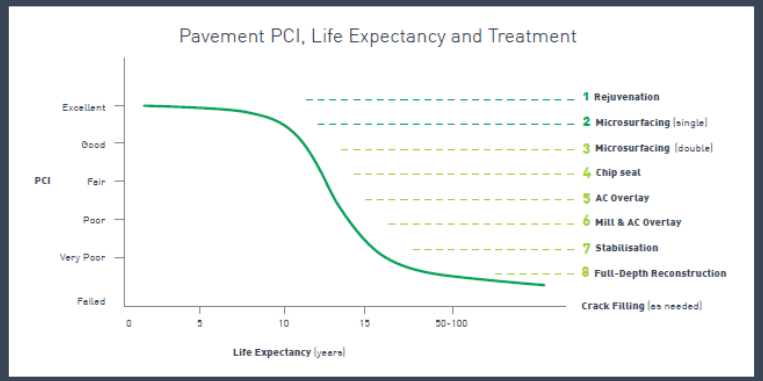
ATTACHMENTS UNDER SEPARATE COVER

ITEM ATTACHMENT DETAILS

8 Alternative Road Surfacing Options

APPENDIX 1

A variety of failure modes are assessed to identify each individual road segment's Pavement Condition Index (PCI) rating. This information is then utilised to identify the appropriate treatment to extend the segment's life and improve its PCI. The PCI, life expectancy and corresponding treatments are detailed below:



As demonstrated in the above chart, Campbelltown applies a broad range of pavement treatments based on PCI and life extension outcomes. The following treatments are being commonly applied based on cost benefit analysis:

01

REJUVENATION

Spray applied binder rejuvenation treatments or Polymer Modified Emulsion / Mastic preservation treatments are used as early life cycle intervention treatments on selected sites to maintain the existing PCI. These applications are limited to existing sound pavements where very minor existing failure modes are exhibited.

02 03

MICROSURFACING

Microsurfacing is used effectively on existing sound pavement where pavement shape may require correction. The final aesthetic is pleasing to residents and offers low road noise with an asphalt-like finish. Microsurfacing is also used in combination with crack sealing or spray sealing to address reflective cracking.

04

CHIP SEALING

Using either hot bitumen or emulsion technology, spray applied treatments provide improved pavement water proofing and resistance to existing surface cracking. Spray treatments are also used in combination with microsurfacing to mitigate residential complaints related to loose aggregate post surfacing and overall aesthetics of the final wearing surface. Council uilises spray applied treatments as a cost effective application on its rural road networks.

05 06

AC (ASPHALT) OVERLAY

Council's low PCI sites are often rehabilitated with asphalt overlays providing a cost effective preservation treatment.

07

IN-SITU STABILISATION

Sites exhibiting the lowest PCI are rehabilitated with full depth bitumen foam / cement or lime in-situ stabilisation. This process allows for full pavement rehabilitation and, once completed, allows a new life cycle to commence. Council's strategy aims to decrease the number of sites requiring full rehabilitation, preferring to increase the life expectancy of the pavement through other means prior to resorting to stabilisation works.

08

FULL DEPTH PAVEMENT RECONSTRUCTION

Full depth pavement reconstruction is the most expensive method and use only when there is no other rehabilitation option available. In this method, after milling and disposing the existing pavement materials, we reconstruct the pavement base and sub-base with new materials followed by a wearing course of asphaltic concrete or spray seal at the top.

Sourced - Extracted from IPWEA Special Technical Paper

APPENDIX 2

The PMS assisted with predictive modeling including maintenance application choices, intervention triggers and life cycle costing etc. Campbelltown City Council has also integrated Pavement Preservation options in PMS to achieve longer term financial sustainability in its road network management.

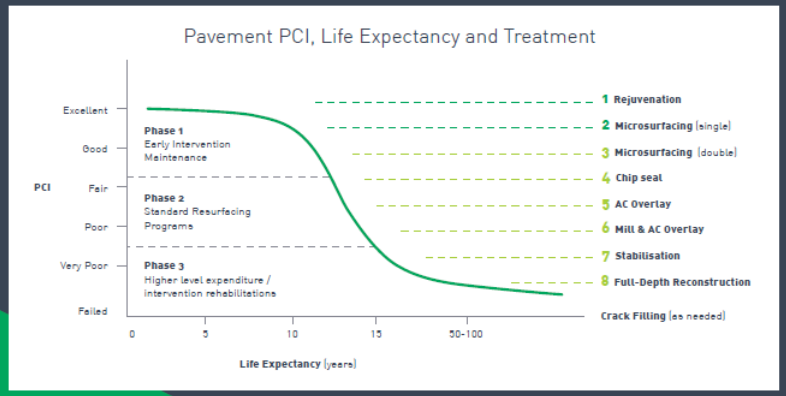
In Campbelltown City Council, road-treatment selections are broken into three distinct phases based on PCI and treatment types as follows:

PHASE 1
Early Intervention
Maintenance-Preservation

PHASE 2
Standard Resurfacing Program-
Resealing and asphalt resurfacing

PHASE 3
Higher Level Expenditure/
Intervention-Rehabilitation

The phases and corresponding treatments are detailed below:



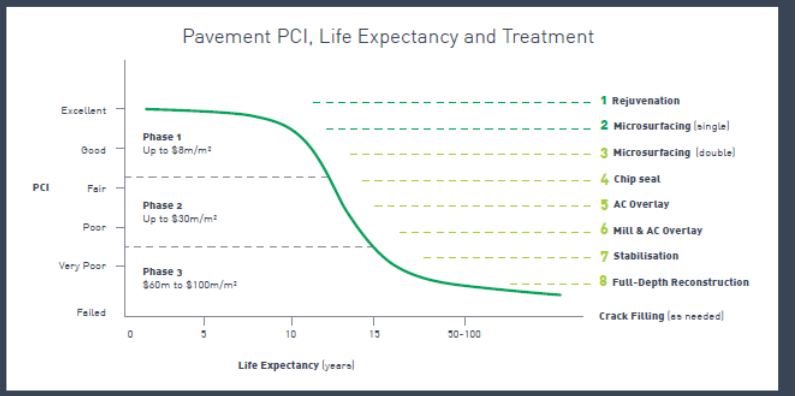
With the help of Finance team, the asset section has also developed a funding strategy of all three phases as follows:

PHASE 1
100% funded since treatments in phase 1 are cost effective proactive maintenance and aimed to keep the good conditioned road in good condition for a long time. (Budget allocation 20%)

PHASE 2
Based on PCI, most of the Council's road renewal backlogs are in this phase. Council strategy is to fund the worst projects so that remaining projects do not go to Phase 3 (Budget allocation 65%)

PHASE 3
Based on current PCI, a small number of projects are only in this phase. Council decided to eliminate these in 5 to10 years. Project selections are based on asset risk score, cost benefit analysis, minimizing road user and future maintenance costs. (Budget allocation 15%)

The phases and corresponding treatments are detailed below:



Sourced - Extracted from IPWEA Special Technical Paper

COLAS SOLUTIONS

Products & Services Capabilities

COLAS

WE OPEN THE WAY

SEALCOATING

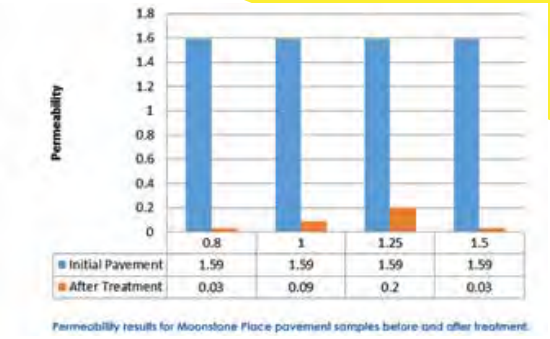
A PREVENTATIVE MAINTENANCE TREATMENT

Introduction

Sealcoating is a preventative maintenance treatment designed to preserve asphalt and spray seal pavements in an as new condition for as long as possible and thereby reduce the need for expensive rehabilitation and reconstruction. Sealcoating treatments are designed to seal the pavement surface against the intrusion of air and water, thereby slowing the oxidation process.

Material

SealCoating involves the application of a polymer modified bitumen emulsion containing specially graded aggregates, fillers, latex, rubber and pigment adjusters, with sand and water being post added on site prior to application. During the application process the macro texture of the initial pavement is filled with the emulsion and fine sand to the point of oversaturation covering the exposed aggregates in the process. During the curing phase separation occurs between the filled emulsion and water resulting in a gradual reduction in layer thickness. After the water has vaporized the residual SealCoat layer remains almost level with the top of the aggregate after curing has ended.



Permeability results for Moonstone Place pavement samples before and after treatment

PENDULUM SKID TEST RESULTS

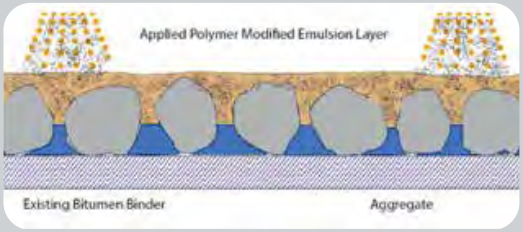
Street Name:	Delong Street, Acacia Ridge		
Sample No	App Rate	Skid Resistance	
		Surface Texture	Test Surface Mean BPN
1	0.5	Average	75
2	0.7	Average	79
3	0.8	Average	76
4	1	Average	81
	Initial Surface Texture:	Average	55

Street Name:	Forgan Street, Acacia Ridge		
Sample No	App Rate	Skid Resistance	
		Surface Texture	Test Surface Mean BPN
1	0.5	Coarse	81
2	0.7	Coarse	81
3	0.8	Coarse	78
4	1	Coarse	78
	Initial Surface Texture:	Coarse	55

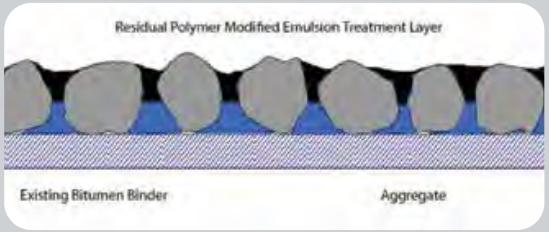
Street Name:	Gemstone Crescent, Acacia Ridge		
Sample No	App Rate	Skid Resistance	
		Surface Texture	Test Surface Mean BPN
1	0.8 + 0.7	Coarse	72
2	1	Coarse	78
3	1.25	Coarse	83
4	0.8	Coarse	78
	Initial Surface Texture:	Coarse	54

Street Name:	Gregory Street, Acacia Ridge		
Sample No	App Rate	Skid Resistance	
		Surface Texture	Test Surface Mean BPN
1	0.7 + 0.8	Very Coarse	84
2	1	Very Coarse	84
3	1.25	Very Coarse	84
4	0.8	Very Coarse	79
	Initial Surface Texture:	Very Coarse	75

SealCoat Treatment Process



Cured SealCoat Conditions



Application Process

Custom built sprayers with larger nozzles than conventional bitumen sprayers, specialist pumps and mixing paddles help to keep the material in suspension. Being an emulsion it is not heated but applied at ambient temperature. Advantages over conventional treatments include the speed of application with an average shift spraying over 6,000m2 in urban streets and a fast drying time of between 30 mins and 2 hours. Disadvantages include no shape correction and a relatively short life span of roughly 5 years between applications. The finished treatment provides a rich black colour that seals and extends the pavement life at a low cost.

