were prepared in the planning stage of each leg of the trials, and reviewed on site by the designer and spray crews for appropriateness to the local conditions at the time of construction.

Table 1: Coober Pedy trial site detail information

Chainage (m)	Section designation	Binder	Design application rate (L/m^2)	PMB factor	Cutter (parts)	Adhesion agent (parts)
0 – 250	A1	C170	1.8	1.2	2	1
251 – 500	A2	C170	1.6	0		
501 – 750	B1	S10E	1.8	1.2		
751 – 1000	B2	S10E	1.6	0		
1001 – 1250	Excluded from trial					
1251 – 1500	C1	S20E	1.9	1.3		
1501 – 1750	C2	S20E	1.7	0		
1751 – 2000	D1	S35E	1.8	1.2		
2001 – 2250	D2	S35E	1.6	0		
2251 – 2500	E1	S5E	1.8	1.1		
2501 – 2750	E2	S5E	1.6	0		
2751 – 3000	F1	S45R	1.9	1.3		
3001 – 3180	F2	S45R	1.7	0		
3181 – 3500	G1	S15E	1.9	1.3		
3501 – 3750	G2	S15E	1.7	0		
3751 – 4000	H1	S20E	1.9	1.3		
4001 - 4250	H2	S20E	1.7	0		

A summary of the test sections included at the Cooma site is compiled in Table 2.

Table 2: Cooma trial site detail information

Chainage (m)	Section designation	Binder	Design application rate (L/m^2)	PMB factor	Cutter (parts)	Adhesion agent (parts)
0 – 300	A	S10E	1.6	1.2	2	1
301 – 600	B	S35E	1.6	1.2		
601 – 900	C	S15E	1.7	1.3		
901 – 1200	D	S15RF	1.8	1.4		
1201 – 1500	E	S20E	1.7	1.3		
1501 - 1800	F - Nthbound	FH Surfix 70X emulsion	1.5	1.5	-	-
	F - Sthbound	SAMI E40HR emulsion	1.6	1.6		
1801 – 2000	G	C170	1.5	-	0	0.5
2001 - 3100	H - left lane Nthbound	S15E	1.4 / 1.7	1.3	2	2
	H - right lane Nthbound		1.8 / 2.1	1.3		
	H - Sthbound	SAMI Polyseal emulsion	1.5 / 1.8	1.3	-	-

PERIODIC INSPECTIONS

To enable the verification and validation of the design procedure and construction techniques, a regular series of inspections of the trial sections has been commenced. Inspections were conducted at pre-construction, post-construction, 3 month (Cooma only at notice of seal distress), 6 months and 12 month stages of life.

Looking forward, it is most important that an inspection be scheduled when the seal is about two years old as it is believed to be the time required for the seal design concepts of required surface texture and binder two-thirds up the stone to fully develop. This will be the stage at which to best judge the performance of the trial seals.

The inspections include detailed assessments of stripping, binder level up stone, binder condition, surface texture, cracking and aggregate condition, amongst other assessments of performance and quality. A brief overview of these findings is presented below.

Coober Pedy Seal Performance

The performance of the seals at the Coober Pedy site after 12 months is generally good. The strength of the bond between binders and aggregate is good and there are no obvious performance issues developing. The seals are quite hungry, but this is not unexpected after 12 months of service life and can be expected to improve as the aggregate is reorientated by traffic over time.

The spread rate of aggregate appears to be inconsistent both along and across sections A through E. This negatively impacts on the quality of the aggregate mosaic and surface texture formed, and can create the appearance of stone loss through stripping. The aggregate was spread across the road width in unison by three trucks, and in parts the difference in spread rate between these sections is obvious to the eye. The spread rate improves in section F and G.

To test the effect of the existing PMB factors, each test section was laid in two parts, with the second half (A2, B2, C2, etc.) subject to a 0.2 L/m^2 reduction from the full design rate, except for the control section C170 which was increased by 0.2 L/m^2 over the design rate to test the effect of bitumen applied at the same rate as the PMBs. The lower application rates have resulted in hungrier textures, with binder less far up the stone in all cases, but otherwise similar performance at this stage of life.

