WAPARC

Western Australian Pavement Asset Research Centre

Validation and Specification of Warm Mix Asphalt

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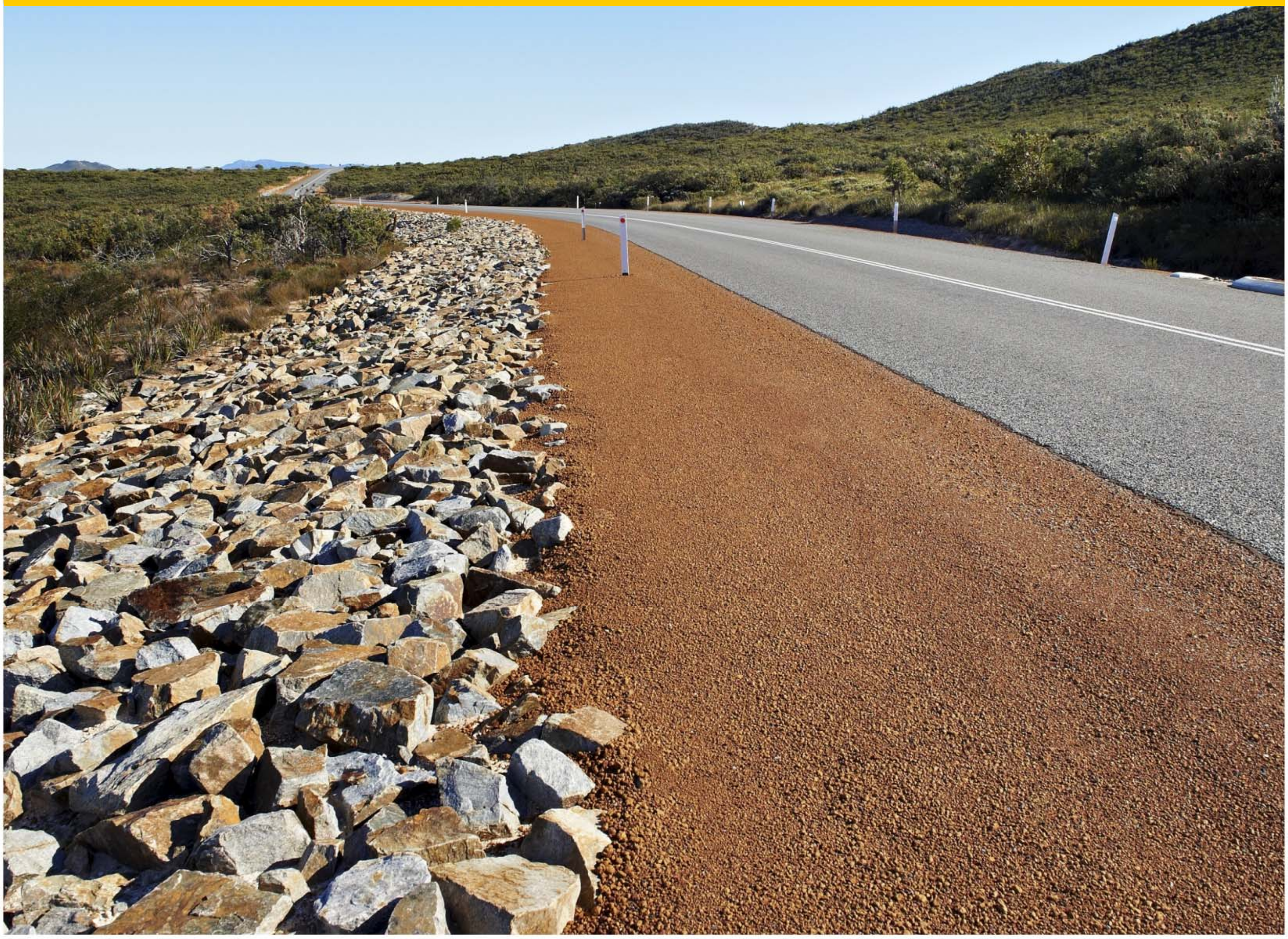

CONTRACT REPORT

Validation and Specification for Warm Mix Asphalt

Project No: 004750

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for Main Roads Western Australia

Validation and Specification for Warm Mix Asphalt
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SUMMARY

As part of the research program being conducted by the WA Pavements and Assets Research Centre (WAPARC), Main Roads WA (MRWA) commissioned ARRB to conduct a project *Validation and Specification for Warm Mix Asphalt (WMA)*. The project is closely linked with Austroads Project TT1454 *Performance of Warm Mix Asphalt Pavements* with some of the outputs of that project feeding directly into the WAPARC project.

The primary issues of concern to MRWA, and indeed to all Austroads members, is the field performance of WMA compared to conventional hotmix asphalt (HMA) pavements and the likely impact of the use of WMA on current specifications for conventional asphalt mixes.

The WAPARC project involved 11 tasks, some of which were related. The two major components of the project were to:

- summarise the state-of-the-art based on European and USA experience
- prepare a draft report: (a) summarising risks and recommended actions to manage these risks, including (b) changes to MRWA Specifications 504 and 510.

The main findings are as follows:

- WMA has been found to provide performance equivalent to, if not better than, HMA in a large number of trials. It is becoming increasingly accepted in many countries, particularly the USA. However, there are some lingering doubts about rutting resistance and moisture susceptibility.
- Risks associated with moisture require the monitoring of moisture as part of QA procedures as well as the use of moisture sensitivity testing and possibly the use of adhesion agents or hydrated lime.
- Potential deficiencies in rutting resistance in foam mixes are partly addressed by the choice of binder grade. Where there is limited choice of available binders, it may mean choosing a polymer modified binder (PMB) for heavy duty applications.
- PMBs are well suited to production using foam technology.

No change is recommended to current provisions for the use of RAP that allow up to 10% RAP in certain mix types and applications. The influence of higher proportions of RAP is a separate area of study that has not been pursued in this report.

Recommended changes to Standard Specifications 504 and 510, specifically modification of Clause 504.38 and Clause 510.38, are presented in the report.

CONTENTS

1 INTRODUCTION

As part of the research program being conducted by the WA Pavements and Assets Research Centre (WAPARC), Main Roads WA (MRWA) commissioned ARRB to conduct a project *Validation and Specification for Warm Mix Asphalt (WMA)*. The project was closely linked with Austroads Project TT1454 *Performance of Warm Mix Asphalt Pavements* with some of the outputs of that project feeding directly into the WAPARC project.

The primary issues of concern to MRWA, and indeed to all Austroads members, was the field performance of WMA compared to conventional hotmix asphalt (HMA) pavements and the likely impact of the use of WMA on current specifications for conventional asphalt mixes.

The project involved the following tasks:

1. Interview MRWA staff to identify perceived risks in warm mix asphalt technology.
2. Review the MRWA City East Alliance (CEA) Specification.
3. Interview Queensland and Victorian asphalt manufacturers regarding Sasobit® and foam bitumen WMA to identify perceived risks, especially with respect to granite aggregates, and to identify risk management strategies.
4. Interview VicRoads staff regarding Sasobit® and foam bitumen WMA to identify perceived risks especially with granite aggregates and identify risk management strategies.
5. Interview AAPA Technology Manager.
6. Summarise the state-of-the-art based on European and USA experience.
7. Prepare a draft report: (a) summarising risks and recommended actions to manage these risks, including (b) changes to MRWA Specifications 504 and 510.
8. Discuss draft report with MRWA.
9. Meet and discuss draft report with Director WAPARC and MRWA staff.
10. Finalise report and changes to Specifications 504 and 510.
11. Prepare a presentation to WAPARC Research and Technical Reference Group.

Three progress reports were prepared during the course of the project:

- Tasks 1, 2, 3 and 5 (March 2012)
- Tasks 6 and 7a (May 2012)
- Task 7b (May 2012).

This final report is a compilation of the three progress reports (Task 10) though some of the material has been re-arranged for reasons of clarity. Some updated information has also been included, e.g. new information regarding VicRoads WMA trials (Trials 3 and 4 in Section 2.2.5).

Tasks 8, 9 and 11, including the presentation, were conducted in June 2012.

2 WARM MIX ASPHALT

Warm mix asphalt (WMA) technologies are additives and/or processes to allow a reduction in the temperatures at which asphalt mixes are produced and placed. Typically, WMA is produced at temperatures that are 20-50 °C below that of hotmix asphalt (HMA). Claimed benefits associated with the use of WMA technologies compared to HMA include improved working conditions (less fumes and lower mat temperatures), reduced emissions and energy usage which contribute to global warming, decreased binder aging during production, improved operational efficiency (early site opening), wider paving conditions (cool weather paving at night and during the winter), improved workability (compaction aid for stiff mixes), longer haul distances, and improved compaction (more consistent field density).

Several WMA technologies have been introduced into Australia to address the need for production and placement efficiency gains. However, from an Austroads member authority perspective, it was necessary to understand and define the performance characteristics of these new products. There is also concern that current practices in material specification, construction standard and pavement design of flexible asphalt pavements in Australia can differ to those in Europe and the USA and those differences might affect potential implementation of WMA technologies in Australia.

As part of the Austroads project, a review of field trials of WMA technologies conducted in various countries in the world, with the emphasis on performance differences between WMA and conventional HMA and the identification of field performance data that could be used to complement the Austroads WMA evaluation field trials for Australian road conditions, was prepared. A summary of that review is presented in Section 5 of this report.