Results / Testing

Current testing includes permeability and skid resistance with results showing the permeability level reduces and an increase in skid resistance values across all treated pavements.

Conclusion

The surface of flexible asphalt pavements designed for a 20 year life, commonly have a functional life of between 12-15 years between major maintenance treatments; however a mid-life surface treatment of SealCoat will help to impede the aging process and potentially delay the timing of major maintenance treatments. After an application the pavements skid resistance is improved and permeability decreased.

Item 8 / Attachment 3.

SRS SEALCOAT

HIGH PERFORMANCE BITUMINOUS PAVEMENT PROTECTION

Your pavement is under constant attack.

You need the protection of a safe, environmentally friendly material that fights back with its own powerful, clean chemistry.

WHAT IS SRS SEALCOAT ?

SRS SealCoat is a micro-surfacing sealant designed to extend the life of existing bituminous surfaces.
By combining SRS SealCoat's high adhesive characteristics with polymer modifiers and varied quantities of solids to suit the condition of individual pavements, SRS SealCoat will seal and protect your pavement.

Asphalt and spray seal surfaces are under constant attack! Sun, rain and hail all take their toll. If the pavement isn't protected it will deteriorate, weaken and begin to shed particles as the binder becomes brittle and fails.

The loss of larger stones, cracking, water penetration and accelerated failure with time. Without timely intervention with SRS SealCoat, the cost of repairing pavement increases substantially.

SRS SEALCOAT +

HIGH PERFORMANCE BITUMINOUS PAVEMENT PROTECTION

Your airport pavement is under constant attack.

You need the protection of a safe, environmentally friendly material that fights back with its own powerful, clean chemistry.

WHAT IS SRS SEALCOAT + ?

SRS SealCoat + is a micro-surfacing sealant designed to extend the life of existing bituminous surfaces. By combining SRS SealCoat's high adhesive characteristics with polymer modifiers and varied quantities of solids to suit the condition of individual pavements, SRS SealCoat will seal and protect your pavement.

Asphalt and spray seal surfaces are under constant attack! Sun, rain and hail all take their toll. If the pavement isn't protected it will deteriorate, weaken and begin to shed particles as the binder becomes brittle and fails.

The loss of larger stones, cracking, water penetration and accelerated failure with time. Without timely intervention with SRS SealCoat, the cost of repairing pavement increases substantially.

Item 8 / Attachment 3.

FRM SEALCOAT

EMULSION ADHESIVE TECHNOLOGY FUEL RESISTANT SEALCOATS

FRM SealCoat, is a FAA Fuel Resistant, non-toxic, Low PAH bitumen based sealcoat that can be custom designed as a Spray Applied Aggregate Slurry.

FRM SealCoat is a plural component, single package, reactive, high molecular weight polymer modified bitumen sealcoat. FRM SealCoat is designed to penetrate deep into pavement substrates where it permanently weather seals airport, street and highway apron surfaces. It may be applied as a mineral filled sealer through spray, broom, or squeegee and may be applied as an un-filled coating through high volume equipment.

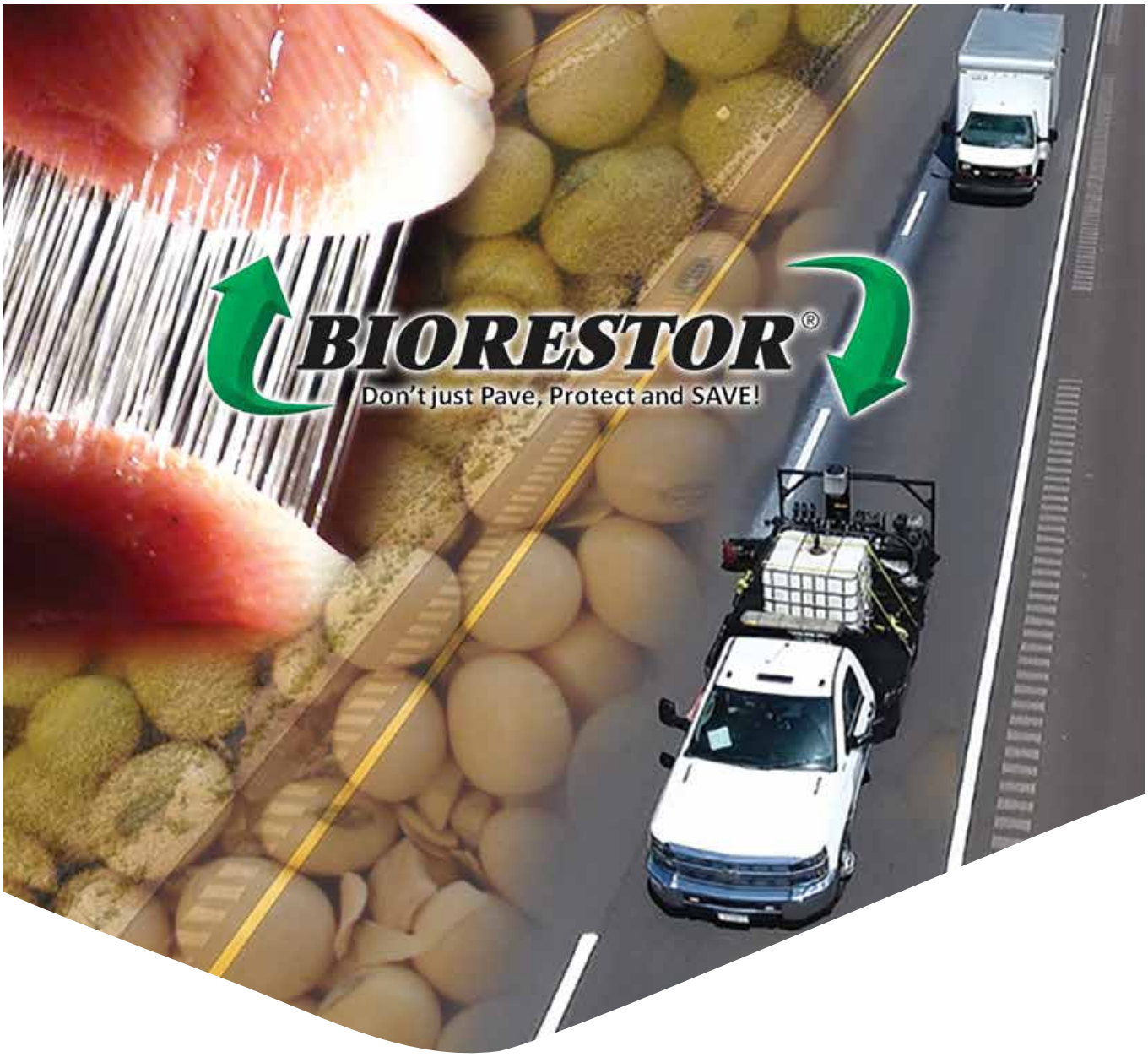
Within as little as a few minutes after installation a tough but ductile, black satin surface permanently protects the underlying asphalt surface from tyre wear, sun degradation and moisture. The high molecular weight and high softening point of this material prevent tracking or displacements by rolling traffic in the heat of the day.