There is no cracking evident on the new seals at the Coober Pedy site.

A section was constructed adjacent to the trial site, using a shandy of the leftover PMBs used in the trial (S15E, S20E, Shell S5E, SAMI S20E SS). After 12 months this section is performing well and is of similar appearance to the other trial sections. Monitoring the performance of this site will allow comparison in performance between products made with the finessed specification and this unknown combination.

Cooma Seal Performance

The trial seals at the Cooma site are performing well in some instances, however several sections have been subject to high levels of stripping and may require maintenance intervention in the near future, which will not allow ongoing monitoring of their performance. Several sections suffered from stone loss along the centreline, as the lanes were sprayed separately, overlap of sprayers in this area may have contributed to this stripping.

Recent research (Austroads 2012) has shown that cutter levels for PMBs in AP-T42/06 (Austroads 2006a) may need to be increased. The observed cutter levels could have been too low on the second, cooler day of the trial seals being laid, which may have influenced the performance of these sections. However, stripping has occurred on the sections laid on the first day also, indicating the cutter level is unlikely to be the sole contributor to the stripping performance of the seals.

The performance of the emulsion seals are generally good, which could be a result of the enhanced wetting characteristics of the emulsions.

The seals are generally hungry, but this can be expected to improve as the aggregate is reorientated by traffic over time.

There is some instances of cracks from cement stabilisation joins reflecting back through at the Cooma site.

BINDER TESTING

All binders used in the Coober Pedy and Cooma trials were subjected to a series of binder tests (detailed in Table 3) to ascertain whether they met the requirements of either the Australian bitumen specification (Standards Australia AS2008-1997) or Australian PMB specification (Austroads 2010), where applicable. In addition to the national specifications, most road jurisdictions have local bitumen and PMB specifications. The test results obtained for the binders used in the Coober Pedy and Cooma trials have also been compared to local South Australian (Department of Planning, Transport and Infrastructure 2011) and New South Wales (Roads and Maritime Services 2009a and 2009b) specifications, respectively, for informational purposes only.

Samples of each binder were taken, with the time and date recorded, at two stages of product delivery:

- as manufactured (collected from the supplier’s tank after manufacture)
- as delivered (collected at the trial site).

Samples were taken from the delivery bulkers on arrival on site, not from sprayers due to the expected addition of adhesion agent and cutter.

The collected samples were subject to the text methods as listed in Table 3.

Table 3: Binder tests and methods

Property	Test method	Tested for PMB	Tested for bitumen
Consistency at 60 °C	AG:PT/T121 2010	✓	
Stiffness at 15 °C	AG:PT/T121 2010	✓	
Viscosity at 165 °C	AG:PT/T111 2006	✓	
Torsional recovery at 25 °C	AG:PT/T122 2006	✓	
Softening point	AG:PT/T131 2006	✓	✓
Viscosity at 60 °C	AS 2341.2-1993		✓
Viscosity at 135 °C	AS 2314.4-1994		✓
Penetration at 25 °C	AS 2341.12-1993		✓
Percentage increase in Viscosity at 60 °C after RTFO test	AS/NZS 2341.10:1994		✓
Matter insoluble in toluene	AS 2341.8-1992		✓
Durability	AS/NZS 2341.13-1997		✓
Storage stability	IS EN 1399:2010	✓	✓

Emulsion Extraction

The binder from the three types of emulsion used in the Cooma trial was extracted using a procedure which was based on a Colas ‘ethanol precipitation method’ (Gueit, Robert and Durand 2007). This method was chosen as their studies indicate that it can be used to recover a binder from an emulsion which has the same penetration at 25 °C, softening point and bitumen acid values as the original binder that was used to produce the emulsion.