2.1 Commercially-available WMA Technologies

In the review of current practice, commercially-available WMA technologies were identified and grouped into the following six main categories depending on their additive contents, aggregate drying temperatures, maximum bitumen temperatures and different requirements in terms of plant modifications:

- sequential aggregate coating and binder foaming techniques
- binder foaming using water-based mechanical systems
- binder foaming using water-bearing additives
- chemical additives
- organic additives
- combined chemical-organic additives.

General details are presented in Table 2.1. Further details can be found in the websites provided by the manufacturers (as listed in the table) and in the review prepared as part of the Austroads project.

Table 2.1: Commercially-available WMA technologies

Category	Product / Process	Supplier	Web Address	Availability of laboratory/field validation trials
Sequential aggregate coating and binder foaming	Low energy asphalt (LEA1)	LEA-CO (France)	www.lea-co.com	yes
	Low emission asphalt (LEA2)	Suit-Kote (McConnaughay) Corporation (USA	www.lowemissionasphalt.com	yes
	WAM-Foam®	Shell International (UK) / Kolo-Veidekke (Norway)	www.shell.com/bitumen	yes
Water-based binder foaming	AQUABlack®	Maxam Equipment, Inc. (USA)	www.maxamequipment.com	not reported herein
	Double Barrel® Green	Astec Industries (USA)	www.astecindustries.com	yes
	Terex® WMA	Terex® Corporation (USA)	www.Terex®rb.com	not reported herein
	Ultrafoam GX®	Gencor Industries, Inc. (USA)	www.gencorgreenmachine.com	yes
Binder foaming with water-bearing additive	Advera® WMA	PQ Corporation (USA)	www.Advera®wma.com	yes
	Aspha-Min®	Eurovia Services GmbH (Germany)	www.Aspha-Min®.com	yes
Chemical additive (surfactants/emulsions)	CECABASE RT®	Arkema Group (France)	www.cecachemicals.com	yes
	Evotherm® Evotherm® 3G Evotherm® DAT	MeadWestvaco Asphalt Innovations (USA)	www.evotherm.com	yes
	HyperTherm®	Coco Paving Inc. (Canada)	www.cocoasphaltengineering.com	yes
	Rediset® WMX	Akzo Nobel NV (The Netherlands)	www.surfactants.akzonobel.com	yes
Organic additives	Asphaltan B	Romonta GmbH (Germany)	www.romonta.de	yes
	Sasobit®	Sasol Wax (South Africa)	www.sasobit.com	yes
	LEADCAP®	Kumho Petrochemical (Korea)	www.leadcapwma.com	yes
Combined binder modifier/and organic additives	Shell Thiopave®	Shell	www.shell.com	yes
	TLA-X®	Trinidad and Tobago Ltd	www.trinidadlakeasphalt.com	not reported herein

3 FEEDBACK FROM MEMBERS OF AUSTROADS AND INDUSTRY: RISKS, USAGE, SPECIFICATIONS

3.1 Perceived Risks Associated with the Use of WMA Technology

3.1.1 Feedback from Austroads Members

Interviews were conducted with various members of the Asphalt Research Working Group (ARWG) and also MRWA. The general views expressed by all those interviewed were that:

- there was more interest in the engineering properties of WMA than any perceived environmental benefits, this being an issue for the CEOs and politicians
- the main perceived threat was the commitment by industry to produce a final quality product; this was not necessarily restricted to WMA, but to any process.

In terms of MRWA, a specification for WMA incorporating Sasobit® had been prepared. However, there was uncertainty regarding WMA incorporating a foam process and a specification for WMA/foam for adoption in WA had yet to be developed. To this end, a field trial incorporating foamed WMA is planned during 2012 on MRWA’s City East Alliance (CEA) project. It is planned to install structural layers rather than surfacing layers. MRWA’s Materials and Engineering Branch (MEB) will monitor performance.

Follow-up discussions with the Austroads members of ARWG also suggested that there were no perceived risks with the use of granite aggregates.

3.1.2 Feedback from AAPA Members

Interviews were conducted with various industry members of ARWG, including Warren Carter and Ian Clarke (Downer EDI), Peter Armstrong and Kevin Embleton (Fulton Hogan) and Ryan Jansz (Boral). There were no perceived risks and no issues with the use of granite aggregates.

3.2 Current Use of WMA Technology by State Jurisdictions

3.2.1 Main Roads WA (MRWA)

There has been limited use of Sasobit® over the last seven or eight years. As well as the environmental issues, its engineering properties are being taken advantage of. The use of Sasobit® by MRWA is two-fold:

- Initially dosing at 1.5% (the standard rate for dense-graded asphalt) at hot temperatures to achieve better compaction outcomes for the wearing course when the mix is transported large distances (up to and exceeding 600 km) and then double-handled from a road train to a small truck for paving. The double handling results in a significant loss in temperature. Anecdotal reports are that conforming levels of compaction can be achieved that were not previously achieved without Sasobit®.
- Dosing intermediate course mix for mill and fill works where 250 mm and more of asphalt is placed in one shift and then opened to traffic. This has successfully been achieved using PMB and Sasobit®.

Sasobit® was used in open-graded asphalt during the construction of a full depth asphalt pavement on The Kwinana Freeway extension in 2009 but was not reported or evaluated. Use by local government has been limited to date.

MRWA has published specifications for the use of Sasobit®-WMA as wearing and intermediate courses. MRWA's main concerns with the product are the security of supply of Sasobit®, and the use of Sasobit® in other than a batch plant. Moisture sensitivity in Sasobit®-WMA can be an issue if plant operators rush the drying of aggregates, especially in drum plants.

Some field trials of full depth foamed WMA (including RAP) are planned for 2012 by CEA (a partnership between MRWA, Leighton, GHD and NRW) using a water-based Astec foaming system attached to the Boral batch plant. MRWA's main concerns with the product are a potential for an increase in the risk of rutting as well as moisture sensitivity.

3.2.2 Department of Planning, Transportation and Infrastructure (DPTI) SA

A 500 m long WMA trial was undertaken by Boral Asphalt on Gallipoli Drive. The road was newly constructed and the pavement was not trafficked immediately upon completion. All the asphalt layers, including AC10, AC14 and AC20, were manufactured and placed at lower temperatures using the foaming technology method. The asphalt was manufactured at a batch plant using an Astec foaming module attached to the bitumen line.

Numerous other projects have been constructed using Sasobit® to achieve the lower production and/or placement temperatures under a variety of traffic conditions.

In terms of DPTI specifications:

- any additive to be used has to be approved by the superintendent
- the design of mixes with an additive must obtain the target air voids as specified by DPTI
- the placement temperature is lower than that required by AS 2150 (2005).

DPTI assumes that the performance of WMA is equivalent to that of HMA.

3.2.3 Queensland Department of Transport and Main Roads (TMR)

Ipswich Motorway

Following successful demonstration trials, the Origin Alliance Group (a partnership formed in June 2008 between TMR, Abigroup Contractors, Seymour Whyte Constructions, Fulton Hogan, Parsons Brinckerhoff Australia and SMEC Australia) established a WMA validation trial using Astec Double Barrel® Green (water-based Astec foam system) on the upgrade of the Ipswich Motorway between Dinmore and Goodna, a project valued at A$1.95B.

The aim of the Ipswich Motorway trial was to examine a number of issues relevant to TMR's asphalt specifications which were not being adequately addressed by the Austroads validation project. The trial was never intended to replicate the Austroads project nor was it intended to provide an evaluation of the structural performance of WMA.

Four trial sites, each 200 m long, were constructed using various combinations of WMA and RAP (0% and 15%) and an HMA control section (50 mm polymer modified binder surfacing DG14HS and 270 mm Class 600 bitumen base DG 20HM). Technical issues addressed included:

- compaction temperature and mix volumetrics
- in situ compacted density
- resilient modulus (for pavement design)
- rut resistance
- constructability.

It was found that adequate compaction could be achieved with WMA produced at 140 °C using the Astec Double Barrel® Green technology. Unfortunately, however, some of the trial sections were affected by the Queensland floods in early 2011. These sites will be overlaid with another layer of dense-graded asphalt prior to the completion of the project in 2012. The current performance of the pavements has yet to be reported.

Demonstration Trials

It was reported in September 2010 that Sasobit® was trialled in a stone mastic asphalt (SMA) surfacing layer on the Gold Coast in 2006. Both the WMA and HMA control sections exhibited similar performance. Based on the outcomes of this trial, TMR now allows the use of Sasobit® as an additive in asphalt mixes. At that time, there had been approximately 20 mix designs with Sasobit® approved by TMR.

General

The general TMR view is that the structural impact of WMA on asphalt thickness design needs to be raised with the Pavement Structures Reference Group (PSRG) and ARWG and that a separate validation project would be required to examine this.

It was also reported that TMR had no experience with the use of granite aggregates.

3.2.4 Roads and Maritime Services (RMS) NSW

Deep Patch Trial in 2006

Figueroa, Hennessy and Hiley (2007) reported a deep patch trial using Sasobit® conducted in August 2006 at Woodville Road (between Oxford and Guildford Roads). The main objective of the trial was to lay four layers of asphalt, each 63 m long (two AC20 60 mm thick layers and two AC14 45 mm thick layers), in one shift without running the risk of rutting in the wearing surface. The total amount of asphalt laid was approximately 100 tonnes.

