LG TRRIP

Local Government Transport & Roads Research & Innovation Program

An initiative by: WALGA, Government of Western Australia, mainroads Western Australia, NTRO

Practitioners' Guideline: Crumb Rubber Modified Binders in sprayed seal applications on Local Government roads in WA

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About LG TRRIP

The Local Government Roads and Research and Innovation Program (LG TRRIP) is an initiative between Main Roads Western Australia and the Western Australian Local Government Association.

LG TRRIP has a strategic commitment to the delivery of collaborative research and development that positively contributes to the design, construction and maintenance of safe, sustainable transport infrastructure in Western Australia.

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1 Introduction

1.1 Purpose

This guide aims to provide practical information regarding the appropriate selection and construction processes for crumb rubber modified bitumen (CRMB) sprayed seals for use on Western Australian local government roads. The information in this guide is to be used in conjunction with current guidance provided by local (Western Australian) as well as national (Austroads, Australian Flexible Pavements Association (AfPA), Institute of Public Works Engineering Australasia (IPWEA)) standards and specifications.

The main objective is to deliver practical advice that will assist local governments to make informed decisions for the selection and use of CRMB in their jurisdictions and guidance on supervision of operational crews undertaking CRMB sealing works.

Figure 1: Crumb rubber bitumen sprayed onsite

1.2 Structure

This guide provides practitioners with an overview of the main elements to consider regarding the selection, design and construction of CRMB sprayed seals for use on the local government road network in Western Australia (WA).

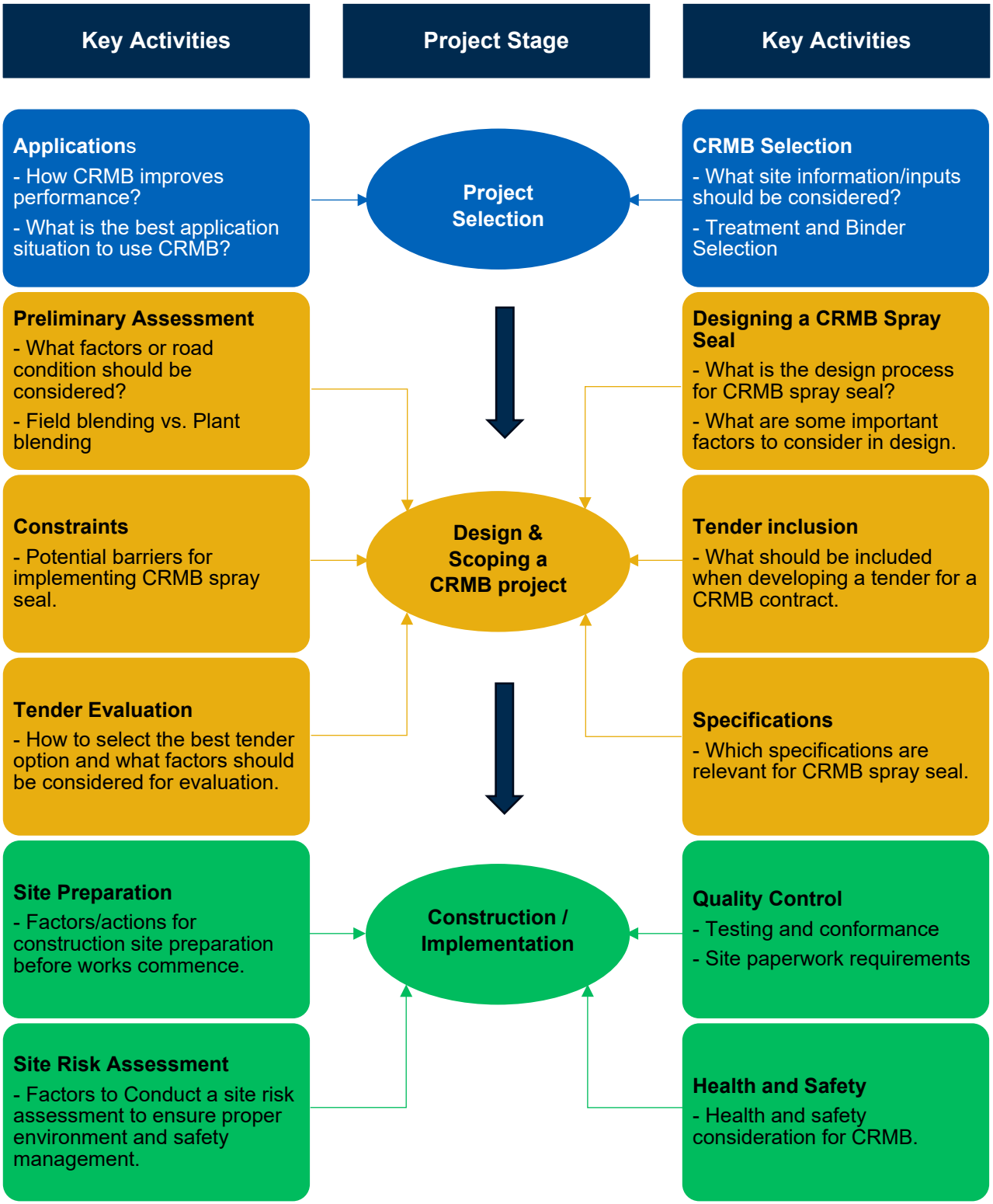
The practitioner's guideline comprises the following sections:

- Section 2 provides detail on where to use and how to select projects suitable for CRMB and lists constraints regarding the safe implementation of both field- and plant-blended CRMB and summarises the factors to be considered when scoping a CRMB project, relevant national and state specifications regarding plant-and field-blended CRMB and tender information to be included for CRMB projects.