Coober Pedy Binder Test Results

C170 Bitumen

Table 4 shows the test results obtained for the ‘as manufactured’ and ‘as delivered’ samples of C170 bitumen which were obtained during the Cooper Pedy trial. Both binders met all tested requirements of the Australian bitumen specification (Standards Australia AS2008-1997) and showed very low results in storage stability tests. The South Australian specification requirements for C170 bitumen are the same as those listed in the Australian bitumen specification, however, limits for binder durability and density at 15 °C are also specified (Department of Planning, Transport and Infrastructure 2011). Both binders met the South Australian durability requirement (9 days minimum) for C170 bitumen.

Table 4: Coober Pedy C170 bitumen test results

Sample description	C170 bitumen as manufactured	C170 bitumen as delivered
Viscosity at 60 °C (Pa s)	195	179
Viscosity at 135 °C (Pa s)	0.35	0.34
Penetration at 25 °C (pu)	71	69
Viscosity at 60 °C after rolling thin film oven (RTFO) treatment (Pa s)	351	280
Percentage increase in viscosity at 60 °C after RTFO treatment (%)	180	157
Toluene insolubles (%)	0.06	0.03
Durability (days)	10.2	12.5
Softening point (°C)	48.5	47.5
Storage stability (3 days storage at 180 °C) (°C)	0.1	0.2
Storage stability: top softening point result (°C)	47.4	47.3
Storage stability: bottom softening point result (°C)	47.3	47.1

Austroads Grade PMBs

Table 5 shows the test results that were obtained for the PMBs which were used in the Coober Pedy trial that represented the different PMB grades in the Australian PMB specification (Austroads 2010). The shaded cells in the table correspond to test results that do not meet the requirements of the Australian PMB specification. As the South Australian requirements for PMBs (Department of Planning, Transport and Infrastructure 2011) feature only minor differences from the national specification, the shaded cells in the table also correspond to those test results which did not meet South Australian requirements. The Australian PMB specification requires that consistency at 60 °C tests be performed on S10E and S35E grade PMBs using a different elastometer mould (Mould B) than the other PMB grades (Mould A). The mould used during the consistency test has therefore been included in brackets in the relevant tables in this report.

Table 5: Coober Pedy Austroads grade PMB test results

Sample description	S10E		S15E		S20E		S35E		S45R	
Stage of testing	**As manufactured**	**As delivered**	**As manufactured**	**As delivered**	**As manufactured**	**As delivered**	**As manufactured**	**As delivered**	**As manufactured**	**As delivered**
Viscosity at 165 °C (Pa s)	0.27	0.26	0.46	0.40	0.39	0.37	0.29	0.24	2.46	0.78
Torsional recovery at 25 °C (%)	40	32	43	38	50	51	26	26	49	36
Softening point (°C)	60.0	56.0	63.0	60.0	74.0	**58.0**	**46.5**	**47.0**	60.5	**54.5**
Consistency at 60 °C (Pa s)	666 (Mould B)	592 (Mould B)	1124 (Mould A)	959 (Mould A)	1137 (Mould A)	862 (Mould A)	**263** (Mould B)	**274** (Mould B)	1721 (Mould A)	**642** (Mould A)
Underlying viscosity at 60 °C (Pa s)	398 (Mould B)	392 (Mould B)	519 (Mould A)	508 (Mould A)	589 (Mould A)	533 (Mould A)	236 (Mould B)	251 (Mould B)	1083 (Mould A)	438 (Mould A)
Consistency 6% at 60 °C (Pa s)	366 (Mould B)	361 (Mould B)	460 (Mould A)	478 (Mould A)	594 (Mould A)	529 (Mould A)	213 (Mould B)	235 (Mould B)	978 (Mould A)	415 (Mould A)
Stiffness at 15 °C (kPa)	85	74	99	105	**> 187***	**> 187***	50	48	168	89
Stiffness at 25 °C (kPa)	–	–	–	–	32	30	–	–	–	–
Storage stability (3 days at storage at 180 °C) (°C)	–0.1	0.7	–0.6	0.3	0.8	1.7	–0.7	0.2	–12.6	–12.1
Storage stability: top softening point result (°C)	56.4	54.8	58.6	57.5	64.8	70.3	46.5	47.1	52.9	50.1
Storage stability: bottom softening point result (°C)	56.5	54.1	59.2	57.2	64.0	68.6	47.2	46.9	65.5	62.2

* The stiffness at 15 °C results for these binders were above the maximum limit of 187 kPa which can be measured with the elastometer. Due to this, values of >187 kPa have been included in the table.