The Sasobit® was added via the RAP belt using a modified hopper at a rate of 2 kg of per minute, giving an end Sasobit® content of approximately 1.5% in Class 450 binder. The AC20 and AC14 asphalt mixes were manufactured and maintained at 130 °C and 140 °C respectively. The temperature of the mixes upon arrival at the site varied between 127 °C and 137 °C. Thermocouples were inserted into the various layers of asphalt by the then RTA to measure temperature profiles. Cores were taken from each layer immediately before the next layer was paved.

It was found that:

- compaction was achieved in all layers despite the very low temperatures on one of the levels
- the manufacture of the asphalt was achieved at the right temperatures and delivered on site with no problems
- there were no problems with the workability of the asphalt despite the low temperatures
- the temperatures of the asphalt as-placed were kept to a minimum.

Current Situation

Since the trial reported in Figueroa et al., warm mix additives have been used in many asphalt patching and overlay works on the RMS road network. It should be noted that these mixes were not produced as WMA; rather, they were produced at conventional asphalt mix temperature with the warm mix additives. Warm mix additives were used in certain situations because of the need to increase workability and when long haulage distances were involved, etc.

3.2.5 VicRoads

Surfacing Trials

Trial 1

This was the first detailed formal field trial of WMA technology in Victoria. Laboratory testing of the WMA mix had been undertaken some years earlier to demonstrate that the laboratory properties of HMA and WAM foam asphalt were comparable. Further details are as follows:

- location of project – Western Freeway/Deer Park Bypass, Caroline Springs
- date of placement – February 2009
- type of WMA (no RAP) – WAM-foam® method
- site allows for direct comparison of HMA and WMA
- testing undertaken is similar to that outlined in the draft WMA Evaluation Protocol
- additional field samples have been taken after two years of service
- data is not currently available.

Trial 2

General details are as follows:

- location of project – Princess Hwy East, Mulgrave
- date of placement – March 2009
- type of WMA with 20% RAP – water foaming method
- site allows for direct comparison of HMA and WMA
- testing undertaken is similar to that outlined in the draft WMA Evaluation Protocol
- additional field samples have been taken after two years of service
- data is not currently available.

Deep Strength Trials

Trial 3

- location of project – M80, Western Ring Rd
- date of completion – June 2012
- WMA used in all asphalt layers including open-graded asphalt surface
- site allows for direct comparison of HMA and WMA
- testing undertaken is similar to that outlined in the draft WMA Evaluation Protocol
- data is not currently available.

Trial 4

- location of project – Nagambie Bypass, Nagambie
- date of completion – December 2012
- WMA used in all asphalt layers at the intersection and thin WMA layer used over a granular pavement
- site allows for direct comparison of HMA and WMA

- testing includes modulus, fatigue and field performance (roughness, rutting, pavement strength and skid resistance (SCRIM))
- data is not currently available.

In addition, between February 2008 and June 2011 Citywide, which uses the Shell WAM-foam® technology, placed 16 000 tonnes of WMA foam for various municipalities in the Melbourne metropolitan area, including the City of Melbourne.

3.2.6 ACT Department of Territory and Municipal Services (TAMS)

There was some use of Sasobit® several winters ago on minor residential roads but without any reduction in mix temperature. Performance was similar to HMA. TAMS has not encouraged or allowed the use of these types of additives on more heavily-trafficked roads.

3.2.7 Department of Infrastructure, Energy and Resources (DIER), Tasmania

Whilst it is possible that WMA is being used in applications in Tasmania, DIER is not aware of any applications or has any involvement.

3.2.8 Department of Construction and Infrastructure (DCI) NT

As at the end of 2011, DCI NT had not conducted any WMA projects or trials, but may in the future when more is learnt about the process and products. One company currently uses Sasobit® (generally 1.5-2%) in its HMA mixes to ensure they meet DCI voids requirements of 7% (larger window for compaction) and to ensure that good wheel-tracking results are met. DCI has not conducted any studies but visual inspection definitely suggests 'harder' asphalt on the ground.

3.2.9 Brisbane City Council

Brisbane City Council trialled two sections of WMA (one with Aspha-Min® and the other with CECABASE) at Park Avenue, Clayfield, Brisbane in 2008. This was an example of the use of a foaming technology using water-bearing additives.

Each site was 100 m long and involved 100 tonnes of asphalt. The mix was Council Type 3 (DG18) with multigrade binder and CECABASE and Aspha-Min® additives. A control section of conventional HMA was also constructed. Apparent viscosity testing was conducted on cores extracted in November 2008. The results showed that the binder was aged more by the HMA process than the WMA process. Various laboratory tests (resilient modulus at 32 °C, 120 Gyratory cycles, Marshall, indirect tensile modulus) were performed on the materials. The results of the resilient modulus testing suggested that there was little difference between the HMA and the WMA. It was concluded that the Zeolite-WMA technologies could be successfully implemented with minor modifications to the asphalt plant.

3.2.10 Industry

In addition to the cooperative trials reported in the previous sub-sections, industry has conducted a large number of development and demonstration trials, particularly in Victoria and NSW. Details of these trials are, however, not available.

3.3 Current State Jurisdictional Specifications for WMA

3.3.1 VicRoads

An interim specific clause (VicRoads 2011) has been added to the current VicRoads specification for hotmix asphalt (Section 407) (VicRoads 2007). This is reproduced in Appendix A.1.

3.3.2 MRWA

Specifications 504 (MRWA 2011a) for wearing course (both hot and warm) and 510 (MRWA 2011b) for full depth asphalt (hot and warm) have been developed. These specifications address Sasobit-based mixes only. There is currently no standard specification for foamed WMA.

3.3.3 RMS NSW

In its latest version of its heavy duty dense-graded asphalt specification (R116 Edition 8 (RMS NSW 2012)), the RMS allows WMA in dense-graded asphalt mixes. Interim clauses based on manufacturers' recommendations are included in the specification. The requirements in these clauses will be reviewed when more data from Australian trials becomes available.

The RMS has no preference for a particular WMA mix. The proportion of additive is limited to:

- for wax, the maximum percentage by mass of binder must not exceed 2.0%
- for surfactants, nominate the maximum percentage by mass of binder
- for water (either directly added or added in the form of water containing crystals), the maximum percentage by mass of the total mix must not exceed 0.06%.

3.3.4 QTMR

Following a number of demonstration trials using Sasobit® since 2006, TMR has made provision for the permissive use of WMA under its technical standard for dense-graded and open-graded asphalt, e.g. MRTS30 (Queensland Department of Transport and Main Roads 2009).

The mix design registration process requires the contractor to nominate all constituents (including additives such as WMA additives) as part of their mix design submission. Where an additive is proposed, and the influence of the additive on asphalt mix performance is not known to TMR, typically the contractor and TMR would undertake an evaluation of the mix properties and field performance as part of the registration process. For example, Sasobit® is now included in a significant number of registered mix designs.

TMR will continue to collaborate with asphalt suppliers to trial other WMA technologies as opportunities arise under a permissive arrangement, i.e. as a competitive alternative to HMA.

3.3.5 DPTI SA

In terms of DPTI specifications:

- any additive to be used has to be approved by the superintendent
- the design of mixes with an additive must obtain the target air voids as specified by DPTI
- the placement temperature is lower than that required by AS 2150.

DPTI assumes that the performance of WMA is equivalent to that of HMA.

3.3.6 TAMS ACT

One company is currently commissioning a new asphalt plant which will allow the production of WMA by foaming the bitumen in the plant. TAMS has encouraged this innovation and amended its specification to accommodate this technology.

3.3.7 Other Jurisdictions

Neither DCI NT nor DIER Tasmania have a specification for WMA.

4 REVIEW OF OVERSEAS FIELD TRIALS OF WMA PAVEMENTS

A review of overseas studies of the field performance of WMA pavements, and their performance relative to that of HMA 'control' pavements, was a major component of the Austroads project[1]. A summary of this review follows.

Three types of field trials of a WMA technology were identified in the review: development, demonstration and validation/implementation. Each type of trial can have a different framework depending on the technologies developed, the asphalt producer's marketing strategy and the road agency's implementation strategy.

At the time of completing the Austroads report (June 2012), more than 160 documents had been identified in a literature search of WMA technologies reporting field trials of some form or another in the USA, Canada, Europe, Asia, South Africa and Australasia. However, of these, only about 30% of the documents sourced provided sufficient information to allow a meaningful review to be conducted. Many of the documents sourced presented details of what were clearly 'development' trials, where there was either no control HMA section involved and/or a lack of data relating to mix type, pavement structure, climate, applied traffic, performance data, etc.

A general overview of European practice, including the outcome of long term performance from early trials in Germany and Norway is provided in a position paper prepared by the European Asphalt Pavement Association (EAPA 2010). Damm (2011) describes current practice in Germany where mainly wax based modifiers (principally Sasobit) are used to provide enhanced stiffness and workability, particularly in adverse weather conditions. Increased stiffness, however, does not appear to have adversely influenced low temperature fatigue or cracking performance.