- Section 3 describes spray seal construction procedures and the processes for plant- and field-blended CRMB, quality control and supervision considerations including site preparation, site risks, binder sampling and testing, quality control documentation, and health and safety information.

Figure 2 illustrates the overall structure and process covered in this practitioner's guideline document. Technical information on available CRMB materials and suppliers, seal design procedure and plant/field blending methodologies have been included in Appendices for further reference.

Figure 2: Structure, stages and key activities covered in this practitioner's guideline



1.3 CRMB Sprayed Seals

Sprayed seals are commonly used in Australia as they provide a low-cost construction and maintenance technique that can effectively serve roads with significant traffic volumes (Figure 1). A CRMB sprayed seal is a waterproofing surfacing application of bituminous binder modified with crumb rubber and covered by a layer of crushed aggregate, a recently sealed road is illustrated in Figure 3.

Crumb rubber is derived from the shredding and crumbing of end-of-life (EoL) tyres. After the removal of other tyre components, such as textile fibres and steel cords, tyres are shredded and crumbed to size.

CRMB may be produced at a plant or blended in the field. Plant-manufactured CRMB are blended by a binder supplier remotely from the application site prior to being used in road construction (Austroads 2021). Field-produced CRMB are made by blending bitumen and crumb rubber immediately prior to their use in road construction, such that only partial digestion of the rubber occurs. The material is generally prepared close to the application site and used within a short timeframe (Austroads 2017).

The most basic form of spray seal consists of one layer of crumb rubber binder with one layer of aggregate (single/single seal). Where a more durable treatment is required, such as where high stress and/or traffic situations are present, multiple layer seals and the incorporation of modified binders such as CRMB can prove beneficial and enhance performance.

The Austroads technical specification ATS 3110 (Austroads 2023) sets out the requirements for the supply of polymer modified binders (PMBs) and CRMB for use in both sprayed sealing and asphalt applications. The CRMB grades specified for use in sprayed seals by ATS 3110 are:

- plant produced – S9R, S15R (Formally S45R)
- field produced – S9RF, S15RF, S18RF.

Specification 511 consists of the supply and use of materials for sprayed bituminous surfacings for Western Australia. S15R is the only CRMB grade specified.

Information on the raw materials required for CRMB are detailed in Appendix A.

Figure 3: Recently sealed laneway

1.4 Advantages of Crumb Rubber Modified Bitumen

CRMB can provide environmental, performance and economic benefits for applications in sprayed seals. Additionally, crumb rubber, in most cases, is a recycled material that supports circular economy outcomes.

CRMB can be considered for all sprayed seal applications if logistical and economic considerations allow it. The incorporation of crumb rubber into bitumen (Figure 4) can improve performance characteristics of the binder. For lower stress sites, these enhanced performance characteristics can improve the performance of sprayed seals compared to conventional bitumen. Both low stress and high stress sprayed seals can incorporate CRMB, although traditionally, it is mainly used with high stress seals.

Table 1 provides an overview of the advantages of incorporating CRMB into different types of spray seals. Specifics should be discussed with the contractor during the design process.

Table 1: Advantages of CRMB in sprayed seals

Seals	CRMB advantage
Single/single (S/S)	• Increases elasticity providing resistance to shear stresses (turning movements)
Double/double (D/D)	• Higher softening point than conventional bitumen, providing reduced susceptibility to flushing in hot climates • Increases cohesion and aggregate retention properties • Improves crack resistance in pavements.
High stress seals (HSS1 & HSS2)	• Assists aggregate retention on roads with high traffic volumes. Improves road durability.
Strain alleviating membrane (SAM)	• Mitigates environmental cracking. • Reduces traffic-induced cracking propagation at a rapid rate but with low severity.
Extreme stress seal (XSS)	Accommodates extreme stresses due to: • High traffic volumes • Heavy vehicle loads • Demanding service conditions such as long ascending lanes or tight radius curves.

Figure 4: Close up of CRMB spray seal on road

2 Scoping a CRMB Project

2.1 Preliminary Assessment

A preliminary assessment of road sections and project scope needs to be undertaken to identify if the site is suitable for CRMB and whether plant- or field-blended CRMB is practical for both the location and project.

Table 2: Parameters for scoping a CRMB spray seal project

Parameters	Comments
Existing condition of road surface (for reseals)	• The improved temperature, adhesion and elasticity performance characteristics of CRMB make the binder a suitable option for cracked pavements and high stress locations. • CRMB is sprayed at higher application rates than standard binders so will also provide increased waterproofing benefits for the surface.
Condition of surface (for new construction)	• Priming and initial sealing practices should be followed prior to the application of a final surfacing treatment with CRMB.
Practicality of treatment type	• Transportation distances to remote locations may adversely impact the CRMB properties. Manageable distances for plant blend are 1,500 km or 2-days transport. • Higher distances should consider the use of field blending, providing sufficient space on-site for additional equipment and laboratory for batch testing.
Cost and scope size	• Plant-blended CRMB is generally transported in minimum batches of approximately 25,000 L, however, larger volumes will be more economical to transport. • Field blending requires more equipment to be transported to site. Transport efforts to deliver the equipment, base bitumen and crumb rubber means that the project must be a significant enough scale to justify the expense.
Traffic logistics	• Bitumen sprayers are limited to only spray at a maximum of 4.0 m width because they are incapable of spraying CRMB at 'full width' . • Limiting bitumen sprayer also allows resurfacing to be completed 'under traffic' with vehicles travelling through the site diverted to the other lane. • The layout of the site and requirements of traffic must be considered in the traffic control plan for the site.
Social & environmental factors	• CRMB 'smell' could be invasive to residents near the job site. • The higher viscosity of the binder may require more cutter to be incorporated into the mix prior to spraying to minimise the risk of tramlining and blockages. The reduction of cutter is an important issue within industry for minimising harmful emissions • CRMB needs to be applied in hot weather

2.2 Design of a CRMB Spray Seal

The design of CRMB sprayed seals will typically be undertaken by the contractor or specialist consultant, following the procedures of the Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals (Austroads 2018).