Note:

Shaded and bold – did not meet the Australian PMB specification requirement for the relevant PMB grade.

Proprietary PMBs

Table 6 shows the test results obtained for the two proprietary PMBs (S5E from Shell and S20E SS from SAMI) which were used in the Coober Pedy trial. The elastic recovery at 60 °C results that were obtained for the SAMI S20E SS binder during the consistency test (Austroads 2010b) have been included in the table so the results could be compared with the specified requirements for an S25E grade binder.

Table 6: Coober Pedy proprietary PMB test results

Sample description	Shell S5E		SAMI S20E SS	
Stage of testing	**As manufactured**	**As delivered**	**As manufactured**	**As delivered**
Viscosity at 165 °C (Pa s)	0.18	0.17	0.70	0.56
Torsional recovery at 25 °C (%)	18	21	68	63
Softening point (°C)	52.0	51.0	93.0	84.0
Consistency at 60 °C (Pa s)	323 (Mould B)	353 (Mould B)	9194 (Mould A)	4988 (Mould A)
Underlying viscosity at 60 °C (Pa s)	295 (Mould B)	321 (Mould B)	551 (Mould A)	553 (Mould A)
Consistency 6% at 60 °C (Pa s)	286 (Mould B)	329 (Mould B)	1053 (Mould A)	735 (Mould A)
Elastic recovery at 60 °C (%)	–	–	93 (Mould A)	99 (Mould A)
Stiffness at 15 °C (kPa)	>187*	161	118	97
Stiffness at 25 °C (kPa)	20	21	18	16
Storage stability (3 days storage at 180 °C) (°C)	0.3	0.2	-0.5	–0.8
Storage stability: top softening point result (°C)	52.9	50.9	94.5	91.7
Storage stability: bottom softening point result (°C)	52.6	50.7	95	92.4

* The stiffness at 15 °C result for this binder was above the maximum limit of 187 kPa which can be measured with the elastometer. Due to this, a value of >187 kPa has been included in the table.

Cooma Binder Test Results

C170 Bitumen

Table 7 shows the test results obtained from a sample of the C170 bitumen which was used in the Cooma trial. As it was not possible to obtain a sample from the tank from which the bitumen was supplied, only an ‘as delivered’ sample was obtained.

Table 7:Cooma C170 bitumen test results

Sample description	C170 bitumen as delivered
Viscosity at 60 °C (Pa s)	164
Viscosity at 135 °C (Pa s)	0.35
Penetration at 25 °C (pu)	74
Viscosity at 60 °C after rolling thin film oven (RTFO) treatment (Pa s)	391
Percentage increase in viscosity at 60 °C after RTFO treatment (%)	238
Toluene insolubles (%)	0.04
Durability (days)	6.8
Softening point (°C)	48.0
Storage stability (3 days storage at 180 °C) (°C)	0.3
Storage stability: top softening point result (°C)	48.7
Storage stability: bottom softening point result (°C)	48.4

Austroads Grade PMBs

Table 8 lists the test results that were obtained from PMB samples obtained during the Cooma trial which represented different PMB grades in the Australian PMB specification (Austroads 2010). Only the test results for an ‘as delivered’ sample of the S15RF binder are included in the table as this binder was manufactured by adding an appropriate amount of crumbed rubber to bitumen at the trial site. The shaded cells in the table correspond to test results that do not meet the requirements of the Australian PMB specification.