FRM SealCoat is filled with an engineered hydrocarbon additive, which is provided as an emulsified, high molecular weight thermoplastic. It exhibits a high softening point, good low temperature ductility and excellent hydrolytic stability; as well as superior adhesion to moist mineral surfaces.

ADVANTAGES:

- Jet fuel (Jet A thru JP-8) and Motor Vehicle Oil/ lube resistant.
- Unique reactive chemicals attack natural metal oxides present in the exposed aggregate surface.
- Chemical resistance, rate of cure, final surface hardness and skid characteristics can be modified to meet local specifications.
- May cure in less than twenty (20) minutes, in optimal conditions, to a track free surface.
- Safe to handle and store.
- Near zero VOC; and odourless.
- High temperature, tyre scuff resistant to power steering abuse
- Easy clean up with water.
- Cured container residue safe for municipal landfill

Item 8 / Attachment 3.



BIORESTOR®

ASPHALT REJUVENATOR

Asphalt Rejuvenator

BIORESTOR® Asphalt Rejuvenator is a restorative asphalt modifier that has been shown to increase a pavements life cycle by up to 40%! It is a participant in the USDA BioPreferred program. It has been developed from bio-based oils with a synthetic polymer modification, to create an environmentally sustainable road treatment.

With the application of BIORESTOR® just after paving, the pavement lifespan can be dramatically increased, saving money for the customer!

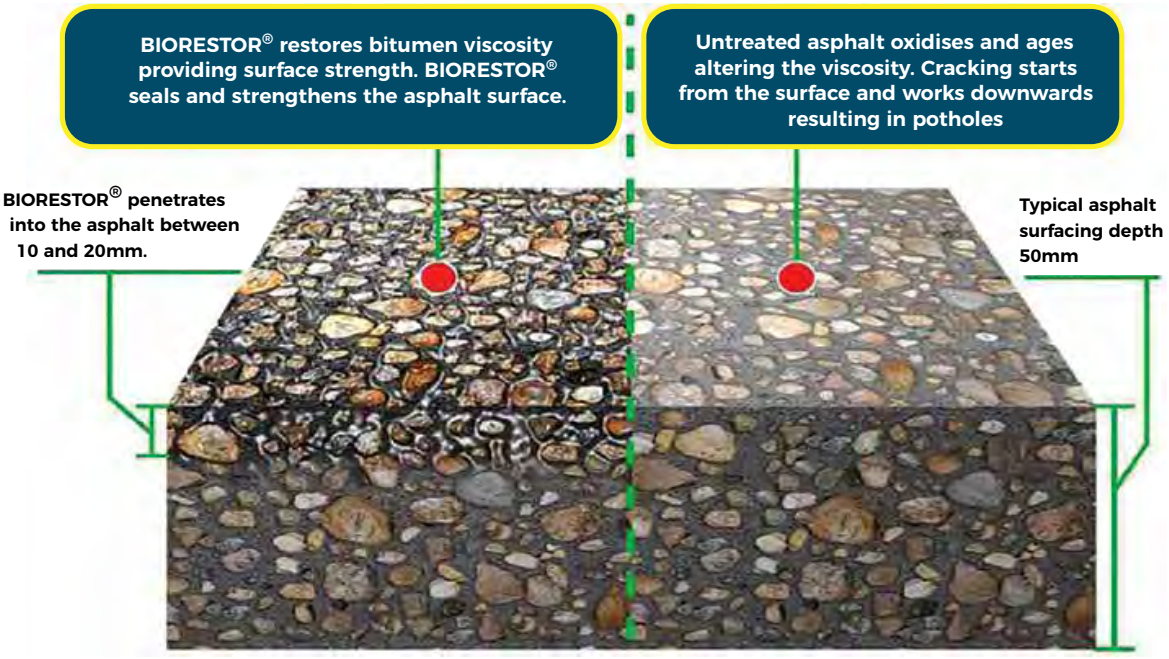
Benefits of BIORESTOR®

- Reduces cracking
- Increases flexibility
- Decreases viscosity (Brittleness)
- Increases penetration (Softness)
- Reduces ravel & pot-holes
- Field tested since 2004