The basis of the design is the procedures for determining binder application rate and aggregate spread rate for single/single sprayed seals with standard bitumen as the binder.

For sprayed seals that incorporate crumb rubber binders, the important modification required is in the adjustment of the binder factor. The binder selected for a sprayed seal influences the necessary application rate. This is managed in the design by employing 'binder factors' tailored to the various treatments and binder types. All PMBs, which includes crumb rubbers, are thicker and more flexible than traditional binders, and can be applied at higher application rates to enhance performance. Binder factors for CRMB are required to ensure enough binder is present with rubber granules, and because the aggregate will often take longer to lay on its ALD.

No cutter is to be used for SAMI seals due to the potential to detrimentally effect the properties of the overlying asphalt.

An overview of the design process is provided in Appendix B.

2.3 Specifications

For local government works in WA, it is recommended that Main Roads Western Australia (MRWA) specifications are used:

- Specification 201 defines the quality management requirements the Contractor must observe during the execution of work under the Contract.
- Specification 509 specifies several construction requirements for CRMB.
  - Includes specifications for spraying temperature, cutter usage, nozzle selection, spraying width, high stress seals, and bridge deck usage.
- Specification 503 covers sprayed bituminous treatments in general, and for CRMB specifies:
  - The rubber binder shall be supplied from a bulk mixing facility. This requires field-produced crumb rubber binders that are used on MRWA works to use specialised on-site blending and storage unit, rather than 'in-line' addition of rubber directly to a bitumen sprayer.
- Specification 511 outlines requirements for crumb rubber to produce CRMB.

A summary of the national and WA specifications is provided in Appendix C and CRMB specifications can be found in Appendix D.

2.4 Tender Inclusion

Comprehensive scoping of job sites is imperative for the development of accurate spray seal tenders. Information that should be included for tendering includes:

- location of section to be sealed
- location of stack sites and distance to job site
- type of seal required – that is, prime and seal or reseal of existing pavement
- ideally, existing pavement condition for reseal work
- length, width and total area of job, including wings, tapers and widenings
- details on additional areas such as intersections, tapers and widenings
- details on road geometry and traffic distribution such as steep grades, curves or where heavy vehicle entrances (into quarries, mines, factories, service stations etc.) are located
- applicable specifications
- seal design provided or design and construct according to the relevant codes and specifications
- treatment type required, such as single/single seal or double/double seal and aggregate sizes
- estimated binder and aggregate application rates for tendering purposes only and the additional cost of materials, for example, cost for every extra litre of binder sprayed
- traffic count for the section including distribution of traffic classes across the lanes
- approximate required timing of works
- For new construction seals, a construction timeframe listing prime or initial seal and secondary seal dates should be provided.
- approved working hours for each section. For example, in front of a school, spray sealing may be limited to the hours of 9:30 am to 2:30 pm so that traffic disruption is minimised.
- number of mobilisations required to complete all works

- other site-specific requirements or identified hazards including (but not limited to):
  - proximity to tramlines, train lines or powerlines
  - low trees in town streets
  - proximity to waterways
  - sites of heritage significance
  - flora or fauna concerns
  - kerb and channel, bridges, guardrail or other areas where a suction sweeper may be required to remove loose aggregate from the site
  - where prior public notification is required for schools and businesses or heavily trafficked sections where variable message sign boards (VMS) may be appropriate
  - identification where additional traffic control or roadwork signage may be required
  - identification of emergency services within the job site for access purposes during works
  - details of maintenance works that have been undertaken on the section such as crack sealing, jet patching and asphalt repairs.

2.5 Tender Evaluation

The evaluation of tenders should be based on a combination of an assessment of price, the availability of a sealing crew and the experience of the sealing crew. The weighting factors allocated to each assessment item will be up to the discretion of the assessor.

Non-priced evaluations under consideration on a suitable tenderer should include:

- a list of exclusions by the tenderer to determine if variations will be required on the contracted works
- a list of proposed crew and relevant experience (as required)
- a list of proposed equipment and confirmation of bitumen sprayer calibration
- a proposed seal methodology/methodologies for treatment types
- where seal design assistance has been requested, confirmation of personnel with relevant experience and expertise in this area
- confirmation contractor has relevant inspection and test plans (ITPs), safe work method statements (SWMS) and work instructions (WIs) as part of their quality documentation that can be provided upon award of tender, if requested
- references from previous clients of similar works conducted.

Note that the above information can be provided post tender award; however, it can be noted on the tender that these items are required to be provided for final assessment and prior to executing a contract.

2.6 Constraints

Table 3 outlines the potential constraints related to the use and implementation of CRMB, along with possible solutions to address these challenges.

