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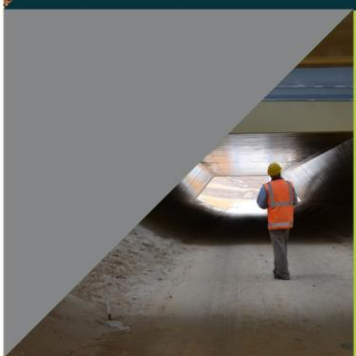
WESTERN AUSTRALIAN ROAD RESEARCH AND INNOVATION PROGRAM

A Review of Stone Mastic Asphalt in Western Australia

Phase 1



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A Review of Stone Mastic Asphalt in Western Australia
2016-002

for Main Roads Western Australia

	Reviewed
Project Leader	Joe Grobler
Quality Manager	Elsabe van Aswegen

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ABN 68 004 620 651

Victoria
80A Turner Street
Port Melbourne VIC 3207
Australia
P: +61 3 9881 1555
F: +61 3 9887 8104
info@arrb.com.au

Western Australia
191 Carr Place
Leederville WA 6007
Australia
P: +61 8 9227 3000
F: +61 8 9227 3030
arrb.wa@arrb.com.au

New South Wales
2-14 Mountain St
Ultimo NSW 2007
Australia
P: +61 2 9282 4444
F: +61 2 9280 4430
arrb.nsw@arrb.com.au

Queensland
21 McLachlan St
Fortitude Valley QLD 4006
Australia
P: +61 7 3260 3500
F: +61 7 3862 4699
arrb.qld@arrb.com.au

South Australia
Level 11,
101 Grenfell Street
Adelaide SA 5000
Australia
P: +61 8 7200 2659
F: +61 8 8223 7406
arrb.sa@arrb.com.au

SUMMARY

Stone Mastic Asphalt (SMA) is a gap graded asphalt mix that can be highly resistant to permanent deformation due to the interlocking stone-on-stone skeleton that the grading provides. The purpose of the project was to review current SMA practices in Western Australia (WA) and identify opportunities for improvement to Main Roads Western Australia (Main Roads) Specification 502 *Stone Mastic Asphalt*.

A review was undertaken of current SMA practices in WA and compared it against practices nationally and in Germany. The review found that the grading specified by Main Roads and VicRoads (heavy duty application) are typically coarser on the intermediate sieve sizes compared to the grading specified by the Queensland Department of Transport and Main Roads (TMR), Department of Planning, Transport and Infrastructure (DPTI) and New South Wales Roads and Maritime Services (RMS) for a 10 mm SMA mix. Furthermore, the Main Roads grading is also coarser than the grading required in Germany.

The German specification also targets a lower air void content compared to Main Roads, which is likely to result in higher binder contents and denser field mixes.

The asphalt production results provided by local asphalt suppliers indicated that the average laboratory air voids were close to the upper specification limit, primarily due to lower binder contents. As a result, the VFB values were also significantly lower than the estimated values for a typical SMA in Germany.

There is therefore an opportunity to align the Main Roads specification more closely with the German and TMR specifications, particularly with regard to laboratory design air voids and grading.

Previous studies found that the wax coating method for determining the bulk density of compacted asphalt currently being used by Main Roads is suitable for SMA mixes with an air void content of less than 7%. However, indications are that some of the SMA mixes currently being placed in WA may exceed the 7% limit in the field. An opportunity was also identified to replace the wax coating method with the less expensive and less time consuming SSD method.

Comparative testing did not show an appreciable difference between the bulk density of SMA specimens determined by AS 2891.9.2-2005 and WA 733.1-2012. There is therefore an opportunity for Main Roads to harmonise test method WA 733.1-2012 with national practice.

Local asphalt suppliers were surveyed as part of the project to identify key areas of concern regarding the supply of SMA in WA. Some of the key findings include difficulties in adding the required filler amounts and fibres when using older asphalt plants, challenging aggregate grading requirements and availability of suitable quantities of baghouse dust. The suppliers also expressed a desire to develop their own SMA mix designs (including performance testing), which could then be approved by Main Roads.

A theoretical analysis undertaken showed the importance of providing adequate support underneath thin SMA surfacings, as well as a good bond between the surfacing layer and underlying pavement to reduce the risk of premature fatigue cracking.

The study found that there is a high risk of achieving undesirable air void contents (i.e. greater than 8%) when a minimum characteristic Marshall density ratio of 95% (as per the current Main Roads specification) is achieved during construction. It is therefore recommended that Main Roads consider increasing the minimum compaction standard to ensure more durable and less permeable SMA mixes in-service.

The laboratory investigation undertaken as part of the project showed that the four SMA mixes (with hydrated lime) tested had voids in the dry compacted filler values of between 40%–48%, exceeding the minimum requirements specified by TMR and RMS. These results suggest that the SMA mixes included in the study should have adequate stability in service.

However, one of the mixes that included lime kiln dust as an added filler, which had voids in the dry compacted filler to a value of 48%, indicating a mix with possible poor workability in the field. This risk was supported by a higher fixed binder fraction compared to the other mixes. This highlighted the potential detrimental effect of adding fillers with high air void contents (such as lime kiln dust) on the workability of SMA mixes.

The Methylene blue values determined for the filler combinations tested are well below the maximum allowable limit specified by some SRAs, which suggests that the filler combinations included in this study does not present a risk to the moisture resistance of the asphalt mixes tested.

All four of the mixes tested had a mix volume ratio of less than 0.9, indicating that the desirable stone-on-stone contact was achieved in the laboratory prepared mixes.

Based on the findings of the project, it is recommended that Main Roads consider the following amendments in an updated version of Specification 502:

- targeting a lower design air void content, including a finer particle size distribution
- introducing a permanent deformation requirement
- increasing the minimum field compaction standard
- replacing the current wax coating test method for determining the bulk density of SMA specimens extracted from the pavement with the SSD method, including a check on water absorption
- replacing test method WA 733.1-2012 with AS 2891.9.2:2014
- introducing a minimum voids in the dry compacted filler requirement
- introducing a maximum fixed binder fraction
- introducing a maximum mix volume ratio
- introducing a maximum Methylene blue value for the combined filler component in SMAs manufactured using fillers from source materials that may contain deleterious clayey materials (such as weathered basalt).

It is important to note that the impact of these recommendations on SMA mixes in WA should be further assessed during the implementation phase. Main Roads could also consider a transition period, whereby a number of the proposed criteria be included initially as ‘report only’ to gather data and gain confidence in the proposed new specification limits.

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

1.1 Background

Stone Mastic Asphalt (SMA) is a gap graded asphalt mix that can be highly resistant to permanent deformation (if properly designed) due to the interlocking stone-on-stone skeleton that the grading provides. The asphalt mix comprises of a coarse aggregate skeleton that is filled with a mastic containing binder, filler and fine aggregate. SMA typically exhibits good durability, low permeability, high resistance to reflective cracking and high deformation resistance. It is also often used in areas that require a textured surface and good skid resistance. Given that SMA is less susceptible to ravelling than open graded asphalt, it is also suitable for use at intersections or other high stress areas where the use of open graded asphalt is not necessarily appropriate (Austroads 2014).

Main Roads Western Australia (Main Roads) previously developed Specification 502 *Stone Mastic Asphalt* for the manufacture and placement of SMA on the state-controlled road network (Main Roads 2016). To date, Main Roads has heavily supervised the design and construction of SMA projects using this specification.

1.2 Purpose

The purpose of the project was to review current SMA practices in Western Australia (WA) and to identify opportunities for improvement to the current version of Specification 502.

1.3 Project Scope

The project scope included the following main activities:

- comparing the Main Roads specification against SMA specifications from the Queensland Department of Transport and Main Roads (TMR), New South Wales Roads and Maritime Services (RMS), Roads Corporation Victoria (VicRoads), Department of Planning, Transport and Infrastructure (DPTI), the Institution of Public Works Engineering Australia (IPWEA) / Australian Asphalt Pavement Association (AAPA) and Germany
- summarising current SMA practices in WA and identifying key areas of concern regarding the manufacture and placement of SMA
- reviewing recent SMA production results from asphalt suppliers in the Perth area
- assessing the historical performance of several sites where SMA was placed in Perth
- reviewing current SMA practices by TMR, RMS and VicRoads
- reviewing current pavement design practices for SMA
- assessing known areas of concern with SMA in WA
- undertaking laboratory testing on typical SMA mixes and fillers used in WA
- documenting the findings and recommendations in a research report.

2 OVERVIEW OF SMA SPECIFICATIONS

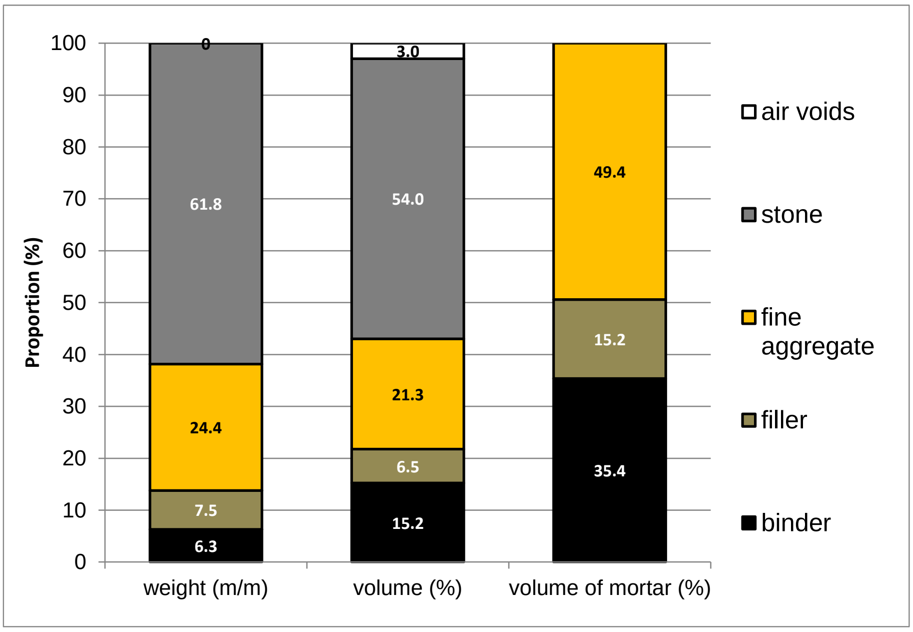
2.1 Stone Mastic Asphalt Composition

SMA is a coarse gap-graded asphalt mix with stone-on-stone contact between the coarse aggregates. This stone-on-stone contact is the primary contributor to the stability of the compacted layer. (Austroads 2013a).

The gap-graded structure of SMA allows for the voids between the coarse aggregates to be filled with a mastic that has higher binder and filler contents compared to dense graded asphalt. In return, the mastic improves the durability of the asphalt mix because of increased cohesion, reduced moisture sensitivity and improved fatigue characteristics (Kreide, Budija & Carswell 2003).

The filler/binder combination is also an important element of the mix design that can influence the workability of SMA mixes (Austroads 2013a). The typical composition of a 10 mm SMA mix is shown in Figure 2.1.

Figure 2.1: Typical composition of a 10 mm SMA mix



Source: Austroads (2013a).

2.2 SMA Specifications in Australia

Currently, most Australian state road agencies (SRAs) have their own specification for SMA. Austroads also published a specification framework for SMA mixes in the 2007 version of the Austroads *Guide to Pavement Technology Part 4B: Asphalt* (Austroads 2007a).

The following specifications and guidelines were reviewed to gain a better understanding of SMA mix design, manufacturing and construction practices in Australia:

- Main Roads: Specification 502, *Stone Mastic Asphalt*, May 2016
- VicRoads: Section 404, *Stone Mastic Asphalt*, April 2012
- RMS: QA Specification R121, *Stone Mastic Asphalt*, November 2013
- TMR: MRTS30, *Asphalt Pavements*, October 2017

- DPTI: Specification R27, *Supply of Asphalt*, May 2017 and Specification R28, *Construction of Asphalt Pavements*, October 2016
- Austroads: *Austroads Guide to Pavement Technology Part 4B, Asphalt*, 2007
- IPWEA / AAPA: Technical Specification, *Tender Form and Schedule for Supply and Laying of Asphalt Road Surfacing*, 2016.

Territory and Municipal Services (TAMS) of the Australian Capital Territory (ACT) adopts the RMS specification for SMA. The Tasmanian Department of State Growth and the Northern Territory Department of Infrastructure, Planning and Logistics do not appear to have any specifications for SMA.

A review of current specifications found that the requirements for SMA vary significantly. The different specification requirements are discussed in more detail below.

2.2.1 SMA types

SMA types are based on the nominal aggregate size of the mix. The different SMA sizes specified by Australian SRAs, Austroads and IPWEA are shown in Table 2.1.

Table 2.1: SMA types defined by jurisdictions

Jurisdiction	Nominal aggregate size
Main Roads	7 mm and 10 mm
VicRoads	10 mm (normal or heavy duty)
RMS	10 mm and 14 mm
TMR	10 mm and 14 mm
DPTI	7 mm and 10 mm
Austroads	7 mm, 10 mm and 14 mm
IPWEA	5 mm, 7 mm, 10 mm and 14 mm

2.2.2 Mix constituents

The specification requirements for the main SMA constituents are presented below.

Binder

Table 2.2 summarises the binder requirements for SMA mixes in Australia.

Table 2.2: Binder requirements for SMA in Australia

Jurisdiction	Mix size	Binder type	Binder content (% by mass)	Maximum binder drain-off (%)
Main Roads(1)	7 mm	A20E	6.5–7.5	0.3
	10 mm		6.0–7.0	
VicRoads(2)	10 mm (normal duty)	A15E, A20E or A25E	6.5–7.5	0.3
	10 mm (heavy duty)	A10E	6.0–7.0	0.3
RMS(3)	10 mm	Polymer modified binder or a multigrade binder	6.2–7.2	0.3
	14 mm		6.0–7.0	

Jurisdiction	Mix size	Binder type	Binder content (% by mass)	Maximum binder drain-off (%)
TMR(4)	10 mm	A15E	≥ 14.5(8)	0.3
	14 mm		≥ 13.5(8)	
DPTI(5)	7 mm	A15E or A5E	7.0 (target)	0.3
	10 mm		6.5 (target)	
Austroads(6)	7 mm	n/a	6.0–7.3	0.3
	10 mm		6.0–7.0	
	14 mm		5.8–6.8	
IPWEA(7)	5 mm	C320	6.0–8.0	0.3
	7 mm		6.0–8.0	
	10 mm		6.0–8.0	
	14 mm		5.5–7.5	

1 Source: Main Roads (2016).
2 Source: VicRoads (2012).
3 Source: RMS (2013).
4 Source: TMR (2017a).
5 Source: DPTI (2017a).
6 Source: Austroads (2007a).
7 Source: IPWEA (2016).
8 TMR specifies a minimum effective binder volume.

The binder type specified by each jurisdiction is as follows:

- VicRoads, TMR, DPTI and Main Roads specify a polymer modified binder (PMB).
- RMS specifies that either a PMB or multigrade (MG) binder must be used.

The typical binder content for a 7 mm and 10 mm SMA varies between 6.0–8.0%. A maximum binder drain-off limit of 0.3% is also specified by all the road agencies, when tested in accordance with Austroads test method AGPT/T235-06 *Asphalt binder drain-off*.

It can be seen from Table 2.2 above that the binder content requirements specified by Main Roads are generally in line with binder contents specified by the other SRAs in Australia.

Mineral Fillers

Austroads defines mineral fillers as the proportion of mineral matter that passes the 0.075 mm sieve. This can include a portion of the coarse and fine aggregate grading, recycling of the dust produced during the manufacturing process, or added material (Austroads 2014).

SRAs in Australia typically specify a combined filler content of between 8% and 12% for SMA mixes, except for TMR that specifies between 6.5% and 12.5% (refer section 2.2.3).

Hydrated lime

Hydrated lime is often added to asphalt as a filler to reduce the moisture susceptibility (i.e. stripping potential) of a mixture. However, hydrated lime also has a stiffening effect on binders and may increase the risk of poor mix workability and low field compaction during construction (Austroads 2013b). The following observations were made regarding the use of hydrated lime in SMA mixes by the Australian SRAs:

- Main Roads specifies that the proportion of hydrated lime (by percentage mass of total aggregate) must be 1.5% for both 7 mm and 10 mm SMA mixes used in Perth.

- The current VicRoads specification makes no reference to hydrated lime.
- RMS specifies a minimum of 1.5% of hydrated lime by mass of total aggregate.
- TMR specifies a minimum of 1% hydrated lime by mass of total aggregate only if the combined filler (excluding hydrated lime) has a methylene blue value of between 10 mg/g and 18 mg/g. The methylene blue value of the filler is determined in accordance with AS 1141.66-2012 *Methods for sampling and testing aggregates: methylene blue absorption value of fine aggregate and mineral fillers* and is an indication of the amount and type of clay in the filler component that could be detrimental to the moisture resistance of asphalt mixes.
- DPTI specifies that all asphalt wearing courses, including SMA, must contain at least 1% of added hydrated lime by mass of total aggregate.

Fibre additives

Fibres are typically added to SMA to control binder drain-off. All the SRA specifications that were reviewed specify a minimum fibre content of 0.3%. Whilst it is a standard requirement that cellulose fibres are used, DPTI also allows for the use of rock wool, glass fibre and other organic sources.

An allowance is made in some specifications for the contractor to propose and use alternative fibre additives (subject to a technical review), provided that the contractor submits documented evidence of successful use or trials are undertaken.

Adhesion agent

Adhesion agents can be used to increase the physio-chemical bond between the binder and aggregate, resulting in a reduced moisture sensitivity of asphalt mixes (Austroads 2014). The following observations were made regarding the use of adhesion agents in the Australian SMA specifications reviewed as part of the project:

- Main Roads specifies that adhesion agents must meet the requirements in Main Roads Specification 511: *Materials for Bituminous Treatments* (Main Roads 2017). The adhesion agent in asphalt mixes is typically hydrated lime. However, an approved liquid adhesion can be used in applications where the use of hydrated lime is not practical (such as rural regions).
- The current VicRoads specification does not appear to make any reference to adhesion agents.
- RMS, TMR and DPTI allow for the use of adhesion agents in SMA mixes.

2.2.3 Grading

The combined aggregate grading envelopes for SMA mixes specified in Australia are summarised in Table 2.3.

Table 2.3: SMA grading requirements in Australia

AS sieve size (mm)	Main Roads[1]		VicRoads[2]		RMS[3]		TMR[4]		DPTI[5]		Austroads[6]			IPWEA[7]			
	Percentage passing sieve size (%)																
	7 mm	10 mm	10 mm (normal duty)	10 mm (heavy duty)	10 mm	14 mm	10 mm	14 mm	7 mm	10 mm	7 mm	10 mm	14 mm	5 mm	7 mm	10 mm	14 mm
19.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
13.2	100	100	100	100	100	76–100	100	84–100	100	100	100	100	90-100	100	100	100	90–100
9.5	100	90–100	90–100	90–100	80–100	31–64	85–100	40–65	100	90–100	100	90–100	30–40	100	100	90–100	30–40
6.7	90–100	25–40	45–65	25–45	31–64	16–44	40–62	25–45	85–100	30–55	90–100	25–40	20–30	100	90–100	25–40	20–30
4.75	25–40	18–30	30–50	18–32	16–44	14–36	25–45	18–32	30–62	20–40	25–45	18–30	18–30	90–100	25–45	18–30	18–30
2.36	15–28	15–28	21–31	15–30	13–31	13–31	18–31	14–28	20–35	15–28	15–28	15–28	15–28	25–40	15–28	15–28	15–28
1.18	13–24	13–24	16–25	13–24	11–27	11–27	14–28	12–24	16–28	13–24	13–24	13–24	13–24	13–24	13–24	13–24	13–24
0.600	12–21	12–21	14–22	12–21	8–24	8–24	12–24	10–20	14–24	12–21	12–21	12–21	12–21	12–21	12–21	12–21	12–21
0.300	10–18	10–18	12–19	10–18	7–21	7–21	10–20	9–17	12–20	10–18	10–18	10–18	10–18	10–18	10–18	10–18	10–18
0.150	9–14	9–14	9–15	9–15	8.5–16.0	8.0–16.0	8–17	7.5–14.5	10–16	9–14	10–16	9–14	9–14	9–14	9–14	9–14	9–14
0.075	8–12	8–12	8–12	8–12	7.5–12.5	7.5–12.5	6.5–12.5	6.5–12.5	8–12	8–12	8–12	8–12	8–12	8–12	8–12	8–12	8–12

1 Source: Main Roads (2016).
2 Source: VicRoads (2012).
3 Source: RMS (2013).
4 Source: TMR (2017a).
5 Source: DPTI (2017a).
6 Source: Austroads (2007).
7 Source: IPWEA (2016).

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Main Roads, DPTI and IPWEA are the only jurisdictions that have a 7 mm SMA specification. The centreline grading specified by these jurisdictions are shown in Figure 2.2. The grading specified by DPTI for a 7 mm SMA mix is finer than the gradings adopted by Main Roads and IPWEA.

Figure 2.2: Centreline grading – 7 mm SMA

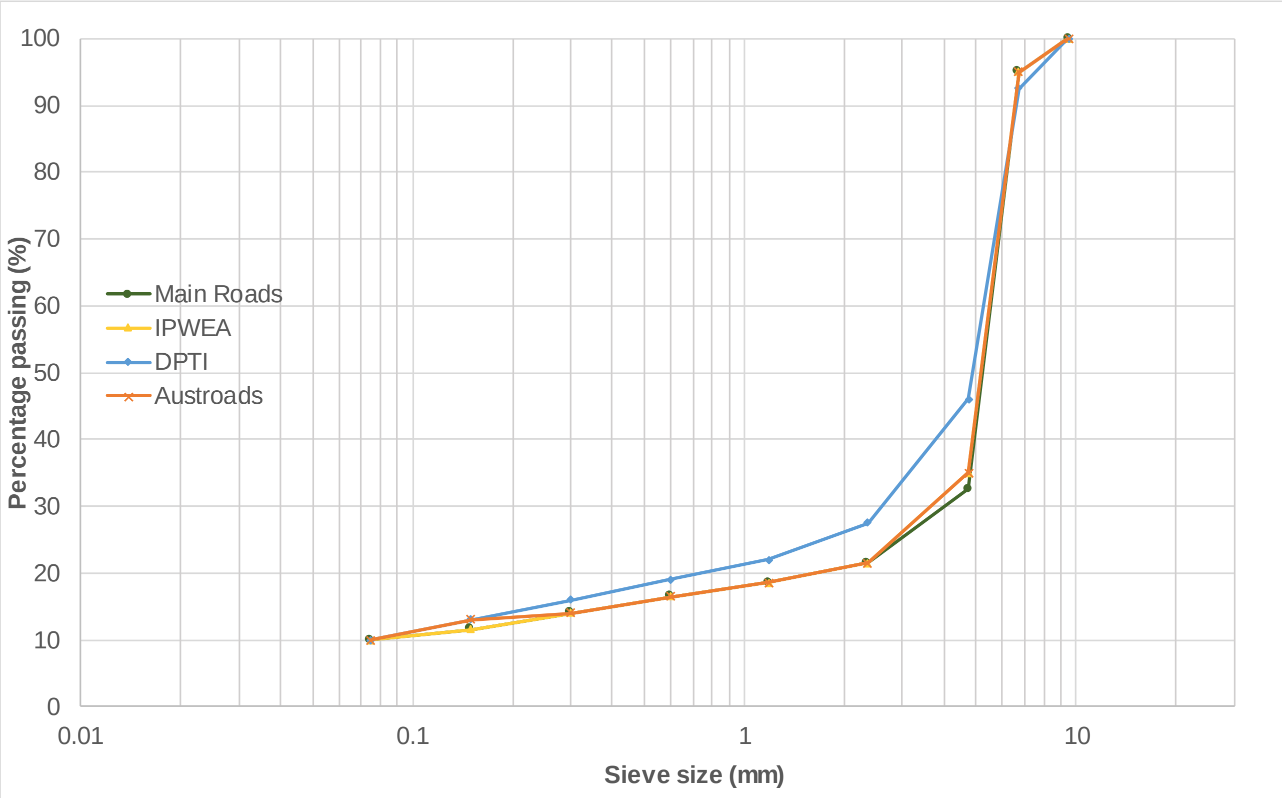
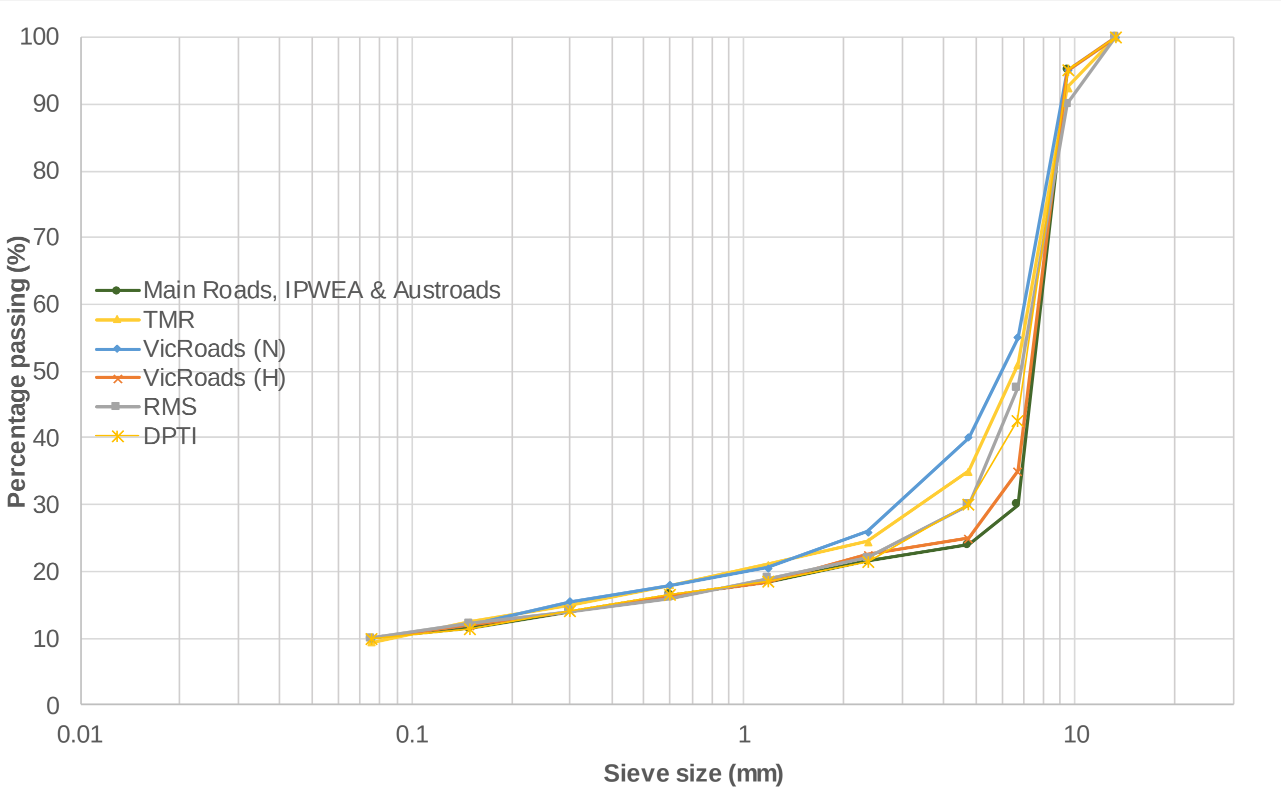


Figure 2.3 provides the centreline grading specified by the various SRAs for a 10 mm SMA mix. It is clear from the comparison that there is a large difference between the grading envelopes, especially on the 4.75 mm and 6.70 mm sieve sizes.