How BIORESTOR works:

Asphalt pavements are termed as flexible pavements, which are constructed of thin layers of bitumen over stone bases or other asphalt layers. All layers are intended to flex to accommodate vehicle weight and provide an undamaged surface for driving. Over time these layers become brittle and inflexible causing them to crack under heavier loads. BIORESTOR® penetrates the asphalt by introducing agriculture oils that soften the asphalt renewing flexibility.

BIORESTOR® is applied to the surface by trained applicators, utilizing a precise spray system. The treatment is applicable to new as well as older pavements in good condition. BIORESTOR® can be used as a construction seal on newer pavements as part of the pavement contract and again 4-5 years later to provide cost savings and add years to the lifecycle of asphalt surface.



Why Choose BIORESTOR Asphalt Rejuvenator Emulsion?

Without asphalt preservation and preventative maintenance, repaving is inevitable in a relatively short period of time. At only a fraction of the cost of paving, BIORESTOR® preserves and protects asphalt pavements ensuring the longevity and quality of your paved investment.

Time and testing have shown that using a rejuvenator such as BIORESTOR®, before asphalt breaks down, provides communities the opportunity to use their road monies more efficiently and expand their annual pavement preservation goals. It is cheaper and easier to take care of a good road than to save a bad one.

Roads and Highway

BIORESTOR® has been applied on various pavements with satisfactory results. As suggested by the Foundation for pavement preservation, asphalt rejuvenators applied to lower volume or traffic roads can provide years of life. Larger volume roadways typically involve a construction joint upon placement of the second pavement mat. This joint is typically lower density and more prone to deterioration. Over 2000 miles of construction joint has been treated with positive outcomes.

Parking Areas

Asphalt parking lots tend to have less heavy traffic as roadways but are still susceptible to oxidation and aging. BIORESTOR® applied topically is a clear penetrative sealer that does not require the need for re-striping. Tired of black tar seal coatings wearing off and becoming eye sores? Instead use an asphalt rejuvenator to maintain flexibility and ensure uniform pavement condition for years.

Airports and Runways

Airports are notorious for large amounts of asphalt pavements in the form of runways, overruns, aprons, and taxiways. While these pavements may not receive large amounts of traffic typically, they still are prone to UV and oxidation deterioration. Asphalt rejuvenators have shown to alleviate the effects of years of aging. FAA-P632 is a aviation specification designed to interpret the effects a rejuvenator offers.

Walking and Bicycle

Bike paths are a luxurious get away from big city street or a practical form of transportation for certain motorist. While funding for them can be crucial for construction, preservation of this investment is important. Treating these desirable assets can extend the operational life of the pavement and delay the large cost of resurfacing or repair work in the future.

GSB-88®

RESTORATIVE AND PROTECTIVE SEALER

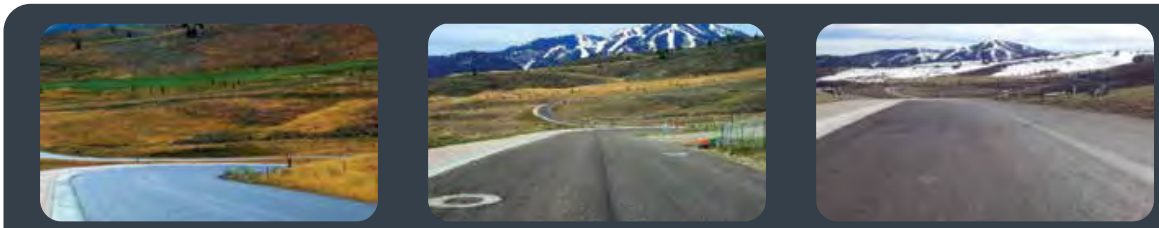
High performance asphalt pavement preservation

GSB-88 HARNESSES SUPERIOR CHEMISTRY

Oxidation ruins asphalt pavement binder. Our Unique GSB Chemistry slows the molecular ageing and deterioration reactions in pavement binder oils, so it keeps the binder healthy.

GSB-88 INTEGRATES INTO THE PAVEMENT

Other sealers sit on the pavement surface and may crack, peel (delaminate), or wear off. GSB-88 becomes part of the surface matrix to restore, restructure, strengthen and protect the ageing pavement



First treatment August 2011

Five years later April 2016

Second treatment August 2016

Photo taken 9 months later

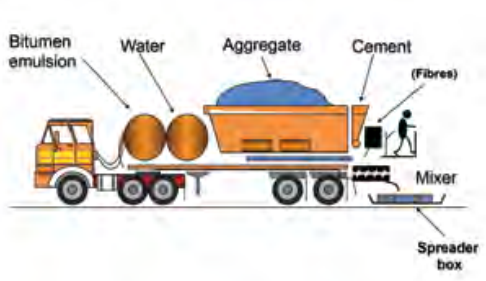
GSB-88 Has been used successfully on roads and airfields around the world for more than 30 years.