A large number of demonstration or validation trials of WMA technologies have been established in the USA to demonstrate the benefits of WMA technology compared to HMA, and to improve the quality and efficiency of construction (i.e. improved workability, improved compaction and more consistent field density). The major application has been overlays using high RAP-content mixes and severe construction conditions (e.g. construction in cold/wet environments). There have also been further developments and improvements in the WMA technologies using water (e.g. foam technologies using water injection nozzles) and emulsions to reduce the amount of water added to the system in order to address the concern of moisture susceptibility issues associated with the use of the water-based WMA products.

In September 2011 the 2nd International Conference on WMA Pavements was held in St Louis, USA. More than 40 papers were presented that provided a comprehensive overview of the development and implementation of WMA technology in the USA, Canada, Europe, Asia and South Africa. In the opening session it was reported that more than 40 million tons of WMA was produced in the USA in 2010, with market share reaching double digits. By December 2011 it was expected that 47 State Departments of Transport (DOTs) would have specifications or contract language that allowed WMA[2].

It appears that WMA technologies associated with water-bearing, chemical and organic additives (e.g. Advera®, Evotherm® and Sasobit®) have received more consideration compared to WMA technologies using water-based mechanical systems (e.g. WAM-Foam®, Low Energy Asphalt, Double Barrel Green®).

1 This report has recently been endorsed for publication by Austroads.

2 A summary of the papers presented at the St Louis Conference is also included in the Austroads report.

These trials have demonstrated that most WMA technologies associated with chemical and organic additives can be successfully implemented with minor modifications to the asphalt plant and, in the case of several products, successful paving could still be possible at low temperatures.

Some of the trials also addressed various concerns regarding the use of WMA, including incomplete drying of the aggregate (especially with absorptive limestones), the potential for increased moisture susceptibility when utilising WMA processes that involve the use of water, the effects of chemical additives on the long-term performance of the binder, the ability of WMA to provide enough radiant energy to heat the reclaimed asphalt component in mixes containing RAP, and the general lack of information regarding the long-term performance of new asphalt mix designs (e.g. with high RAP content or rubber asphalt).

Consequently, laboratory trials have focussed more on moisture susceptibility, rut resistance and durability. Many demonstration and validation trials established in the USA are also being subjected to both accelerated loading trials and long-term performance monitoring. It is recommended that the outputs of relevant NCHRP projects currently being conducted be reviewed in terms of their relevance to Australian road conditions. This would assist in the establishment of a list of approved WMA technologies suitable for Australian conditions.

Several asphalt producers and road agencies have collaboratively conducted accelerated loading studies of the comparative performance of WMA and HMA technologies under accelerated heavy loading. Examples include the work at the National Center for Asphalt Technology (NCAT) in Auburn, Alabama, and the work at the University of California Pavement Research Center (UCPRC) using the Heavy Vehicle Simulator (HVS). These trials have involved the production of the mixes, the construction of test pavements, and the monitoring of field performance, including detailed (within-pavement) response-to-load data. Extensive laboratory studies of both field and laboratory samples were also carried out in order that the relative performance of WMA and HMA could be compared with recommendations made regarding the implementation of WMA into current HMA mix design procedures.

4.1 Summary

As a result of the review of overseas practice with respect to the field evaluation of WMA pavements, the following recommendations are offered:

- There is no immediate need for an accelerated pavement test in Australia; the work being conducted at NCAT and UCPRC has suggested that the performance of WMA pavements is at least equivalent to that of HMA. It was noted, however, that UCPRC is planning a follow-up test program of rubberised gap-graded control sections and seven WMA technologies (Advera® WMA, Double Barrel Green®, CECABASE RT®, Evotherm®, Ultrafoam GX®, Rediset® WMX, and Sasobit®). Those studies will also include laboratory testing of specimens removed from the test pavements, and the monitoring of pavements constructed with a range of different mixes on State highways. Monitoring of this work and a review of the results, as well as any further work conducted by NCAT, should be continued.
- Future laboratory studies, if deemed necessary, should focus on moisture susceptibility, rut resistance and durability. This may include the evaluation of the current moisture sensitivity test, its relationship to observed field performance and, if necessary, the refinement of the current test.

- Despite the successful outcomes of the large number of field trials, there is still some concern regarding long-term performance (e.g. moisture susceptibility, rut resistance and durability) associated with lowering WMA production temperatures (including higher moisture sensitivity due to aggregates that are not adequately dried) and altering of the binder performance grade (when chemical and organic additives are used to produce WMA mixes). It is therefore recommended that current projects being conducted overseas (particularly NCHRP projects in the USA) be monitored and their outputs examined in terms of any possible application to practice in Australia.
- Consequently, laboratory trials have focussed more on moisture susceptibility, rut resistance and durability. Many demonstration and validation trials established in the USA are also being subjected to both accelerated loading trials and long-term performance monitoring. It is recommended that the outputs of relevant NCHRP projects currently being conducted be reviewed in terms of their relevance to Australian road conditions. This would assist in the establishment of a list of approved WMA technologies suitable for Australian conditions.
- The validation protocols of WMA technologies established in the USA, and their revisions based on the outputs of NCHRP projects 9–43, 09–47A and 09–49 need to be assessed, along with other relevant information, before recommendations are made regarding required amendments to the current draft Evaluation Protocol adopted in Australia.
- One issue that may need to be addressed is the possible impact of the introduction of a carbon tax on the widespread use of WMA in Australia.
- There is no funding in the current Austroads project to support these tasks, which concluded at the end of 2011/2012.

5 REVIEW CITY EAST ALLIANCE SPECIFICATION

5.1 Introduction and Background

This task involved a review, undertaken by John Rebbechi, of specifications for asphalt work on the City East Alliance (CEA) Great Eastern Highway Upgrade project with specific reference to the use of reclaimed asphalt pavement (RAP) and WMA. Both the addition of RAP and the adoption of WMA processes are relatively new concepts in Western Australia.

The CEA asphalt specifications are based on MRWA standard specification Sections 504 (Asphalt Wearing Course) and 510 (Full Depth Asphalt Pavement). Variations made to the MRWA specifications include detailed changes made in advance of updates to the standard specifications that were implemented in September and December 2011 but with some differences in detail, including variations to the application of RAP and WMA that are discussed below.

A workshop was held at the CEA offices on 11 January 2012 to consider asphalt pavement requirements for the Great Eastern Highway upgrade with a focus on potential issues associated with rutting. The workshop was attended by representatives of the Alliance partners and invited external technical experts; it included reference to both use of RAP and WMA.

5.2 Reclaimed Asphalt Pavement

The addition of RAP to asphalt mixes has been widely adopted in the Eastern States for many years with varying proportions allowed depending on asphalt mix type and application. Possibly, its introduction has been held back in WA by the predominance of pavements constructed with granular bases and thin asphalt surfacings; hence the limited availability of RAP and the limited application for its use in intermediate and base asphalt. This has now changed with greater use of thicker asphalt pavements.

Up to 10% RAP is permitted in MRWA specifications for intermediate courses but not permitted in asphalt bases (fatigue layer) or wearing courses. Provision for unconditional use of 10% RAP has also been adopted for intermediate courses in the CEA Specification. RAP was briefly discussed at the workshop on 11 January with a consensus that the 10% limit would not be increased at this time.

It is widely accepted in other State jurisdiction specifications that 10% RAP has minimal influence on the performance properties of asphalt. Higher proportions of RAP can result in an increase in asphalt mix stiffness but it also requires greater control in the design and manufacturing process. The use of higher proportions of RAP is a major topic in itself and, as it is not being considered here, is not discussed any further in this report.

CEA Specification 504 (Asphalt Wearing Course) makes reference to an intention to conduct trials with RAP in wearing course asphalt in conjunction with trials of WMA. Some State jurisdictions restrict the use of RAP in heavy duty wearing courses on two grounds:

- the uncertainty regarding the quality and polishing characteristics of the aggregate
- the potential reduction in polymer modified binder performance, where specified, by the proportion of binder in the RAP.

In Perth, all recycled asphalt would be expected to contain aggregates from common sources that conform to MRWA requirements; hence there need be no concerns regarding aggregate quality. However, the fact that polymer modified binder is to be adopted for the wearing course on this project may require further consideration.

5.3 Warm Mix Asphalt

Reference to the development of WMA technology in Australia has already been made in this report and it is unnecessary to provide a detailed description here other than a brief outline as an aid to understanding its application to CEA specifications.

Essentially, there are just two processes of direct relevance to current availability in WA:

- modification of asphalt binder flow characteristics by the addition of an organic wax
- foamed bitumen.

The addition of an organic wax changes the flow characteristics of bitumen at elevated temperatures thus enabling a reduction in the temperatures required for mixing, spreading and compaction of the asphalt. On fully cooling, the asphalt performance properties are claimed to be unaffected by the wax. This was one of the first WMA processes to be introduced in Australia; it can be used in both batch and drum mix asphalt plants without any mixing plant modifications. The proprietary product, Sasobit®, is the market leader and is usually blended at a recommended rate of 1.5% by mass of bitumen. This process has been adopted in MRWA standard specification Sections 504 and 510.

The second process, using foam bitumen, is rapidly gaining acceptance. In simple terms, the injection of a small quantity of water into the hot bitumen entering the asphalt mixer creates a significant increase in volume, thus enabling blending and coating of aggregates with bitumen at a lower temperature than otherwise required. Although primarily developed for use in continuous mixing plants, it has also been adapted for batch plants on a limited scale. Major asphalt companies in Australia are installing this facility in many new and upgraded asphalt plants as it enables the production of WMA, and attendant benefits of lower energy costs and improved workability, without the use of additives or other increased production costs.