The grading specified by Main Roads and VicRoads (heavy duty application) are typically coarser on the intermediate sieve sizes (i.e. 6.70 mm, 4.75 mm and 2.36 mm) compared to the grading specified by TMR, RMS and DPTI for a 10 mm SMA mix. The grading specified by TMR and VicRoads (normal duty application) are typically finer across all the sieve sizes compared to the other road agencies.

Figure 2.3: Centreline grading – 10 mm SMA



2.2.4 SMA volumetric properties in Australia

The SMA mix design requirements vary between the various specifications reviewed. The laboratory compaction and volumetric requirements specified for SMA mixes in Australia are summarised in Table 2.4.

RMS and DPTI specify gyratory compaction for the design of their SMA mixes, whereas all the other road agencies specify a 50 blow Marshall compaction level.

The air void limits for a 7 mm SMA specified by Main Roads, DPTI, IPWEA and Austroads vary between a lower limit of 3.0–3.5% and an upper limit of 4.5–5.5%.

The air voids specified by Main Roads for a 10 mm SMA range between 3.5–5.5%, which is similar to the limits specified by VicRoads for a normal duty mix, DPTI and IPWEA. RMS specifies a 1.0% higher air void content for their 10 mm SMA compared to Main Roads. TMR has the lowest minimum air void requirement (2%) compared to the other agencies. However, TMR advised ARRB that between 3.0% and 3.5% air voids are typically targeted during the mix design process.

It is worth noting that Main Roads uses Marshall compaction for the design of their SMA mixes, whereas RMS and DPTI use gyratory compaction. The laboratory compacted air voids specified by these agencies may therefore not necessarily be directly comparable.

The minimum voids in mineral aggregate (VMA) limits specified are similar across all jurisdictions. RMS and TMR are the only SRAs that do not specify a minimum VMA value. They do however specify a maximum mix volume ratio, which is a function of the volume of air voids in the coarse aggregate of the mix.

Table 2.4: Laboratory compaction and volumetric requirements for SMA mixes in Australia

Jurisdiction	Mix size	Laboratory compaction level	Laboratory compacted air voids (%)		VMA (%)
			Min.	Max.	Min.
Main Roads[1]	7 mm	50 blows (Marshall)	3.0	5.0	19
	10 mm		3.5	5.5	18
VicRoads[2]	10 mm (normal duty)	50 blows (Marshall)	3.5	5.0	18
	10 mm (heavy duty)		4.8	5.2	18
RMS[3]	10 mm	80 cycles (Gyratory)	3.5	6.5	n/a
		350 cycles (Gyratory)	2.0	n/a	
	14 mm	80 cycles (Gyratory)	3.5	6.5	n/a
		350 cycles (Gyratory)	2.5	n/a	
TMR[4]	10 mm	50 blows (Marshall)	2	5	n/a
	14 mm	50 blows (Marshall)			
DPTI[5]	7 mm	80 cycles (Gyratory)	3.5[8]		n/a
	10 mm	80 cycles (Gyratory)			n/a
Austroads[6]	7 mm	50 blows (Marshall - normal/medium duty) or 80 cycles (Gyratory - normal/medium duty) 75 blows (Marshall - heavy duty) or 120 cycles (Gyratory - heavy duty)	3.5	4.5	19
	10 mm		3.5	4.5	18
	14 mm		3.5	4.5	17
IPWEA[7]	7 mm, 10 mm and 14 mm	50 blows (Marshall) or 80 cycles (Gyratory)	3.5	5.5	n/a

1 Source: Main Roads (2016).
2 Source: VicRoads (2012).
3 Source: RMS (2013).
4 Source: TMR (2017a).
5 Source: DPTI (2017a).
6 Source: Austroads (2007).
7 Source: IPWEA (2016).
8 Design air voids are targeted at 3.5% for all mixes.

2.2.5 SMA mix performance requirements in Australia

The performance requirements specified by the various road jurisdictions are summarised in Table 2.5.

Table 2.5: Mix performance requirements for SMA in Australia

Jurisdiction	Property	Test method	Requirement
Main Roads[(1)]	Stability (kN)	WA731.1-2017	6 (min.)
	Flow (mm)		2–5
VicRoads[(2)]	Stability (kN)	AS/NZS 2891.5:2015	5.5 (min.)
	Resilient modulus (MPa)	AS/NZS 2891.13.1:2013	Report only
RMS[(3)]	Deformation resistance (mm)	AG:PT/T231-06	2.5 (max.)
TMR[(4)]	Resilient modulus (MPa)	AS/NZS 2891.13.1:2013	Report only
	Deformation resistance (mm)	AG:PT/T231-06	2.0 (max.)
DPTI[(5)]	Indirect tensile strength	DPTI: TP460-2013	Report only
	Deformation resistance (mm)	AG:PT/T231-06	3.0 (max.)
	Flexural fatigue (min. microstrain at 1 million cycles)	DPTI: TP477-2015	350 (SMA 10M15E)
			250 (SMA 10M5EP)
	Resilient modulus (MPa)	AS/NZS 2891.13.1:2013	1000–3000
			4000–6000
IPWEA[(6)]	Cantabro abrasion loss (%)	Not specified	25 (unconditioned)
			35 (conditioned)

1 Source: Main Roads (2016).
2 Source: VicRoads (2012).
3 Source: RMS (2013).
4 Source: TMR (2017a).
5 Source: DPTI (2016).
6 Source: IPWEA (2016).

There is not currently a harmonised approach to specifying performance properties for SMA mixes in Australia. Deformation resistance is however the most commonly specified performance property.

2.2.6 SMA field compaction requirements in Australia

The field compaction requirements specified by the various jurisdictions are summarised in Table 2.6. A review of the compaction requirements indicates that there is currently not a harmonised approach to specifying field compaction of SMA mixes in Australia. RMS, TMR and DPTI specify a minimum and maximum limit for the in situ air voids of the compacted SMA layer, whereas Main Roads, VicRoads and IPWEA specify a minimum Density Ratio based on Marshall compaction. The Density Ratio is defined as the ratio between the compacted in situ field density and the Marshall density of an asphalt specimen determined in the laboratory. This ratio can however not be directly related to an in situ air void content without first determining the maximum theoretical density of the SMA mix in the laboratory.

The maximum in situ air void content specified by RMS, TMR and DPTI varies between 6–7%. This is considered to be the upper desirable limit for SMA. An upper air void content of 10% specified by IPWEA is considered very high and could potentially lead to permeable SMA layers in the field (Soward 2009).

Table 2.6: Compaction requirements for SMA in Australia

Jurisdiction	Mix size	In situ air voids (%)(1)		Density Ratio (%)(2)
		Minimum	Maximum	Minimum
Main Roads(3)	7 mm and 10 mm	Not specified	Not specified	95% characteristic value of Marshall density
VicRoads(4)	10 mm (normal or heavy duty)	Not specified	Not specified	96% characteristic value of Marshall density or 97.5% mean value of Marshall density(9)
RMS(5)	10 mm and 14 mm	3	7	Not specified
TMR(6)	10 mm	2	7	Not specified
	14 mm	2	6	
DPTI(7)	7 mm and 10 mm	2.5	7	Not specified
IPWEA(8)	7 mm, 10 mm and 14 mm	3.5	10	94.5

1 Based on characteristic values.
2 Ratio between the bulk density of field cores and Marshall density.
3 Source: Main Roads (2016).
4 Source: VicRoads (2012).
5 Source: RMS (2013).
6 Source: TMR (2017a).
7 Source: DPTI (2016).
8 Source: IPWEA (2016).
9 Characteristic value used where 6 or more tests are available.

2.3 SMA Specifications in Germany

SMA originated in Germany and was first developed to provide high levels of rut resistance, skid resistance, wear resistance, and low susceptibility to cracking (Rebbechi et al. 2003). The requirements for SMA mixes and the constituent materials in Germany are summarised below.

2.3.1 SMA types in Germany

Germany specifies the following SMA categories namely, SMA 11 S, SMA 8 S and SMA 5 S for heavy loading, and SMA 8 N and SMA 5 N for normal loading conditions (Austroads 2013a). The SMA used in normal loading applications has a finer grading and allows for softer binders to be used (Rebbechi et al. 2003).

2.3.2 Mix constituents

The requirements for manufacturing SMA in Germany are specified in TL Asphalt-StB 07/13 and some of the key elements are discussed below (FGSV 2013a).

Binder

FGSV (2013a) specifies PMBs for SMA mixes in heavy loading conditions and conventional (i.e. non-modified) binders for mixes in normal loading conditions. However, the specification also notes that in special circumstance a PMB can be replaced with a conventional binder and vice versa. The properties of the binders used in Germany for SMA mixes are summarised in Table 2.7.

Table 2.7: Binder types typically used in German SMA mixes

Property		Test method	Unit	Conventional binder class(6) 50/70	Conventional binder class(6) 70/100(5)	PMB class(7) PmB 45	PMB class(7) PmB 65
Penetration at 25°C		EN 1426	0.1 mm	50–70	70–100	45–80	65–105
Softening point		EN 1427	°C	46–54	43–51	≥ 70	≥ 60
Resistance to hardening(1)	Retained penetration	EN 12607-1	%	≥ 50	-	≥ 45	≥ 55
	Increase in softening point – severity 1 or Increase in softening point – severity 2(2)	EN 12607-1	°C	≤ 9 or ≤ 11	–	≤ 12	–
	Change of mass(3) (absolute value)	EN 12607-1	%	≤ 0.5	–	≤ 0.8	–
Cohesion(4)	Force ductility (50 mm/min traction)(4)	EN 13589 followed by EN 13703	J/cm^2	–	–	≥ 1 at 5°C	≥ 2 at 10°C
	Tensile test (100 mm/min traction)(4)	EN 13587 followed by EN 13703	J/cm^2	–	–	≥ 1 at 5°C	≥ 3 at 10°C
Flash point		EN ISO 2592	°C	≥ 230	≥ 230	≥ 220	–
Solubility		EN 12592	%	≥ 99.0	≥ 99.0	–	–
Penetration index(2)		EN 12591	–	-1.5 to +0.7	-1.5 to +0.7	–	–
Dynamic viscosity at 60°C		EN 12596	Pa. s	≥ 145	≥ 90	–	
Fraass breaking point(2)		EN 12593	°C	≤ –8	≤ –10	≤ –7	≤ –12
Kinematic viscosity		EN 12595	mm^2/s	≥ 295	≥ 230	–	–
Elastic recovery at 25°C		EN 13398	%	–	–	≥ 60	–

1 Main test is the RTFO test at 163°C but for some highly viscous PMBs where the viscosity is too high to provide a moving film it is not possible to carry out the RTFO test at the reference temperature of 163°C. In such cases the procedure shall be carried out at 180°C in accordance with EN 12607-1.
2 When severity 2 is selected it shall be associated with the requirement for Fraass breaking point or penetration index or both measured on the unaged binder.
3 Change of mass can be positive or negative.
4 One cohesion method shall be chosen based on the end application. Vialit cohesion (EN 13588) shall only be used for surface dressing binders.
5 Typically used for thin SMA wearing courses.
6 Source: EN 12591:2009.
7 Source: EN 14023:2010.

It is not possible (without any comparative testing) to compare the German binders directly to the binders used in Australia given the different specification requirements. However, the conventional binder classes used in Germany appear to be similar to the softer binder grades ((i.e. C240 and C170)) used in Australia based on the penetration values. The German PmB 45 and PmB 65 binders used in heavy loading conditions appear to be similar to an A20E binder, based on the softening point values.

Fillers

The filler type is not specified by TL Gestein-StB 04 (FGSV 2004), but the specification allows the use of mineral fillers and mineral fillers mixed with calcium hydroxide. Furthermore, the use of baghouse fines is also permitted in the German SMA mixes (Austroads 2013a). The German filler requirements are summarised in Table 2.8.

Table 2.8: German filler requirements

Filler type	Filler grading (% passing sieve)[(1)]	Other properties	Test method	Requirement
Mineral filler, mineral filler mixed with calcium hydroxide, fly ash	2 mm – 100% 0.125 mm – 85–100% 0.063 mm – 70–100%	Methylene blue value	DIN EN 933-9	Report
		Water content	DIN EN 1097-5	≤ 1% by mass
		Rigden voids content[(2)]	DIN EN 1097-4	28–45% or 44–55%
		Increased softening point[(3)]	DIN EN 13179-1	8–25 °C or >25 °C
		Water solubility	DIN EN 1744-1	≤ 10% by mass
		Water susceptibility	DIN EN 1744-4	Report
		Calcium carbonate content of limestone fillers[(3)]	DIN EN 196-21	≥ 90% by mass ≥ 80% by mass ≥ 70% by mass
		Calcium hydroxide content of mixed filler[(3)]	DIN EN 459-2	≥ 25% by mass ≥ 20% by mass ≥ 10% by mass
		Loss by combustion of coal fly ash	DIN EN 1744-1	< 10% by mass ≤ 6% by mass

1 Grading in accordance with DIN EN 933-10, maximum grading range 10% by mass.
2 Must satisfy the requirements of one of the categories, maximum declared void content range of 4%.
3 Must satisfy the requirements of one of the categories.
Source: FGSV (2004).

Some of the key filler requirements in Germany include the Methylene blue value, Rigden voids content and the allowable increase in softening point of the mastic.

2.3.3 Grading

The grading envelopes specified in Germany for SMA mixes are shown in Table 2.9. The centreline grading specified by Main Roads and Germany for the different SMA mix types are also shown in Figure 2.4 and Figure 2.5.

Table 2.9: German grading requirements for SMA

Sieve size (mm)	SMA 11 S[(1)]	SMA 8 S[(1)]	SMA 5 S[(1)]	SMA 8 N[(2)]	SMA 5 N[(2)]
	Percentage passing sieve by mass (%)				
16.0	100	100	100	100	100
11.2	90-100	100	100	100	100
8.0	50–65	90–100	100	90–100	100
5.6	35–45	35–55	90–100	35–60	90–100
2.0	20–30	20–30	30–40	20–30	30–40
0.063	8–12	8–12	7–12	7–12	7–12

1 'S' = heavy traffic.
2 'N' = medium traffic.

Source: FGSV (2013a).

Figure 2.4: Centreline grading comparison (7 mm Main Roads vs 8 mm German SMA)

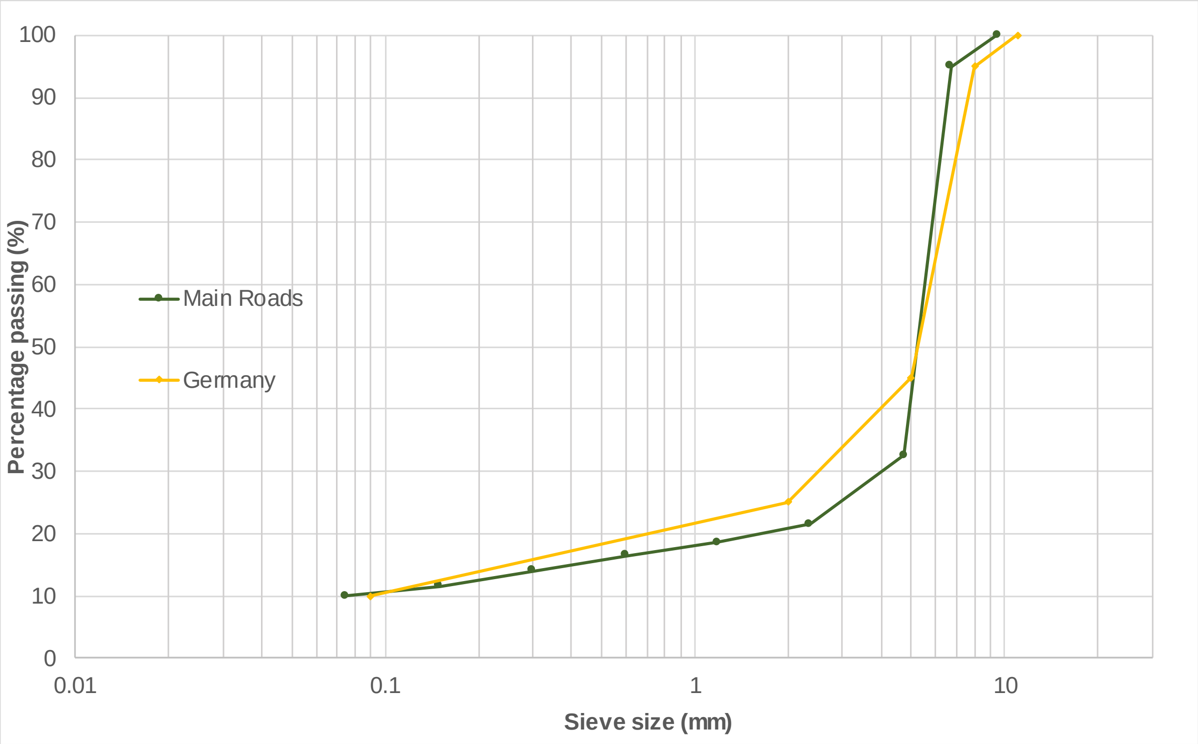
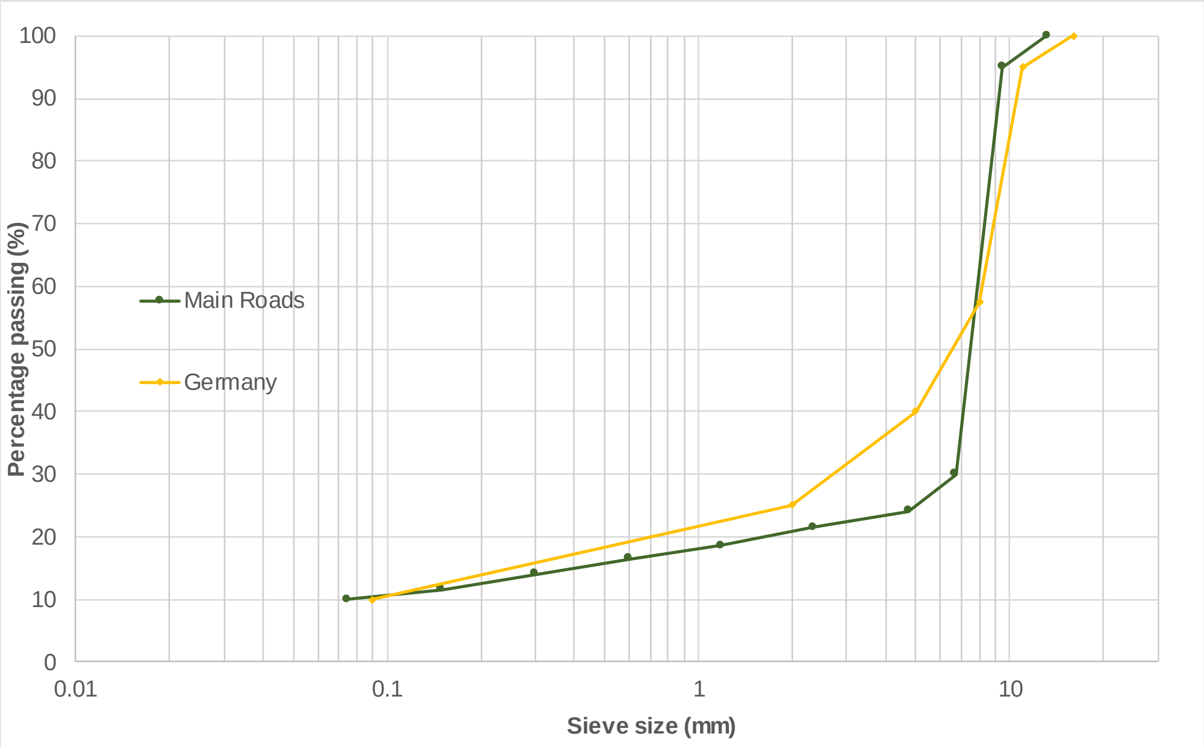


Figure 2.5: Centreline grading comparison (10 mm Main Roads vs 11 mm German SMA)



The gradings specified by Main Roads for SMA mixes are typically coarser than the gradings adopted by Germany for extreme loading applications, particularly on the sieve sizes smaller than 6.70 mm.

2.3.4 Volumetric properties and binder content of SMA mixes in Germany

The laboratory air void and binder contents for SMA mixes specified by Main Roads and Germany are summarised in Table 2.10.

Table 2.10: Main Roads and German volumetric and binder content requirements

Jurisdiction	Mix size	Laboratory compacted air voids (%)		Binder content (%)
		Minimum	Maximum	Target
Main Roads(1)	7 mm	3.0	5.0	6.5–7.5
	10 mm	3.5	5.5	6.0–7.0
Germany(2)	8 mm (heavy duty)	3.0	4.0	7.2 (min)
	11 mm (heavy duty)	3.0	4.0	6.6 (min)

1 Source: Main Roads (2016).
2 Source: FGSV (2013a; 2015).

The German mix design requirements for air void content range between 3.0–4.0% for SMA 8 S and SMA 11 S mixes (these mixes are considered to have a similar maximum aggregate size compared to the Main Roads mixes). The maximum air void content allowed in Germany is between 1.0–1.5% (depending on mix type) lower than the maximum value currently specified by Main Roads.

The minimum binder content specified in Germany is 6.6% for SMA 11 S and 7.2% for SMA 8 S and SMA 8 N respectively. These values are higher than the minimum binder content specified by Main Roads (i.e. 6.0% for SMA 10 and 6.5% for SMA 7).

2.3.5 SMA field compaction requirements in Germany

The German specification specifies a higher degree of field compaction for SMA when compared to Main Roads (i.e. minimum 98% vs 95% density ratio against Marshall density). In addition to the degree of compaction, a maximum absolute in situ air void content of 5% is specified in Germany (FGSV 2013b).

2.3.6 Summary

Considering the lower target laboratory air voids, finer grading, higher minimum binder content, as well as higher compaction standard specified in Germany, it would be reasonable to assume that the SMA mixes placed in Germany are likely to have a lower permeability compared to the mixes placed in WA.

3 A REVIEW OF RECENT SMA PRODUCTION RESULTS IN WA

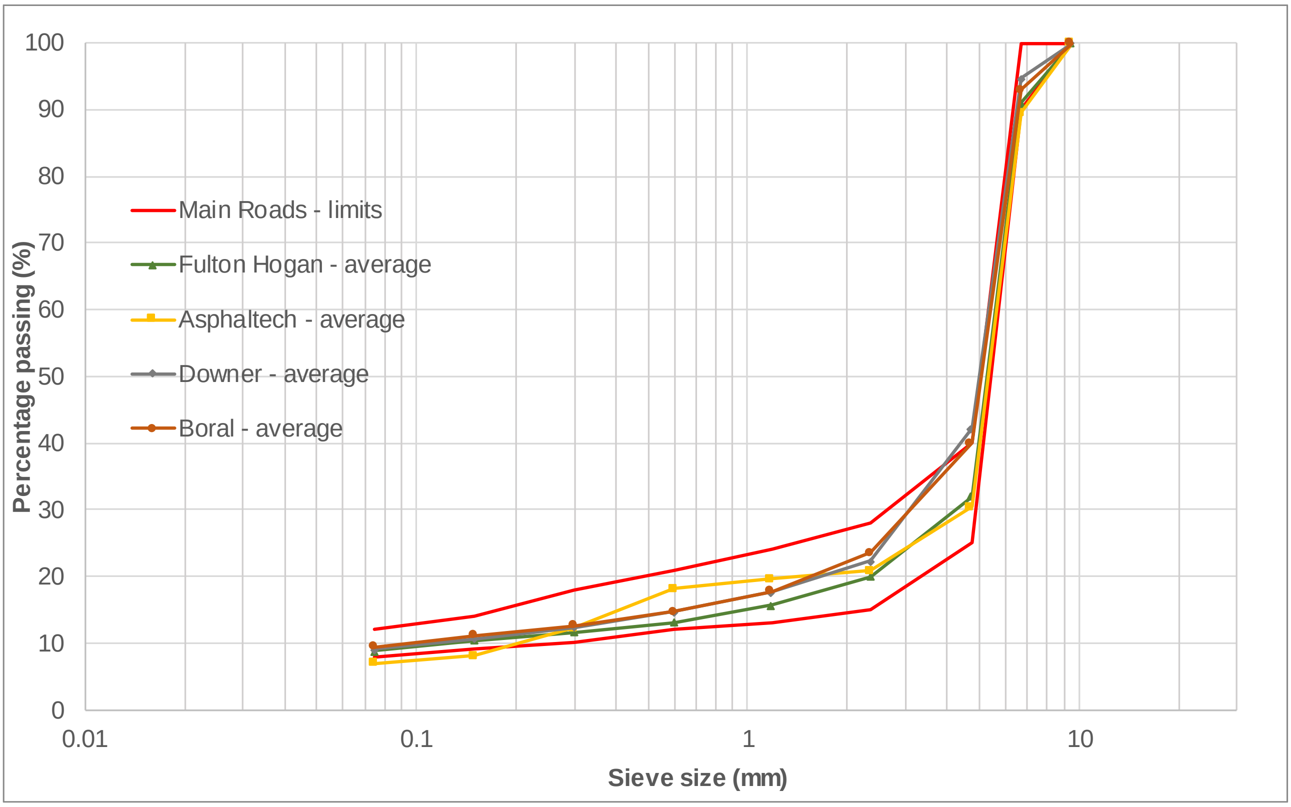
Fulton Hogan, Downer, Boral and Asphaltech provided some production results for their 7 mm SMA and 10 mm SMA mixes produced between 2014 and 2016. Some of the 7 mm SMA mixes were produced in accordance with Main Roads Specification 502, however most of the mixes were produced in accordance with the IPWEA specification. It should be noted that the IPWEA specification allows for the use of conventional C320 binders, whereas an A20E PMB is specified by Main Roads.

3.1 Aggregate Grading and Volumetric Properties

3.1.1 Average grading produced

The average aggregate grading of the SMA mixes analysed are shown in Figure 3.1 and Figure 3.2.