Table 8:Cooma Austroads grade PMB test results

Sample description	S10E		S15E		S20E		S35E		S15RF
	As manufactured	As delivered	As manufactured	As delivered	As manufactured	As delivered	As manufactured	As delivered	As delivered
Viscosity at 165 °C (Pa s)	0.32	0.27	0.38	0.34	0.47	0.38	0.25	0.23	0.82
Torsional recovery at 25 °C (%)	42	43	54	38	47	49	24	21	**23**
Softening point (°C)	61.0	61.0	67.5	58.0	**91.0**	**88.5**	**58.0**	55.0	**51.0**
Consistency at 60 °C (Pa s)	1066 (Mould B)	651 (Mould B)	820 (Mould A)	822 (Mould A)	1846 (Mould A)	2100 (Mould A)	618 (Mould B)	598 (Mould B)	468 (Mould A)
Underlying viscosity at 60 °C (Pa s)	662 (Mould B)	495 (Mould B)	537 (Mould A)	494 (Mould A)	718 (Mould A)	567 (Mould A)	415 (Mould B)	441 (Mould B)	349 (Mould A)
Consistency 6% at 60 °C (Pa s)	610 (Mould B)	468 (Mould B)	494 (Mould A)	462 (Mould A)	680 (Mould A)	559 (Mould A)	380 (Mould B)	422 (Mould B)	352 (Mould A)
Stiffness at 15 °C (kPa)	**>187***	136	104	103	**167**	103	**>187***	**>187***	81
Stiffness at 25 °C (kPa)	37	21	–	–	19	14	21	24	–
Storage stability (3 days storage at 180 °C) (°C)	1.2	0	–0.8	0.6	0.4	–1.0	–0.2	0.5	–8.5
Storage stability: top softening point result (°C)	74.9	66.7	61.8	58.1	90.5	83.3	56.4	55.5	44.7
Storage stability: bottom softening point result (°C)	73.7	66.7	62.6	57.5	90.1	84.3	56.6	55	53.2

* The stiffness at 15 °C results for these binders was above the maximum limit of 187 kPa which can be measured with the elastometer. Due to this, values of >187 kPa have been included in the table.

Note:

Shaded and bold – did not meet the Australian PMB specification requirement for the relevant PMB grade.

1.1.1 Proprietary PMBs - Extracted Emulsion Binders

Table 9 shows the test results obtained after the binders from the 'as manufactured' and 'as delivered' samples of the emulsions were extracted.

Two separate 'as manufactured' samples of the SAMI Samiflex E40 HR were subjected to the extraction process so that the repeatability of results could be ascertained. As the results obtained in the repeat experiments were overall quite similar, it was concluded that the extraction process was reproducible.

Table 9:Test results obtained for extracted SAMI Samiflex E40 HR emulsion binders

Sample description	SAMI Samiflex E40 HR			SAMI Polyseal HR		Fulton Hogan Surfix 70X	
	As manufactured (Sample 1)	As manufactured	As delivered	As manufactured	As delivered	As manufactured	As delivered
Viscosity at 165 °C (Pa s)	0.28	0.26	0.25	0.23	0.21	30.2	7.2
Torsional recovery at 25 °C (%)	42	47	49	49	46	40	43
Softening point (°C)	51.5	56.5	54.0	51.5	52.0	86.0	85.5
Consistency at 60 °C - mould A (Pa s)	488	642	441	374	512	1449	3285
Underlying viscosity at 60 °C - mould A (Pa s)	309	338	224	300	320	316	843
Consistency 6% at 60 °C - mould A (Pa s)	302	334	205	294	311	329	894
Consistency at 60 °C - mould B (Pa s)	358	432	305	330	579	840	1416
Underlying viscosity at 60 °C - mould B (Pa s)	292	300	192	299	495	292	732
Consistency 6% at 60 °C - mould B (Pa s)	269	280	178	279	491	277	625
Stiffness at 15 °C (kPa)	135	122	56	139	130	30	97
Loss on heating (% mass)	0.3	0.2	1.0	0.2	0.2	2.0	0.8