In addition to the coating advantages, it has also been observed that increased workability of foamed WMA is retained below 100 °C thus enabling improved compaction or the ability to transport asphalt longer distances. Surprisingly, this characteristic is not really explained in the literature on foam WMA. Possibly, it is an outcome of very small bubbles of water vapour remaining in the bitumen, thus retaining extra bitumen fluidity until further reduction in temperature and compaction of the asphalt. This is due to the fact that water vaporisation actually occurs at much lower temperatures than the boiling point where water becomes steam. The amount of moisture retained in the asphalt is within normal specification limits once the asphalt is placed and compacted.

A number of papers presented at the 2nd International Conference on WMA in St Louis in October 2011 examined the influence of foam on the moisture susceptibility and stiffness of asphalt mixes. Although there were a range of outcomes, the general consensus seemed to be that any increase in moisture susceptibility was minimal and that marginal reductions in stiffness due to reduced binder hardening did not have a significant influence on field performance. Interestingly, one report referred to improved performance from PMB as a consequence of reduced hardening during mixing.

Provision for the use of WMA by the foaming process is made in CEA specifications. This is in contrast to the adoption of Sasobit® wax in the standard MRWA specification. In practical terms, either process should be fully acceptable.

Boral Asphalt, the supplier to the CEA project, is in the process of commissioning the foam capability at its Perth mixing plant. Although the CEA specifications refer to the use of WMA on a trial basis only, there is very little risk associated with using the foam process considering its successful use elsewhere. As there is no modification of binder properties, it can be applied independently of the type of asphalt mix, the addition of low proportions (10%) of RAP, or the use of polymer modified binders.

6 ISSUES OF SPECIFIC RELEVANCE TO WESTERN AUSTRALIA

6.1 Relevant Technologies

At this stage there are only two commercial WMA technologies currently on offer in Western Australia: the organic (wax) modifier Sasobit® and the Astec Double Barrel Green® foaming technology.

The Astec Double Barrel Green® foaming technology was initially developed as a modification to the Astec double-barrel mixing plant. Astec has also made the process available to batch mixing plants. Boral has installed this process on their batch mixing plant in Adelaide and is in the process of commissioning a similar unit on its Perth batch mixing plant. In a drum mixing plant, foaming takes place immediately before discharge into the mixing drum. Similarly, in a batch plant, foaming takes place immediately prior to discharge into the pugmill. Bitumen is pumped from the weigh hopper by a positive displacement pump to the foaming unit. The expansion chamber and foaming mechanism in the foaming unit is similar to that on the drum plant. The foam is then discharged into the pugmill through spray nozzles in the same manner as the normal batch mixing process.

Sasobit® involves no plant modifications being introduced as an additive to the binder. Although the following additive discussion relates specifically to Sasobit®, it must also be considered that, potentially any of the competing organic additives (e.g. Asphaltan B® or LEADCAP®) could be offered as alternatives as well as other additive technologies (chemical additives, combined chemical/organic modifiers or even water-bearing foaming additives) as further alternatives.

Ignoring the water-based foaming alternative, a significant difference between the organic (wax type) additives and the chemical additives (surfactants) is that Sasobit® modifies the binder viscosity so that it is reduced at mixing temperatures but slightly increased at service temperatures. The surfactants achieve lower mixing temperatures through a different mechanism that has only a minor effect on binder viscosity.

The foam process does not alter binder viscosity at service temperatures as the only additive is water, which is dispersed in the mixing, transport and placement of the asphalt. Lower mixing temperatures do, however, create a slight shift in binder stiffness through reduced hardening through the mixing process.

A number of the studies sourced in reference documents specifically addressed the use of higher proportions of RAP as well as rubber-asphalt mixes. The use of higher levels of RAP is a separate area of study that has not been addressed this report.

6.2 Performance Risks

6.2.1 Risk Categories

The performance studies referred to in Section 4 made reference to a large number of laboratory and field studies examining a broad range or performance objectives. In simplistic terms, the four main areas of risk are:

- rutting
- moisture sensitivity
- fatigue
- low temperature cracking.

As can be expected, with a large number of trials and different performance conditions or evaluation procedures, there is a degree of scatter in the outcomes. The following summary is an attempt to distil the outcomes into what appears to be the generally accepted performance characteristics.

6.2.2 Sasobit®

Sasobit® was one of the earliest WMA technologies and possibly the most widely reviewed. It has now been in use in Germany for 15 years where it is reported to have around 5-8% of the market share (Damm 2011). Stiffening of the binder provides a slight increase in rutting resistance but it has been shown to have no effect on fatigue or low-temperature cracking.

Mixed results are reported in terms of moisture susceptibility. Some reports indicate a slight increase in susceptibility to moisture but most seem to conclude that, in practical terms, there is no real performance reduction.

Almost none of the investigative reports indicated the type of aggregate used so it is difficult to relate any of the outcomes to aggregate type or to granite aggregates in particular. It is noted, however, that liquid anti-strip agents appear to be widely and routinely used in HMA mixes in North America. It is recommended in the South African Bitumen Association (SABITA 2012) specification guidelines that 1% hydrated lime be added as a precaution.

Chemical additives, which are based on surfactants are, in effect, anti-stripping agents and hence provide no risk of increased moisture susceptibility.

6.2.3 Astec Double Barrel Green®

As already discussed, the only additive used in the Astec Double Barrel Green® and other similar mechanical water-based foaming systems is a small quantity of water. Although there is a small capital cost associated with plant modification there is virtually no additional cost of production, but rather cost savings associated with reduced heating costs.

As with the reports on the *Sasobit®* trials, there was variability in the outcomes of the trials but it is generally accepted that the lower temperatures resulted in reduced binder hardening during production, although some of this difference was narrowed by subsequent hardening in service.

The reduced hardening can lead to a decrease in stiffness at lower temperatures. This particularly showed up as poorer performance in laboratory tests for rutting and binder stiffness but not necessarily a reduction in rutting performance in field trials. It was also suggested that reduced binder hardening was a specific advantage in polymer modified binders (PMBs).

Increases in moisture sensitivity appeared to be mostly related to retained moisture. Where the final moisture content was no more than normal HMA there seemed to be little, if any, increase in moisture sensitivity. The SABITA guidelines specifically refer to the need to monitor moisture content as part of the production process.

MRWA specifications currently require the use of 1.5% hydrated lime in asphalt mixes produced with granite aggregates in the Perth region (or approved adhesion agent in areas outside Perth where the use of hydrated lime is impracticable). While these provisions should provide adequate protection against the effects of moisture, the use of the moisture sensitivity test (Austroads 2007) could provide a further level of assurance.

A side benefit of the increased workability associated with foam technology is improved compacted density. There are a number of anecdotal reports of routine running of the foam system with conventional HMA for the sole purpose of improving handling properties and compaction.

Another issue raised in discussion is whether there are any increased risks associated with extended hot storage of WMA. There is little reference to this in any of the literature. The South Carolina DOT specification referred to in Section 6.4 restricts storage time of WMA to a maximum of 8 hours with specific exclusion of extended overnight storage. On that basis, it is assumed that no special reference is required to hot bin storage conditions where the normal practice is for short-term storage to balance plant production rates with the loading of delivery trucks.

6.3 Mix Design

A comprehensive guide to the design of WMA is provided in the recently released NCHRP Report No 691 (Bonaquist 2011). The design guide has been prepared as an Appendix to the standard design procedures in AASHTO R35 (AASHTO 2009). It has the following main sections:

1. Equipment for designing WMA: specific guidelines are given for laboratory foam equipment although other guidelines elsewhere state that, where such equipment is not available, final mix properties should be verified on production samples.
2. WMA process selection.
3. Binder grade selection.
4. RAP in WMA.
5. Process-specific specimen fabrication procedures.
6. Evaluation of coating, compactability, moisture sensitivity and rutting resistance.
7. Adjusting the mixture to meet specification requirements.

Advice is also provided regarding the conversion of HMA designs to WMA based on the project design experiment. There was little difference in the volumetric properties of properly-designed WMA and HMA.

6.4 Specifications/Quality Control

In opening the St Louis Conference, Greg Nadeau, Deputy Administrator, Federal Highway Administration (FHWA) spoke in terms of State Departments of Transport (DOTs) adopting specifications or contract language that allowed WMA (Nadeau 2012). The key words here are ‘contract language allowing WMA’. There is very little prescriptive detail in specifications used in the USA. A somewhat typical example of specification modifications adopted by the Wisconsin DOT is included in Appendix A.2.

Naidoo et al. (2011) pointed out that the new SABITA guidelines (SABITA 2012) similarly avoid being prescriptive but adopt an approach that includes the following elements:

- guidelines for mix design, manufacture, etc.
- a list of approved technologies
- a protocol for new technologies
- a draft specification that covers all HMA with specific provision for WMA. An extract of the WMA provisions is included as Appendix A.3.

An example of a slightly more detailed supplementary specification for WMA from the South Carolina DOT (2011) is reproduced as Appendix A.4.

A further example is the interim clauses adopted by VicRoads, referred to in Section 3.3.1 and reproduced as Appendix A.1.