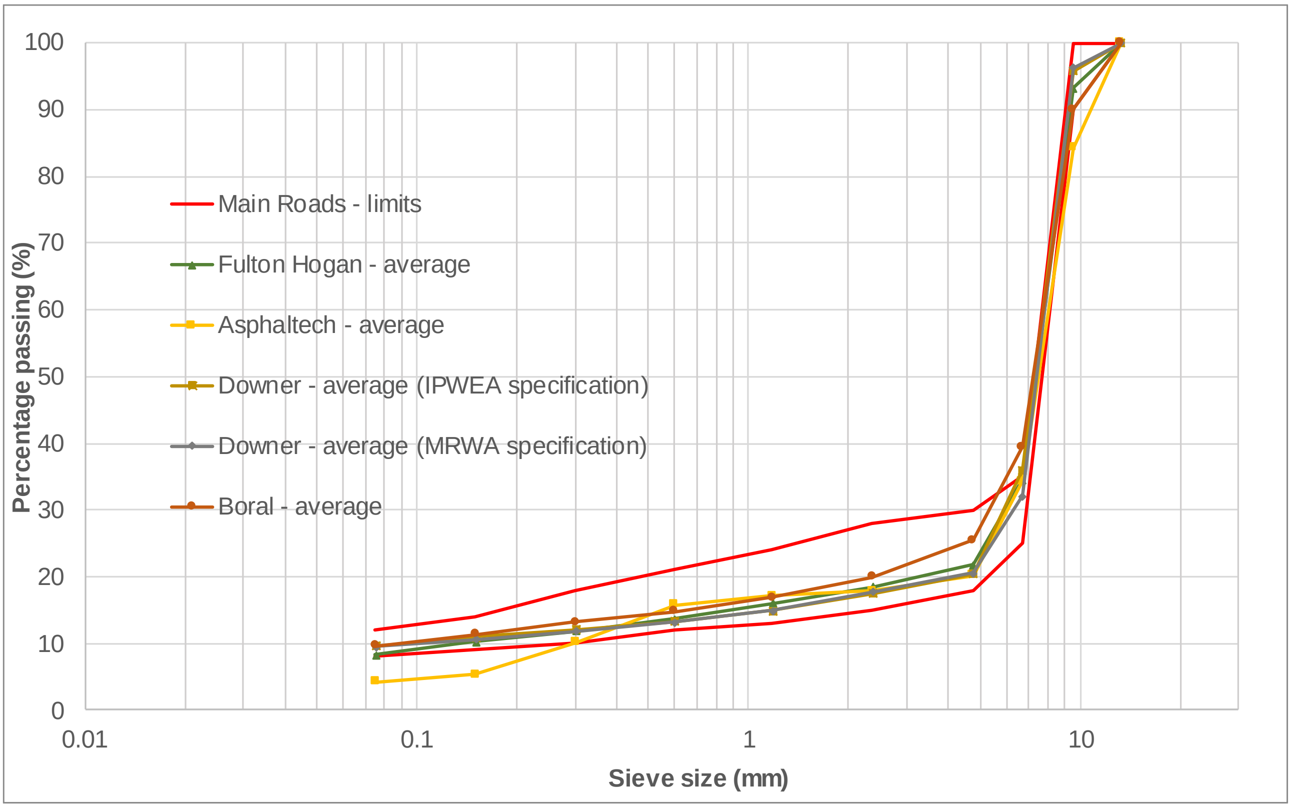
Figure 3.1: 7 mm SMA grading



The average grading of the 7 mm SMA mixes analysed is approaching the lower specification limit (i.e. coarser limit) for the finer particles, particularly the material smaller than the 0.600 mm sieve. In addition, the average grading of the 7 mm SMA mixes produced by Asphaltech was below the minimum limits specified by Main Roads for the 0.150 mm and 0.075 mm sieves.

The mixes produced by Downer and Boral were consistently finer on the 4.75 mm sieve compared to the other suppliers, with several Downer mixes exceeding the maximum allowable value specified by Main Roads.

Figure 3.2: 10 mm SMA grading



Again, the average grading of the 10 mm SMA mixes produced by the various suppliers is on the coarser side of the grading envelope specified for the materials smaller than 4 mm.

The average grading of the 10 mm SMA mixes produced by Asphaltech is also significantly coarser on the 0.150 mm and 0.075 mm sieves (most likely due to a lack of baghouse fines), suggesting that these mixes could potentially be permeable in the field.

All the mixes assessed appear to be finer on the 6.70 mm sieve, with several mixes exceeding the maximum allowable limit specified by Main Roads.

3.1.2 Volumetric properties

The volumetric properties of the 7 mm and 10 mm SMA mixes reviewed are summarised in Table 3.1 and Table 3.2 respectively.

Table 3.1: Summary of 7 mm SMA mix production results

Property	Range of values	Average value[1]	Standard deviation	Main Roads 502 specification		IPWEA specification	
				Minimum	Maximum	Minimum	Maximum
Bitumen content (%)	5.8–7.3	6.8	0.5	6.5	7.5	6.0	8.0
Air voids (%)	3.1–6.0	4.8	0.9	3.0	5.0	3.0	5.5
VMA (%)	18.3–21.4	20.1	0.8	19.0	–	19.0	–
VFB (%)	68.4–84.4	76.0	4.5	–	–	–	–
Marshall Stability (kN)	4.8–8.4	6.4	1.0	6.0	–	–	–
Marshall Flow (mm)	2.7–4.5	3.5	0.4	2.0	5.0	–	–

1 Based on 27 test results.

The test results in Table 3.1 indicate that the 7 mm SMA mixes assessed complied, on average, with the volumetric and Marshall Stability and Flow properties specified by Main Roads. However, a review of the individual test results found that approximately 55% of the air void results exceeded the maximum value of 5% specified by Main Roads. Another 40% of the Marshall Stability values were less than the minimum value specified by Main Roads.

Table 3.2: Summary of 10 mm SMA mix production results

Property	Range of values	Average value(1)	Standard deviation	Main Roads 502 specification		IPWEA specification	
				Minimum	Maximum	Minimum	Maximum
Bitumen content (%)	5.5–6.8	6.2	0.3	6.0	7.0	6.0	8.0
Air voids (%)	3.9–5.7	5.0	0.5	3.5	5.5	3.0	5.5
VMA (%)	18.0–20.7	19.0	0.7	18.0	–	18.0	–
VFB (%)	68.5–78.5	73.9	2.6	–	–	–	–
Marshall Stability (kN)	3.7–9.6	6.3	1.5	6.0	–	–	–
Marshall Flow (mm)	2.6–5.0	3.6	0.5	2.0	5.0	–	–

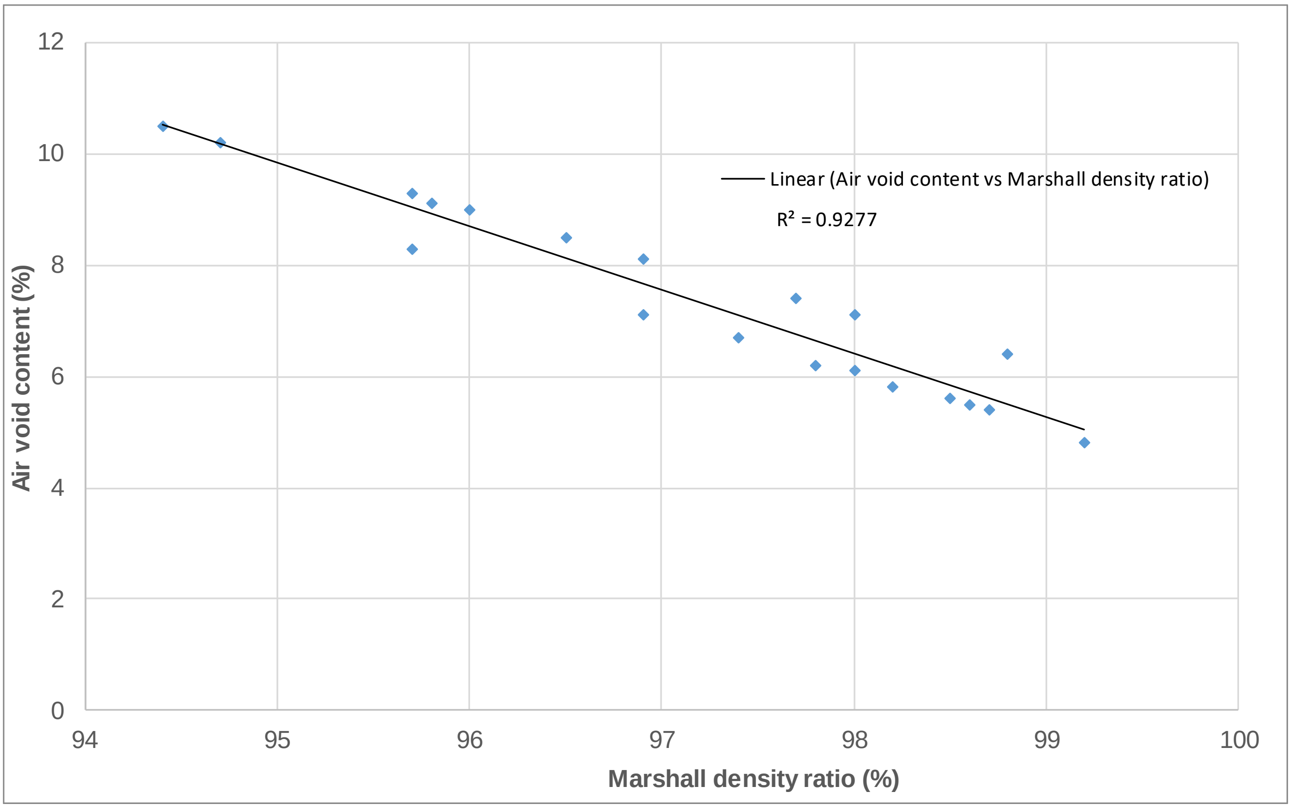
1 Based on 39 test results.

The test results in Table 3.2 indicate that the 10 mm SMA mixes assessed also complied, on average, with the volumetric and Marshall Stability and Flow properties specified by Main Roads. However, a large proportion (i.e. approximately 36%) of the Marshall Stability values were less than the minimum value specified by Main Roads.

3.2 In Situ Air Void Contents of SMA in WA

Main Roads Specification 502 specifies a minimum characteristic percent Marshall density (Rc) ratio of 95% for compacted SMA layers (Main Roads 2016). However, the Marshall density ratio alone does not provide enough information to estimate the in situ air void content of a compacted asphalt layer. Main Roads did however provide ARRB with average Marshall density ratio versus average air void content data for a number of 7 mm and 10 mm SMA projects (refer Figure 3.3).

Figure 3.3: Average Marshall density ratio vs average air void content



The data show a good correlation between the Marshall density ratio and air void content. Furthermore, the data indicate that SMA mixes compacted to a Marshall density ratio of between 95–96.5% (as per current Main Roads criteria) in the field are expected to have air void contents of greater that 8%. These in situ air void contents are considerably higher than the maximum allowable in situ air void content specified by the other SRAs in Australia and in Germany; and could potentially lead to permeable (and less durable) SMA layers in the field.

3.3 Key Observations

The following observations were made regarding the production test results provided by the various suppliers:

- It would appear that the available aggregates typically have relatively low VMA values which could in turn lead to lower binder contents for the SMA mixes. This typically resulted in relatively high laboratory air void contents that are close to the upper specification limits.
- The lower binder and high air void contents typically resulted in low voids filled with binder (VFB) values (i.e. less than 80%). In comparison, if a maximum density of 2.4 t/m^3, binder content of 7.2% and air void content of 2.7% were assumed in accordance with the German specification, the mix would have a VFB value of 85.8% which is considerably higher than the average value determined for the mixes in WA (refer Table 3.1 and Table 3.2).
- Targeting a lower mix design air void content could result in the mixes not meeting the criteria specified for Marshall Stability and Flow. International experience suggests that the Marshall Stability and Flow are not necessarily an appropriate strength test for SMA (Austroads 2007b). A permanent deformation requirement based on wheel tracking tests (similar to TMR) could be considered as an alternative to the Marshall Stability and Flow requirements currently being specified by Main Roads.

- There is a risk of undesirably high in situ field air void contents (i.e. greater than 8%) occurring when a minimum 95% Rc compaction standard is adopted in accordance with Main Roads Specification 502.

4 HISTORIC PERFORMANCE OF SMA IN WA

In order to assess the overall performance of SMA mixes laid on the Main Roads network, ARRB and Main Roads personnel conducted a series of site visits on 9 May 2016. The list of the candidate sites, provided by Main Roads prior to the site visits, is summarised in Table 4.1 and the sites visited are highlighted in grey.

Table 4.1: Site visit locations of SMA on the Main Roads network

Road type	Road	SLK	Lanes	Producer	Date	Mix size / thickness	Binder type	Notes
High stresses or high proportion heavy vehicles	Toodyay Road	7.37	FW	PRS	Nov 2009	10 mm	A20E	Quarry entrance. Gritted at placement. Gets lots of dust from trucks leaving the quarry
	Great Northern Hwy Upper Swan	15.25 16.84 17.25	FW	Downer	2010	10 mm	Unknown	3 sites N of Apple Street. SMA is cracking but adjacent DGA and sealed pavement are not. Suspect possible use of EVA added at the plant instead of A20E.
	Great Northern Hwy Wandena Rd	32.72	FW	Asphaltec	2007	10 mm	C320	Some of the SMA at the south end near road from Catalano gravel pit may have a seal over it
	Gin Gin Roundabout	TBA	FW	Asphaltec	May 2002	10 mm / 35–40 mm	C320	Mooliabeenee/Cockram Rd
	Gin Gin	Not available	FW	Asphaltec	May 2002	10 mm / 35–40 mm	C320	Mooliabeenee Rd/Old Mooliabeenee Rd
	Great Eastern Hwy Bypass	13.08 – 13.43	R1 / R2	Fulton Hogan	2014	7 mm / 25 mm	A20E	Stirling Cst to Abernethy
	South Western Hwy	12.95 – 13.07	FW	Fulton Hogan	2012	10 mm / 35 mm	A20E	Quarry entrance
	South Western Hwy	13.36 – 13.45	FW	Fulton Hogan	2011	10 mm / 30 mm	A20E	Quarry entrance
Mixed heavy and light vehicles	Leach Hwy	Nth Lake Rd Intersection	L1 / L2 / L3	PRS	Nov 2001	10 mm	C320	First SMA on Main Roads network
	Leach Hwy	Nth Lake Rd Intersection	R1 / R2 / R3	PRS	Nov 2001	10 mm	C320	First SMA on Main Roads network
	Roe Hwy	14.30 – 15.45	R1 / R2	Emoleum	Dec 2005	10 mm & 7 mm	C320	Trials on Stage 7 (South St to Karel Ave). See plan of 6 trial sections
	Roe Hwy	37.71 – 39.23	R1 / R2	Fulton Hogan	2015	10 mm	A20E	Bypass to Clayton St
	Roe Hwy	38.40 – 39.20	L1 / L2	Fulton Hogan	2016	10 mm	A20E	Bypass to Clayton St
	Tonkin Hwy	22.99 – 23.49	R1 / R2	Fulton Hogan	2013	10 mm / 35 mm	A20E	First use of Sasobit
	Tonkin Hwy	23.49 – 24.13	R1 / R2	Fulton Hogan	2011	10 mm / 35 mm	A20E	
	Tonkin Hwy	25.94 – 26.47	R1 / R2	Fulton Hogan	2014	7 mm / 30 mm	A20E	

Road type	Road	SLK	Lanes	Producer	Date	Mix size / thickness	Binder type	Notes
	Great Eastern Hwy	35.10 – 36.38	FW	Boral	2011	10 mm / 35 mm	C320	C170 GRS under SMA Conformance issues with mix
	Great Eastern Hwy	44.99 – 45.18	R1 / R2	PRS	2006	10 mm / 30 mm	C320	Over a FDA large patch
	Kwinana Fwy	TBA	FW	Boral	2016	10 mm / 35 mm	A20E	SB Lakes on ramp
	Kwinana Fwy	TBA	FW	Boral	2016	10 mm / 35 mm	A20E	SB Pinjarra on ramp
	Kwinana Fwy	TBA	FW	Boral	2016	10 mm / 35 mm	A20E	NB Pinjarra on ramp
	Kwinana Fwy	TBA	FW	Boral	2016	10 mm / 35 mm	A20E	NB Lakes on ramp
Mainly light vehicles	Marmion Ave	3.43 – 4.55 Beach – Warwick Rd	L1 / L2	Boral	Oct 2005	10 mm / 30 mm	C320	Placed in hot weather Water applied to cool before trafficking. Re-emulsified tack coat.
	Marmion Ave	5.63 – 6.12 Seacrest – Harman Rd	L1 / L2	Boral	2003	7 mm / 25 mm	C320	-
	Wanneroo Road	25.27 – 25.82 South of Joondalup Dr	R1 / R2	Downer	2009	7 mm / 30 mm	C320	Resurfacing of existing road
	Wanneroo Road	23.67 – 26.16	L1 / L2	Downer	2009	7 mm / 30 mm	C320	New carriageway
	Albany Hwy - Kelmscott	22.31 – 22.86	L1 / L2	PRS	Feb 2003	10 mm	C320	Page Rd to Denny Ave
	Roe Hwy	TBA	L1 / L2	Downer	Late 2015	10 mm	A20E	Maida Vale Rd to Kalamunda
	Roe Hwy	TBA	L1 / L2	Downer	Mar 2016	10 mm	A20E	North of Kalamunda Rd
	Roe Hwy	TBA	FW	Boral	2016	10 mm	A20E	Tonkin to Berkshire
	Tonkin Hwy	7.95 – 8.27	L1 / L2	Boral	2015	7 mm / 30 mm	A15E	With Sasobit but hard to work
	Tonkin Hwy	31.15 – 31.35	R1 / R2	Downer	2009	7 mm / 30 mm	A20E	Trials opposite Champion Lakes
	Tonkin Hwy	31.35 – 31.55	R1 / R2	Downer	2009	7 mm / 30 mm	C320	Trials opposite Champion Lakes
	Melville – Mandurah Rd	42.77 – 43.52 Port Kennedy	L1 / L2	PRS	2007	10 mm / 30 mm	C320	Required for noise reduction
	Melville – Mandurah Rd	42.67 – 43.52 Port Kennedy	R1 / R2	PRS	2007	10 mm / 30 mm	C320	Required for noise reduction

4.1 Site Observations

The condition of the various sites inspected are presented in the sections below.

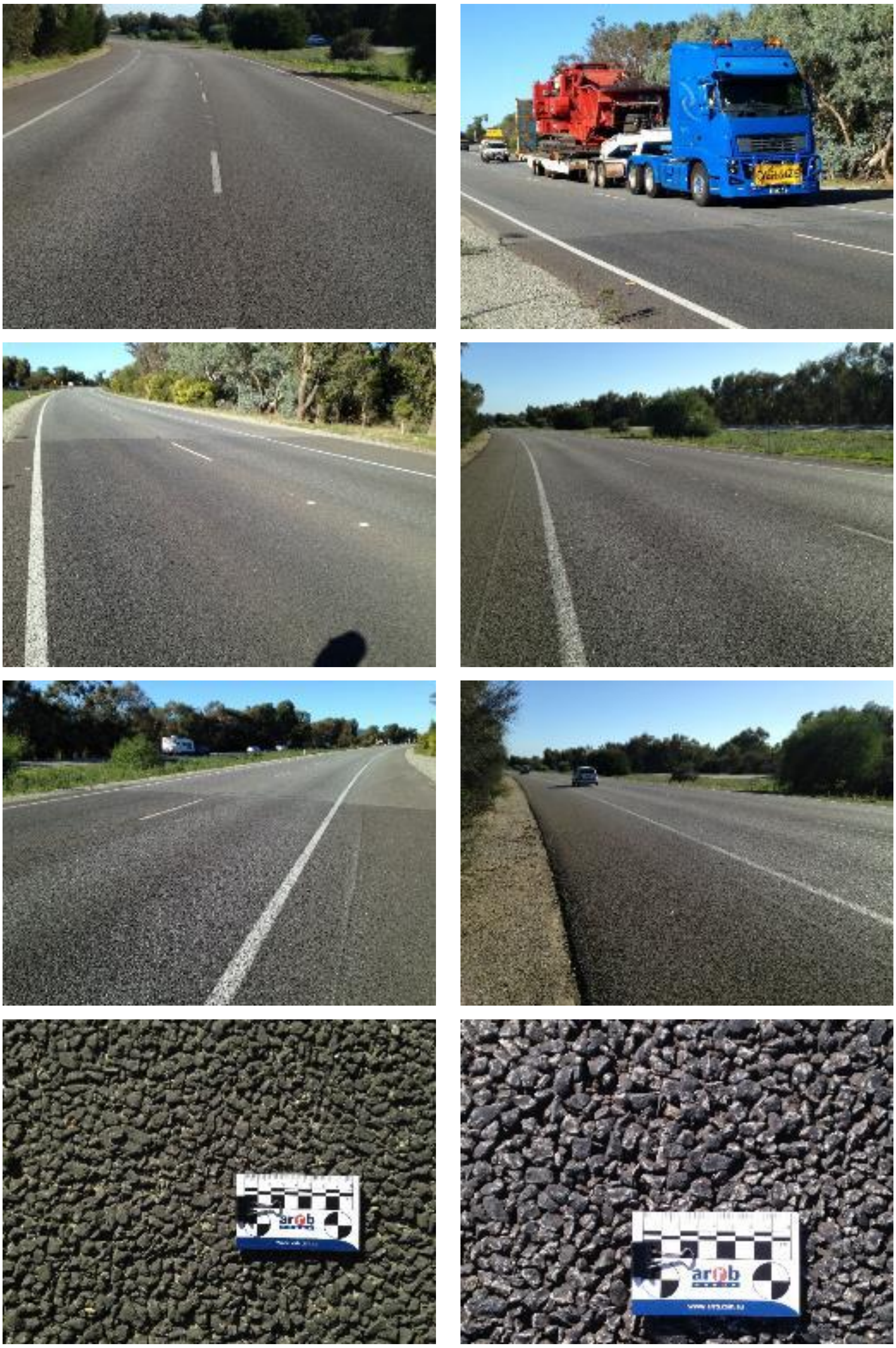
4.1.1 Tonkin Highway

The condition of the Tonkin Highway (northbound carriageway) between Gosnells Road East and Kelvin Road, approximately 200 m from Gosnells Road East is shown in Figure 4.1. The 35 mm thick SMA wearing course was constructed in 2011 by Fulton Hogan with a 10 mm nominal aggregate size and an A20E binder. The section appears to be performing satisfactorily in between the wheelpaths, however significant flushing in the wheelpaths was observed. It is understood that the cause of flushing could possibly be related to the C170 bitumen in the underlying geotextile reinforced seal bleeding through the SMA.

Figure 4.1: Tonkin Hwy, northbound carriageway, Gosnells Rd East – Kelvin Rd (SLK 23.49 – 24.13)

Fulton Hogan also constructed a SMA wearing course using a 10 mm nominal aggregate size and an A20E binder in 2013 on the northbound carriageway of the Tonkin Highway between Gosnells Road East and Kelvin Road, approximately 700 m from Gosnells Road East (Figure 4.2). No signs of distress were observed along this section of the road and the SMA appears to be performing satisfactorily.

Figure 4.2: Tonkin Hwy, northbound carriageway, Gosnells Rd East – Kelvin Rd (SLK 22.99 – 23.49)



Similar to the Tonkin Highway section approximately 700 m from Gosnells Road East, the SMA 1000 m from Gosnells Road East did not show any signs of distress (Figure 4.3).

Figure 4.3: Tonkin Hwy, northbound carriageway, Gosnells Rd East – Kelvin Rd (SLK 22.99 – 23.49)

Another section of the Tonkin Highway, next to the Great Eastern Hwy southbound on-ramp is also performing satisfactorily under heavy traffic conditions (Figure 4.4).

Figure 4.4: Tonkin Hwy, next to Great Eastern Hwy southbound on-ramp

4.1.2 Roe Highway

The condition of the SMA on the Roe Highway westbound carriageway between the South Street and Karel Avenue interchanges is shown in Figure 4.5.

This section was constructed in 2005 by Emoleum using C320 bitumen and a nominal aggregate size of 7 mm and 10 mm. Some aggregate loss and minor rutting were observed along this section of the highway, but overall the SMA still appears to be in a reasonably good condition considering its age.

Figure 4.5: Roe Hwy, westbound carriageway, South St – Karel Ave

A section of the Roe Highway (southbound carriageway) north of the Helena Valley Road overpass is also still performing well under heavy traffic conditions, and no distress was observed (Figure 4.6).

Figure 4.6: Roe Hwy, southbound carriageway, North of Helena Valley Rd overpass

4.1.3 Leach Highway

The first SMA on the Main Roads network was constructed in 2001 at the intersection between the Leach and North Lake Road by PRS. The SMA comprised a 10 mm nominal aggregate size and a C320 binder. Although some minor loss of mastic could be observed, the SMA is generally in a good condition (Figure 4.7).

Figure 4.7: Leach Hwy, North Lake Rd intersection

4.1.4 Marmion Avenue

The SMA wearing course on Marmion Avenue (northbound carriageway) between Burragah Way and Parnell Avenue was constructed by Boral in October 2005 using a 10 mm nominal aggregate size aggregate and a C320 binder. Signs of bleeding and loss of mastic on the surface was observed at some locations (Figure 4.8).

Figure 4.8: Marmion Ave, northbound carriageway, Burragah Wy – Parnell Ave

Previously, Boral constructed a 25 mm thick, 7 mm C320 SMA wearing course in 2003 with a 7 mm nominal aggregate size and C320 binder on another section of Marmion Avenue (northbound carriageway) between Readshaw Road and Seacrest Drive. The SMA is generally performing satisfactorily along this section of the road, with only a minor loss of mastic observed (Figure 4.9).

Figure 4.9: Marmion Ave, northbound carriageway, Readshaw Rd – Seacrest Dr

4.1.5 Wanneroo Road

The northbound carriageway of Wanneroo Road between Tadorna Entrance and Ashley Road comprises of a SMA wearing course constructed by Downer in 2009 (using a C320 binder and a 7 mm nominal aggregate size). The surface voids along this section appear to be closing up, but the SMA is still performing satisfactorily (Figure 4.10).

Figure 4.10: Wanneroo Rd, northbound carriageway, Tadorna Ent – Ashley Rd

Similarly, the southbound carriageway of Wanneroo Road between Tadorna Entrance and Ashley Road showed only minor signs of a loss of mastic (Figure 4.11).

Figure 4.11: Wanneroo Rd, southbound carriageway, Tadorna Ent – Ashley Rd

Although some localised flushing and surface void closure was observed on the SMA wearing course on Wanneroo Road between Clarkson Avenue and Tadorna entrance (Figure 4.12), the SMA along this section still appears to be performing satisfactorily.