1.2 General Discussion

The results obtained during binder tests indicate that the two C170 bitumens used in the sprayed sealing trials met the requirements of the Australian bitumen specification (Standards Australia AS2008-1997) where tested. Three of the five Austroads grade PMB binders which were used in the Coober Pedy trial, and one of the five Austroads grade PMB binders which were used in the Cooma trial, met all tested requirements of the Australian PMB specification (Austroads 2010) at the as manufactured stage. Two of the five Austroads grade PMB binders met all tested requirements of the Australian PMB specification (Austroads 2010) at the as delivered stage at both trial locations. All PMB binders, except for the crumbed rubber binders, showed very low results in storage stability tests. The polymer in these PMBs would therefore be unlikely to segregate during storage and transport of these materials. Both crumbed rubber binders (i.e. S45R and S15RF) showed appreciable negative results in storage stability tests. The crumbed rubber in these materials would therefore be expected to sink towards the bottom of storage tanks, trucks and bitumen sprayers if the materials were not thoroughly mixed during use.

The results obtained for the proprietary PMBs used in the Coober Pedy trial indicated that the Shell S5E binder was similar to an S35E or S10E grade PMB. The SAMI S20E SS binder met the requirements of A15E and A10E asphalt grade PMBs and appeared to be similar to an S25E grade binder. Binders that were extracted from the SAMI Samiflex E40 HR and SAMI Polyseal HR emulsions used in the Cooma trial met the requirements of an S10E grade PMB. The binders extracted from the Fulton Hogan Surfix 70X emulsions were extremely viscous and appeared to form 'gelled' materials. The test results obtained from binder extracted from the

Fulton Hogan ‘as manufactured’ emulsion appeared to be most similar to a PMB which had properties between S15E and S20E grade PMBs. All extracted emulsion binders appeared to contain a small percentage (≤ 2% by mass) of a volatile organic component such as cutter or flux oil.

The S20E and SAMI S20E SS binders in the Coober Pedy trial and the S20E and S35E binders in the Cooma trial showed test properties which conformed to specified properties for asphalt grade, rather than sprayed grade, PMBs. As each of these materials has been used as part of a sprayed seal, future monitoring will give an indication of how asphalt grade PMBs will perform in sprayed sealing applications.

Many of the PMB binders used in the Coober Pedy trial showed a reduction in a number of test result parameters when the results for as manufactured and as delivered samples were compared. This reduction in binder test properties was not as marked for PMB samples obtained during the Cooma trial. This difference in behaviour may be related to the far greater transport distance between PMB production plants and the Coober Pedy trial site, compared with the Cooma trial site, as binders that have been transported long distances will have been heated for longer time periods.

CHARACTERISATION OF RECOVERED BINDERS

This section provides a review of the properties of binders that were collected from the two trial sites (Coober Pedy and Cooma) when the binders had been in service for about one year. The purpose was to compare these ‘aged’ binder properties with those of the ‘unaChoiuged’ binders and thus to investigate the field ageing characteristics.

The Dynamic Shear Rheometer (DSR) is a binder test device used widely in many parts of the world, and was used for this characterisation work.

The device is currently a key instrument for binder characterisation tests in Europe (EN 14770: 2012) and the US (AASHTO T315: 2012). The DSR test is typically conducted under oscillation loadings and provides viscoelastic parameters, namely *G** (complex shear modulus) and δ (phase angle). The *G**, in a simplistic term, represents how stiff the sample is, whereas δ shows whether the sample behaves in a more elastic (or viscous) manner (regardless of how stiff the sample is). Since most of the binders used in this study were PMBs having mostly viscoelastic properties, the DSR was a suitable tool. The DSR also requires only about 2 g of sample per testing and thus resolved the critical operational issue (i.e. very limited amount of recovered binders available).

Age Hardening

For this paper, a brief data overview is provided by using a simple hardening index which could broadly represent each *G** curve in a single number.