The position paper prepared by the EAPA (2010) refers to European standards for bituminous mixtures, adopted in 2008, that do not preclude WMA by virtue of specifying maximum temperatures for particular mixes, but no minimum temperatures. The standards also contain provisions for dealing with mixtures containing additives, subject to demonstration of equivalent performance.

7 MRWA SPECIFICATIONS 504 AND 510

7.1 General

In reviewing the WMA specifications already adopted overseas and in Australia, the general approach is to require the supplier to nominate all constituents (including additives) as part of a mix design registration process as well as full details regarding the proposed technique to be used in the manufacture and placement of WMA. Examples of such specifications have been referred to in Sections 3.3 and 6.4 and Appendix A.

The current approach to WMA adopted by MRWA is to provide detailed requirements for procedures and the proportion of Sasobit® additive and its application. The advantage of this approach to specifications is that it provides confidence to the specifying authority that the application of the process, and its manufacture, will be undertaken in accordance with appropriate good practice. In particular, it provides surveillance officers with the necessary tools to verify that such good practice is being applied.

A potential disadvantage of this approach is that it could inhibit, or delay, the opportunity for the introduction of alternative technologies. It could also be seen as implying a greater responsibility on the road agency for outcomes associated with the application of technologies and procedures that are nominated and described by the agency.

In discussion with MRWA personnel, a strong preference has been expressed that, at this stage, the standard specification should refer only to the known process of the addition of Sasobit® or the use of foam bitumen, rather than an open approach to allowing the contractor to nominate alternative technologies.

On this basis, contracts let with the standard specification would allow only those processes already assessed and approved by MRWA. Any new processes could be subsequently evaluated outside existing contracts for possible inclusion in standard specifications after appropriate assessment. The draft Austroads WMA Evaluation Protocol provides suitable guidelines for the evaluation and introduction of such new technologies.

Asphalt specifications used by MRWA provide the option for contractors to use a ‘conforming mix’ to a standardised asphalt mix design or a ‘job mix’ to a mix design prepared by the contractor. Reporting requirements for job mix designs using a combination of Marshall and Gyratory compaction are set out in the specification.

Some elements of the asphalt industry might propose that certain WMA processes can be applied to existing hotmix asphalt (HMA) mixes without any special requirements. Experience of road agencies in Australia, however, is that asphalt suppliers are often reluctant to provide adequate detail of asphalt component materials, mix design, process control and validation of field performance. It is considered important that such information be provided to address uncertainties associated with the performance of WMA and provide confidence that the materials will perform to required standards. Such information will also assist in guidelines applied to the audit and surveillance of asphalt production.

Consequently, it is recommended that all WMA mix designs become, in effect, ‘job mixes’.

For processes such as foam, where there is no available equipment for replicating the mixing process in the laboratory, it is considered appropriate to undertake mix design to normal HMA criteria (or use an existing approved mix) but verify properties, including both volumetric and performance properties, on samples taken from production.

In the WMA validation trial undertaken in Melbourne as part of Austroads Project TT1454, a number of anomalies (unusually low air voids) occurred in the volumetric properties of laboratory-compacted samples taken from asphalt production. The reasons for the anomalies have not been adequately explained but it is noted that the testing of volumetric properties of manufactured asphalt is not routine practice in Victoria and hence laboratories are not accustomed to such testing. This may have led to some variation in laboratory procedures that influenced the outcomes.

The testing of volumetric properties (Marshall compaction) is a routine procedure in Western Australia so there should be a reasonable degree of confidence in the validity of volumetric properties of Marshall-compacted samples taken from production.

7.2 Specification Clauses

It is recommended that changes to Standard Specifications 504 and 510 include modification of Clause 504.38 and Clause 510.38 to incorporate the following elements:

- A change of title to 'Warm Mix Asphalt'.
- A definition of WMA.
- Modification of the existing 504/510.38 (1) to indicate approved use of both Sasobit® and foamed bitumen WMA processes. By way of comment, the use of WMA, particularly foam, could be extended to base asphalt as well as intermediate asphalt.
- A requirement that all proposals for WMA mixes comply with the requirements for the design and approval of a job mix, including full details of any additives used in the mix design and full details of the proposed technique to be used in the manufacture and placement of the WMA.
- Retention of existing requirements for the proportion and blending of Sasobit® (504/510.38 (2)).
- A requirement that proposals for the use of water-foaming processes be based on a mix design prepared for a standard HMA and verified by the determination of volumetric and performance properties on samples taken from asphalt production.
- The possible addition of a moisture sensitivity test (Austroads 2007) to the testing requirements.
- A brief description of the foaming process. In this respect selected clauses from the South Carolina DOT specification previously referred to, in particular the monitoring of water delivery into the foaming system and maximum quantity of water as a percentage of the binder, could be used as a guide. A detailed review of the Boral foam installation should be made before finalising this part of the specification.
- Sub-clauses 504/510 (3) and (4) could be retained although the specification of moisture content in the final mix should be defined.
- Clauses 504.41 (3) and 510.41 (3) should include delivery temperatures for foamed WMA as well as Sasobit®.

Recommended draft amendments to MRWA Standard Specifications 504 (September 2011) and 510 (December 2011 are presented in Appendix B.

8 CONCLUSIONS

This report has presented the findings of a project *Validation and Specification for Warm Mix Asphalt (WMA)* as part of the research program being conducted by the WA Pavements and Assets Research Centre (WAPARC). The project is closely linked with Austroads Project TT1454 *Performance of Warm Mix Asphalt Pavements* with some of the outputs of that project feeding directly into the WAPARC project.

The primary issues of concern to MRWA, and indeed to all Austroads members, is the field performance of WMA compared to conventional hotmix asphalt (HMA) pavements and the likely impact of the use of WMA on current specifications for conventional asphalt mixes.

The project involved 11 tasks, some of which were related. The two major components of the project were to:

- summarise the state-of-the-art based on European and USA experience
- prepare a draft report: (a) summarising risks and recommended actions to manage these risks, including (b) changes to MRWA Specifications 504 and 510.

The main findings are as follows:

- WMA has been found to provide performance equivalent to, if not better than, HMA in a large number of trials. It is becoming increasingly accepted in many countries, particularly the USA. However, there are some lingering doubts about rutting resistance and moisture susceptibility.
- Risks associated with moisture require the monitoring of moisture as part of QA procedures as well as the use of moisture sensitivity testing and possibly the use of adhesion agents or hydrated lime.
- Potential deficiencies in rutting resistance in foam mixes are partly addressed by the choice of binder grade. Where there is limited choice of available binders, it may mean choosing a PMB for heavy duty applications.
- PMBs are well suited to production using foam technology.

No change is recommended to current provisions for the use of RAP that allow up to 10% RAP in certain mix types and applications. The influence of higher proportions of RAP is a separate area of study that has not been pursued in this report.

Recommended changes to Standard Specifications 504 and 510, specifically modification of Clause 504.38 and Clause 510.38, are discussed and presented in Appendix B.

REFERENCES

American Association of State and Highway Transportation Officials 2009, *Standard practice for Superpave volumetric design for hot-mix asphalt (HMA)*, specification R 35-09, AASHTO, Washington, DC.

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South Carolina Department of Transportation 2011, *Supplementary technical specification for warm mix asphalt (WMA)*, SCDOT designation: SC-M-408 (04/11), South Carolina Department of Transportation, Columbia, SC, USA.

VicRoads 2007, 'Hotmix asphalt'*,* standard specification section 407, VicRoads, Kew, Vic.

VicRoads 2011, 'Hotmix asphalt: interim specific clause for WMA', standard specification section 400.15*,* VicRoads, Kew, Vic*.*

Appendix A SPECIFICATION EXTRACTS

A.1 Interim Specific Clause for WMA (400.15) Added to VicRoads Standard Specification Section 407: Hotmix Asphalt

Further to Clause 407.08, tenders may be submitted for the use of Warm Mix Asphalt (WMA) for jobs where WMA is permitted as per Table 400.181 – Schedule of Asphalt details. For jobs where WMA is permitted, tenderers shall specify their choice by indicating either WMA or HMA (Hot Mix Asphalt) within the box in the appropriate column provided in Schedule 1.

If the tenderer leaves this box blank against any job, it shall be treated as HMA.

WMA may be produced using one of the following methods:

i. sequential aggregate coating and binder foaming techniques

ii. binder foaming using water-based mechanical systems

iii. binder foaming using water-bearing additives

iv. chemical additives

v. organic additives

vi. combined chemical-organic additives.

The tenderers are required to provide full details as to the proposed technique to be used in the manufacture and placement of WMA.

WMA mixes are registered as separate mix designs in accordance with Specification Clause 407.06. For Types H, V, HP and HG WMA, a detailed mix design meeting all the requirements of Clause 407.06 is required. Where the WMA is produced using methods i), ii), iii) and vi) the mix registration shall be based on its production mix. For Type SI, the mix design registered as 'General' for HMA may be used for WMA. A separate WMA mix design is not required.

The inclusion percentage of RAP in WMA shall be in accordance with Clause 407.09.

If the WMA mix design submitted by the contractor does not meet the above requirements the contractor is required to supply HMA at no additional cost to VicRoads.

A.2 Wisconsin Department of Transportation Specification Modification for WMA

Warm mix asphalt: **a**ny asphaltic mixture that contains a warm mix additive, or utilizes a warm mix process, as part of its mixture design that has the ability to reduce the mixing and compaction temperature requirements below the typical temperatures used for that application.