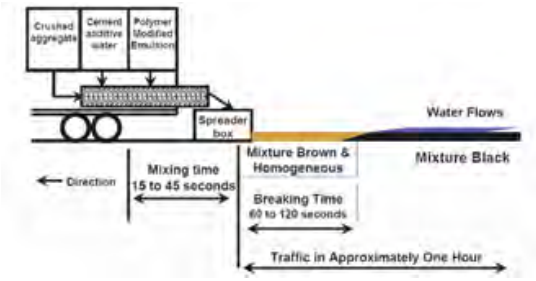
Item 8 / Attachment 3.

MICROSURFACING

DELIVERING SUSTAINABLE CONSTRUCTION SOLUTIONS

A low carbon alternative to conventional hot surfacing treatments.





With increasing focus on sustainable procurement, COLAS Microsurfacing solutions offer a cold applied, low carbon alternative compared to the conventional hot surfacing treatments.

By reducing the output of energy, emissions and waste, COLAS are able to aid clients in significantly lowering their carbon footprint.

Colmat Microsurfacing is specially formulated so that it can be:

- Applied in 5mm, 7mm, or 10mm aggregate blends – dependent on texture requirements.
- Used as a single coat wearing course or a double coat void filling, regulating or correction treatment.
- Specially designed by our engineers to suitable treat any bituminous or concrete surface.

Microsurfacing for residential or urban roads

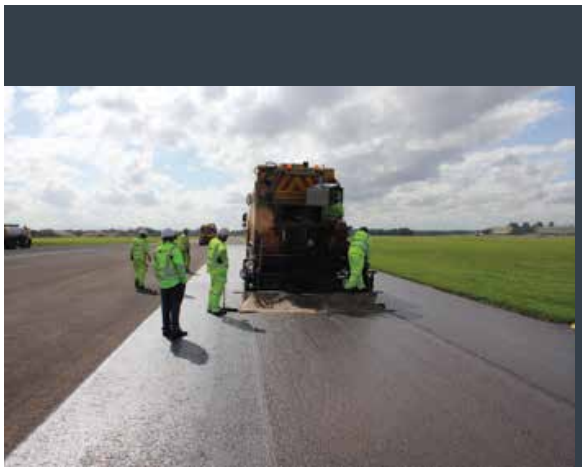
- Cost effective maintenance application to preserve existing pavements and extend service life
- No loss of curb reveal and no impact on existing drainage
- Provides a smoother, safer surface with excellent skid resistance
- Durable impervious surface
- Reduced traffic disruption
- Can be utilised to restore pavement profile and shape
- Zero waste – Lower carbon footprint

COLMAT FOR AIRFIELDS

"Colmat" is the product name of the Colas Solutions advanced Polymer Modified Microsurfacing systems. Microsurfacing is a generic term used for proprietary Slurry surfacing products. Colas worldwide are highly experienced in designing & applying various Colmat treatments to suit individual runways & taxiways. Colas UK technical have been instrumental in co-designing an approved specification for runways & taxiways in conjunction with the Defense Infrastructure Organization in the UK. Colas Solutions have now introduced this process, along with a wealth of experience into Australia, in order to provide environmentally friendly, less disruptive, competitive alternatives to conventional treatments.

COLMAT 5mm:

As a single coat application, this process is primarily used on Asphalt or Concrete pavements as a preventative measure to extend the lifespan of existing runways, taxiways or aprons, that have oxidized over time or are showing signs of deterioration despite maintaining a reasonable profile. This should be applied to ageing Asphalt or Concrete prior to any significant loss of existing coarse aggregate, in order to reduce the risk of F.O.D. The treatment can be effective in sealing fine embrittlement cracks that may be present. Although only a 5mm aggregate blend the finished texture depth will be around 1.5mm.



Application of 5mm Microsurfacing on existing Asphalt

Rapid application & minimum disruption

Colmat 5mm application is a swift process, with typical production levels of above 25,000m2 per shift & an initial curing period of around 30 minutes. All materials are batched through specialist computerized equipment to ensure quality, efficiency & consistency, which is backed up by Colas Solutions QA. The nominal thickness being around 5mm will seal in the existing surface, with normal life expectancy to be in excess of 5 years. The treatment can be re-applied when required, on the top of the existing Colmat.

COLMAT 7 or 10mm:

Colmat 7/10mm has been designed to treat Airfields & Taxiways with a greater level of deterioration or deformation. The design advised by experienced Colas Solutions surveyors would normally be a 2-coat application with a nominal 15m thickness. The 7 or 10mm base would be applied as a correction course to alleviate any wheel rutting or deformities. The wearing course can be applied after 24 hours & can be either the 5,7 or 10mm system. Curing time remains the same for each application of Colmat.

During application of Colmat 7mm

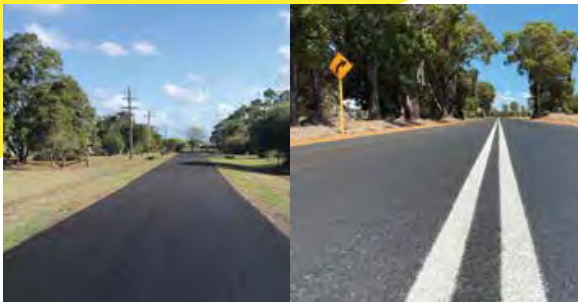
COLMAT FOR ROADS & FOOTPATHS

Colas worldwide has years of experience and expertise in repairing, protecting and extending the usable lifespan of infrastructure roads, footways and other surfaces. Colas Solutions Australia have recently invested in the latest technology, expertise, process & equipment to meet the needs of a rapidly growing market in Australia. This has cumulated into performing superbly on several major contracts across the country, including Main Roads, town streets, Cul-de-Sacs & runways.