Figure 4.12: Wanneroo Rd, Clarkson Av – Tadorna entrance

4.1.6 *Great Northern Highway*

Asphaltec constructed a SMA wearing course with a 10 mm nominal aggregate size and a C320 binder in 2007 at the intersection between the Great Northern Highway and Wandena Road. Only minor signs of mastic loss were observed at the intersection and the SMA still appears to be performing satisfactorily under extreme traffic loading conditions (Figure 4.13).

Figure 4.13: Great Northern Hwy, Wandena Rd intersection (SLK 32.72)

4.1.7 Toodyay Road

PRS constructed a SMA wearing course using a 10 mm nominal aggregate size and A20E binder along Toodyay Road in November 2009. The section near the quarry is showing signs of aggregate loss along the westbound carriageway, but overall the SMA appears to be performing satisfactorily under heavy traffic loading conditions (Figure 4.14).

Figure 4.14: Toodyay Rd, westbound lane, quarry entrance

4.1.8 Great Eastern Highway Bypass

A SMA wearing course comprising of a 7 mm nominal aggregate size and A20E binder was constructed by Fulton Hogan in 2014 along the Great Eastern Highway Bypass (eastbound carriageway), between Stirling Crescent and Abernethy Rd. Some minor mastic loss and localised flushing were observed (Figure 4.15), but generally the SMA appears to be performing satisfactorily under heavy traffic loading conditions.

Figure 4.15: Great Eastern Hwy Bypass, eastbound carriageway, Stirling Cres – Abernethy Rd

4.2 Summary of Findings

SMA wearing courses have an expected service life of between 10 and 20 years (Austroads 2009a). The age of the SMA wearing courses inspected as part of the project varies between approximately 2 and 17 years, and most of the sections appear to be performing satisfactorily based on visual observations. The most prominent defects observed include flushing, bleeding and minor loss of mastic on the surface.

The visual inspections did however not reveal any systemic issues with SMA wearing courses in WA.

5 THE USE OF SMA BY OTHER SRAs

Consultation with representatives from RMS, TMR and VicRoads was undertaken with respect to the performance of SMA in their jurisdiction and any issues that may have been encountered. The nominated representatives for each SRA are presented in Table 5.1.

Table 5.1: State road agency representatives consulted

SRA	Agency	Persons consulted
New South Wales	Roads and Maritime Services	Paul Morassut
Queensland	Queensland Department of Transport and Main Roads	Jason Jones
Victoria	VicRoads	John Esnouf

5.1 RMS

RMS has used SMA in various applications since the mid-1990s and although performance has not always been to the expected level, there have not been any major failures (Carter 2009). An investigation into 18 sites containing SMA by Carter (2009) found that SMA using unmodified binders was prone to loss of texture in wheel paths for applications above lightly trafficked residential streets, whilst SMA containing PMBs can be successfully used on heavily trafficked roads with minimal loss of texture or a risk of deformation.

Recent consultation with RMS (as part of the study) also indicated that SMA is performing well in NSW. However, RMS has previously experienced problems with thin layers of SMA (30 mm) that contain up to 9% in situ air voids (which was allowed under the previous version of their SMA specification). These high air void contents resulted in an inter-connected void structure that allowed water to penetrate the layers. As a result, wet patches that remained for up to 24 hours after a rain event were observed in some locations. Although no adverse performance was associated with these wet patches, the specification has subsequently been updated to limit the maximum in situ air voids to 7%. The next revision of RMS's SMA specification will also limit minimum layer thickness to 3.5 times the nominal aggregate size.

Although there are no noted limitations on the use of SMA in NSW, it is predominantly used on highways where the speed limit is greater than 80 km/h to improve the noise characteristics of concrete pavements or to reduce the risk of aquaplaning on asphalt pavements.

RMS also noted that mix designer's experience varies within industry and the less experienced practitioners may struggle to achieve an appropriate balance between aggregate packing and volumetrics, particularly with regard to the air void content of the mix.

5.2 TMR

In Queensland, the use of SMA has been prevalent since its first use in 1996. Whilst most of the SMA placed have been performing satisfactorily, in 2002 TMR noticed issues related to moisture ingress through the SMA layers that resulted in stripping of the underlying asphalt. This led to the withdrawal of TMR's SMA specification until the durability issues could be adequately addressed. The issues observed included:

- moisture infiltrating through the SMA surfacing into the lower asphalt layer after long periods of rain. The moisture content exceeded 1% for many of the asphalt cores, with some as high as 2–3%
- white fines occurred on the surface of the SMA wearing course
- bleeding surfaces

- development of potholes and premature rutting
- stripping of asphalt layers below the SMA surface.

Soward (2009) detailed the development of SMA specifications by TMR. An investigation of the durability issues associated with earlier SMAs found that these issues could be attributed to SMA placed with high air voids (i.e. 7–9%), thus increasing the permeability of the surfacing and allowing moisture to infiltrate the lower asphalt layers. Therefore, significant changes were made to the TMR SMA specification that are still reflected in current practice. The more important mix design changes included:

- introducing fixed binder fraction limits to reduce workability issues and control rutting and flushing
- lowering the design air voids from 4.5% to 2.5–3.5%.

Recent consultation with TMR (as part of the study) indicated that they frequently use SMA and although there have been several durability issues in the past, recent realignment of TMR's SMA specification to better reflect German practice has significantly reduced the occurrence of these issues.

It is also important to note that although SMA received negative publicity by the Queensland media in 2005 and 2007 due to a number of fatal crashes, a comprehensive review by Troutbeck & Kennedy (2005) of 537 sections of road using SMA surfacing found that there was not a systematic safety issue with SMA. Furthermore, Troutbeck (2007) evaluated an additional 124 sites with SMA and concluded that there were no safety issues with the use of SMA.

5.3 VicRoads

VicRoads constructed their first trial of SMA on the Princes Highway in 1990 using a 14 mm nominal aggregate size mix based on German SMA specifications. However, an inspection in 1992, as reported by Lancaster & Holtrop (1993), found flushing in the wheelpaths along the trial sections. Tests performed on cores extracted from the pavement found that:

- the cellulose fibre was thermally damaged during the dry mixing process due to high dry aggregate temperatures (i.e. 200°C)
- the field voids generally varied between 7–9%
- low cellulose fibre and bitumen contents
- the particle size grading was too fine on some sieves.

Subsequently, to avoid thermal damage to the cellulose fibres, the specification for future SMA works was amended to reduce the maximum dry aggregate temperature from 200°C to 180°C (Lancaster & Holtrop 1993).

Additional trials constructed in 1993 were completed without any major concerns and a trial section on the Mulgrave Freeway (now called Monash Freeway) remained in a good condition following inspections in 2003 (Rebbechi et al. 2003).

Although the SMA mixes initially used C320 bitumen, PMBs were introduced in 1999 for high fatigue applications (Allen 2006).

Recent consultation with VicRoads (as part of the study) found that SMA mixes used in Victoria are generally performing well and there have not been any recent issues with this particular mix type that they are aware of. Although VicRoads do not generally place any limitations on the use of SMA, local bias and preferences may lead to varying levels of SMA usage across the state.

6 SMA PAVEMENT DESIGN CONSIDERATIONS

The scope of the project included a review of current pavement design considerations for the use of SMA in Australia. The review included the presumptive moduli for SMA used by other SRAs, as well as the fatigue behaviour of SMA in different pavement applications. The findings of the review are discussed in more detail below.

6.1 Presumptive Design Moduli and Binder Volume

Main Roads does not currently provide any guidance on the presumptive design moduli values that should be used for SMA mixes in WA. However, the presumptive design moduli for SMA used by TMR (2017b), VicRoads (2013), DPTI (2014) and RMS (2015) are summarised in Table 6.1.

Table 6.1: Summary of SMA presumptive design moduli and binder volume used by SRAs

SRA	SMA ID	Mix size (mm)	Binder type	Binder volume (%)	WMAPT[1] (°C)	Asphalt modulus at heavy vehicle operating speed and WMAPT (MPa)[2]					
						10 (km/h)	30 (km/h)	40 (km/h)	50 (km/h)	60 (km/h)	80 (km/h)
TMR[3]	SM14	14	A15E	13.0	32	1000 (1000)	1000 (1150)	NA	1100 (1400)	NA	1300 (1650)
VicRoads[4]	SMAH	10	A10E	14.5	24	1000 (650)	NA	1300 (850)	NA	1500 (1000)	1700 (1150)
	SMAN	10	A20E or A25E	14.5	24	1200 (800)	NA	1700 (1150)	NA	1900 (1300)	2100 (1400)
DPTI[5]	SMA10	10	C320	15.1	27	830 (550)	1490 (1000)	NA	1880 (1250)	NA	2320 (1550)
RMS[6]	SMA14	14	n/a[7]								

1 WMAPT – weighted mean annual pavement temperature (Austroads 2012).

2 Values in brackets are modulus values adjusted to 29 °C (WMAPT in Perth), rounded to the nearest 50 MPa using the temperature adjustment relationship in Austroads (2012).

3 Source: TMR (2017b).

4 Source: VicRoads (2013).

5 Source: DPTI (2014).

6 Source: RMS (2015).

7 There is no information available on presumptive design modulus values for asphalt RMS mixes. In the absence of reliable data, the design modulus of SMA used by RMS must be 50% of the design modulus of dense graded AC14 asphalt containing Class 450 bitumen (RMS 2015).

TMR provides a lower limit of 1000 MPa for the design modulus of SMA mixes. Austroads (2012) also states that a minimum design modulus of 1000 MPa should be adopted for dense graded asphalt mixes with conventional binders. However, Austroads does not provide any guidance for the minimum design modulus of SMA mixes with PMBs.

It is clear from the summary in Table 6.1 that there are differences between the presumptive design moduli for SMA adopted by the different SRAs. The reason for the different presumptive modulus values is not clear at this stage but could be as a result of differences in the type of binder, volumetric properties and grading of the SMA mixes used in each state.

Furthermore, the volume of binder used by the SRAs to determine the theoretical fatigue life of SMA layers varies between 13–15.1%. This difference could potentially have a significant impact on the design life of SMA layers, with a higher binder volume typically resulting in improved fatigue performance. The difference in presumptive binder volume could be as a result of differences in typical binder and air void contents achieved by the various SRAs.

6.2 SMA as Thin Surfacing Layer on Unbound Granular Pavements

As mentioned previously, SMA is a wearing course that was originally developed for high traffic volume roads in Germany. The original intent was to replace the widely used mastic asphalt (defined as a bituminous mixture where the volume of filler and binder exceeds the voids content of the aggregate mix in a hot state (FGSV 2013a)) in Germany with a highly rut resistant mix that coped well with high speed heavy traffic on freeways. The absence of fatigue capacity from the original mix design requirements most likely stems from the fact the traffic loads in Germany are typically carried by stiff asphalt base layers and fatigue of the wearing course is unlikely to occur in those applications.

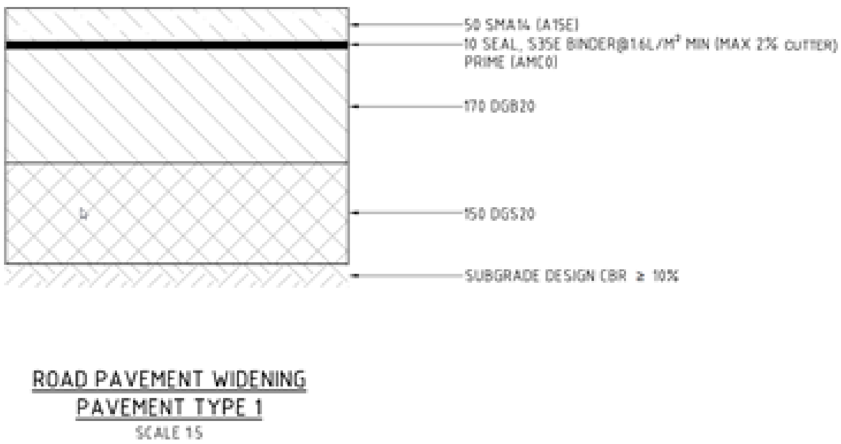
SMA mixes can provide improved fatigue resistance compared to dense graded asphalt mixes due to the higher mastic contents (Kreide, Budija and Carswell 2003). However, the fatigue life of asphalt layers is affected by the density of the material and underlying supporting conditions. Given the stone-on-stone gap-graded matrix of SMA, these mixes can be difficult to compact in the field and as a result be prone to higher in situ air voids. Higher air voids and a lower density typically result in a reduction in the fatigue life of asphalt layers. Furthermore, high field voids can often lead to a permeable surfacing layer which increases the risk of moisture entering the underlying pavement layers.

A literature search did not find any significant evidence of SMA being placed on unbound granular pavements internationally, which suggest that this is not common practice.

6.2.1 Premature pavement failures

The risks associated with placing SMA over an unbound granular pavement are demonstrated by means of a local case study presented in this section. An SMA layer was placed on an unbound flexible pavement in an Australian city (Figure 6.1).

Figure 6.1: Unbound granular pavement with SMA surfacing



Shortly after opening the road to traffic, the pavement exhibited signs of premature distress, including crocodile cracking, pumping and localised deformations (Figure 6.2).

Figure 6.2: Severe pavement distress

The investigation undertaken suggested several potential causes for the distress observed, including:

- a lack of support provided by the granular pavement structure as a result of moisture ingress, resulting in premature fatigue of the SMA surfacing layer, or
- poor compaction of the SMA surfacing layer due to inadequate supporting conditions.

6.3 Horizontal Strain Profile as a Function of Pavement Depth

The distribution of horizontal strains, as a function of pavement depth, was assessed for two different pavement structures, i.e.:

- unbound granular pavement with a thin SMA surfacing layer.
- full depth asphalt pavement with a thin SMA surfacing layer.

The horizontal tensile strains were determined using CIRCLY, which is a linear elastic software program that is endorsed by Austroads and commonly used in Australia.

The aim of the analysis was to determine the theoretical risk of asphalt fatigue associated with a thin SMA surfacings on unbound granular pavements.

6.3.1 Benchmark strain values

The horizontal strains calculated for the abovementioned structures were benchmarked against the strains calculated in the four full depth asphalt (FDA) heavy duty pavement structures used during the EME2 study in WA, i.e.:

- Kwinana Freeway northbound / Russel Road Intersection (ID: FDA1)
- Kwinana Freeway southbound / Gibbs Road Intersection (ID: FDA2)
- Gibbs Road / Lyon Road Intersection (ID: FDA3)
- Kwinana Freeway northbound off ramp H692 Widening (ID: FDA4).

The results of the benchmarking analysis are summarised in Table 6.2.

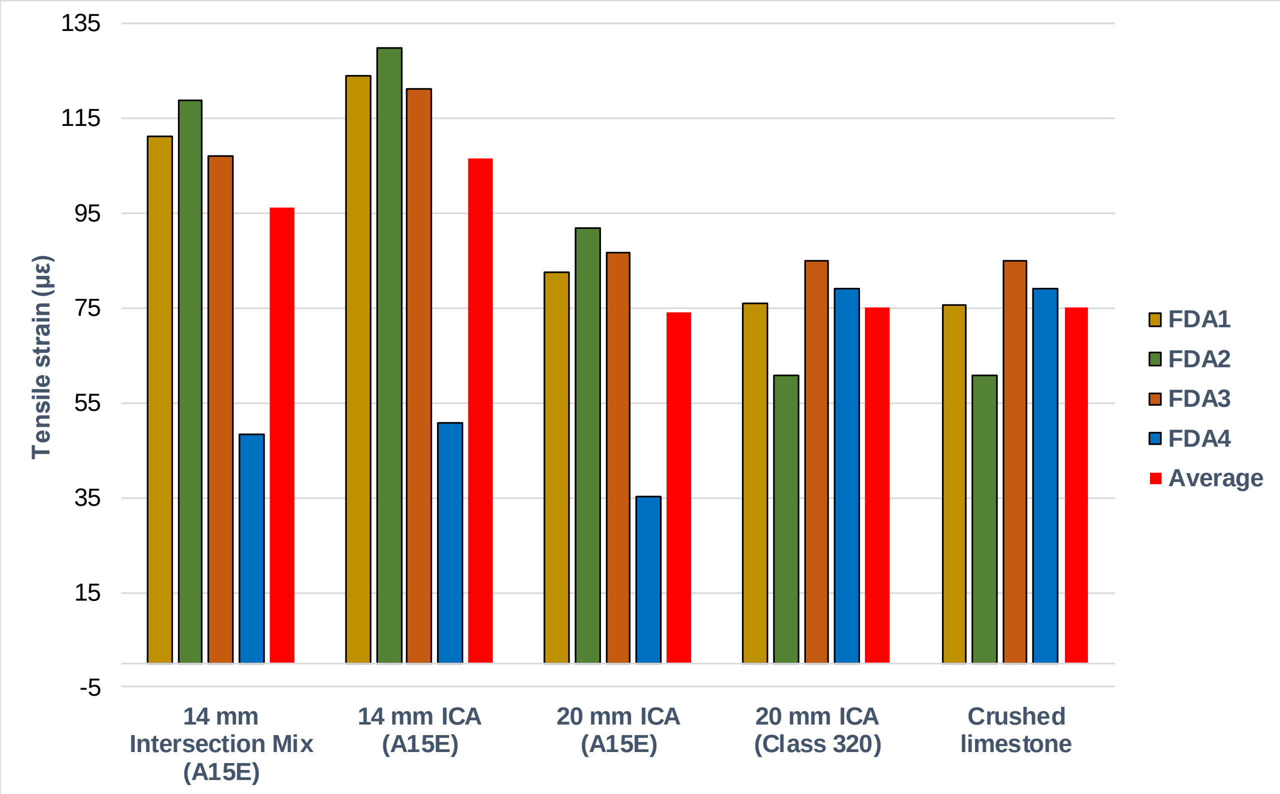
Table 6.2: Maximum horizontal tensile strain in asphalt layers of the selected pavement sections

Analysis ID	Design speed (km/h)	WMAPT (°C)	Pavement layer	Material type	Nominal thickness (mm)	Design modulus (MPa)	Maximum horizontal tensile strain (rough layer interface) (με)
FDA1	10	29	Asphalt wearing course	14 mm Intersection Mix (A15E)	40	1000	111
			Asphalt intermediate course	14 mm ICA (A15E)	50	1000	124
			Asphalt intermediate course	20 mm ICA (A15E)	60	1290	83
			Asphalt intermediate course	20 mm ICA (Class 320)	155	1710	76
			Basecourse	Crushed limestone	200	150	–
			Subgrade	Sand (CBR 12%)	Infinite	120	–
FDA2	10	29	Asphalt wearing course	14 mm Intersection Mix (A15E)	40	1000	119
			Asphalt intermediate course	14 mm ICA (A15E)	50	1000	130
			Asphalt intermediate course	20 mm ICA (A15E)	60	1290	92
			Asphalt intermediate course	20 mm ICA (Class 320)	200	1710	61
			Basecourse	Crushed limestone	200	150	–
			Subgrade	Sand (CBR 12%)	Infinite	120	–

FDA3	10	29	Asphalt wearing course	14 mm Intersection Mix (A15E)	40	1000	107
			Asphalt intermediate course	14 mm ICA (A15E)	50	1000	121
			Asphalt intermediate course	20 mm ICA (A15E)	60	1290	87
			Asphalt intermediate course	20 mm ICA (Class 320)	135	1710	85
			Basecourse	Crushed limestone	200	150	–
			Subgrade	Sand (CBR 12%)	Infinite	120	–
FDA4	60	29	Asphalt wearing course	10mm OGA	30	800	–
			Asphalt intermediate course	14 mm Intersection Mix (A15E)	40	1760	48
			Asphalt intermediate course	14 mm ICA (A15E)	50	1760	51
			Asphalt intermediate course	20 mm ICA (A15E)	60	2470	35
			Asphalt intermediate course	20 mm ICA (Class 320)	50	3300	79
			Basecourse	Crushed limestone	200	150	–
			Subgrade	Sand (CBR 12%)	Infinite	120	–

The maximum horizontal tensile strain for each asphalt layer in the FDA benchmark sections are shown in Figure 6.3. The maximum tensile strain in the asphalt layers ranges between 35 με and 130 με, and this range was used as the benchmark for tensile strains calculated in the SMA layer.

Figure 6.3: Maximum horizontal tensile strain for different asphalt layers including average and standard deviation



6.3.2 *SMA design modulus*

The design modulus of the SMA used in the analysis was determined based on TMR's presumptive values provided in Table 6.1. A design speed of 60 km/h and WMAPT of 29°C was adopted for the analysis. The following equations recommended by Austroads were used to correct the design modulus for pavement temperature and speed (Austroads 2012):

$$\frac{Modulus\ at\ WMAPT}{Modulus\ at\ test\ temperature\ (T)} = e^{-0.08(WMAPT-T)} \qquad 1$$

$$\frac{Modulus\ at\ speed\ V}{Modulus\ at\ test\ loading\ rate} = 0.19V^{0.365} \qquad 2$$

Considering the above, a design modulus of 1490 MPa was adopted for the SMA surfacing.

6.3.3 *SMA on full depth asphalt*

The OGA surfacing of the FDA benchmark pavement structure was replaced with a 30 mm thick SMA layer (7 mm nominal stone size) to assess the distribution of horizontal strains in a FDA pavement with SMA surfacing. The pavement structure adopted is summarised in Table 6.3.

Table 6.3: Pavement composition for SMA in full depth asphalt (FDA)

Analysis ID	Design speed (km/h)	WMAPT (°C)	Pavement layer	Material type	Nominal thickness (mm)	Design modulus (MPa)
FDA_SMA	60	29	Asphalt wearing course	7 mm SMA	30	1490
			Asphalt intermediate course	14 mm Intersection mix (A15E)	40	1760
			Asphalt intermediate course	14 mm ICA (A15E)	50	1760
			Asphalt intermediate course	20 mm ICA (A15E)	60	2470
			Asphalt intermediate course	20 mm ICA (C320)	50	3300
			Basecourse	Crushed limestone	200	150
			Subgrade	Sand (CBR 12%)	Infinite	120

The maximum tensile strains calculated in each of the asphalt layers are summarised in Table 6.4.

Table 6.4: Maximum horizontal tensile strain in different layers of the pavement

Analysis ID	Pavement layer	Material type	Nominal thickness (mm)	Design modulus (MPa)	Maximum horizontal tensile strain (με)	
					Rough interface	Smooth interface
FDA_SMA	Asphalt wearing course	7 mm SMA	30	1490	–	255
	Asphalt intermediate course	14 mm Intersection Mix (A15E)	40	1760	54	229
	Asphalt intermediate course	14 mm ICA (A15E)	50	1760	55	244
	Asphalt intermediate course	20 mm ICA (A15E)	60	2470	36	201
	Asphalt intermediate course	20 mm ICA (Class 320)	50	3300	67	154
	Basecourse	Crushed limestone	200	150	–	–
	Subgrade	Sand (CBR 12%)	Infinite	120	–	–

The results of the analysis indicate that the entire SMA layer is in compression when assuming a rough interface (i.e. standard Australian design practice). This suggests that fatigue failure of the SMA surfacing is unlikely to occur under these conditions.

However, when a smooth interface (i.e. a poor bond between SMA and the underlying layer) is assumed, very high tensile strains (i.e. greater than 250 με) occur at the bottom of the SMA layer. These tensile strains are significantly higher than the values determined for the benchmark structures and suggest an increased risk of asphalt fatigue occurring when the SMA is not adequately bonded to the underlying pavement. It is however worth noting that the significant effect of bonding between asphalt layers on the strain distribution is not unique to SMA and will apply to all asphalt mixes.

6.3.4 SMA on unbound granular materials

A typical unbound granular pavement structure with a thin SMA surfacing was selected to assess the horizontal strain profile at depth throughout the surfacing layer. The pavement structure adopted is summarised in Table 6.5.

Table 6.5: Pavement composition and maximum horizontal strain for SMA on unbound granular materials

Design speed (km/h)	WMAPT (°C)	Pavement layer	Material type	Nominal thickness (mm)	Design modulus (MPa)	Maximum horizontal tensile strain (με)	
						Rough interface	Smooth interface
60	29	Asphalt wearing course	7mm SMA	30	1000–1490	186	1316
		Basecourse	Crushed rock	190	500	–	–
		Subbase	Crushed limestone	150	150	–	–
		Subgrade	Sand (CBR 12%)	Infinite	120	–	–

The maximum tensile strains calculated at the bottom of the SMA layer are 186 με and 1316 με for a rough interface and smooth interface respectively (refer Table 6.5). The analysis indicates that tensile strains do occur at the bottom of a thin SMA surfacing on an unbound granular pavement (as expected). These values are however higher than the benchmark values, which indicates a higher risk of asphalt fatigue occurring if the SMA is placed on an unbound granular pavement compared to SMA placed on asphalt layers.

However, given that the maximum tensile strain at the bottom of the SMA layer is a function of the modulus of the SMA, the effect of adopting a lower SMA modulus of 1000 MPa was also assessed. For this scenario, the maximum tensile strains calculated at the bottom of the SMA layer ranged between 130 με and 1345 με for a rough and smooth interface respectively. Again, these strains are higher than the benchmark values, indicating an increased risk of asphalt fatigue occurring.

It is important to note that the actual expected impact of these strain levels on the fatigue life of an SMA layer is not known at this stage. The analysis did however show the increased risk of asphalt fatigue when placing a thin asphalt layer over an unbound granular pavement. The importance of achieving a good bond between thin asphalt surfacings and the underlying pavement structure was also demonstrated. This bond can generally be achieved by good surface preparation (i.e. cleaning, tack coating, etc.) and appropriate paving practices.

The analysis also highlighted the impact of the modulus of the thin asphalt layer on the tensile strain at the bottom of the layer. The tensile strains increase significantly with an increase in modulus and it is therefore prudent to avoid placing thin stiff asphalt layers over flexible pavements.

7 KNOWN AREAS OF MAIN ROADS CONCERN

Main Roads has identified three known areas of concern for SMA in WA, i.e.:

- specification of filler, especially with regard to the stiffness of the mastic
- the measurement methods used to determine bulk density
- the ability of local contractors to consistently produce and place SMA in accordance with Main Roads Specification 502.

These areas of concern are discussed in more detail below.

7.1 Specification of Fillers

The total filler in asphalt comprises the combined fractions of fines produced from the crushing of aggregates and any added filler which passes the 0.075 mm sieve. Fillers are typically used to fill the voids, meet grading requirements, increase mix stability and improve the stripping resistance of asphalt mixes (Austroads 2013b). The various specification requirements for fillers in SMA are presented below.

7.1.1 Filler specification requirements

A summary of SMA filler requirements by Australian SRAs are presented in Table 7.1.