Table 3: Constraints for CRMB application and potential solutions

Constraint	Description	Potential solution
'Tramlining' - Achieving uniform binder distribution	A commonly reported fault with spraying CRMBs has been longitudinal streaking of the sprayed binder, often referred to as 'tramlining', where the sprayed bituminous binder resembles sheets of corrugated iron.	Control binder viscosity – Binder viscosity is directly affected by its temperature (viscosity reduces as temperature increases), and cutter oil can be added to temporarily reduce viscosity. Specification 509 requires that bitumen sprayers spray at a maximum width of 4.0 m, due to the capacity of the sprayers pumps). Sprayer nozzles – Larger output nozzles are sometimes preferred for CRMBs, because they are perceived to provide better performance and present less risk of blockages due to the larger sized nozzle outlet. Specification 509 requires that CRMBs must be sprayed with A27 or B36 nozzles. . 
Transport over long distances – Segregation	Crumb rubber binders may be susceptible to segregation of the bitumen and crumb rubber components (where the crumb rubber particles settle at the bottom of a tanker or bitumen sprayer) if stored at high temperatures for long periods, such as during transport over long distances.	When transporting CRMBs over long distances, it is highly important that adequate measures are taken to ensure that segregation does not occur. Suppliers of plant-produced CRMBs are expected to advise on required conditions for agitating the binder during transport to avoid segregation. Crumb rubber binder segregation issues can be addressed by equipping storage tanks or trucks with augers or paddles, or piping to circulate the binder, which agitates the blended binder. Where long transport distances are required from a fixed plant, field-blended CRMB may be a more suitable manufacturing method.
Transport over long distances – Degradation	Crumb rubber binders can degrade when stored for extended periods at high temperatures, predominantly due to dissolution of the rubber particles in the bitumen, and devulcanisation.	Degradation can be addressed by limiting the storage time between binder manufacture and use, and/or storing/transporting the binder at the lowest practicable temperature. This is predominantly due to dissolution of the rubber particles in the bitumen and devulcanisation (a process that reverses the vulcanisation of rubber, which is the cross-linking of rubber molecules with sulphur or other agents to improve its strength and elasticity) of the crumb rubber. Suppliers of plant-produced CRMBs are expected to advise on required conditions for agitating the binder during transport to avoid segregation. Where long transport distances are required from a fixed plant, field-blended CRMB may be a more suitable manufacturing method. AfPA Advisory Note 7 *Guide to the heating and storage of binders for sprayed sealing* provides a general guide to heating temperatures and storage times of bituminous binders used in sprayed sealing applications.
Climatic conditions	The successful application of crumb rubber binders in sprayed seals can depend on the climatic conditions during construction.	Specification 509 requires that the surface to be sealed shall be dry and no binder shall be applied during wet or rainy conditions, or when adverse weather conditions may prevail at any time during such work. When binder is applied and rain is forecast during the 24 hour period after application of the seal the Contractor shall be responsible for any damage to or defects in the seal and action and cost to maintain or repair the seal. No binder shall be applied whilst the pavement surface temperature is less than 20 °C. Seals constructed in winter with high proportions of cutter and likely to flush with the onset of warmer weather.
Safety considerations	To minimise the risk of burns, handling of both plant- and field-blended CRMB should be in accordance with the Austroads *Bituminous Materials Safety Guide* (Austroads 2015) in conjunction with each company's work health and safety management system, complementing standard operating procedures (SOP) and safe work method statements (SWMS).	

3 Construction Guidelines

3.1 Construction Procedures

Sprayed seals with CRMB are constructed following similar procedures to those for other binders, with some specific requirements. A brief outline of the principal activities involved in sprayed sealing operations is detailed as follows.

3.2 Site Preparation

CRMB spraying operations have the same inherent risks and operational requirements as unmodified and standard modified binders. Relevant state specifications regarding the management of the site should be adhered to in conjunction with sealing contractor work instructions (WIs) and safe work method statements (SWMS).

Site preparation includes (but is not limited to) the following:

- Prior to any materials being delivered or works commencing, identification of appropriate stack sites, blend sites and bitumen transfer sites are undertaken, ensuring all relevant environmental and safety risks are considered.
- All relevant site risks are documented and communicated to crew via a prestart or toolbox meeting. Guidance on risks to address are noted in Section 3.2.1.
- The site is set-up in accordance with traffic control legislation and relevant management guidelines.
- Binder is handled and delivered in accordance with Specification and manufacturer's guidelines and transportation practices.
- Correct binder transfer procedures are used and heating and incorporation of cutter and adhesion agent are in accordance with specifications.
- Weather conditions must be considered. Specification 509 specifies that no binder shall be applied whilst the pavement surface temperature is less than 20 °C. Pavement temperature also affects the amount of cutter specified by Specification 509.
- Binder spraying width and nozzle selection is appropriate for the nominal binder application rates and site layout.
- The appropriate number of aggregate spreader trucks is available to cover binder per spray run within specified time limits. Aggregate adhesion is a critical element in the performance of the seal.
- Aggregate is precoatedas per the requirements of Specification 511.

3.2.1 Site Risk Assessment

Hazard identification, hazard controls and residual risk ratings should be completed for the spray seal site noting general and site-specific risks. Items that should be addressed include:

- minimum requirements for personal protective equipment (PPE) on-site and additional PPE for bitumen batching, handling and transfer operations
- procedures for fire fighting
- procedures for first aid and bitumen burns
- personnel qualifications, licensing and training requirements
- traffic control/management and management of congestion throughout the worksite and at stack sites
- plant and pedestrian interaction, such as minimum safe distances to maintain and communicate protocols

- flora and fauna management
- dust and noise management.