The hardening index was calculated according to Equation 1:

$$\text{Hardening index (\%)} = \frac{G^*(1year) - G^*(0year)}{G^*(0year)} \times 100 \qquad (1)$$

where

*G** (1 year)	=	*G** of ‘1 year’ binder (log Pa s)
*G** (0 year)	=	*G** of ‘0 year’ binder (log Pa s)

The hardening index was calculated respectively at 25 and 60 °C and was then averaged to a single index for simplicity.

The hardening indexes of all the binders used in this study are presented in Table 10, Table 11, Table 12 and Table 13. The most evident fact from the table is that the same class binders placed in the Coober Pedy site experienced more hardening than those placed in the Cooma site. For the binders that were placed only in one of the sites (e.g. S20E SS and Polyseal from SAMI), similar results are expected if they had been placed in the other site, based on the fact that all the Coober Pedy binders displayed higher hardening indexes than those of the Cooma binders.

Table 10:Hardening index results – C170 bitumens

Binder	Hardening index (%)	
	Coober Pedy	Cooma
C170	19.8	6.3

Table 11:Hardening index results – Austroads grade PMBs

Binder	Hardening index (%)	
	Coober Pedy	Cooma
S10E	23.4	2.3
S15E	10.5	3.1
S20E	8.0	2.1
S35E	11.0	5.6

Table 12:Hardening index results – emulsion PMBs

Binder	Hardening index (%)	
	Coober Pedy	Cooma
SAMI E40HR	-	6.2
SAMI Polyseal	-	5.5
FH Surfix 70X	-	1.9

Table 13:Hardening index results –proprietary PMBs

Binder	Hardening index (%)	
	Coober Pedy	Cooma
SAMI S20E SS	8.2	-
Shell S5E	14.2	-

The different ageing levels experienced between the two sites appear to be due to the contrasting climates of the two sites. The finding agrees with the general expectation that a faster ageing process would occur in a hotter climate.

Changes in Viscoelastic Properties

The DSR δ results (60 °C, at 1 rad/s) of all the binders used in this study are provided in Table 14, Table 15, Table 16 and Table 17. The changes in δ values after ageing are quantified using the percentage increase (to the 0 year binders). The negative percentage values indicate that the materials became more elastic, whereas positive percentage values indicate more viscous behaviours (after ageing).

Table 14:DSR δ test results (at 60 °C) – C170 bitumen

Site	Binder	δ (°)		% increase in δ (from the '0 year' binder)
		0 year	1 year	
Coober Pedy	C170	89.2	87.1	-2.35
Cooma	C170	88.6	86.2	-2.71

Table 15:DSR δ test results (at 60 °C) – Austroads grade PMB

Site	Binder	δ (°)		% increase in δ (from the '0 year' binder)
		0 year	1 year	
Coober Pedy	S10E	73.3	71.6	-2.32
	S15E	67.9	68.5	0.88
	S20E	78.8	79.6	1.02
	S35E	81.3	78.5	-3.44
Cooma	S10E	69.5	74.8	7.63
	S15E	69.2	73.1	5.64
	S20E	59.0	69.2	17.29
	S35E	78.2	80.1	2.43

Table 16:DSR δ test results (at 60 °C) – Emulsion PMBs

Site	Binder	δ (°)		% increase in δ (from the '0 year' binder)
		0 year	1 year	
Cooma	SAMI E40HR	82.9	83.3	0.48
	SAMI Polyseal	82.4	84.9	3.03
	FH Surfix 70X	68.3	80.3	17.57

Table 17:DSR δ test results (at 60 °C) – Proprietary PMBs

Site	Binder	δ (°)		% increase in δ (from the '0 year' binder)
		0 year	1 year	
Coober Pedy	S20E SS	53.9	63.5	17.81
	S5E	84.4	84.3	-0.12

Noteworthy observations from these results are:

- The two C170 binders display negative changes of the δ after ageing (i.e. became more elastic).
- Other binders (i.e. PMBs and emulsions) display mostly positive changes of the δ after ageing (i.e. became more viscous).
- All the binders that showed negative changes after ageing (i.e. more elastic) have small values (i.e. the magnitude of change is small).
- Negative changes are generally associated with high unaged δ values
  - — this suggests that the binders were generally viscous when unaged (indicating low polymer contents) and became more elastic when aged (likely due to binder hardening).
- Particularly large positive changes (e.g. over 17%) are generally associated with low unaged δ values
  - — this suggests that the binders were very elastic when unaged (possibly due to high elastomeric polymer contents) and then became more viscous when aged (could be due to the reduction in elastic properties of the polymer components).
- The Austroads grade binders from Cooma have relatively larger changes after ageing than those of the Cooper Pedy binders, except in the case of S35E.