Table 7.1: Comparison of state road agency SMA filler requirements

SRA	Fillers permitted	Filler contents (% passing 0.075 mm sieve)	Other properties	Requirement	Test method
Main Roads(1)	Mineral filler Hydrated lime	8.0–12.0	None specified	–	–
RMS(2)	Mineral filler Cement works flue dust Ground limestone Fly ash Hydrated lime	7.5–12.5	Dry compacted filler voids Methylene blue value of combined filler	≥ 40% ≤ 10 mg/g (excluding hydrated lime)	AS 1141.17 AS/NZS 1141.66
TMR(3)	Mineral filler Cement works flue dust Ground limestone Fly ash Hydrated lime Rock dust	6.5–12.5	Fixed binder fraction Dry compacted filler voids Methylene blue value of combined filler	≤ 0.55 ≥ 38% 10 – 18 mg/g (excluding hydrated lime) ≤10 mg/g (including hydrated lime)	Q321-2017 AS 1141.17 AS/NZS 1141.66

DPTI[4]	Mineral filler Hydrated lime	8.0–12.0	Dry compacted filler voids Moisture content Loss on ignition Particle size distribution Specific surface Water soluble fraction	Report only ≤ 3% ≤ 4% by mass Report only Report only ≤ 20% by mass	AS 1141.17 AS 1289.B1.3 AS 3583.3 AS 1141.11.1 AS/NZS 2350.8 AS/NZS 1141.8
VicRoads[5]	Mineral filler	8.0–12.0	Added filler	≥ 8% (SMAN) ≥ 6% (SMAH)	–

1 Source: Main Roads (2016).
2 Source: RMS (2013, 2016).
3 Source: TMR (2017a).
4 Source: DPTI (2017a, 2017b).
5 Source: VicRoads (2012).

The filler contents for SMA are identical in the Main Roads, DPTI, and VicRoads specifications whereas RMS and TMR allow a slightly lower and higher filler content. Mineral filler and hydrated lime are permitted for use by each of the SRAs. RMS and TMR specifications also allow the use of several other filler types not referenced by other states.

Although not strictly a filler requirement, it is worth noting that TMR is the only SRA that has a fixed binder fraction requirement (0.55 maximum), tested in accordance with TMR Test Method Q321-2017. The fixed binder fraction requirement has been introduced by TMR to ensure SMA mixes meet minimum workability requirements during construction.

Cement works flue dust

RMS and TMR allow for the use of cement works flue dust (also known as baghouse dust) in SMA. The quality requirements for cement works flue dust are presented in Table 7.2.

Table 7.2: Comparison of cement works flue dust quality requirements

SRA	Property	Requirement	Standard/Specification
RMS[1]	Loss on ignition Water soluble fraction Methylene blue value passing 0.075 mm AS sieve	≤ 6.0% ≤ 20.0% Report	AS 3583.3 AS 1141.8 RMS T659
TMR[2]	Particle size distribution	Grading conformance	AS 2150

1 Source: RMS (2016).
2 Source: TMR (2017c).

Ground limestone

The grinding of sound limestone produces rock dust that can be used as a filler in asphalt, known as ground limestone. Both RMS and TMR allows for the use of ground limestone in SMA and the quality requirements are presented in Table 7.3.

Table 7.3: Comparison of ground limestone quality requirements

SRA	Property	Requirement	Standard/Specification
RMS[(1)]	Mass of $CaCO_3$	≥ 75.0%	–
	Total organic carbon if <80% $CaCO_3$	≤ 0.5%	RMS T659
	Total clay content if <80% $CaCO_3$	1.2%	RMS T659
TMR[(2)]	Mass of CaCO3	≥ 75.0%	–
	Total organic carbon if <80% $CaCO_3$	≤ 0.5%	EN 13639

1 Source: RMS (2016).
2 Source: TMR (2017c).

Fly ash

Fly ash used as an added filler in asphalt in RMS (2016) and TMR (2017c) mixes must be fine or medium grade and conform to AS 3582.1-1998 *Supplementary cementitious materials for use with Portland and blended cement fly ash*.

Hydrated lime

Hydrated lime is typically used as a filler in asphalt mixes to improve stripping resistance. However, hydrated lime has also been shown to have a stiffening effect on the mix which may decrease the workability and ease of compaction during construction. The hydrated lime quality requirements for use in asphalt for each of the SRA specifications reviewed are presented in Table 7.4.

Table 7.4: Comparison of hydrated lime quality requirements

SRA	Filler content (%)	Property	Requirement	Standard/Specification
Main Roads[(1)]	1.5 (by mass of total aggregate)	Available lime content (CaH_2O_2)	≥ 65.0%	AS 4489.6.1
		Percentage retained on 600 µm sieve	≤ 5.0%	AS 4489.2.1
		Moisture content before use	≤ 2.5%	AS 4489.8.1
		Soundness	≤ 10 mm expansion	AS 4489.4.2
		Carbon dioxide	≤ 4% at works	AS 4489.5.1
RMS[(2)]	≥1.5 (by mass of total aggregate)	Available lime content (CaH_2O_2)	≥ 80.0%	AS 4489.6.1
		Percentage retained on 300 µm sieve	≤ 2.0%	AS 4489.2.1
		Moisture content before use	≤ 1.0%	AS 4489.8.1
		Soundness	≤ 10 mm expansion	AS 4489.4.2
		Carbon dioxide	≤ 4% at works	AS 4489.5.1

SRA	Filler content (%)	Property	Requirement	Standard/Specification
TMR(3)	≥1.0 (by mass of the combined filler)[5]	Available lime content (CaH_2O_2)	≥ 80.0%	AS 4489.6.1
		Percentage retained on 300 µm sieve	≤ 2.0%	AS 4489.2.1
		Moisture content before use	≤ 1.0%	AS 4489.8.1
		Soundness	≤ 10 mm expansion	AS 4489.4.2
		Carbon dioxide	≤ 4% at works	AS 4489.5.1
DPTI(4)	≥1.0 (by mass of total mix)	Available lime content (CaH_2O_2)	≥ 65.0%	AS 4489.6.1
		Percentage retained on 600 µm sieve	≤ 5.0%	AS 4489.2.1
		Moisture content before use	≤ 2.5%	AS 4489.8.1
		Soundness	≤ 10 mm expansion	AS 4489.4.2
		Carbon dioxide	≤ 4% at works	AS 4489.5.1

1 Source: Main Roads (2017).
2 Source: RMS (2013, 2016).
3 Source: TMR (2017a, 2017c).
4 Source: DPTI (2017a;2017b.
5 Only required if the Methylene blue value > 10 mg/g and ≤ 18 mg/g.

Main Roads and DPTI specify the same properties for hydrated lime, which is in accordance with AS 1672.1-1997 *Limes and limestones, Part 1: Limes for building*. However, RMS and TMR have different requirements for the available lime content, percentage retained on the 300 µm sieve and moisture content before use.

Rock dust

TMR allows for the use of fillers derived from rock that conforms to the requirements of MRTS101 *Aggregates for Asphalt* (TMR 2017d).

Main Roads also advised that two suppliers in Perth use lime kiln dust as an added filler in addition to baghouse dust.

7.1.2 The impact of fillers on the stiffness of the mastic

Fillers used in asphalt manufacturing are known to have a stiffening effect on the mastic in asphalt mixes. This stiffening effect can be more significant in SMA mixes, given the higher binder and filler contents associated with this particular mix type.

Previous researchers have found a good correlation between the voids in the dry compacted filler and stiffening of the mastic. European standards also assess the stiffening effect of fillers using the softening point test (Austroads 2013b).

Voids in the dry compacted filler and fixed binder fraction

Voids in the dry compacted filler, also known as Rigden voids, can have a significant impact on the workability and performance of SMA mixes. Generally, as the surface area of the filler increases, so does the stiffening effect on the mastic. The results from a study conducted by Bryant (2005) indicated that fillers with high voids in the dry compacted filler (such as hydrated lime) have a stiffening effect on the mastic and could reduce the workability of SMA mixes during construction.

However, insufficient voids in the dry compacted filler could lead to excess free binder that may adversely affect the stability of SMA mixes, resulting in flushing and/or rutting (Soward 2009).

RMS and TMR are currently the only two SRAs in Australia that specify a minimum value for voids in the dry compacted filler to ensure stability of their SMA mixes.

The significance of the voids in the filler on the workability of an SMA mix can be represented by the free and fixed binder fractions, a concept that assumes there are a percentage of voids within the volume of filler that can be filled with bitumen, known as the fixed binder fraction. The fixed binder fraction is calculated in accordance with test method Q321-2017: *Fixed and free binder in asphalt* using Equation 3.

$$f_{binder} = \frac{V_{airvoids}}{V_{binder}} = \frac{F}{B} * \left(\frac{100 - B}{100}\right) * \left(\frac{G_b}{G_f}\right) * \left(\frac{V}{1 - V}\right) \quad 3$$

where

f_{binder}	=	fixed binder fraction
$V_{airvoids}$	=	volume of air voids in the dry compacted filler
V_{binder}	=	volume of binder in the mix
F	=	percentage by mass of filler in the combined aggregates
B	=	percentage by mass of binder in the mix
G_b	=	density of the binder
G_f	=	density of filler
V	=	voids in the dry compacted filler

The fixed binder fraction is unable to coat the non-filler portion of the SMA or provide adhesion to underlying materials (Austroads 2013d). It was also found that as the fixed binder fraction increases so does the mastic viscosity, independent of filler type (Bryant 2005 & Austroads 2013d). As a result, TMR specifies a maximum fixed binder fraction of 0.55 to ensure adequate workability of SMA mixes during construction.

Increase in softening point

European standards use the delta ring and ball softening point test (EN 13179-1:2013 *Tests for filler aggregate in bituminous mixes – part 1: delta ring and ball test*) as a simple and quick method to determine the stiffening effect of fillers in asphalt (Austroads 2013b). The softening point of a base binder is determined with and without added filler. The increase in softening point is used as an indication of the stiffening potential of the filler binder combination.

The delta ring and ball softening point test is not currently included in any of the Australian SMA specifications reviewed as part of this study. However, the German specification for SMA specifies two categories as follows (FGSV 2004):

- change in softening point of between 8 °C and 25 °C
- change in softening point of higher than 25 °C.

7.2 Bulk Density Measurements

The density of an asphalt briquette or core is a function of the specimen's volume and mass. Measuring the volume of compacted asphalt specimens accurately can however be challenging due to irregularities on the surface of the specimens. The volume of irregular shaped objects is often measured by means of the water displacement method. However, this method of measurement could be inaccurate for specimens that have open surfaces with interconnected voids. If water can penetrate the specimen, the measured volume will be lower than the actual volume, resulting in an overestimate of the density. Some road jurisdictions have found that the open surface of SMA mixes could lead to incorrect density measurements as a result of water penetrating the specimen (Austroads 2013c).

7.2.1 Previous research

Previous studies have found that the bulk density measurement of specimens using the water displacement method, without any coating of the specimen, was inaccurate when the air void content was greater than 7% (Austroads 2013c).

Austroads commissioned ARRB to undertake a study into measuring the bulk density of SMA in Australia. The findings of the study were documented in Austroads Technical Report AP-T218-13 *A Study of Stone Mastic Asphalt Bulk Density Measurement* (Austroads 2013c). The study investigated the following sample preparation methods prior to determining the volume of SMA using the water displacement method:

- Vacuum sealing in accordance with Main Roads test method WA 733.2-2008 *Bulk density of void content of asphalt, Vacuum sealing method*
- Saturated surface dry (SSD) method in accordance with AS 2891.9.2-2005 *Methods of sampling and testing asphalt, Method 9.2: Determination of bulk density of compacted asphalt – Presaturation method*
- Silicone sealing in accordance with test method Q306C-2017 *Compacted density of asphalt (silicone sealed)*
- Paraffin wax coating in accordance with WA 733.1-2011 *Bulk density and void content of asphalt.*

The main findings of the study were (Austroads 2013c):

- The vacuum sealing method produced the highest air void content given that the surface texture of the sample is considered as part of the compacted mix in the test method.
- The silicon sealing method was suitable for samples with an air void content between 7%–10% and would provide little benefit for samples with an air void content of less than 7%.
- The SSD method was suitable for SMA samples with an air void content of less than 7%. However, it is not possible to know if the sample has less than 7% air voids prior to testing and it was therefore recommended to include a maximum absorption limit of 1% if the SSD method is used.
- The wax coating method produced results similar to the SSD method.
- Neither of SSD and wax coating methods were found to be suitable for samples with an air void content greater than 7%. The authors also suggested that the wax method provides limited benefit compared to the SSD method.
- The study found that the current Australian Standard SSD test method specifies a significantly shorter soaking period compared to European Standards. It was recommended that further investigations be undertaken to assess the impact of soaking periods on bulk density measurements when using the SSD method.

7.2.2 Current methods used to determine the bulk density of SMA specimens in Australia

The methods currently being used by SRAs to determine the bulk density of SMA specimens are presented in Table 7.5.

Table 7.5: Bulk density measurements

SRA	Sample preparation method / Test method	
	Laboratory prepared specimen	Field core
Main Roads(1)	Water displacement method / WA 733.1-2012 (without pre-saturation)	Wax coating method / WA 733.1-2012
TMR(2)	SSD method / TMR Q306B-2017 or Silicon sealing method / TMR Q306C-2017	Silicon sealing method / TMR Q306C-2017
RMS(3)	SSD method / AS/NZS 2891.9.2	SSD method / AS/NZS 2891.9.2
VicRoads(4)	Not specified(6)	Not specified(7)
DPTI(5)	SSD method / AS/NZS 2891.9.2	Not specified

1 Source: Main Roads (2016).
2 Source: RMS (2013).
3 Source: TMR (2017a).
4 Source: VicRoads (2017, 2016).
5 Source: DPTI (2016).
6 Reference is made to the wax sealing method in accordance with AS/NZS 2891.9.1 for dense graded asphalt.
7 Reference is made to the wax sealing method in accordance with AS/NZS 2891.9.1 and the pre-saturation method in accordance with RC 202.02.

It can be seen that the methods for determining the bulk density of SMA specimens are currently not harmonised across the various SRAs in Australia.

Main Roads currently uses the wax coating method to determine the density of SMA cores extracted from the pavement. Previous research undertaken by Austroads (2013c) found that the wax coating method is only suitable for specimens with an air void content of less than 7%. Based on the findings in section 3.2 of this report, there is a risk that SMA cores extracted for density control from pavements in WA may have an air void content of greater than 7%, which can therefore affect the reliability of the measurements if the wax coating method is used in accordance with current Main Roads practice.

It is however difficult to estimate if cores extracted from the pavement are likely to have an air void content greater than 7% prior to testing. Austroads (2013c) therefore recommends that the water absorption of the cores be determined prior to testing the cores for density. If the water absorption exceeds 1%, the SSD or wax coating methods are not considered suitable to determine the density of the cores and an alternative test method should be considered. It should be noted that the absorption check cannot be undertaken if the wax coating method is used to determine the density of specimens.

The same study undertaken by Austroads (2013c) also suggested that there appeared to be little benefit in using the more expensive and time consuming wax coating method instead of the SSD method.

It is therefore recommended that Main Roads considers adopting the SSD method, including an absorption check, to determine the density of SMA cores extracted from the pavement. Furthermore, the silicon sealing method should be considered for cores extracted from the pavement that have an air void content greater than 7%. However, the implications of adopting the silicon sealing method would have to be considered prior to implementation. Some of the implications noted by Austroads (2013c) include the requirement for skilled personnel, extensive labour requirements and increased testing time. A change in test method may also result in a step change in density measurements compared to using the current wax coating method, which would have to be considered when setting new specification criteria.

Alternatively, Main Roads could consider increasing the compaction standard for SMA layers to reduce the risk of greater than 7% air voids occurring in asphalt specimens and continue using the wax coating method as per current practice.

7.3 The Ability of Local Suppliers to Produce SMA in Accordance with MAIN ROADS Specification 502

Several local asphalt suppliers were surveyed as part of the project to identify key areas of concerns that they have regarding the supply of SMA in WA. The following key observations were made:

- Production issues can occur when using older asphalt plants, mainly related to the addition of added fillers and fibres.
- The suppliers found it challenging to meet the current grading specification with the available aggregates.
- Some suppliers found it difficult to acquire suitable quantities of baghouse dust to meet the specification requirements. Advanced notice of likely projects that will include SMA would be beneficial to ensure adequate supply of filler quantities.
- Some suppliers suggested that performance tests be considered during the mix design process, rather than a purely recipe-based approach.
- A workshop addressing best practice in manufacturing and placing SMA would be beneficial to the industry.

Notwithstanding the above, the main request by the suppliers was for them to develop their own SMA mix designs (complying to the current specification), which could then be approved by Main Roads.

8 LABORATORY INVESTIGATION

A review of current practices in WA found that the SMA mixes typically have air voids in laboratory compacted specimens on the higher side of the specification range (refer Section 3.1), which could potentially lead to harsh mixes and low field compaction (refer Section 3.2). As mentioned in Section 7.1.2, one of the reasons for a harsh mix could be the stiffening effect that the filler has on the mastic of the SMA.

Laboratory testing was subsequently undertaken on several SMA mixes produced by local asphalt suppliers, including Boral, Downer and BGC. The primary objective of the assessment was to characterise the volumetric and filler properties of typical SMA mixes with a 10 mm nominal maximum aggregate (SMA10) produced in WA.

The raw materials (including binder, aggregate and added filler) were sourced from the three suppliers, together with information regarding their mix proportions. These materials were provided to the TMR laboratory at Bulwer Island (Brisbane) to prepare the laboratory specimens for testing. Filler testing was also undertaken by both the TMR and Main Roads laboratories.

The findings of the laboratory investigation are discussed in the following sections. The detailed test reports are included in Appendix A of this report.

8.1 Mix Design Information

The laboratory specimens were prepared using 50 Marshall blows per face at a compaction temperature of 160°C ± 3°C. The asphalt suppliers only provided their nominated mix proportions (refer Table 8.1 below) without any target gradings. Main Roads subsequently nominated the target grading to prepare the asphalt samples in the laboratory for testing (refer Table 8.2).

Table 8.1: SMA mix proportions

Material	Proportion (% by mass)				
	Boral (mix 1)	Boral (mix 2)	Downer	BGC	BGC (amended)
10 mm aggregate	73.7	73.7	73.3	72.9	72.7
Quarry sand	11.0	11.0	11.1	9.5	12.6
Baghouse filler	4	7	7.4	9.4	6.5
Lime kiln dust	3	not used	not used	not used	not used
Lime	1.5	1.5	1.4	1.4	1.4
Fibre	0.3	0.3	0.5	0.3	0.3
Bitumen	6.5	6.5	6.3	6.5	6.5

The only difference between Boral (mix 1) and Boral (mix 2) was that 'mix 1' included added lime kiln dust as per Main Road's request.

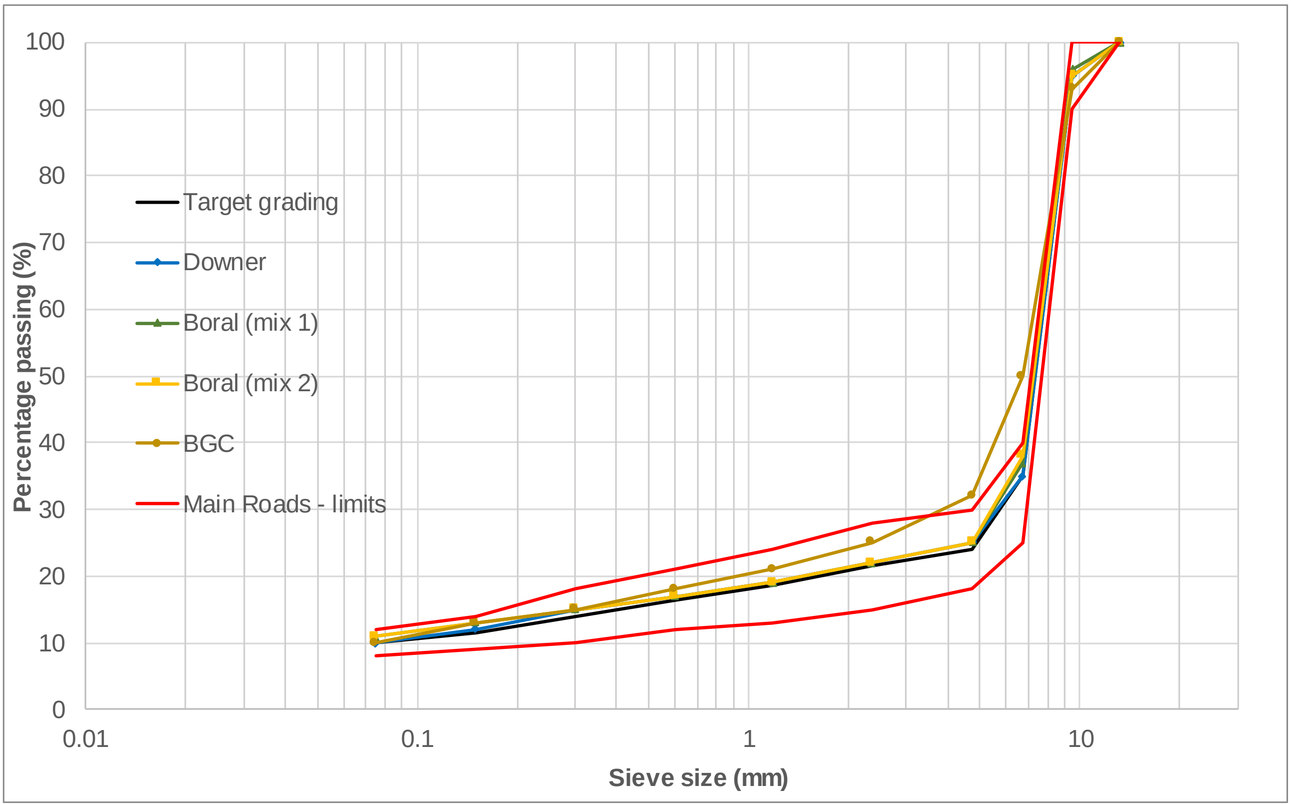
The TMR laboratory had to make minor amendments to the mix design proportions provided by Downer and Boral to achieve the target grading nominated by Main Roads. However, the 10 mm stone provided by BGC was significantly finer on the 6.70 mm sieve compared to the other suppliers and the laboratory was therefore not able to achieve the nominated target grading.

The actual gradings achieved in the laboratory (together with the target grading) are summarised in Table 8.2 and shown in Figure 8.1.

Table 8.2: SMA gradings

AS sieve size (mm)	Percentage passing AS sieve size by mass (%)				
	Target	Boral (mix 1)	Boral (mix 2)	Downer	BGC
13.2	100	100	100	100	100
9.5	95	96	95	95	93
6.70	35	37	38	35	50
4.75	24	25	25	25	32
2.36	21.5	22	22	22	25
1.18	18.5	19	19	19	21
0.600	16.5	17	17	17	18
0.300	14.0	15	15	15	15
0.150	11.5	13	13	12	13
0.075	10.0	11	11	10	10

Figure 8.1: SMA gradings



It can be seen that, except for the BGC mix, the laboratory was able to closely match the target grading that was nominated for the assessment.

8.2 Filler Properties

As discussed in section 7.1 of this report, the properties of the filler component are important to the performance of SMA mixes. The following filler properties were tested as part of the laboratory assessment:

- apparent particle density
- voids in the dry compacted filler (with and without hydrated lime)

- increase in softening point of the mastic (with and without hydrated lime)
- Methylene blue value of the combined filler component (with and without hydrated lime)

It is important to note that the filler component was identified as the portion passing the AS 0.075 mm sieve and includes material from the coarse aggregate, sand, baghouse, lime kiln dust (if added) and hydrated lime. This definition is consistent with current practice in Australia. However, for the purpose of testing the increase in softening point of the mastic, the filler was defined as the component passing the 0.125 mm sieve (consistent with German practice).

The results of the filler testing undertaken are discussed in the following sections.

8.2.1 Apparent particle density

The apparent particle density of the different fillers and filler combinations included in this study are summarised in Table 8.3. The apparent particle density of the fillers is used as input to determine the voids in the dry compacted filler.

Table 8.3: Filler apparent particle density

Filler combination	Apparent particle density (t/m^3)(1)			
	Boral (mix 1)	Boral (mix 2)	Downer	BGC
Baghouse	2.811	2.811	2.676	2.660
Lime kiln dust	2.891	–	–	–
Baghouse / lime kiln dust	2.715	–	–	–
Natural (without added filler)	2.736	2.736	2.682	2.638
Hydrated lime only	2.256	2.256	2.256	2.324
Total filler (without hydrated lime)(2)	2.720	2.708	2.682	2.633
Total filler (with hydrated lime)(2)	2.642	2.626	2.627	2.582

1 Testing undertaken in accordance with test method AS/NZS 1141.7:2014.
2 Total filler is defined as the total fines component produced from crushing of aggregates and any added filler which passes the AS 0.075 mm sieve.

8.2.2 Voids in the dry compacted filler

The voids in the dry compacted filler of the various filler combinations tested are summarised in Table 8.4. The voids in the dry compacted filler values of the combined filler components (with and without hydrated lime) are also shown in Figure 8.2.

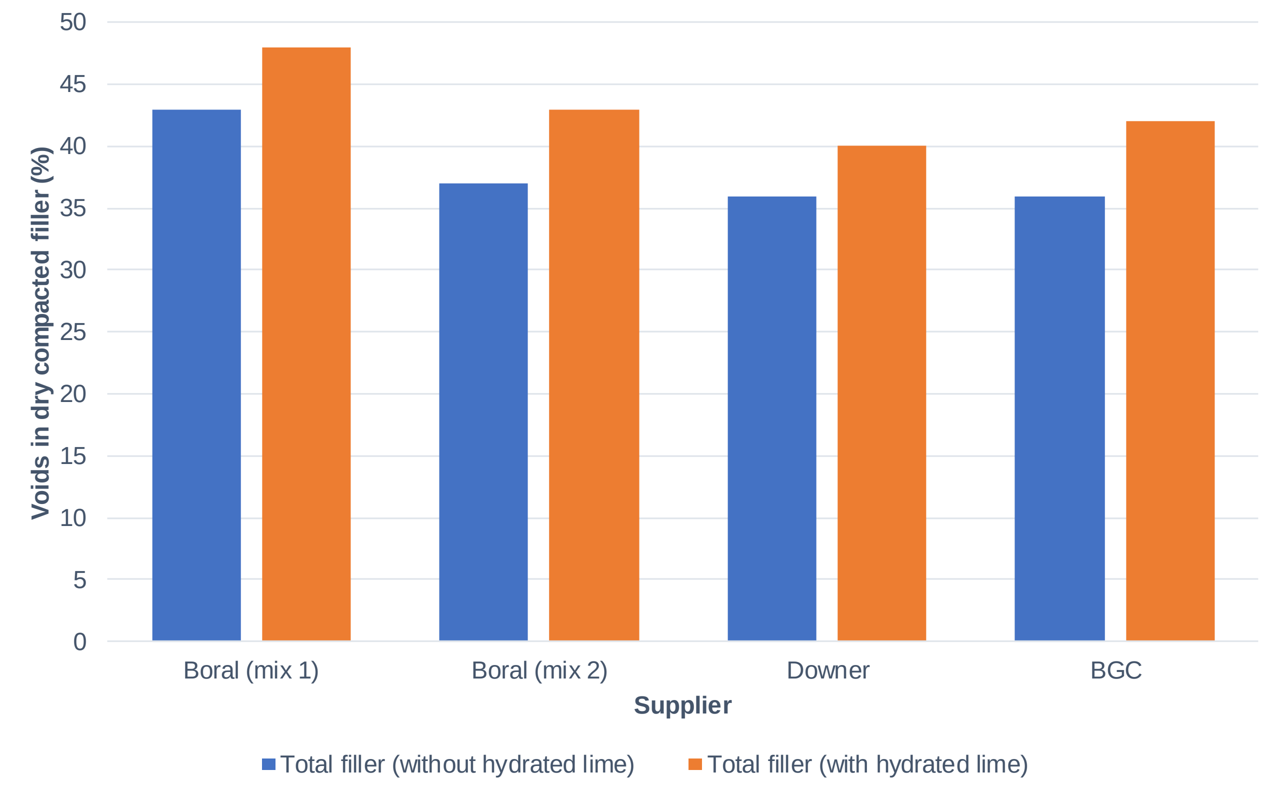
TMR and RMS specify a minimum dry compacted voids content of 38% and 40% for the total filler (including hydrated lime if used) respectively. As mentioned previously, minimum voids in the dry compacted filler values are often specified to avoid the risk of excess free binder and ensure the stability of SMA mixes in the field.