Standard documentation such as WIs, SWMSs and prestart meeting forms can be used for capturing the above information.

3.2.2 Standard Construction Procedures

A typical procedure for the construction of CRMB sprayed seals is as follows:

1. Establish traffic management for the worksite.
2. Mark out the extent of works on the site.
3. Fit appropriate nozzles to the bitumen sprayer. Specification 509 specifies B27 or B36 nozzles, with nominal outputs of 27 L/min and 36 L/min, respectively.
4. Transfer binder to bitumen sprayer from the bulk delivery tanker or the vessel holding the field-blended CRMB.
5. Cutting oil (following guidance in Appendix E) and adhesion agents are to be incorporated into the binder and heated to spraying temperature as per manufacturer's recommendations (generally, 190–200 °C).
6. Spray binder at the specified application rate. Specification 509 specifies that the sprayer shall cross the protective paper at its correct spraying speed at the start of each run. The sprayer shall maintain its correct spraying speed over the full length of each run and shall cross the finish paper at this speed. Specification 509 specifies that spray bar widths are limited to 4.0 m. Length of spray run will depend on location and traffic and safety considerations.
7. Spread aggregate with the appropriate number of trucks for coverage requirements.
8. Roll aggregate with the appropriate number of rollers for coverage requirements. Drag brooming is required as per the requirements of Specification 509.
9. If constructing a double/double sprayed seal, repeat steps 6, 7 and 8 to apply the second seal coat.
10. Set up aftercare signage for road marking (where required) at the end of each day.
11. Spreading and rolling of aggregate is to be in accordance with the contract documents and inspection and test plans. Loose aggregate is to be removed and clear from the edge of seal with minimal disturbance of the embedded aggregate.
12. Further guidance of sprayed seal construction processes is provided in the following documents:
    - Section 7 of Austroads (2018)
    - *Guide to Pavement Technology Part 8: Pavement Construction* (Austroads 2009)
    - Austroads/AfPA Pavement Work Tips that are accessible from the Austroads website.

Further information and guidance on both plant and field blending can be found in Appendix F.

Bitumen sprayers used on Australian state road works are required to be calibrated annually, and copies of the current bitumen sprayer calibration certificate should always be with the bitumen sprayer.

3.3 Quality Control

3.3.1 Binder Sampling and Testing

All plant-blended CRMB delivered to site shall have an accompanying certificate showing conformance to specification limits as per Specification 511 and at the testing frequency show in Specification 201. Field-blended crumb rubber is sampled upon completion of blending and an adequate circulation/agitation period to ensure binder properties are in accordance with Specification 511 and at the testing frequency show in Specification 201.

A summary of CRMB specification limits for MRWA and Austroads is provided in Appendix D.

3.3.2 Quality Documentation

The standard site paperwork for sprayed sealing and CRMB applications include:

1. daily prestart meeting records and/or toolbox meetings
2. ITPs for works detailing hold point, witness point and inspection point requirements
3. site memos or site instructions for scope changes or variations
4. binder test reports for plant-blended crumb delivered to site
5. daily record sheets (spray sheets) recording material quantities, air/pavement temperatures, binder additive quantities, design and actual application rates per spray run.
6. blend sheets for field-blended crumb rubber showing blend times, binder and crumb quantities added per batch and blend/agitation time prior to incorporation of additives and spraying.

3.4 Health and Safety

LG TRRIP 03 Local Government guideline on Sustainable Road Construction Practices for Local Government Roads in WA (Howland et al. 2023) provides a detailed list of relevant legislation surrounding environmental and work health and safety requirements for the use of recycled materials in road construction in WA. The report includes:

- waste legislation
- environmental protection legislation and licensing
- work health and safety legislation
- legislation for the management of local roads.

Some environmental considerations for waste tyres and the crumb rubber produced from these include:

- potential to be a source of fire
- they contain heavy metals
- they contain volatile organic compounds (VOCs).

It has been noted that the incorporation of crumb rubber into heated bitumen has the potential to emit fumes and emissions VOCs and polycyclic aromatic hydrocarbons (PAHs); however, the levels of these pollutants are reported to be well below the Safe Work Australia Standards.

Tyre Stewardship Australia (2022) provided commentary on leaching of CRMB binder to waterways and environmentally sensitive areas. Their findings concluded that leaching may be a minor risk, with no significant issues observed under most conditions investigated. It should be noted that leaching of binder can occur for unmodified bitumen, cutback binders and emulsions and risk ratings based on prevailing weather conditions should be assessed prior to spraying any bitumen.

Handling crumb rubber binder should be in accordance with the Austroads Bituminous Materials Safety Guide (Austroads 2015), which details:

- first aid relating to bitumen burns
- fire fighting
- site set-up for handling, transfer, heating and blending
- product changeover and cleaning
- binder sampling
- PPE.

References

Australian Flexible Pavements Association, Advisory Note 7, *Guide to the heating and storage of binders for sprayed sealing and asphalt manufacture*, AfPA, Melbourne, VIC.