It is noted that the last observation point was conflicting with the trend observed from the *G** results which showed larger physical changes (i.e. hardening) of the Coober Pedy binders (due to the hotter climate of the site).

A viable explanation may be that the bitumen component hardening (i.e. reduction in δ value) actually offset the reduction in elasticity of the polymer component (i.e. increase in δ value). For example for the Coober Pedy S10E binder, the hardening index was the largest among the binders (increase of 23.4% after ageing, refer to Table 13). This suggests that the bitumen components in this binder may have hardened particularly more than other binders, and this resulted in a negative change of the δ value after ageing (i.e. the binder became apparently more elastic because the bitumen components became more elastic). The S10E class binders are known to contain relatively small amounts of polymers. With only a small amount of polymer included, it is possible that the bitumen components are still dominant even at 60 °C. The polymer components may have experienced certain physical changes (e.g. reduction in elasticity) but their contribution to the apparent binder properties would not be as evident as some of the high content PMBs.

Likewise, if the Coober Pedy binders experienced generally more hardening in the bitumen components than those of the Cooma binders, the magnitude of δ changes after ageing may actually be smaller than those of the Cooma binders due to the larger property changes of bitumen components (i.e. larger offset in elasticity between bitumen and polymer components).

CONCLUSIONS

A series of trial sprayed seals using PMB binders, located at Coober Pedy, South Australia, and Cooma, New South Wales, have been assessed after 12 months of service life.

On-site visual inspections found the seals at the Coober Pedy site are in generally good condition. Whilst surface texture is more hungry than ultimately desired, there are no major signs of distress or failures at this stage. Some of the seals at the Cooma site are performing well, however there has been significant stripping in parts which may require maintenance intervention before long. There is no cracking evident on the new seals at the Coober Pedy site, but there are some instances of cracks from cement stabilisation joins reflecting back through at the Cooma site.

Laboratory binder testing indicates that both C170 bitumens used in the trials met the requirements of the Australian bitumen specification (Standards Australia AS2008-1997). Three of the five Austroads grade PMB binders which were used in the Coober Pedy trial, and one of the five Austroads grade PMB binders which were used in the Cooma trial, met all tested requirements of the Australian PMB specification (Austroads 2010) at the ‘as manufactured’ stage.

Differences between ‘as manufactured’ and ‘as delivered’ samples were not as marked for PMB samples obtained during the Cooma trial, which may be due to the longer transport distances and thus additional heating required for the Coober Pedy trial.

The emulsions and proprietary products used in the trials have been tested and likened to equivalent grades from the Australian PMB specification (Austroads 2010).

Several binders from the trial showed test properties which conformed to specified properties for asphalt grade, rather than sprayed grade, PMBs. Future monitoring will give an indication of how asphalt grade PMBs will perform in sprayed sealing applications.

DSR testing was used as a characterisation tool for age hardening and changes in viscoelastic properties of the binders. The investigation on the age hardening showed that the binders placed in the Coober Pedy site experienced larger changes compared to the Cooma site, agreeing with the general expectation that a faster ageing process would occur in the hotter climate. The investigation on the viscoelastic changes showed rather complicated results and this appears to be due to complex interactions between bitumen and polymer components (e.g. changes in elastic properties of one component offsetting that of the other component) which could not be fully explained in the study.

It is expected that after two years of surface life, more definitive judgements of key sprayed seal performance indicators, surface texture and binder level can be made, compared to this stage of the seal life when they are still actively developing.

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