Table 8.4: Voids in the dry compacted filler

Filler combination	Voids in the dry compacted filler (%)(1)			
	Boral (mix 1)	Boral (mix 2)	Downer	BGC
Baghouse	40	40	36	37
Lime kiln dust	60	–	–	–
Baghouse / lime kiln dust	45	–	–	–
Natural (without added filler)	36	36	35	35
Hydrated lime only	64	64	64	51
Total filler (without hydrated lime)(2)	43	37	36	36
Total filler (with hydrated lime)(2)	48	43	40	42

1 Testing undertaken in accordance with test method AS 1141.17:2014.
2 Total filler is defined as the total fines component produced from crushing of aggregates and any added filler which passes the AS 0.075 mm sieve.

Figure 8.2: Voids in the total dry compacted filler (with and without lime)



The voids in the dry compacted filler determined for the WA mixes with hydrated lime varied between 40–48%. The filler in the Boral (mix 1) had the highest void content (i.e. 48%), which appears to be as a result of the additional lime kiln dust that was added. Previous researchers (Austroads 2009b) found that fillers with very high voids in the dry compacted filler (typically greater than 50%) could have an adverse effect on the workability of SMA mixes during construction.

The voids in the dry compacted filler varied between 36–37% for the mixes without any lime kiln dust or hydrated lime (i.e. Boral (mix 2), Downer and BGC). These values are marginally lower than the minimum values specified by TMR and RMS. The impact of the marginally lower voids in the dry compacted filler on the performance of SMA mixes in WA is not known at this stage. A previous study by Austroads suggested that the minimum voids in dry compacted filler value could be lowered to 28% to be in line with German requirements. However, the same study also noted that a stiffer mastic may be required in Australia due to the higher in-service temperatures (Austroads 2013b). The latest specification published by the Australian Asphalt Pavement Association (2017) for a 7 mm SMA mix also specify minimum voids in the dry compacted filler of 28%.

The test results suggest that if a minimum voids in the dry compacted filler requirement of 38% or 40% is introduced by Main Roads (similar to TMR and RMS), the suppliers may be forced to incorporate hydrated lime or other filler types (with higher void contents) to achieve the minimum requirements. Care should therefore be taken that this approach does not have an adverse effect on the workability of SMA mixes in WA.

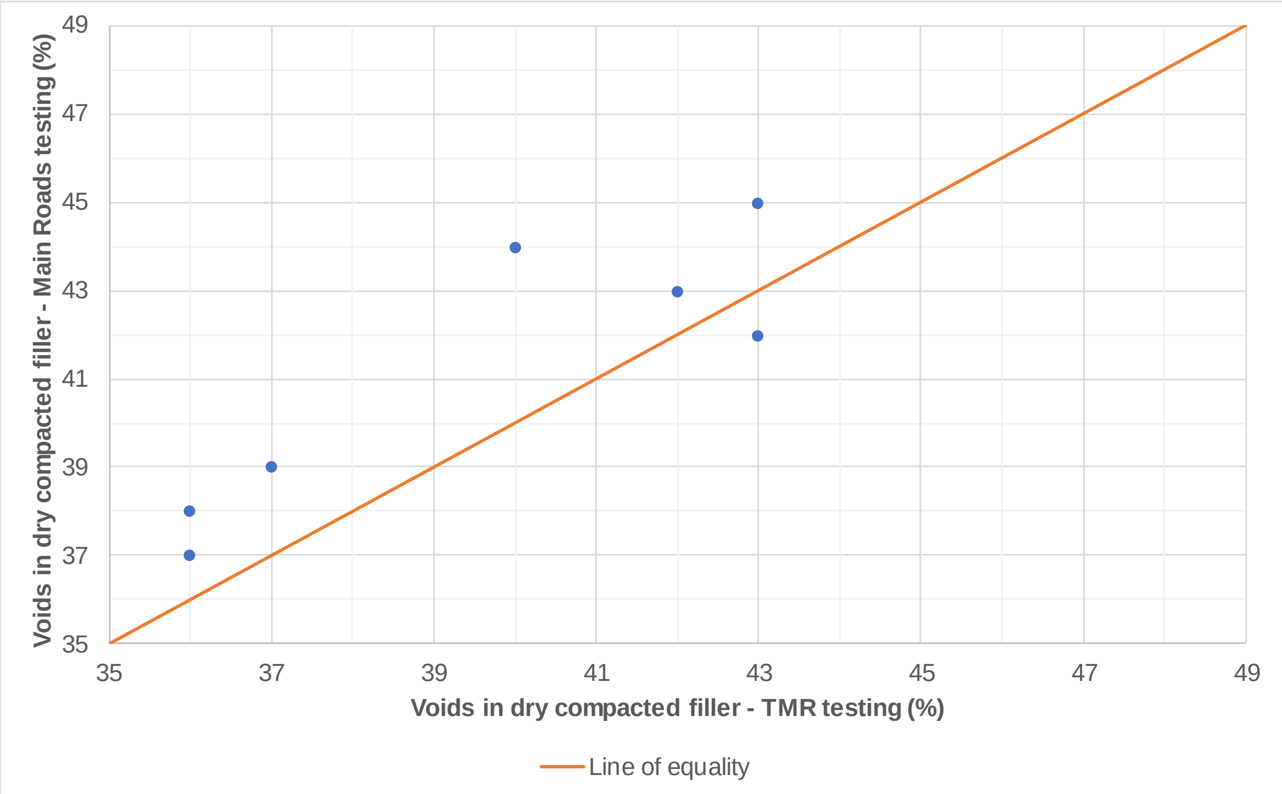
The Main Roads laboratory does not have experience with testing the voids in dry compacted filler. Parallel testing was therefore undertaken as part of this project to compare the test results between TMR's laboratory and Main Road's laboratory. The test results are summarised in Table 8.5 and shown in Figure 8.3.

Table 8.5: Apparent particle density and voids in the dry compacted filler – comparative testing

Filler combination	Apparent particle density (t/m³)(1) / Voids in the dry compacted filler (%)(2)							
	Boral (mix 1)		Boral (mix 2)		Downer		BGC	
	TMR Laboratory	Main Roads Laboratory	TMR Laboratory	Main Roads Laboratory	TMR Laboratory	Main Roads Laboratory	TMR Laboratory	Main Roads Laboratory
Baghouse	–	–	–	–	2.676 / 36.0	2.722 / 37	–	–
Total filler (without hydrated lime)(3)	2.720 / 43	2.812 / 45	2.708 / 37	2.800 / 39	2.682 / 36	2.754 / 37	2.633 / 36	2.705 / 38
Total filler (with hydrated lime)(3)	2.642 / 48	2.682 / / 51	2.626 / 43	2.631 / 42	2.627 / 40	2.741 / 44	2.582 / 42	2.691 / 43

1 Testing undertaken in accordance with test method AS 1141.7:2014.
2 Testing undertaken in accordance with test method AS 1141.17:2014.
3 Total filler is defined as the total fines component produced from crushing of aggregates and any added filler which passes the AS 0.075 mm sieve.

Figure 8.3: Voids in the dry compacted filler – comparative testing



The voids in the dry compacted filler determined by Main Roads laboratory were generally between 1–2% higher than the values determined by TMR. The reason for the difference between the two laboratories is not known at this stage but could be as a result of the differences in the apparent particle density determined (refer Table 8.5), variability in the test or sample variability. Further work is therefore recommended to reduce the inter-laboratory variability of apparent particle density values if Main Roads chooses to include a voids in dry compacted filler requirement in their specification.

A study by Austroads (2013b) showed a range of between 0.1–3.0% in the voids in the dry compacted filler for sub-samples of a single filler type and a difference of 1–2% between the two laboratories are not considered to be significant for this study.

8.2.3 *Stiffening effect of the aggregate filler*

The stiffening effect of the filler component on the mastic was determined in accordance with EN 13179-1:2013 *Tests for filler aggregate in bituminous mixes – part 1: Delta ring and ball test*. The test results are summarised in Table 8.6 and Figure 8.4.

The results show that the increase in softening point for the mixes without hydrated lime or lime kiln dust (i.e. Boral (mix 2), Downer and BGC) varied between 13.5–18.0 °C. The addition of hydrated lime stiffened the mastic of the same mixes, with an increase in softening point of between 21.5–29.5 °C.

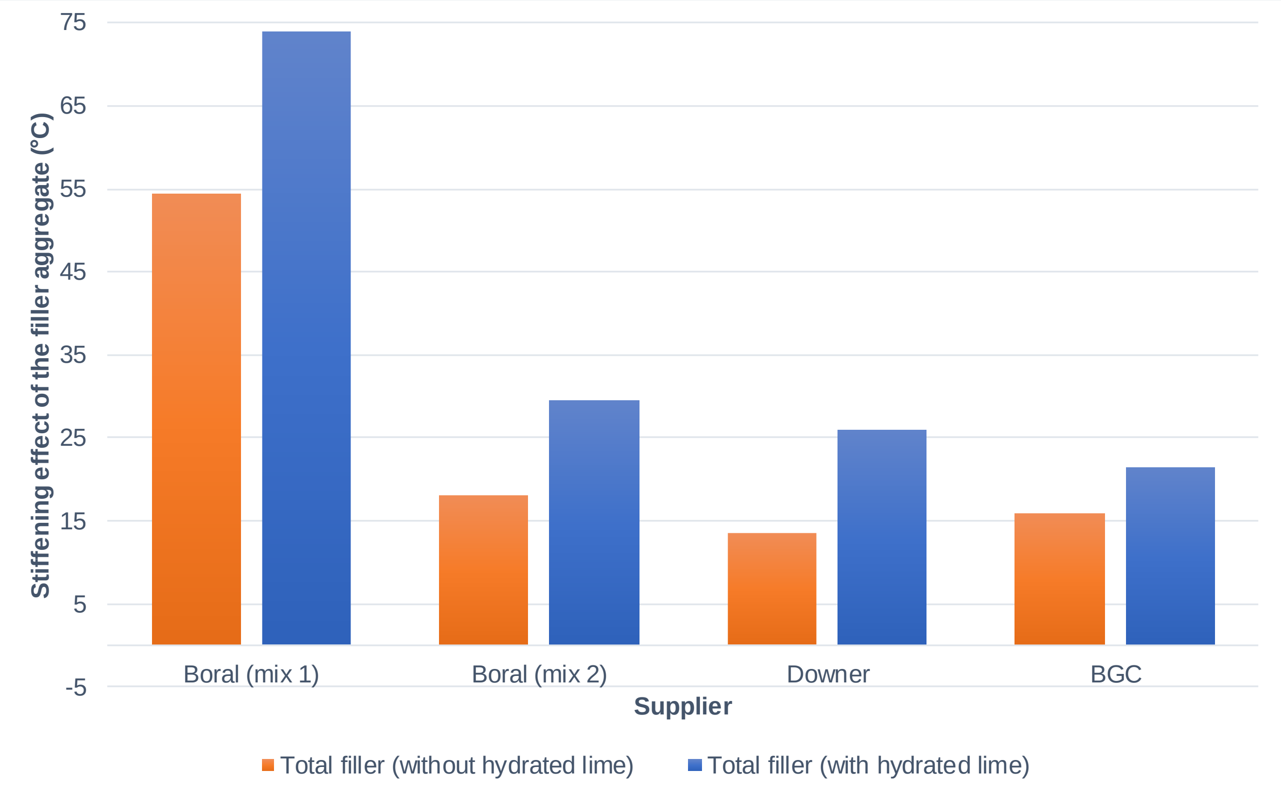
The addition of lime kiln dust to the Boral (mix 1) resulted in a significant increase of between 54.5–74.0 °C in the softening point of the mastic. This increase in softening point is significantly higher than the upper limit (25 °C) specified by some states in Germany (Austroads 2013b) and could be indicative of a mix that may be prone to poor workability during construction.

Table 8.6: Stiffening effect of the aggregate filler

Filler combination	**Softening point (°C)[1]**							
	Boral (mix 1)		**Boral (mix 2)**		**Downer**		**BGC**	
	Without hydrated lime	With hydrated lime	Without hydrated lime	With hydrated lime	Without hydrated lime	With hydrated lime	Without hydrated lime	With hydrated lime
Bitumen (no filler)	49.5							
Mastic (bitumen and filler)	104.0	123.5	67.5	79.0	63.0	75.5	65.5	71.0
Increase in softening point (°C)	54.5	74.0	18.0	29.5	13.5	26.0	16.0	21.5
Percentage increase (%)	110	149	36	60	27	53	32	43

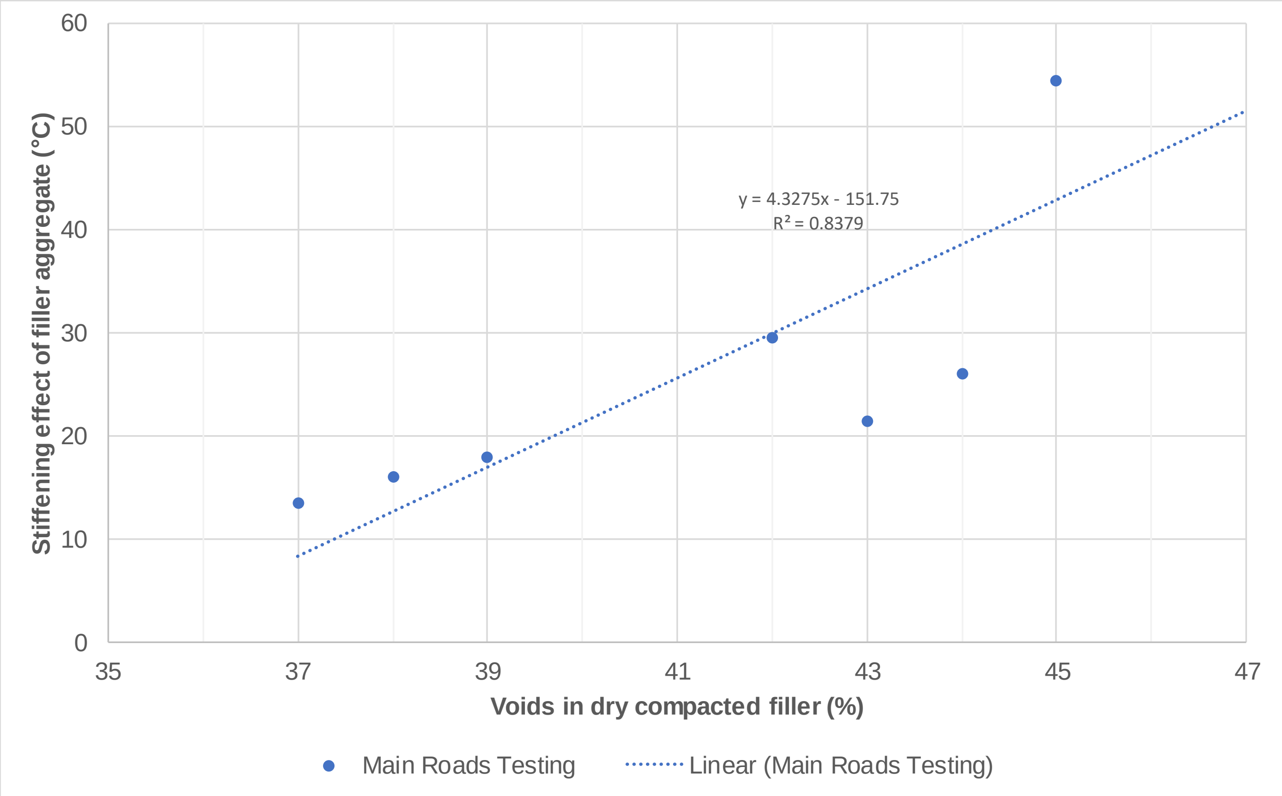
1 Testing undertaken in accordance with test method EN 13179-1:2013.

Figure 8.4: Stiffening effect of the aggregate filler (with and without lime)



Previous researchers (Austroads 2013b) found a good correlation between the voids in the dry compacted filler and the stiffening effect of the aggregate filler. In this study, a reasonably good correlation between these two properties was also found, as shown in Figure 8.5.

Figure 8.5: Stiffening effect of the aggregate filler vs voids in dry compacted filler (with and without lime)



8.2.4 Methylene blue value of the combined filler

As noted in section 2.2.2 of this report, the Methylene blue value of fillers is an indication of the amount and type of clay in the filler component that could be detrimental to the moisture resistance of asphalt mixes.

The Methylene blue values determined for the combined filler component (with and without hydrated lime) as part of this study are summarised in Table 8.7.

Table 8.7: Methylene blue value of the combined fillers

Filler combination	Methylene blue value (mg/g)(1)			
	Boral (mix 1)	Boral (mix 2)	Downer	BGC
Total filler (without hydrated lime)(2)	2.0	2.5	2.0	2.0
Total filler (with hydrated lime)(2)	1.5	1.5	1.5	1.0

1 Testing undertaken in accordance with test method AS 1141.66-2012.

RMS specifies a maximum Methylene blue value of 10 mg/g for the combined filler component without any hydrated lime added. TMR also specifies that if the combined filler component (without hydrated lime) has a Methylene blue value of between 10–18 mg/g, hydrated lime must be added to the SMA mix. The Methylene blue value of the combined filler component (including hydrated lime) must then be less than 10 mg/g.

The Methylene blue values in Table 8.7 were all below 10 mg/g which suggests that the filler combinations tested as part of this study does not present a risk to the moisture resistance of the asphalt mixes.

8.3 SMA Volumetric and Marshall Properties

The volumetric properties of the laboratory prepared specimens are summarised in Table 8.8.

Table 8.8: SMA volumetric and Marshall properties

Property	Test method	Supplier			
		Boral (mix 1)	Boral (mix 2)	Downer	BGC
Binder content (%)	Q308A-2017	6.65	6.55	6.35	6.45
Maximum density (t/m^3)	AS/NZS 2891.7.1:2015	2.461	2.459	2.444	2.383
Compacted density - TMR (t/m^3)	AS 2891.9.2-2005	2.353	2.376	2.35	2.342
Compacted density - Main Roads (t/m^3)	WA 733.1-2012 (uncoated)	2.356	2.376	2.352	2.344
Air voids - TMR (%)	Q311-2017	4.4	3.4	3.8	1.7
Air voids - Main Roads (%)	WA 733.1-2012 (uncoated)	4.3	3.4	3.8	1.6
VMA (%)	Q311-2017	18.8	17.9	17.9	16.1
Stability (kN)	Q305-2017	11.1	11.3	10.3	12.2
Flow (mm)	Q305-2017	4.2	4.2	4.3	4.8
Stiffness (kN/mm)	Q305-2017	2.6	2.7	2.4	2.6
Mix volume ratio	Q318-2017	0.83	0.81	0.83	0.89
Effective binder volume (%)	Q321-2017	14.4	14.5	14.0	14.4
Fixed binder fraction (%)	Q321-2017	0.54	0.44	0.4	0.44
Free binder volume (%)	Q321-2017	6.7	8.1	8.4	8.1

Some of the key volumetric properties are discussed below.

8.3.1 Air void content

The air void content of the four mixes tested varied between 1.6–4.3%, when tested in accordance with test method WA 733.1-2012 (refer Figure 8.6).

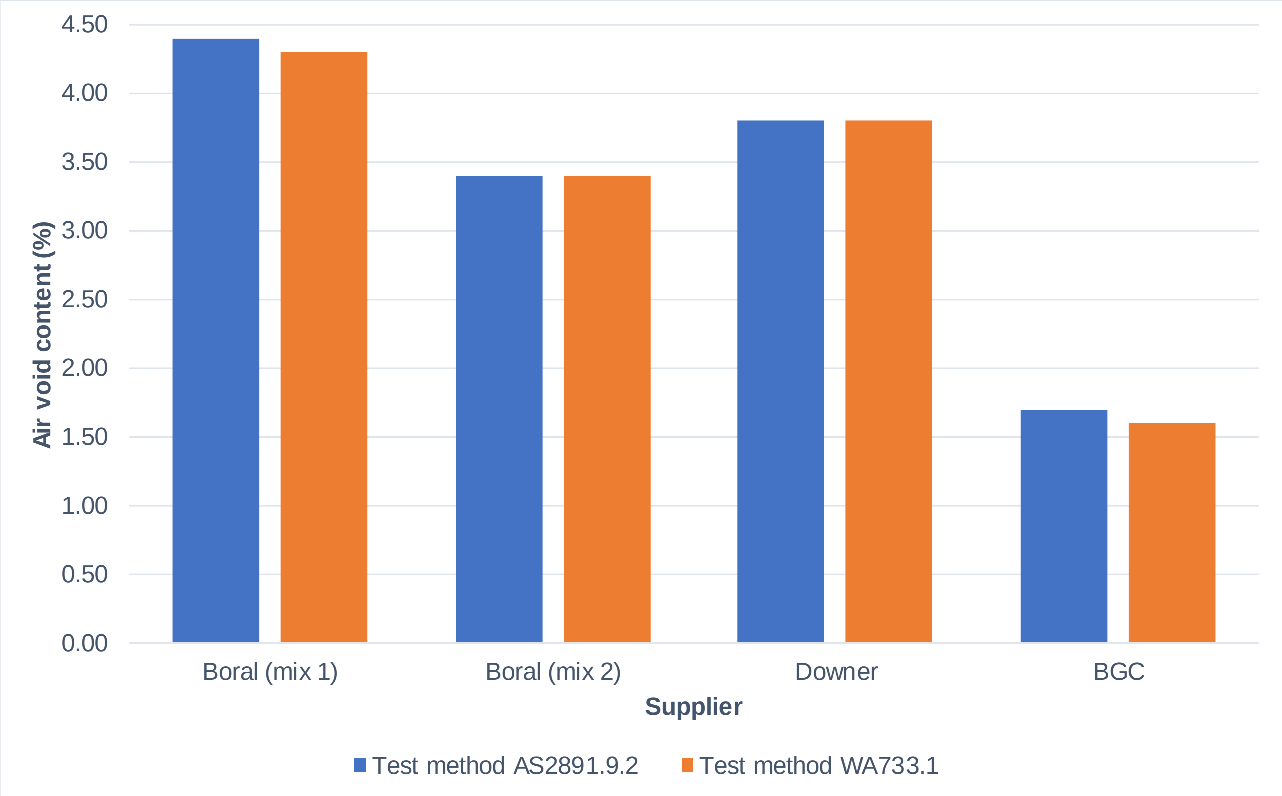
The Boral mix with added lime kiln dust (mix 1) achieved the air void and VMA requirements specified by Main Roads. Furthermore, the mix had an air void content of 4.3%, which is close to the target content of 4.5%. It is however worth noting that the laboratory air void content of this mix was higher than the maximum value (4%) allowed in Germany.

The Boral mix without lime kiln dust (mix 2) had an air void content of 3.4% and VMA value of 17.9%, which are marginally below the minimum specified limits of 3.5% and 18.0% respectively.

The Downer mix complied with the air void requirements in the specification, but the VMA was marginally lower (i.e. 17.9%) than the minimum value specified by Main Roads.

The BGC mix had an air void content of 1.6%, which is significantly lower than a minimum value of 3.5% specified by Main Roads for a 10 mm SMA mix. The VMA of the BGC mix was also significantly lower than the minimum value specified by Main Roads. The main reason for the low air void content appears to be the finer grading of the materials supplied by BGC which resulted in a lower VMA mix compared to the other SMA mixes.

Figure 8.6: Air void content



Comparative bulk density testing was also undertaken using test method AS/NZS 2891.9.2:2014 *Methods of sampling and testing asphalt, Method 9.2: Determination of bulk density of compacted asphalt - Presaturation method* and Main Roads test method WA 733.1-2012 *Bulk density and void content of asphalt* (presaturation method without coating). The main difference between the two methods is that the Australian Standards test method specifies a minimum immersion time of at least 5 minutes, whereas the Main Roads test method does not specify a minimum time period. The results of the testing undertaken suggest that the bulk density of the asphalt specimens was slightly higher when measured in accordance with test method WA733.1-2012, but the difference in air voids is not considered significant (refer Figure 8.7 and Figure 8.8).