When road surfaces develop ruts and deformations, have water problems and where skid resistance starts to fail, our affordable, innovative and unique specialist surface treatment "Colmat" will help maintain safety standards and extend the life of your road or footpath by up to 10 years.

Colmat innovative surface treatments are flexible and can be prepared to meet your individual site requirements. They are available in 5, 7 or 10mm aggregate gradings & can be used as a 5 or 7mm single coat application for lower traffic counts as a preventative solution to deterioration, or a regulatory / rut correction course can be applied prior to the Colmat wearing course for sites with a higher level of deterioration, correction requirements or heavy vehicle usage.

Before & after hand applied footway Microsurfacing



Colmat 7mm single application

Our range of Colmat Microsurfacing treatments offer several benefits:

- Seal & protect the existing surface
- Improve the rideability, profile & aesthetics
- Quick & easy to apply, minimum preparatory work required
- Cold applied, low carbon footprint, minimum waste materials, low cost
- Minimum traffic disruption
- Improved texture / skid resistance
- Can be batched & hand applied to footpaths
- Low traffic noise
- Rapid curing, open to traffic typically within 10 minutes
- All materials contained & batched in the specialist Machine on-site
- Minimal loose chippings, minimal aftercare

All our Colmat treatments are subject to our thorough Quality Assurance process & all Colmat treatments carry our standard 12 month maintenance warranty.

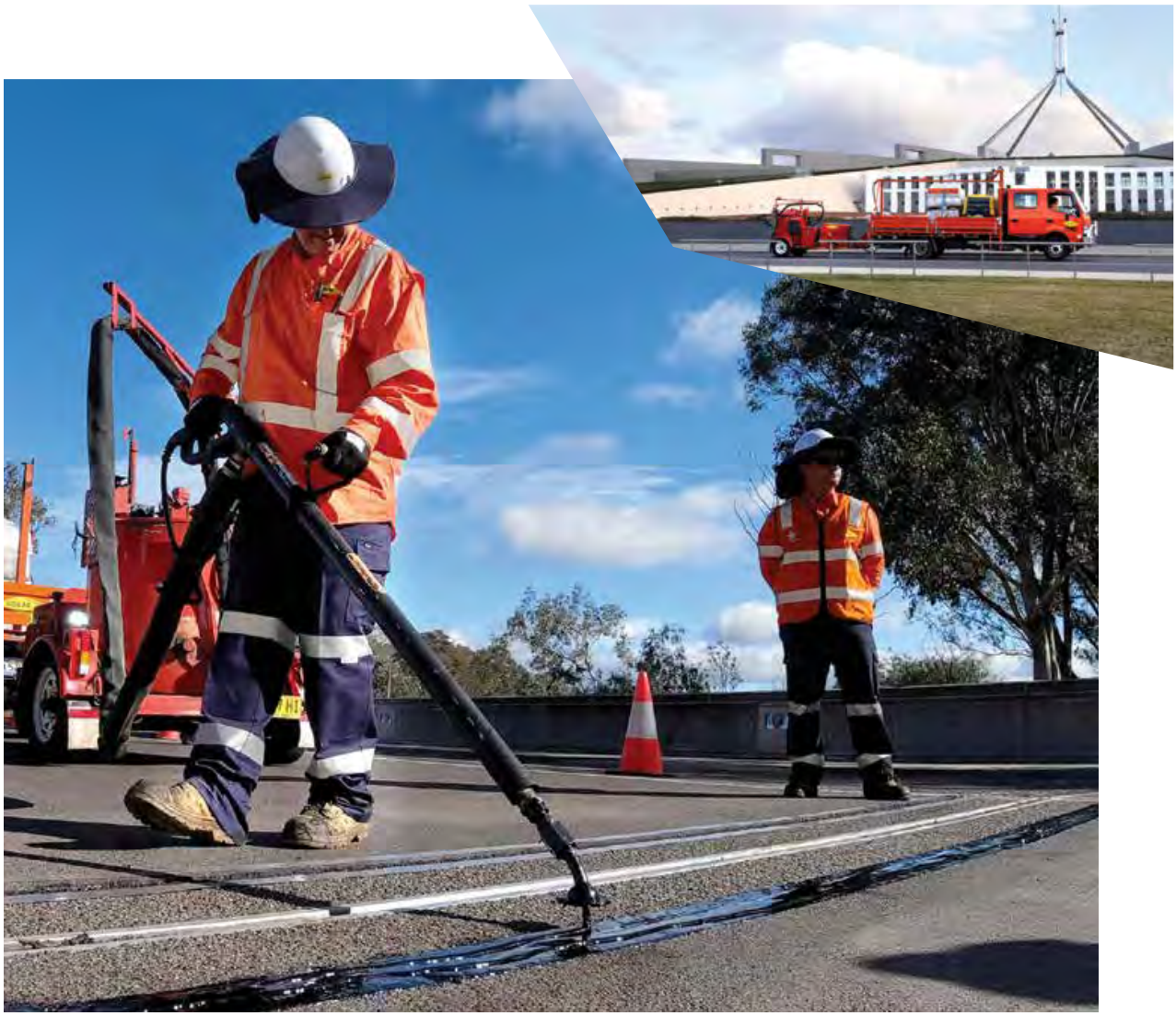
Our 2 coat 7mm process is typically a 15mm nominal thickness, which equates to around 24kg/pm2, although rutting can be filled up to 30mm in 1 pass with the same material. Variable application rates are always available to cover individual needs. Our experienced surveyors will design & recommend a Colmat process to suit.