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Western Australia Local Governments Association 2022, *Sprayed bituminous surfacing: road building model specification,* WALGA, Perth, WA, viewed 13 February 2024,

Austroads Test Methods

AGPT/T131:2006, *Softening point of polymer modified binders*

AGPT/T143:2010, *Particle size and properties of crumb rubber*

AGPT/T144:2006, *Morphology of crumb rubber – bulk density test*

ATM-101:2022, *Method of sampling polymer modified binders, polymers and crumb rubber*

ATS-3110-23, *Supply of Polymer Modified Binders*

Main Roads Western Australia Specifications

Specification 503 Bituminous surfacings

Specification 511 Materials for bituminous treatments

Specification 509 Polymer modified bituminous surfacing

Specification 201 Quality Management

Main Roads Western Australia Test Methods

Test Method WA 201.1:2021, *Sampling and preparation of granulated rubber*

Test method WA 235.1:2021, *Bulk density of granulated rubber*

Test method WA 236.1:2022, *Particle size distribution of granulated rubber*

Test method WA 237.1:2022, *Steel content of granulated rubber*

Appendix A CRMB Materials

A.1 Description of Available Products

Bituminous binders used in sprayed seals can have their softening point, elasticity and torsional recovery properties enhanced by incorporating crumb rubber. This modification enhances the binder's ability to adhere to the aggregate (especially in areas subjected to high stress) and reduce susceptibility to the effects of binder flushing and bleeding during extreme temperatures. Additionally, the modified binder can be used to create thicker and more flexible membranes, providing better protection against water infiltration and minimising the reflection of cracks on the road surface (Austroads 2018).

The national specification for the supply of crumb rubber and crumb rubber binders is ATS 3110 (Austroads 2023). The specification details the performance requirements of S9R and S15R produced at a bulk mixing facility (that is, plant blended) and S9RF, S15RF and S18RF, which are produced on-site (field blended). Generally, field-produced CRMB are favoured for use in remote locations and the binder is to be used within a short timeframe (no case more than 2 hours travelling time from the blend site). The numerical parts of the grade names represent the nominal percentages by weight of crumb rubber in each binder grade.

For use in Western Australia, Specification 511 specifies the properties of S15R.

The predominant reason for using the crumb rubber binders included in Specification 511 and ATS 3110 (Austroads 2023) instead of unmodified bitumen is to limit the amount of cracking that occurs in sprayed seals (Austroads 2017). Guidance from Austroads (2018) provides further details of the suitability of S15R and S15RF grades (nominal crumb rubber content of 15% w/w) in the following applications:

- strain alleviating membrane (SAM) applications that mitigate slow rate environmental cracking propagation or the traffic-induced cracking propagation at a rapid rate with low cracking severity
- extreme stress seal (XSS) applications that accommodate extreme stresses induced by high traffic volumes and percentage of heavy vehicles, or demanding service conditions such as long ascending lanes or tight radius curves.

The S18RF grade, which has a nominal crumb rubber content of 18% by mass, is suitable for strain alleviating membrane interlayer (SAMI) and SAM applications that mitigate rapid rate traffic-induced cracking propagation with high cracking severity.

The S9R grade was added to ATS 3110 in 2023 and is a field-produced mixture of C170 bitumen and nominally 9% w/w of crumb rubber. Some Australian jurisdictions use S9R in high stress seal (HSS) applications to assist aggregate retention on roads with high traffic volumes; however, formal guidance to its use has not yet been included in the Austroads (2018) guide.

A.2 Crumb Rubber Sources

The crumb rubber most used in pavements is derived from the shredding and crumbing of end of life tyres or other suitable rubber products. After the removal of other tyre components, such as textile fibres and steel cords, tyres are shredded and crumbed to size. Crumb rubber can be incorporated at a fixed plant (plant-blended crumb) and transported to site or field blended near the job location. The use of plant- or field-blended crumb is dependent upon the quantity of binder required, transportation distances, availability of sealing crew and equipment and expertise of the sealing crew.

Specification 511 specifies that Crumb rubber shall be sourced from a Tyre Stewardship Australia accredited tyre recycler or a Main Roads approved supplier. In Western Australia, these include:

- Tyrecycle in Port Hedland (operational in 2024) (Paten 2023)
- Tyrecycle in O'Connor (City of Fremantle)

- WA Tyre Recovery in Albany
- Elan Energy Matrix Pty Ltd in Welshpool
- Lomwest Enterprises Pty Ltd in Dumbarton (Tyre Stewardship Australia n.d.).

Appendix B Guidelines – Sprayed Seals and CRMB

The general process for spray seal selection is dependent on the input parameters in Table 4.

Table 4: Guidelines and Parameters for spray seal selections

Parameters	Description
Low stress vs high stress areas	• Low stress areas are sections of roads where there is continuously traffic flow and limited breaking, examples include rural roads, highways and freeways • High stress areas are generally road sections where vehicles tend to slow/break more often, examples include roundabouts, steep inclines, intersections and turning lanes.
Heavy vehicle percentage	Estimated percentage or ratio between light vehicles and heavy vehicles (trucks, road trains etc). Can also be known as EHV % (equivalent heavy vehicle percentage)
Design traffic	The number of vehicles expected to use the roads. In this case it is measured in vehicles per day per lane
Pavement temperature (low, med, high)	• Low: < 52 °C • Medium: 52– 58 °C • High: > 58 °C
Grades	How steep the incline on a road. Generally anything with > 5% grade is considered a high stress area.

After determining the above parameters, refer to Table 4.7 in *Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals*. An example of a single/single design process is given below.