Figure 8.7: Bulk density – test method AS2891.9.2:2014 versus WA733.1-2012

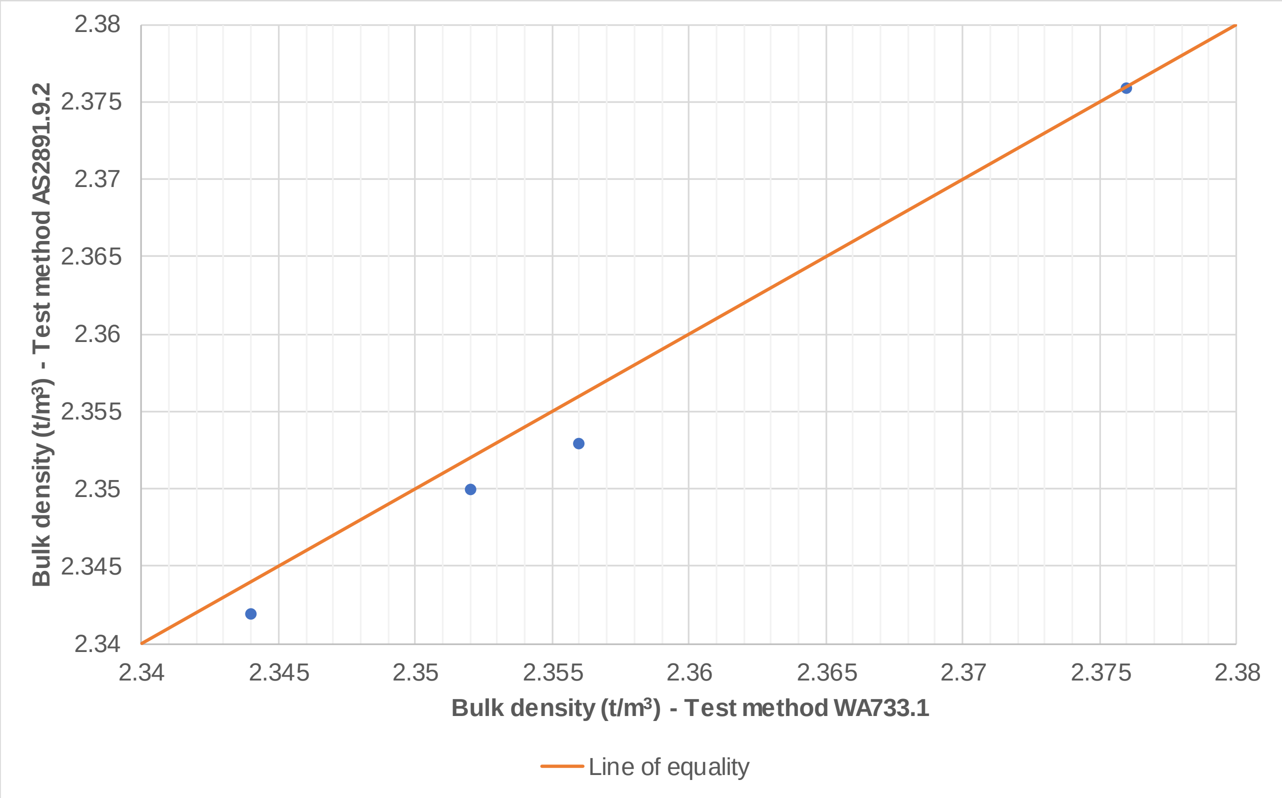
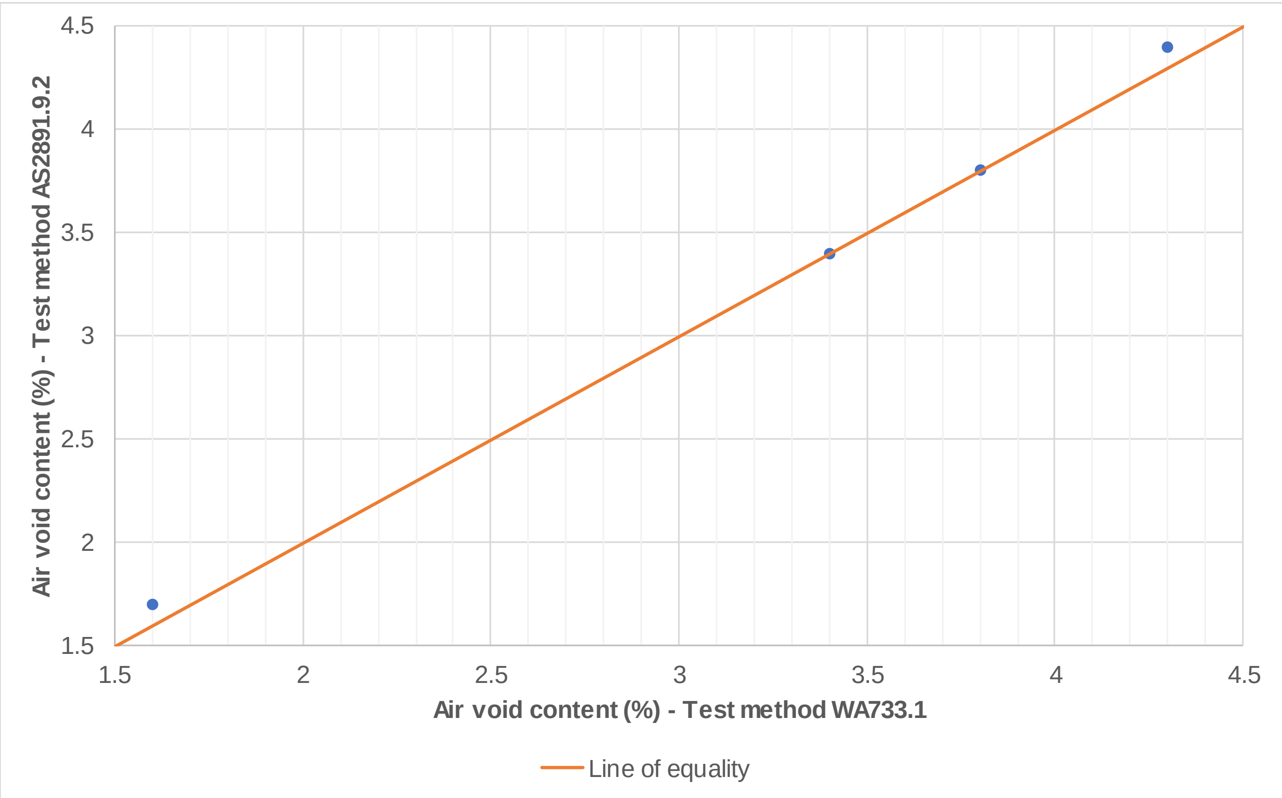


Figure 8.8: Bulk density – test method AS2891.9.2:2014 versus WA733.1-2012



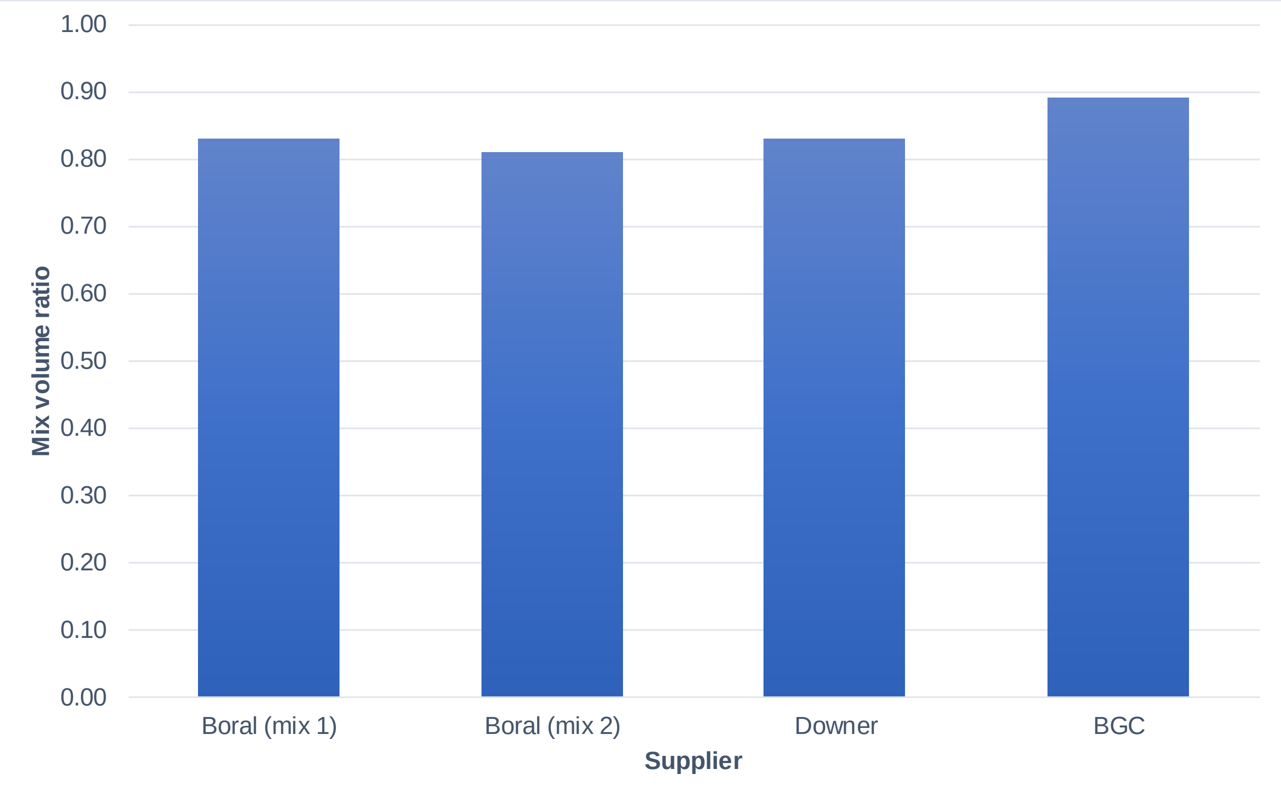
8.3.2 Mix volume ratio

The mix volume ratio is defined as the volume of mastic (i.e. all mix constituents excluding the coarse aggregate) expressed as a percentage of the voids in the coarse aggregate. If the volume of mastic exceeds the void space available in the coarse aggregate, the coarse aggregate structure must dilate in order to accommodate the mastic volume, which means that some of the traffic loads would be transferred to the weaker mastic instead of the stronger stone skeleton (Austroads 2013a). A maximum mix volume ratio is therefore specified by some SRAs in order to ensure that the stone-on-stone skeleton of the SMA mix is maintained.

TMR and RMS specify a maximum mix volume ratio for SMA mixes of ≤ 1.04 and < 1.0 respectively. The mix volume ratio of the SMA mixes tested varied between 0.81–0.89 (refer Figure 8.9), suggesting that appropriate stone-on-stone contact was achieved in the laboratory prepared samples.

The mix volume ratio of the BGC mix was significantly higher than the other mixes because of the lower air void content in the laboratory prepared specimens.

Figure 8.9: Mix volume ratio



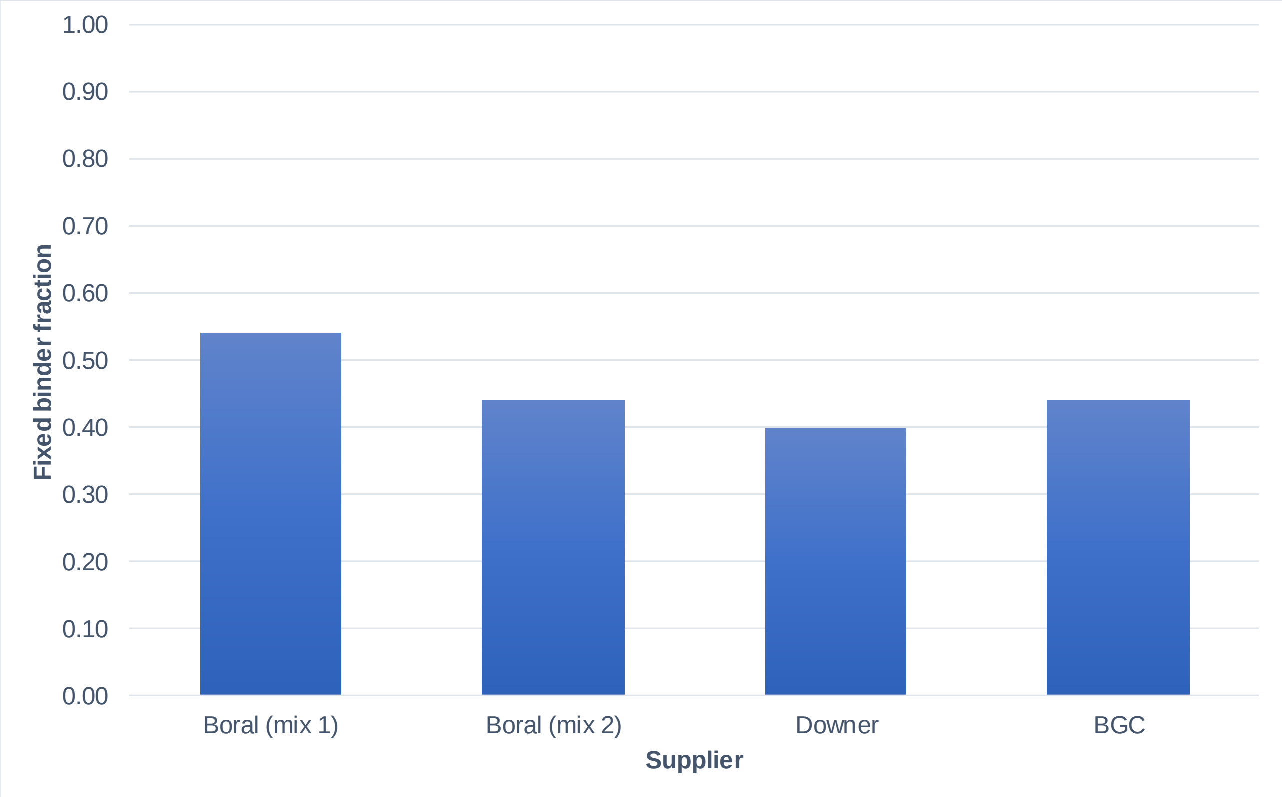
8.3.3 Fixed binder fraction

As discussed in section 7.1.2 of this report, the fixed binder fraction can be used to assess the expected workability of an SMA mix in the field. The fixed binder fractions of the mixes tested in the laboratory varied between 0.40–0.54 (refer Figure 8.10), which are below the maximum limit of 0.55 specified by TMR (TMR 2017a). However, TMR (2017a) also states that SMA mixes with a fixed binder fraction greater than 0.50 may also exhibit poor workability in the field.

Only the Boral SMA mix with baghouse fines and added lime kiln dust (i.e. Boral mix 1) had a fraction greater than 0.50 on and could therefore be prone to poor workability in the field based on this criterion. The risk of poor workability identified by the relatively high fixed binder fraction correlates well with the high voids in the dry compacted filler of the lime kiln dust added to this mix.

The SMA mixes from Downer, BGC and Boral (mix 2) had fixed binder fraction values below 0.5, suggesting that these mixes should have adequate workability in the field.

Figure 8.10: Fixed binder fraction



8.4 Summary of Main Laboratory Findings

The laboratory investigation undertaken as part of this study identified the following:

- The voids in the dry compacted filler determined for the SMA mixes included in this study varied between 40–48% when hydrated lime was added and between 36–37% without hydrated lime. The filler in the Boral (mix 1) had the highest void content (i.e. 48%) due to the additional lime kiln dust that was added. All of the four filler combinations tested will exceed the minimum voids in the dry compacted filler requirement specified by RMS (40%) and TMR (38%) if hydrated lime is added.
- The test results show that the addition of lime significantly increases the stiffness of the mastic when using the delta ring and ball softening point test. The addition of lime kiln dust to the Boral (mix 1) resulted in a significant increase of between 54.5–74.0 °C in the softening point of the mastic, which could be indicative of a mix that may be prone to poor workability during construction.
- The Methylene blue values of the filler combinations tested were well below the maximum limits specified by RMS and TMR, suggesting that the filler combinations tested as part of this study does not present a risk to the moisture resistance of asphalt mixes.

- The Boral with added lime kiln dust (mix 1) had a laboratory air void content of 4.3% in the compacted mix, which is close to the target air void content specified by Main Roads but higher than the maximum value (4%) allowed in Germany. The higher air void content is consistent with the higher voids in the dry compacted filler and significant increase in softening point determined for this particular mix.
- The comparative bulk density testing undertaken using test method AS 2891.9.2-2005 and Main Roads test method WA 733.1-2012 suggest that the difference in air voids determined using these two test methods is not significant.
- The mix volume ratio of the SMA mixes tested varied between 0.81–0.89, suggesting that appropriate stone-on-stone contact was achieved in the laboratory prepared samples.
- The SMA mixes from Downer, BGC and Boral (mix 2) had fixed binder fraction values below 0.5, suggesting that these mixes should have adequate workability in the field. However, Boral mix 1 (with added lime kiln dust) had a fraction greater than 0.50 and could be prone to poor workability during construction.

9 CONCLUSIONS AND RECOMMENDATIONS

A review was undertaken of current SMA practice in WA and how it compares to other SRAs in Australia and current SMA practices in Germany.

The literature review found that there is currently not a harmonised approach to specifying SMA across Australia. Some of the more important differences include the type of binders used, aggregate grading, volumetric requirements and the minimum field density specified.

The grading specified by Main Roads, VicRoads (heavy duty application) and DPTI are typically coarser on the intermediate sieve sizes than the grading specified by TMR and RMS for a 10 mm SMA mix. The Main Roads grading is also coarser than the grading required in Germany. The German specification also targets a lower air void content compared to Main Roads, which is likely to result in higher binder contents and denser field mixes.

There is therefore an opportunity to align the Main Roads specification more closely with the German and TMR specifications, particularly with regard to laboratory design air voids and grading. It is however understood that Main Roads has traditionally targeted a courser grading for their SMA mixes in order to achieve adequate texture on their higher speed roads. Any changes to the specified grading envelope should therefore consider possible impacts on the texture depth of SMA mixes produced in WA. Furthermore, targeting a lower mix design air void content could result in the mixes not meeting the criteria specified for Marshall Stability and Flow. The available literature suggests that Marshall Stability and Flow are not necessarily the most appropriate stability tests for SMA mixes and a permanent deformation requirement based on wheel tracking testing could be considered as an alternative.

A review of production results provided by local asphalt suppliers found that the average laboratory air void contents were close to the upper specification limit, primarily due to lower binder contents and coarser gradings. As a result, the VFB values were also lower than the estimated values for a typical SMA in Germany.

Several local asphalt suppliers were surveyed as part of the project to identify key areas of concern regarding the supply of SMA in WA. Some of the key findings include difficulties in adding the required filler amounts and fibres when using older asphalt plants, challenging aggregate grading requirements and availability of suitable quantities of baghouse dust. The suppliers also expressed a desire to develop their own SMA mix designs (including performance testing), which could then be approved by Main Roads.

A theoretical mechanistic analysis undertaken as part of the project showed the importance of providing adequate support underneath thin SMA surfacings, as well as a good bond between the surfacing layer and underlying pavement to reduce the risk of premature fatigue cracking.

A review of Marshall density ratio versus air void content data provided by Main Roads found that there is a high risk of achieving undesirable air void contents (i.e. greater than 8%) when a minimum characteristic Marshall density ratio of 95% (as per the current Main Roads specification) is achieved during construction. It is therefore recommended that Main Roads considers increasing the minimum compaction standard to ensure more durable and less permeable SMA mixes in-service.

Main Roads identified several known issues regarding the use of SMA in WA, including the measurement of bulk density, specification requirements for filler and industry’s ability to produce and place SMA in accordance with the current Main Roads specification.

Previous work undertaken by ARRB, as part of an Austroads study found that the wax coating method currently being used by Main Roads to determine the bulk density of SMA, was suitable for asphalt mixes with an air void content of less than 7%. The same study also found that the wax coating method provided similar density results compared to the SSD method. Given the increased costs and testing time associated with the wax sealing method, Main Roads could consider replacing their current test method for determining the bulk density of SMA specimens with the SSD method. If the SSD method is adopted, a maximum water absorption value of 1% should be included to ensure that this test method is appropriate for the air void contents being tested.

Alternatively, consideration should be given to adopting the silicon sealing method or to increasing the minimum compaction standard given that some of the SMA mixes currently being placed have a high likelihood of exceeding the 7% limit in the field.

Comparative testing did not show an appreciable difference between the bulk density of SMA specimens determined by AS 2891.9.2:2014 and WA 733.1-2012. There is therefore an opportunity for Main Roads to harmonise test method WA 733.1-2012 with national practice.

The project identified several filler requirements that could be included in Main Road's specification to ensure that minimum workability requirements can be achieved, whilst maintaining adequate mix stability. These requirements include minimum voids in the dry compacted filler, a maximum Methylene blue value, as well as a maximum fixed binder fraction.

The laboratory investigation undertaken as part of the project showed that the four SMA mixes (with hydrated lime) tested had voids in the dry compacted filler values of between 40–48%, exceeding the minimum requirements specified by TMR and RMS. These results suggest that the SMA mixes included in the study should have adequate stability in-service.

However, the Boral (mix 1) included lime kiln dust as an added filler and had a voids in the dry compacted filler value of 48%, indicating a mix with possible poor workability in the field. This risk was supported by a higher fixed binder fraction compared to the other mixes, as well as a significant increase in softening point when the filler was added to bitumen. This highlighted the potential detrimental effect of adding fillers with high air void contents (such as lime kiln dust) on the workability of SMA mixes.

The Methylene blue values determined for the filler combinations tested are well below the maximum allowable limit specified by some SRAs, which suggests that the filler combinations included in this study does not present a risk to the moisture resistance of the asphalt mixes tested.

All four of the mixes tested had a mix volume ratio of less than 0.9, indicating that the desirable stone-on-stone contact was achieved in the laboratory prepared mixes.

Based on the findings of the project, it is recommended that Main Roads consider the following future amendments to Specification 502 (the main specification clauses that may be affected by these amendments are included in brackets):

- targeting a lower design air void content of 3.5%, including a finer particle size distribution (Clause 502.26.01 & 502.26.02)
- introducing a permanent deformation requirement of between 2.0–3.0 mm using test method AG:PT/T231-06, similar to TMR, RMS and DPTI specifications (Clause 502.26.01)
- Increasing the minimum field compaction standard to a maximum allowable in situ air void content of 7%, similar to TMR, RMS and DPTI specifications. A minimum air void content of between 2–3% could also be considered to reduce the risk over over-compaction (Clause 502.55).

- replacing the current wax coating test method for determining the bulk density of SMA specimens extracted from the pavement with the SSD method, including a check on water absorption (Clause 502.02 & 502.55)
- replacing test method WA 733.1-2012 with AS 2891.9.2:2014 (Clause 502.02 & 502.55)
- introducing a minimum voids in the dry compacted filler requirement of 38% (Clause 502.10)
- introducing a maximum fixed binder fraction of 0.55, noting that mixes with a value greater than 0.50 could still be prone to poor workability (Clause 502.26.01)
- introducing a maximum mix volume ratio of 1.0, similar to the RMS specification (Clause 502.26.01)
- introducing a maximum Methylene blue value of 10 mg/g for the combined filler component in SMAs manufactured using fillers from source materials that may contain deleterious clayey materials (such as weathered basalt).

It is important to note that the impact of these recommendations on SMA mixes in WA should be further assessed during the implementation phase. Main Roads could also consider a transition period, whereby a number of the proposed criteria be included initially as ‘report only’ to gather data and gain confidence in any proposed new specification limits.

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Q321-2017, *Fixed and free binder in asphalt.*

APPENDIX A LABORATORY TEST REPORTS

A.1 Asphalt Testing

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON ASPHALT

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

MIX IDENTIFICATION	Boral SM10	-
ARTICLE NUMBER	BA18-027	-
SAMPLING DATE	-	-

PROPERTY	**TEST METHOD**	**TEST RESULTS**		**TARGET**
Bitumen Content (%)	Q308A	6.65		6.50
Maximum Density (t/m^3)	AS2891.7	2.461		-
Compacted Density (t/m^3)	AS2891.9.2	2.353		-
Air Voids (%)	Q311	4.4		-
Voids in Mineral Aggregate (%)	Q311	18.8		-
Compacted Density (t/m^3)	WA 733.1	+2.356		-
Air Voids (%) (from WA 733.1 method)	Q311	4.3		-
Stability (kN)	Q305	11.1		-
Flow (mm)		4.2		-
Stiffness (kN/mm)		2.6		-
Mix Volume Ratio	Q318	0.83		-
Effective Binder Volume (%)	Q321	14.4		
Fixed Binder Fraction (%)	Q321	0.54		-
Free Binder Volume (%)	Q321	6.7		-
13.2 mm		100		100
9.5 mm		96		95
6.70 mm		37		35
4.75 mm		25		24
2.36 mm		22		21.5
1.18 mm		19		18.5
0.600 mm		17		16.5
0.300 mm		15		14
0.150 mm		13		11.5
0.075 mm		11		10

Variation(s) to Test Method(s) / Remark(s): The samples were tested as received.
Compacted density values were obtained from pats manufactured by Marshall compaction 50 blows per face.
Compaction temperature was 160+-3 degrees. Bitumen content and grading tested in accordance with Q308A - 2014. +NATA accreditation not held for test method WA 733.1.

Checked By: T. Jones

Signatory: P. Watts
(Principal Materials Officer)

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON ASPHALT

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-902
DATE: 13/04/18

MIX IDENTIFICATION	Boral SMA10	-
ARTICLE NUMBER	BA18-102	-
SAMPLING DATE	-	-

PROPERTY	**TEST METHOD**	**TEST RESULTS**		**TARGET**
Bitumen Content (%)	Q308A	6.55		6.50
Maximum Density (t/m^3)	AS2891.7	2.459		-
Compacted Density (t/m^3)	AS2891.9.2	2.376		-
Air Voids (%)	Q311	3.4		-
Voids in Mineral Aggregate (%)	Q311	17.9		-
Compacted Density (t/m^3)	WA 733.1	+2.376		-
Air Voids (%) (from WA 733.1 method)	Q311	3.4		-
Stability (kN)	Q305	11.3		-
Flow (mm)	Q305	4.2		-
Stiffness (kN/mm)	Q305	2.7		-
Mix Volume Ratio	Q318	0.81		-
Effective Binder Volume (%)	Q321	14.5		
Fixed Binder Fraction (%)	Q321	0.44		-
Free Binder Volume (%)	Q321	8.1		-
13.2 mm		100		100
9.5 mm		95		95
6.70 mm		38		35
4.75 mm		25		24
2.36 mm		22		21.5
1.18 mm		19		18.5
0.600 mm		17		16.5
0.300 mm		15		14
0.150 mm		13		11.5
0.075 mm		11		10

Variation(s) to Test Method(s) / Remark(s): The samples were tested as received.
Compacted density values were obtained from pats manufactured by Marshall compaction 50 blows per face. Compaction temperature was 160+-3 degrees. Bitumen content and grading tested in accordance with Q308A - 2014. +NATA accreditation not held for test method WA 733.1.

Checked By: T. Jones

Signatory: P. Watts
(Principal Materials Officer)

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON ASPHALT

CLIENT:	ARRB 191 Carr Place Leederville WA 6007	**REPORT NO.:** **DATE:** **PAGE:**	SAS-927 28/06/18 1 of 4

MIX IDENTIFICATION	Downer SM10	-
ARTICLE NUMBER	BA18-025	-
SAMPLING DATE	-	-

PROPERTY	TEST METHOD	TEST RESULTS		TARGET
Bitumen Content (%)	Q308A	6.35		6.50
Maximum Density (t/m^3)	AS2891.7	2.444		-
Compacted Density (t/m^3)	AS2891.9.2	2.350		-
Air Voids (%)	Q311	3.8		-
Voids in Mineral Aggregate (%)	Q311	17.9		-
Compacted Density (t/m^3)	WA 733.1	+2.352		-
Air Voids (%) (from WA 733.1 method)	Q311	3.8		-
Stability (kN)	Q305	10.3		-
Flow (mm)		4.3		-
Stiffness (kN/mm)		2.4		-
Mix Volume Ratio	Q318	0.83		-
Effective Binder Volume (%)	Q321	14.0		
Fixed Binder Fraction (%)	Q321	0.40		-
Free Binder Volume (%)	Q321	8.4		-
13.2 mm		100		100
9.5 mm		95		95
6.70 mm		35		35
4.75 mm		25		24
2.36 mm		22		21.5
1.18 mm		19		18.5
0.600 mm		17		16.5
0.300 mm		15		14
0.150 mm		12		11.5
0.075 mm		10		10

Variation(s) to Test Method(s) / Remark(s): This report replaces SAS-910. The samples were tested as received. Compacted density values were obtained from pats manufactured by Marshall compaction 50 blows per face. Compaction temperature was 160+-3 degrees. Bitumen content and grading tested in accordance with Q308A - 2014. +NATA accreditation not held for test method WA 733.1.