460.1 Description

Replace paragraph one with the following:

(1) This section describes HMA mixture design, providing and maintaining a quality management program for HMA mixtures, and constructing HMA pavement. Unless specifically indicated otherwise, references within section 460 to HMA also apply to WMA.

460.2.1 General

Replace paragraph one with the following:

(1) Furnish a homogeneous mixture of coarse aggregate, fine aggregate, mineral filler if required, SMA stabilizer if required, recycled material if used, warm mix asphalt additive or process if used, and asphaltic material.

460.2.4.4 Warm Mix Asphalt Additive or Process

Add a new subsection as follows:

(1) Use additives or processes from the department's approved products list. Follow supplier or manufacturer recommendations for additives and processes when producing WMA mixtures.

A.3 Draft WMA Specification Provisions from South African Bitumen Association 'Best Practice Guideline & Specification for Warm Mix Asphalt'

Warm Mix Asphalt (WMA) Technologies

The WMA technology shall be approved by the engineer and shall enable the asphalt mix to be manufactured and paved at the temperatures given in Table 7.1, or otherwise as specified in the project specifications. The technologies may include the addition of substances to the binder or into the mixer, or other processes such as foamed bitumen.

The contractor shall supply, at the time of tender, the following information regarding the particular WMA Technology that is to be used:

- a materials safety data sheet (MSDS)
- technical details regarding mixing plant and capabilities
- technical data including recommended dosage rates
- details of the relationship between the treated binder viscosity versus temperature within the range of 90 °C and 160 °C
- Penetration and Softening Point of the treated binder
- detailed instructions regarding the way in which the WMA technology is blended with the binder and/or introduced into the asphalt mixing plant, and
- detailed information regarding mixing, paving, and compaction of the mix.

Warm Mix Asphalt (Mixing Plant)

In addition to the requirements of subclause 5(b), the asphalt plant shall be modified to suit the WMA technology used. Where applicable, systems that enable accurate and uniform addition as well as blending of substances into the binder and or the mixer shall be installed. When technologies are used where moisture is added to the binder to produce foam, a system shall be fitted that ensures a constant ratio of binder to water.

Bituminous binders shall be stored at temperatures not exceeding those given in (Table 7.1 in SABITA 2012), or as specified in the project specifications.

Blending of bitumen with WMA technologies shall be carried out within the temperature range recommended by the suppliers. The minimum binder temperature for WMA technologies shall be within the temperature range recommended by the asphalt supplier.

The aggregates, reclaimed asphalt, and bituminous binders shall be heated at the mixing plant to such temperatures that the mixed product shall have a temperature within the ranges given in Table 7.2, or as specified in the project specifications.

Table 7.1: Binder Storage Temperatures

Material	Maximum Storage Temperature	
	Under 24 hours (°C)	Over 24 hours(°C)
40/50 pen grade bitumen	175	145
60/70 pen grade bitumen	175	135
80/100 pen grade bitumen	175	125
homogeneous modified binders	See project specifications	

Table 7.1 from SABITA (2012).

Table 7.2: Manufacturing and Paving Temperatures

Binder type	Manufacturing (°C)	Upon arrival at paver (°C)
40/50 pen	130-140	120-140
60/70 pen	120-130	110-130
A-P1	140-150	130-150
A-E2	140-150	130-150

Table 7.2 from SABITA (2012).

A.4 Supplemental Technical Specification for Warm Mix Asphalt (WMA) South Carolina Department of Transportation (SCDOT)

SCDOT Designation: SC-M-408 (04/11)

1. SCOPE

1.1 This is a specification intended for use in placing Warm Mix Asphalt (WMA) on primary and secondary routes with ADT less than 10,000 and truck volumes less than 15 per cent.

This work consists of an asphalt mixture composed of mineral aggregate, aggregate screening, natural sand, asphalt binder, and hydrated lime mixed in an accepted asphalt hot mix plant. The mixtures will be produced in a SCDOT qualified asphalt plant that has been equipped with a foaming system or uses additives listed on Qualified Product List No. 77 to produce Warm Mix Asphalt (WMA). All foaming asphalt plants and additives used for this type of technology must be accepted by the Asphalt Materials Manager prior to production of this product. The asphalt mixes must be placed on a prepared surface in accordance with these Supplemental Specifications, applicable sections of the Standard Specifications, other appropriate Special Provisions and in conformity with the plans. WMA will use the same acceptance criteria for conventional hot mix asphalt mixes.

2. REFERENCED DOCUMENTS

2.1 SCDOT Standard Specifications

2.1.1 Division 300, Division 400, SC-M-401, SC-M-402, and SC-M-407

2.2 AASHTO Standards

2.2.1 AASHTO M303 and M320

2.3 SCDOT Test Methods

2.3.1 SC-T-70, SC-T-75, SC-T-80, and SC-T-84

3. MATERIALS

3.1 Aggregate: ensure that aggregates used in the production of Warm Mix Asphalt (WMA) meet the requirements found in the 2007 Standard Specifications section 401.2.2 and in SC-M-407 without exception.

3.2 Asphalt Binder: ensure that the binder is a neat asphalt binder that complies with the requirements of the SCDOT Standard Specifications section 401.2.1.1 using only PG64-22. Additives used in the production of the WMA may be pre-blended with the PG Binder at the asphalt terminal or introduced into the plant with other metering equipment as stated in Section 5.6. PG binders that have chemical additives added at the terminal or at the asphalt plant must be heat and storage stable and continue to meet AASHTO M 320.

3.3 Anti-Strip Additives: ensure that hydrated lime is incorporated into all mixes and meets the requirements of AASHTO M 303 Type 1 regardless of mix type. Ensure that the hydrated lime is blended with the damp aggregate at a rate of 1.0% +/- 0.1 % by weight of dry aggregate. Ensure that blending of the hydrated lime is accomplished according to subsection 401.2.1.3.

3.4 Water: ensure that potable water is used in water injection systems for foaming the asphalt binder.

4. MIX DESIGN

4.1 Warm mix designs utilize the same asphalt binder grade, aggregate and RAP sources, and material gradations as identically-formulated hot mix asphalt (HMA), although it may be in a HMA Contractor's benefit to provide additional equipment in their mix design laboratories to establish or simulate the foaming process to set optimum binder content and volumetric properties. WMA mix designs utilizing additives will use asphalt that may be pre-blended from the asphalt terminal or may be introduced by adding the correct dosage of additives to establish mix design volumetric properties. Additional equipment may be required by the WMA additive manufacturer in the design process to ensure the proper dosage and to achieve a homogenous mixture. Additive manufacturers will provide documentation of proper mixing and compaction temperatures to produce and compact WMA mixtures. Ensure that WMA mixtures comply with SC-M-402.

Design WMA job mix formulas in accordance with SC-T-80. Ensure that all designs are accepted by the Materials and Research Engineer prior to use on SCDOT work. Ensure that mix designs are prepared in a laboratory approved by the Asphalt Materials Manager and by technicians certified as a SCDOT Level 2, HMA Job Mix Technician. Ensure that technicians are trained on the use of foaming equipment if necessary to provide mix designs that will comply with all specifications herein and in the applicable Standard Specifications, Supplemental Specifications, and Special Provisions.

5. FIELD REQUIREMENTS

5.1 Ensure that all WMA systems or additives used are listed on QPLNo. 77. WMA foaming systems and additives are used to allow lower asphalt mix temperature. Use foaming equipment or an additive that is compatible with the asphalt plant and acceptable to the Asphalt Materials Manager in producing WMA, and ensure that asphalt plant conforms to SC-M-401 after any modification. Ensure that the burner in the aggregate dryer is properly adjusted so that there is no burner fuel in the WMA.

5.2 Ensure that on any WMA foaming system, or when any new metering equipment is installed on a contractors plant, that a trial run is done so all plant controls and metering equipment can be verified to be working accurately prior to production. Prior to full production of WMA mixtures for the Department, the contractor’s quality control manager will be responsible for verifying that all acceptance properties are within job mix tolerances as well as tensile strength ratio requirements during the trial run.

5.3 Ensure that all WMA mixtures are stored a maximum of 8 hours in a separate storage silo from conventional HMA mixtures. Extended overnight storage of WMA mixtures will not be permitted.

5.4 Ensure that only one WMA foaming system or WMA additive is used during a day of production of WMA mixtures.

5.5 Water Injection Foaming Systems

5.5.1 The use of a water injection system is not permitted on an asphalt batch plant.

5.5.2 Ensure that the foaming system manufacturer can provide technical assistance to the WMA producer by having a representative on site in the event of issues arising during use of the system within 24 hours of identifying the problem.

5.5.3 Ensure that injection equipment is tied into the computer in the plant control room so that metering of the injected water can be continuously monitored by the plant operator.

5.5.4 Ensure that injection systems have variable water injection that is automatically controlled by the plant production rate. Do not allow water injection system to exceed 2.0% water by weight of asphalt binder.

5.5.5 Ensure that the water injection rate cannot be manually overridden by the plant operator once established in the plant’s computer.

5.5.6 Ensure that in the event of control or equipment failure in the injection system occurs or if the injection equipment stops water flow the computer system immediately notifies the plant operator and all WMA production is stopped until the water injection system is repaired and checked by the contractor’s quality control manager before WMA production resumes.