Example single/single seal design process

The design procedure for all sprayed seals is based on the standard single/single design method detailed in Austroads (2018). The design process can be summarised in the following steps:

1. Obtain aggregate and binder properties from test reports.
2. Calculate design aggregate spread rate from Average Least Dimension (ALD.)
3. Calculate design traffic and EHVs from traffic volumes and distributions.
4. Determine basic voids factor (Vf) from vehicles/land/day (v/l/d).
5. Determine design voids factor (VF) after applying voids factor adjustments for aggregate shape (Va) and traffic effects (Vt).
6. Calculate basic binder rate (Bb) using equation VF x ALD.
7. Determine binder factor (BF).
8. Calculate modified binder rate (Bbm) using equation Bb x BF.
9. Determine applicable allowances for surface texture (As), absorption (Aba) and embedment (Ae).
10. Add allowances to modified binder rate to obtain final design binder application rate (Bd).

Appendix C Specifications

The national specifications for the use of crumb rubber binders in sprayed seals are listed in Table 5.

Table 5: List of Austroads documents on the use of crumb rubber modified binders

Specification/Guideline	Authority	Applications	Reference
ATS 3110 Supply of polymer modified binders	Austroads	• Sprayed sealing binder properties (S9R, S15R, S9RF, S15RF, S18RF)	Austroads (2023)
AGPT04K Guide to Pavement Technology Part 4K: Selection and design of sprayed seals	Austroads	• Historical background • Operational environments • Selection • Design • Construction procedures	Austroads (2018)

Specifications from MRWA and Western Australia Local Government Association (WALGA) regarding sprayed seals are listed in Table 6.

Table 6: List of Western Australian specifications on the use of crumb rubber modified binders

Specification	Agency	Applications
Specification 201, Quality Management	MRWA	Specifies the quality management requirements the Contractor must observe during the execution of work under the Contract.
Specification 509, Polymer modified bituminous surfacing	MRWA	Specifies the supply and application of sprayed polymer modified bituminous treatments including SAM, SAMI, HSS and waterproof bridge deck membranes.
Specification 503, Bituminous surfacings	MRWA	Specifies the supply and application of sprayed bituminous treatments, including primes, primerseals, bitumen and emulsion seals and reseals.
Specification 511, Materials for bituminous treatments	MRWA	Specifies the supply and use of materials for sprayed bituminous surfacings and asphalt.
Sprayed bituminous surfacing: Road building model specification	WALGA	Specifies the requirements for supply of material and application of sprayed bituminous surfacing including primes, primerseals, bitumen seals and reseals, PMB seals, CRMB seals, geotextile reinforced seals.

Appendix D CRMB Specification Requirements

D.1 Austroads

Austroads (2023) specifies that crumb rubber used for the manufacture of crumb rubber binders must be:

1. processed from waste tyres generated in Australia
2. processed by a supplier accredited with Tyre Stewardship Australia or another organisation approved by the principal Engineer
3. free from cord, wire, fluff and other deleterious material
4. meet the properties included in Table 7.

Table 7: Summary of Austroads crumb rubber requirements for the production of crumb rubber modified binders

Property	Test method	Austroads	
		Size 16	Size 30
Grading	AGPT/T143		
Passing 2.36 mm		100	100
Passing 1.18 mm		80 min.	100
Passing 600 µm		10 max.	60 min.
Passing 300 µm		–	30 max.
Particle length (max, mm)	AGPT/T143	3	3
Bulk density (kg/m^3)	AGPT/T144	TBR	TBR
Water content (max, %)	AGPT/T143	1	1
Foreign materials – metallic iron (max, %)	AGPT/T143	0.1	0.1

Source: Austroads (2023).

D.2 MRWA

Specification 511 specifies that crumb rubber used for the manufacture of crumb rubber binders shall:

1. consist of rubber processed from EoL tyres or other suitable rubber products
2. Uncured or devulcanised rubber shall not be used as a source material.
3. be sourced from a Tyre Stewardship Australia–accredited tyre recycler or an MRWA approved supplier
4. be supplied in a dry condition, shall be protected against moisture ingress and shall be stored undercover to ensure the product remains dry
5. be sampled and prepared for testing in accordance with ATM-101, AGPT/T143 and WA 201.1.
6. meet the requirements shown in Table 8.
7. Crumb rubber shall not contain any foreign material such as sand, fibres or aggregate. Crumb rubber shall not contain more than 20% of elongated particles. An elongated particle is one where the length of the major axis of the particle is more than double the length of the minor axis.

Table 8: Summary of MRWA crumb rubber requirements for the production of CRMB

Property	Test method	Requirement
Grading	AGPT/T143 or WA 236.1	
Passing 2.36 mm		100
Passing 1.18 mm		100
Passing 0.60 mm		60–100
Passing 0.30 mm		0–22
Passing 0.075 mm		0–2
Particle shape (mm)	AGPT/T143	Mean of measured particles Maximum 3 mm
Bulk density (kg/m^3)	AGPT/T144 or WA 235.1	< 350
Moisture content (max, %)	AGPT/T143	1
Iron or steel content (max, %)	AGPT/T143 Or WA 237.1	≤ 0.1% by mass

Source: Specification 511.

Appendix E Cutter Rates

Cutter oil is commonly used in sprayed sealing to achieve the initial wetting of aggregate and modification (reduction) of the binder viscosity. Depending upon the anticipated pavement temperature, medium curing cutting oil shall be added to the binder in accordance with Table 9.

Specificaiton 509 specifies that, for double/double seals where both layers are applied on the same day using CRMB, only 2% medium curing cutting oil should be added to the first layer. For the second coat, a medium curing cutting oil should be added in accordance with Table 9 and accompanying notes. Please note, these rates are being updated in MRWA Specifications and national guidelines, and typically no more than 3% is used.