Checked By: ____________________
T. Jones

Signatory: ____________________
P. Watts
(Principal Materials Officer)

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON ASPHALT

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-901
DATE: 03/04/18
PAGE: 1 of 6

MIX IDENTIFICATION	BGC SM10	-
ARTICLE NUMBER	BA18-026	-
SAMPLING DATE	-	-

PROPERTY	**TEST METHOD**	**TEST RESULTS**		**TARGET**
Bitumen Content (%)	Q308A	6.45		6.50
Maximum Density (t/m^3)	AS2891.7	2.383		-
Compacted Density (t/m^3)	AS2891.9.2	2.342		-
Air Voids (%)	Q311	1.7		-
Voids in Mineral Aggregate (%)	Q311	16.1		-
Compacted Density (t/m^3)	WA 733.1	+2.344		-
Air Voids (%) (from WA 733.1 method)	Q311	1.6		-
Stability (kN)	Q305	12.2		-
Flow (mm)		4.8		-
Stiffness (kN/mm)		2.6		-
Mix Volume Ratio	Q318	0.89		-
Effective Binder Volume (%)	Q321	14.4		
Fixed Binder Fraction (%)	Q321	0.44		-
Free Binder Volume (%)	Q321	8.1		-
13.2 mm		100		100
9.5 mm		93		90.9
6.70 mm		50		46.0
4.75 mm		32		31.7
2.36 mm		25		25.3
1.18 mm		21		21.5
0.600 mm		18		18.3
0.300 mm		15		15.1
0.150 mm		13		12.7
0.075 mm		10		10.2

Variation(s) to Test Method(s) / Remark(s): Tested as received.
Compacted density values were obtained from pats manufactured by Marshall compaction 50 blows per face. Compaction temperature was 160+-3 degrees. Bitumen content and grading tested in accordance with Q308A - 2014. +NATA accreditation not held for test method WA 733.1.

Checked By: T. Jones

Signatory: P. Watts
(Principal Materials Officer)

NATA ACCREDITED FOR TECHNICAL COMPETENCE
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A.2 Filler Testing

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

ARTICLE NUMBER	BA18-061
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 Baghouse Combined 3% Kiln Dust / 4% Baghouse
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	28/02/18

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	45	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.715	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
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CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: P. Watts, Principal Materials Officer Date: 1/3/18

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

ARTICLE NUMBER	BA18-060
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 (Naturals)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	22/02/18

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	36	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.736	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: Date: 1/3/18
P. Watts
Principal Materials Officer

SWF921

Rev 1

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

ARTICLE NUMBER	BA18-010
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 (Hydrated Lime)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	18/01/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	64	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.256	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: P. Watts Date: 1/3/18.
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

ARTICLE NUMBER	BA18-010
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 (Hydrated Lime)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	18/01/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	64	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.256	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 - TESTING

CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: P. Watts, Principal Materials Officer Date: 1/3/18.

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-877
DATE: 01/03/18

ARTICLE NUMBER	BA18-027
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 Combined Filler (Naturals, Kiln Dust / Baghouse & Hydrated Lime)
SUPPLIER	Boral
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	22/02/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	48	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.642	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

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CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: P. Watts, Principal Materials Officer Date: 1/3/18

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-902
DATE: 13/04/18

ARTICLE NUMBER	BA18-102
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 Combined Filler (Naturals, Baghouse & Hydrated Lime)
SUPPLIER	Boral
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	04/04/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	43	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.626	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s):Testing was carried out on the passing 75 micron portion of the sample.

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CHECKED BY: T. Jones Date: 13/4/18

SIGNATORY: P. Watts Date: 13/4/18
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-917
DATE: 25/05/18

ARTICLE NUMBER	BA18-141
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 Combined Filler without Lime (Naturals, Baghouse)
SUPPLIER	Boral
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	23/05/2018

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	37	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.708	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	*Percent Passing*	*AS2357 Limits*
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: T. Jones Date: 25/5/18

SIGNATORY: P. Watts Date: 25/5/18
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-917
DATE: 25/05/18

ARTICLE NUMBER	BA18-142
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Boral SM10 Combined Filler without Lime (Naturals, Baghouse, Lime Kiln Dust)
SUPPLIER	Boral
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	23/05/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	43	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.720	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample.

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Accreditation Number: 2302
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CHECKED BY: T. Jones Date: 25/5/18

SIGNATORY: P. Watts Date: 25/5/18

P. Watts
Principal Materials Officer

MINERAL FILLER TEST REPORT

Report No : S8153 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information: Boral Combined Filler - Kiln Dust (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 10/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Boral Combined Filler - Kiln Dust (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.891**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**60.2**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**1.0**

Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	
Softening Point of Binder / Filler Blend (°C)	
Stiffening Effect of the Filler Aggregate (°C)	

Binder Sample Number
Not Supplied

Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

MINERAL FILLER TEST REPORT

Report No : S8009 / 1

Customer : Main Roads WA

Project / Contract : Investigation of Tenderness of High Modulus Asphalt (EME2)

Other Details / Information :

Asphalt Filler Properties

Filler Supplier :	Boral	Date/s Filler Tested :	9/05/2018
Name / Type of Filler :	Baghouse Dust Passing 75 Micron Sieve	Date Filler Sampled :	17/10/2017
Filler Sampling Method :	Supplied by Others, Tested as Received		
Other Filler Details / Information :			

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.811**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**39.6**

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	9/05/2018
Name / Type of Binder :	C170	Date Binder Sampled :	18/06/2015
Binder Sampling Method :	Supplied by Others, Tested as Received		
Other Binder Details / Information :	Batch: B 191. Tank: TK 901		

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**48.5**	Refer to Report : S8007 / 1
Softening Point of Binder / Filler Blend (°C)	**65.0**	
Stiffening Effect of the Filler Aggregate (°C) Calculated in accordance with EN 13179-1	**16.5**	

Comments / Distribution
Reports
TRIM 17/9582
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 10/05/2018

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Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No :	S8318 / 1	Customer :	Main Roads Western Australia
Project / Contract :	WARRIP - Stone Mastic Asphalt Filler		
Other Details / Information	Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust (Passing 150 micron sieve)		

Asphalt Filler Properties

Filler Supplier :	Boral	Date/s Filler Tested :	23/07/2018
Name / Type of Filler :	Mineral Filler	Date Filler Sampled :	22/05/2018
Filler Sampling Method :	Sampled by othersTested as received.		
Other Filler Details / Information :	Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust (Passing 150 micron sieve)		

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.812**	Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8152 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	89

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	7/08/2018
Name / Type of Binder :	Not Supplied	Date Binder Sampled :	Not Supplied
Binder Sampling Method :	Sampled by others. Tested as received		
Other Binder Details / Information :	Nil.		
Asphalt Filler :	As Above		
Sample Preparation :	EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test		
Asphalt Filler / Binder Blend by Volume :	37.5% Asphalt Filler Aggregate and 62.5% Binder		

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**104.0**	
Stiffening Effect of the Filler Aggregate (°C)	**54.5**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 8/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8317 / 1
Customer : Main Roads Western Australia
Project / Contract : WARRIP - Stone Mastic Asphalt Filler
Other Details / Information: Boral Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral
Date/s Filler Tested : 16/07/2018
Name / Type of Filler : Mineral Filler
Date Filler Sampled : 22/05/2018
Filler Sampling Method : Sampled by othersTested as received.
Other Filler Details / Information : Boral Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.800**	Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8151 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	87

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP
Date/s Binder Tested : 18/07/2018
Name / Type of Binder : Not Supplied
Date Binder Sampled : Not Supplied
Binder Sampling Method : Sampled by others. Tested as received
Other Binder Details / Information : Nil.
Asphalt Filler : As Above
Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test
Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**67.5**	
Stiffening Effect of the Filler Aggregate (°C)	**18.0**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

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JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8316 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information: Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust / Lime (Passing 150 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 23/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust / Lime (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.631**

Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8150 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	93

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP

Date/s Binder Tested : 7/08/2018

Name / Type of Binder : Not Supplied

Date Binder Sampled : Not Supplied

Binder Sampling Method : Sampled by others. Tested as received

Other Binder Details / Information : Nil.

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**123.5**	
Stiffening Effect of the Filler Aggregate (°C)	**74.0**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 8/08/2018

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

mainroads WESTERN AUSTRALIA

MINERAL FILLER TEST REPORT

Report No :	S8315 / 1	Customer :	Main Roads Western Australia
Project / Contract :		WARRIP - Stone Mastic Asphalt Filler	
Other Details / Information		Boral Combined Filler - Naturals, Baghouse Dust and Hydrated Lime (Passing 150 micron sieve)	

Asphalt Filler Properties

Filler Supplier :	Boral	Date/s Filler Tested :	10 - 13/07/2018
Name / Type of Filler :	Mineral Filler	Date Filler Sampled :	22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Boral Combined Filler - Naturals, Baghouse Dust and Hydrated Lime (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.631**	Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8149 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	90

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	17/07/2018
Name / Type of Binder :	Not Supplied	Date Binder Sampled :	Not Supplied

Binder Sampling Method : Sampled by others. Tested as received

Other Binder Details / Information : Nil.

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)	**79.0**	
Stiffening Effect of the Filler Aggregate (°C)	**29.5**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Document:71/05/1141.7_5 Issue: 18/06/2018 TRIM:D18#435830

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8152 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information: Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 28 - 29/06/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.812**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**45.3**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**2.0**

Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	
Softening Point of Binder / Filler Blend (°C)	
Stiffening Effect of the Filler Aggregate (°C)	

Binder Sample Number
Not Supplied

Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Document:71/05/1141.7_5 Issue: 18/06/2018 TRIM:D18#435830

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5-9 Colin Jamieson Drive
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MINERAL FILLER TEST REPORT

Report No :	S8151 / 1	Customer :	Main Roads Western Australia
Project / Contract :		WARRIP - Stone Mastic Asphalt Filler	
Other Details / Information		Boral Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)	

Asphalt Filler Properties

Filler Supplier :	Boral	Date/s Filler Tested :	25/06/2018
Name / Type of Filler :	Mineral Filler	Date Filler Sampled :	22/05/2018
Filler Sampling Method :	Sampled by othersTested as received.		
Other Filler Details / Information :	Boral Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)		

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.800**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**39.3**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**2.5**	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	Not Supplied	Date/s Binder Tested :	
Name / Type of Binder :	Not Supplied	Date Binder Sampled :	

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

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Materials Engineering Branch
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5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No :	S8149 / 1	Customer :	Main Roads Western Australia
Project / Contract :		WARRIP - Stone Mastic Asphalt Filler	
Other Details / Information	TMR Qld Lab No. BA18-027, Boral Combined Filler - Naturals, Baghouse Dust and Lime (Passing 75 micron sieve)		

Asphalt Filler Properties

Filler Supplier :	Boral	Date/s Filler Tested :	22 - 28/6/2018
Name / Type of Filler :	Mineral Filler	Date Filler Sampled :	22/05/2018
Filler Sampling Method :	Sampled by othersTested as received.		
Other Filler Details / Information :	Boral Combined Filler - Naturals, Baghouse Dust and Lime (Passing 75 micron sieve)		

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.631**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**41.9**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**1.5**	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	Not Supplied	Date/s Binder Tested :	
Name / Type of Binder :	Not Supplied	Date Binder Sampled :	
Binder Sampling Method :			
Other Binder Details / Information :			
Asphalt Filler :	As Above		
Sample Preparation :	EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test		
Asphalt Filler / Binder Blend by Volume :	37.5% Asphalt Filler Aggregate and 62.5% Binder		

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution TRIM 16/180 S Halligan	Approved Signatory: Function: Project Officer Name: Mark Hopgood Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8150 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information TMR Qld Lab No. BA18-027, Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust and Lime (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 22 - 29/6/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Boral Combined Filler - Naturals, Baghouse Dust, Lime Kiln Dust and Lime (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.682**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**51.2**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**1.5**	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-927
DATE: 28/06/18

ARTICLE NUMBER	BA18-025
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Downer SM10 Combined Filler (Naturals, Baghouse & Hydrated Lime)
SUPPLIER	Downer
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	13/02/2018

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	40	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.627	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	*Percent Passing*	*AS2357 Limits*
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): This report replaces SAS-910. Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: ____________________ Date: __________
T. Jones

SIGNATORY: ____________________ Date: __________
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-927
DATE: 28/06/18

ARTICLE NUMBER	BA18-010
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Downer SM10 (Hydrated Lime)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	18/01/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	64	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.256	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): This report replaces SAS-910. Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: ____________________ Date: __________
T. Jones

SIGNATORY: ____________________ Date: __________
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-927
DATE: 28/06/18

ARTICLE NUMBER	BA18-045
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Downer SM10 (Naturals)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	20/02/18

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	35	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.682	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	*Percent Passing*	*AS2357 Limits*
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): This report replaces SAS-910. Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: ______________________ Date: __________
T. Jones

SIGNATORY: ______________________ Date: __________
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-874
DATE: 22/02/18

ARTICLE NUMBER	BA18-013
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Downer SM10 (Baghouse Fines)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	28/02/2018

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	36	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.676	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	*Percent Passing*	*AS2357 Limits*
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample. Tested as received.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 - TESTING

CHECKED BY: T. Jones Date: 1/3/18

SIGNATORY: P. Watts Date: 1/3/18
P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-917
DATE: 25/05/18

ARTICLE NUMBER	BA18-140
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	Downer SM10 Combined Filler without Lime (Naturals, Baghouse)
SUPPLIER	Downer
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	23/05/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	36	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.682	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
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CHECKED BY: T. Jones Date: 25/5/18

SIGNATORY: P. Watts Date: 25/5/18

P. Watts
Principal Materials Officer

mainroads WESTERN AUSTRALIA
ABN: 50 860 676 021

MINERAL FILLER TEST REPORT

Report No : S8010 / 1 Customer : Main Roads WA

Project / Contract : Investigation of Tenderness of High Modulus Asphalt (EME2)

Other Details / Information :

Asphalt Filler Properties

Filler Supplier :	Downer	Date/s Filler Tested :	7/05/2018
Name / Type of Filler :	Baghouse Dust Passing 75 Micron Sieve	Date Filler Sampled :	27/10/2017

Filler Sampling Method : Supplied by Others, Tested as Received

Other Filler Details / Information :

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.722

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	36.9

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	9/05/2018
Name / Type of Binder :	C170	Date Binder Sampled :	18/06/2015

Binder Sampling Method : Supplied by Others, Tested as Received

Other Binder Details / Information : Batch: B 191. Tank: TK 901

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	48.5	Refer to Report : S8007 / 1
Softening Point of Binder / Filler Blend (°C)	65.0	
Stiffening Effect of the Filler Aggregate (°C) Calculated in accordance with EN 13179-1	16.5	

Comments / Distribution	Approved Signatory:
Reports TRIM 17/9582 S Halligan	Function: Project Officer Name: Mark Hopgood Date: 10/05/2018

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Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No :	S8320 / 1	Customer :	Main Roads Western Australia
Project / Contract :	WARRIP - Stone Mastic Asphalt Filler		
Other Details / Information	Downer Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)		

Asphalt Filler Properties

Filler Supplier :	Downer	Date/s Filler Tested :	16/07/2018
Name / Type of Filler :	Mineral Filler	Date Filler Sampled :	22/05/2018
Filler Sampling Method :	Sampled by othersTested as received.		
Other Filler Details / Information :	Downer Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)		

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.754**	Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8155 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	73

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	18/07/2018
Name / Type of Binder :	Not Supplied	Date Binder Sampled :	Not Supplied
Binder Sampling Method :	Sampled by others. Tested as received		
Other Binder Details / Information :	Nil.		
Asphalt Filler :	As Above		
Sample Preparation :	EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test		
Asphalt Filler / Binder Blend by Volume :	37.5% Asphalt Filler Aggregate and 62.5% Binder		

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**63.0**	
Stiffening Effect of the Filler Aggregate (°C)	**13.5**	Calculated in accordance with EN 13179-1

Comments / Distribution	Approved Signatory:
TRIM 16/180 S Halligan	Function: Project Officer Name: Mark Hopgood Date: 2/08/2018

Document:71/05/1141.7_5 Issue: 18/06/2018 TRIM:D18#435830

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

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MINERAL FILLER TEST REPORT

Report No : S8155 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information Downer Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 9 - 13/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Downer Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.754**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**37.1**

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	**2.0**	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8157 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information BGC Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 10/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : BGC Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.705

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	37.7

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	2.0	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

mainroads WESTERN AUSTRALIA

MINERAL FILLER TEST REPORT

Report No : S8319 / 1 Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information Downer Combined Filler - Naturals, Baghouse Dust and Hydrated Lime (Passing 150 micron sieve)

Asphalt Filler Properties

Filler Supplier : Downer Date/s Filler Tested : 16/07/2018

Name / Type of Filler : Mineral Filler Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Downer Combined Filler - Naturals, Baghouse Dust and Hydrated Lime (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.741**

Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8154 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	78

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP Date/s Binder Tested : 23/07/2018

Name / Type of Binder : Not Supplied Date Binder Sampled : Not Supplied

Binder Sampling Method : Sampled by others. Tested as received

Other Binder Details / Information : Nil.

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**75.5**	
Stiffening Effect of the Filler Aggregate (°C)	**26.0**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8154 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information TMR QGL Lab Number BA18-028, Downer Combined Filler - Naturals, Baghouse Dust, Lime (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 9 - 13/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : Downer Combined Filler - Naturals, Baghouse Dust, Lime (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.741

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	43.6

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	1.5	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-891
DATE: 03/04/18

ARTICLE NUMBER	BA18-026
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	BGC SM10 Combined Filler (Naturals / Baghouse & Hydrated Lime)
SUPPLIER	BGC
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	27/03/2018

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	42	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.582	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample. Tested as received.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: T. Jones Date: 3/4/18

SIGNATORY: P. Watts Date: 3/4/18

P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-892
DATE: 03/04/18

ARTICLE NUMBER	BA18-007
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	BGC SM10 (Hydrated Lime)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	18/01/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	51	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.324	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample. Tested as received.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: T. Jones Date: 3/4/18

SIGNATORY: P. Watts Date: 3/4/18

P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-891
DATE: 03/04/18

ARTICLE NUMBER	BA18-101
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	BGC SM10 (Naturals)
SUPPLIER	-
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	27/03/18

PROPERTY	TEST RESULT	SPECIFICATION LIMITS
Voids in Dry Compacted Filler (%) AS1141.17	35	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.638	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	*Percent Passing*	*AS2357 Limits*
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample. Tested as received.

NATA
ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 - TESTING

CHECKED BY: T. Jones Date: 3/4/18

SIGNATORY: P. Watts Date: 3/4/18

P. Watts
Principal Materials Officer

Department of Transport and Main Roads
Materials Laboratory Services
398 Tingira Street Bulwer Island Qld 4008

Queensland Government

REPORT ON MINERAL FILLER

CLIENT: ARRB
191 Carr Place
Leederville WA 6007

REPORT NO.: SAS-917
DATE: 25/05/18

ARTICLE NUMBER	BA18-139
SENDER'S/BATCH NUMBER	-
ARTICLE DESCRIPTION	BGC SM10 Combined Filler without Lime (Naturals, Baghouse)
SUPPLIER	BGC
SAMPLING DATE	-
SAMPLER	-
DATE TESTED	23/05/2018

PROPERTY	**TEST RESULT**	**SPECIFICATION LIMITS**
Voids in Dry Compacted Filler (%) AS1141.17	36	-
Moisture Content (% by mass) AS3583.2	-	-
Specific Surface (m^2/kg) AS2350.8	-	-
Loss on Ignition (% by mass) AS3583.3	-	-
Water Soluble Fraction (% by mass) AS1141.8	-	-
Apparent Particle Density (t/m^3) AS1141.7	2.633	-

PARTICLE SIZE DISTRIBUTION AS1141.11		
Sieve Size	***Percent Passing***	***AS2357 Limits***
0.600mm	-	100
0.300 mm	-	95-100
0.075mm	-	75-100

Variation(s) to Test Method(s) / Remark(s): Testing was carried out on the passing 75 micron portion of the sample.

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accreditation Number: 2302
Accredited for compliance with ISO/IEC 17025 – TESTING

CHECKED BY: T. Jones Date: 25/5/18

SIGNATORY: P. Watts, Principal Materials Officer Date: 25/5/18

MINERAL FILLER TEST REPORT

ABN: 50 860 676 021

Report No :	S8007 / 1	Customer :	Main Roads WA
Project / Contract :	Investigation of Tendemess of High Modulus Asphalt (EME2)		
Other Details / Information :			

Asphalt Filler Properties

Filler Supplier :	BGC	Date/s Filler Tested :	4/05/2018
Name / Type of Filler :	Baghouse Dust Passing 75 Micron Sieve	Date Filler Sampled :	18/10/2017
Filler Sampling Method :	Supplied by Others, Tested as Received		
Other Filler Details / Information :			

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.660**

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	**36.5**

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier :	BP	Date/s Binder Tested :	8/05/2018
Name / Type of Binder :	C170	Date Binder Sampled :	18/06/2015
Binder Sampling Method :	Supplied by Others, Tested as Received		
Other Binder Details / Information :	Batch: B 191. Tank: TK 901		
Asphalt Filler :	As Above		
Sample Preparation :	EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test		
Asphalt Filler / Binder Blend by Volume :	37.5% Asphalt Filler Aggregate and 62.5% Binder		

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**48.5**
Softening Point of Binder / Filler Blend (°C)	**63.5**
Stiffening Effect of the Filler Aggregate (°C) Calculated in accordance with EN 13179-1	**14.5**

Comments / Distribution
Reports
TRIM 17/9582
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 10/05/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8322 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information: BGC Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)

Asphalt Filler Properties

Filler Supplier : BGC

Date/s Filler Tested : 16/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : BGC Combined Filler - Naturals and Baghouse Dust (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.705**

Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8157 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	76

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP

Date/s Binder Tested : 23/07/2018

Name / Type of Binder : Not Supplied

Date Binder Sampled : Not Supplied

Binder Sampling Method : Sampled by others. Tested as received

Other Binder Details / Information : Nil.

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**65.5**	
Stiffening Effect of the Filler Aggregate (°C)	**16.0**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8157 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information BGC Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 10/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : BGC Combined Filler - Naturals and Baghouse Dust (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.705

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	37.7

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	2.0	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

mainroads WESTERN AUSTRALIA

MINERAL FILLER TEST REPORT

Report No : S8321 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information: BGC Combined Filler - Naturals, Baghouse Dust and Lime (Passing 150 micron sieve)

Asphalt Filler Properties

Filler Supplier : BGC

Date/s Filler Tested : 16/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : BGC Combined Filler - Naturals, Baghouse Dust and Lime (Passing 150 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	**2.691**

Note: Apparent Particle Density of Filler obtained from material passing the 0.075mm sieve : Refer to report S8156 / 1

AS 1141.11.1 - Particle Size Distribution - Dry Sieving Method

Sieve Size (mm)	Mass Passing (%)
0.150	100
0.075	78

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : BP

Date/s Binder Tested : 18/07/2018

Name / Type of Binder : Not Supplied

Date Binder Sampled : Not Supplied

Binder Sampling Method : Sampled by others. Tested as received

Other Binder Details / Information : Nil.

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)	**49.5**	Binder Softening Point obtained from report S8315 / 1
Softening Point of Binder / Filler Blend (°C)	**71.0**	
Stiffening Effect of the Filler Aggregate (°C)	**21.5**	Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 2/08/2018

Document:71/05/1141.7_5 Issue: 18/06/2018 TRIM:D18#435830

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing
ACCREDITATION No. 1989 SITE No. 1982

Main Roads Western Australia
Materials Engineering Branch
JJG Punch Laboratory
5-9 Colin Jamieson Drive
WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766

MINERAL FILLER TEST REPORT

Report No : S8156 / 1

Customer : Main Roads Western Australia

Project / Contract : WARRIP - Stone Mastic Asphalt Filler

Other Details / Information TMR QLD Lab Number BA18-026, BGC Combined Filler - Naturals, Baghouse Dust and Lime (Passing 75 micron sieve)

Asphalt Filler Properties

Filler Supplier : Boral

Date/s Filler Tested : 10 - 13/07/2018

Name / Type of Filler : Mineral Filler

Date Filler Sampled : 22/05/2018

Filler Sampling Method : Sampled by othersTested as received.

Other Filler Details / Information : BGC Combined Filler - Naturals, Baghouse Dust and Lime (Passing 75 micron sieve)

AS 1141.7 - Apparent Particle Density of Filler

Dilatometric Liquid Used : Distilled Water

Apparent Particle Density of Filler (t/m^3)	2.691

AS 1141.17 - Voids in Dry Compacted Filler

Voids in Dry Compacted Filler (%)	42.5

AS 1141.66 - Methylene Blue Adsorbtion Value of Fine Aggregate and Mineral Fillers

Methylene Blue Value (mg/g)	1.0	Not covered by our NATA scope of accreditation.

Stiffening Effect of Filler Aggregate When Mixed With Binder

Binder Supplier : Not Supplied

Date/s Binder Tested :

Name / Type of Binder : Not Supplied

Date Binder Sampled :

Binder Sampling Method :

Other Binder Details / Information :

Asphalt Filler : As Above

Sample Preparation : EN 13179-1 Tests for Filler Aggregate in Bituminous Mixes - Part 1: Delta Ring and Ball Test

Asphalt Filler / Binder Blend by Volume : 37.5% Asphalt Filler Aggregate and 62.5% Binder

AS 2341.18 - Determination of Softening Point - Ring and Ball Method

Softening Point Of Binder (°C)		Binder Sample Number Not Supplied
Softening Point of Binder / Filler Blend (°C)		
Stiffening Effect of the Filler Aggregate (°C)		Calculated in accordance with EN 13179-1

Comments / Distribution
TRIM 16/180
S Halligan

Approved Signatory:

Function: Project Officer
Name: Mark Hopgood
Date: 1/08/2018

NATA ACCREDITED FOR TECHNICAL COMPETENCE

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WELSHPOOL WA 6106
Tel: 08 9323 4744 Fax: 08 9323 4766