5.5.7 Ensure that the water injects into the asphalt binder flow before the asphalt binder spray makes contact with aggregate. Do not allow water to come in contact with aggregate prior to binder spray.

5.5.8 Ensure that the injection equipment includes water storage and a pump control that is tied into the injection computer controls.

5.5.9 Ensure that the water flow alarm is installed in the control room to indicate a shortage of water in the storage tank, or a disruption in the water flow equipment.

5.5.10 Provide an additional asphalt binder sampling valve at the injection equipment to sample binder prior to the spray system.

5.5.11 Heat and prepare the materials in a manner that produces a warm mixture that, when discharged, is at a mixture temperature that can be maintained from **220°F - 285°F (104.4°C - 140.5°F) (no exceptions).** Use SC-T-84 to measure mix temperature at the asphalt plant and on the road in the delivery trucks.

5.6 **WMA Additives**

5.6.1 Ensure that if the additive has been pre-blended at the asphalt terminal, it has been documented on the Bill of Lading (BOL) coming from the binder supplier. Ensure that the percent additive added to the PG 64-22 is printed on the BOL. Store the binder in a storage tank without any contamination from previous loads of virgin PG 64-22. Label binder storage tanks noting the addition of WMA additives. All other WMA additives must be clearly identified at the asphalt plant and the WMA producer must have all documentation for the additives readily available for review at the asphalt plant.

5.6.2 Ensure that the WMA additive and or metering equipment manufacturer can provide technical assistance to the WMA producer by having a representative on site in the event of issues arising during use of the system within 24 hours of identifying problem. 5.6.3 Ensure that the additive metering equipment is tied into the computer in the plant control room so that metering of the non-terminally blended additives can be continuously monitored by the plant operator.

5.6.4 Ensure that metering systems can vary the amount of additives introduced into the asphalt plant and are automatically controlled by the plant production rate. Do not allow the WMA additive rate to go outside of the manufacturer's recommendations as stated in the WMA QC Plan, as stated in section 6. The recommendations should include a target dosage for the additives and upper and lower tolerance limits.

5.6.5 Ensure that if the additive equipment stops flow or if a control or equipment failure in occurs, the computer system immediately notifies the plant operator and all WMA production is stopped until the system is repaired and checked.

5.6.6 Heat and prepare the materials in a manner that produces a warm mixture that, when discharged, is at a mixture temperature that can be maintained from **220 °F - 285°F (104.4°C - 140.5°F) (no exceptions).** Use SC-T-84 to measure mix temperature at the asphalt plant and on the road in the delivery trucks.

6. QUALITY CONTROL

6.1 Provide the Asphalt Materials Manager, at least 30 days prior to starting production, a QC Plan to document the manufacturer's suggestions for target production rates when using water injection equipment in foaming systems or when using chemical additives, and produce an outline with acceptable variations the asphalt plant and acknowledge that the mixture will remain within 220 °F-285°F (104.4°C - 140.5°F) at all times.

6.2 Ensure that laboratory compaction ranges are established in the QC Plan used for making gyratory specimens for mix acceptance.

6.3 Ensure that all WMA samples taken for field determination of binder content are dried to constant weight if necessary prior to running SC-T-75 as outlined in the WMA QC Plan.

6.4 When using Intermediate Type C, Surface Type CM or Surface Type C mix types, perform Indirect Tensile Strength (ITS) testing using SC-T-70 at least one time during the first day's production, then at least once every 30 days thereafter. Forward the results by e-mail to the Asphalt Materials Manager immediately upon completion. Failure to comply with Section 401.2.3.4 of the standard specifications will cause Asphalt Materials Manager to immediately suspend production. Redesign will be required for any job mix formula which fails to meet Tensile Strength Ratio (TSR) field requirements.

7. CONSTRUCTION

7.1 Seasonal and Ambient Air Temperatures: Ensure that ambient air temperatures and seasonal restrictions during placement of WMA follow the requirements set forth in subsection 401.4.4 of the Standard Specifications without exception.

7.2 Failure to comply with WMA mix temperature requirements as stated in the Section 6.1 and the Contractors QC plan will result in mix being rejected as directed by the Asphalt Materials Manager.

8. FIELD ACCEPTANCE

8.1 During the production and quality control of WMA, make all necessary provisions to ensure that plant unit operations comply with SCDOT specifications regarding the production of HMA as stipulated in Division 310 and Division 401.

Appendix B DRAFT SPECIFICATION CLAUSES FOR MRWA SPECIFICATIONS 504 AND 510

Listed below are suggested draft amendments to MRWA Specification 504 (September 2011) to provide for WMA. Similar provisions may also be applied to the equivalent Clauses in Specification 510 (December 2011) with some minor variations as noted.

504.02 References

Add: Sub heading **Austroads Test Methods**

Add: AG:PT/T232 - Stripping Potential of Asphalt – Tensile Strength Ratio

Explanatory note: Use of this test is recommended as an additional requirement for WMA, being particularly relevant to water-based foam systems.

504.03 Definitions

Add: 9. “warm mix asphalt (WMA)” is asphalt that contains a warm mix additive, or utilizes a warm mix process, that has the ability to reduce the mixing and compaction temperature requirements below the typical temperatures used for that application.

MATERIALS

Add: **504 14 ORGANIC WAX COMPOUND**

Organic wax compound used in the production of warm mix asphalt shall be Sasobit®.

Explanatory note: Further products could be added as approved products after suitable evaluation.

504.26.03 JOB MIX DESIGN FOR DENSE GRADED ASPHALT

Add: 3 (f) Test results for tensile strength and tensile strength ratio conforming with Clause 504.26.04 (warm mix asphalt only)

504.26.04 APPROVAL OF A JOB MIX DESIGN

Add: Tensile Strength Ratio (warm mix asphalt only)

The design mix shall be gyratory compacted to 8 ± 1.0% air voids and tested in accordance with Austroads Test Method AG:PT/T232 to determine the Minimum Wet Tensile Strength and Minimum Wet to Dry Tensile Strength Ratio when. The Minimum Wet Tensile Strength shall be not less than 850 kPa for 10 mm and 14 mm mixes (*and not less than 650 kPa for 20 mm mixes – Specification 510*). The Minimum Wet to Dry Tensile Strength Ratio shall be not less than 80% for 10 mm and 14 mm mixes (*and not less than 85% for 20 mm mixes – Specification 510*).

504.38 USE OF ORGANIC WAX COMPOUND

Replace entire clause with the following:

504.38 WARM MIX ASPHALT

1. Warm mix asphalt may be used in the production of dense graded asphalt in the following applications:
   - Where asphalt is being transported for long distances and temperature loss may occur during transport or transfer at the paving site. The use of a polymer modified binder shall not be used in this circumstance; OR

- Production of asphalt at a lower temperature (warm mix). This may include the use of a polymer modified binder.

Editorial comment: This wording is based on the existing Clause 504.38. However, it is recommended that approval of warm mix asphalt should be extended to open graded asphalt, particularly as it is understood that WMA Sasobit®) has already been successfully used in open graded asphalt in WA. Similarly, the current version of 510.38 excludes the use of WMA in asphalt base, which should also be acceptable.

2. Dense graded asphalt mixes used as warm mix asphalt shall meet the requirements for design and authorisation of Job Mix Designs as specified in Clause 504.26

3. Warm mix asphalt may be manufactured using either of the two following processes:

- Addition of organic wax (Sasobit®) at a dosage rate of 1.5% by mass of the binder, OR
- Binder foaming using water-based mechanical system

4. Sasobit®) shall be added to the binder in accordance with the following:

- For small jobs in batch type plants where the total mass of asphalt manufactured in one day is 120 tonnes or less Sasobit® can be added as pellets directly to the pugmill.
- Where Sasobit® is to be used on a continuing basis of two consecutive days or more liquid or pelletised Sasobit® shall be added to hot binder and stirred in the tank or mixing container prior to its use.

5. Water-based foaming systems shall employ the Astec® system incorporating the following:

- Injection system tied into the computer in the control room to ensure that the injected water is continuously monitored by the operator.
- Injection rate limited to a maximum of 2.0% of water by mass of binder.
- Designed to ensure that water injects into the binder spray before the binder contacts the aggregate. Water must not be allowed to come in contact with the aggregate prior to the binder spray.
- Fitted with a water flow alarm to indicate shortage of water in the storage tank or disruption in the water flow equipment.

Editorial comment: It would be desirable it check the capability of the Boral system before finalising these provisions. In general terms it is undesirable to specify systems by proprietary manufactures and the wording of this clause could be altered to generic requirements. The Boral system, which has been supplied by Astec, is fitted to a batch plant but the general requirements for the proportion and monitoring of water flow should apply equally to drum mix plants.

6. The mixing process shall be such as to produce a uniform distribution of aggregate sizes and a uniform coating of binder on 100% of aggregate particles when tested in accordance with AS 2891.11. The mixing and drying processes shall be sufficient to ensure that moisture in asphalt is not greater than specified in Clause 504.32.

7. Where warm mix asphalt processes are used in the production of asphalt for use as hotmix asphalt the temperature of the mixed material at the discharge point shall not exceed 170°C. Where produced as warm mix asphalt the mixed material at the discharge point shall not be less than 130°C (*similar provisions to be made in 510.38*).