Table 9: Percentage of cutting oil to be added

Pavement temperature (°C)	Traffic (vehicle/lane/day based on AADT)	% of cutter for S45R
20 to 25	Less than 1,000	9
	1,000 or more	7 to 8
26 to 32	Less than 1,000	6 to 8
	1,000 or more	6
33 to 38	Less than 1,000	6
	1,000 or more	4 to 6
39 to 45	Less than 1,000	Min 4
	1,000 or more	
Above 45	All	Min 4

Notes:

- Cutter amount is a percentage by volume of the total binder.
- Assessment of pavement temperature should consider shaded areas. Areas significantly shaded should be treated separately from adjacent non-shaded areas. Ambient weather conditions in the days and week following must be considered when deciding on adding cutting oil.
- If manufacturer's instructions differ from Table 9, follow the manufacturer's instructions.
- If heavy vehicles exceed 20% of total traffic, reduce the cutter content by 2%.
- When using AN36 nozzles for a single coat seal with a BAR of ≥ 1.5 L/m², no cutter is required above a pavement temperature of 45 °C, and the cutter content below 45 °C is reduced by 2 °C.

Source: Specification 509.

Appendix F Plant and Field Blending Procedures

F.1 Plant-blended CRMB

The process for crumb rubber blended at fixed plants is similar to standard polymer blending; however, the crumb blending process requires fewer material components than Styrene-butadiene-styrene (SBS) or Polybutadiene (PBD) PMBs. Blending is completed using the following process:

1. Binder is heated to a sufficient temperature in a suitable vessel to permit the stirring of the binder.
2. Crumb rubber is added to the binder and blended within the vessel using either fixed stirrers located at the bottom of the tank or top-mounted agitators.
3. The binder and crumb rubber mixture is stirred at temperature and for a period sufficient to provide homogeneity of mixture (note that the crumb particles are suspended in the binder).
4. Blended product is transferred to a holding tank where it is stabilised to assist with storage and transportation.
5. The final blended product is transported to site in bulk tankers fitted with heating and circulation capabilities to ensure product homogeneity at point of delivery.

CRMB for sprayed sealing may be susceptible to segregation if stored at high temperatures for long periods. When transporting CRMB over long distances, it is highly important that adequate measures are taken to ensure that segregation does not occur. Suppliers of plant produced CRMB are expected to advise on required conditions for agitating the binder during transport to avoid segregation.

Where correct blending, transportation and handling procedures are adhered to for both field- and plant blended crumb rubber binder, some additional benefits of use include:

1. improved elasticity and crack-resistance properties
2. improved aggregate retention/adhesion
3. increased binder softening point, minimising the risk of bleeding seals in hot weather
4. improved shear strength
5. use of recycled materials
6. potential cost savings on field-blended crumb due to significantly cheaper cost of crumb rubber in comparison to bitumen.

F.2 CRMB Field-blending Procedure

Field blending generally involves loading crumb rubber from bulk bags into a delivery unit, which will have a hopper to store the rubber and means to weigh the load. Bitumen is transferred from a storage unit, typically a bulk tanker, through a pugmill mixing device, which combines the bitumen with the rubber and transfers the combined material into the bitumen sprayer (or other storage vessel). Additionally, a shear mill may be used for secondary mixing and agitation between the pugmill and bitumen sprayer to enhance blending. The binder is then circulated for a period of time in the bitumen sprayer to ensure the binder and crumb rubber are incorporated. Bitumen additives such as cutter and an adhesion agent are incorporated and circulated in accordance with specifications prior to spraying.

Practitioners undertaking field blending should follow defined processes in a work instruction, or similar type document, that is specific to their equipment and requirements.

A general overview of the process for field blending of CRMB is:

1. Crumb rubber is loaded into the delivery unit, typically from 1 tonne bulk bags.
2. C170 bitumen is transported to site and heated to an appropriate temperature for transfer and blending, typically around 200 °C. The bitumen should be circulated through the pipework of the tanker for preheating to minimise the risk of blockages due to loss of heat.

3. The components are connected by transfer hoses. The bitumen tanker is connected to the input of the pugmill mixing device. The output of the mixing device is connected to the bitumen sprayer via the shear mill, if used.
4. Transfer of the bitumen commences. Approximately 500–1,000 L of bitumen should be transferred before crumb rubber is added, to heat the components, minimise the risk of blockages and to aid mixing.
5. Crumb rubber is introduced from the delivery unit into the delivery chamber of the pugmill. The delivery unit will have the means to measure the amount of crumb rubber being introduced. The rate of bitumen and crumb rubber flows can be adjusted by the operator, according to the requirements of the resultant binder and the capabilities of the equipment.
6. The pugmill provides initial mixing of the bitumen and crumb rubber as the binder continues to flow into the bitumen sprayer. If a shear mill is being used, it will provide secondary mixing, which aids incorporation of the crumb rubber into the bitumen before the binder enters the bitumen sprayer.
7. Transfer of the crumb rubber and bitumen is completed. The addition of the crumb rubber should be finished before all the bitumen has been transferred, leaving approximately 500–1,000 L of neat bitumen to clear the transfer lines.
8. The transfer hoses are disconnected.
9. The blended CRMB is circulated or agitated in the bitumen sprayer for a minimum of 20 minutes to complete the incorporation process and provide a homogeneous binder.
10. The binder is heated to the desired spraying temperature in the bitumen sprayer, and additives such as cutter oil or adhesion agents are incorporated to prepare for spraying.

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