Unique Specialist Computerized equipment

Item 8 / Attachment 3.

CRACKSEALING

Overband Crack Sealing is one of the most economical pavement maintenance tools for asphalt and concrete pavements.



SAMIfilla HM uses elastomeric polymers which produce a strong yet flexible seal that bonds well to the walls of the crack.

This process is the key to keeping water out of the pavement sub-base which in turn will help to extend the service life period of the pavement.

FEATURES

- Excellent ductility in cold temperatures
- Superior tensile strength supports heavy traffic loading
- Applied under pressure to fill and seal cracks
- Excellent seal integrity yielding longer service life

BENEFITS

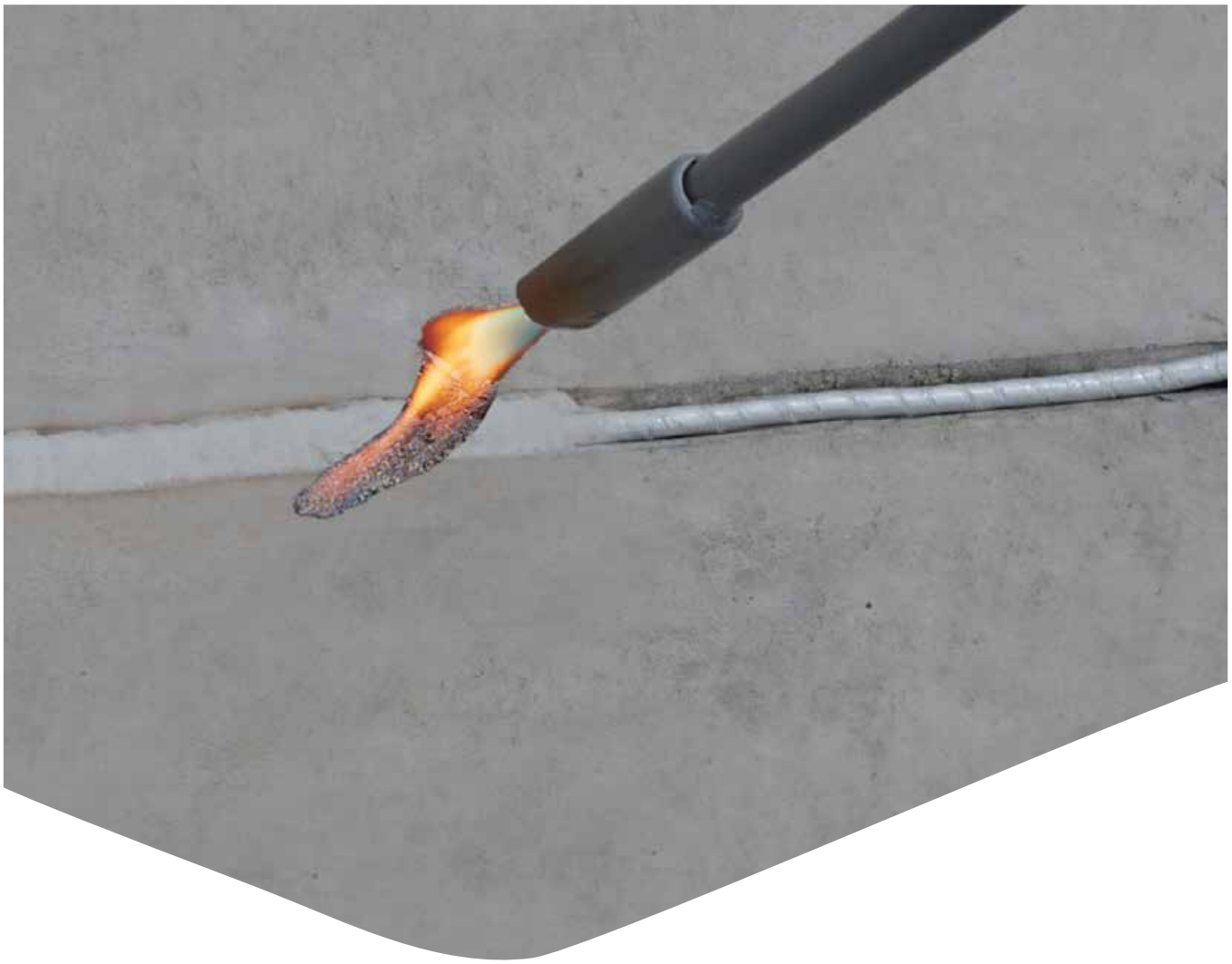
- Delays and minimizes reflective cracking
- Low stiffness, highly elastic and good memory
- Extends overall pavement service life
- One of the most economical pavement repair process
- Consistent quality application with high production

APPLICATIONS

- Highways
- Streets and Roadways
- Race Tracks
- Airport Runways and Taxiways
- Car Parks
- Asphalt and Concrete Pavements

COMMON USES

- Random cracking
- Transverse cracking
- Longitudinal cracking
- Reflective cracking
- Concrete construction joints



CRACK STIX

DIRECT HEAT "RUBBERISED" CRACK & JOINT SEALANT

Elastomeric compound.
Polymer modified.
100% water tight seal.
Traffic ready in 20 minutes.
Multi-use for asphalt and concrete.

TECHNOLOGY BREAKTHROUGH

Now for the first time, Industry professionals can get contractor type results in 3 easy steps using 3 tools. **CRACKSTIX** are available in two standard sizes, small 6mm and medium 12mm. They are User Friendly & Ready-To-Use: no mixing, nothing to add, just uncoil, cut to length, pack and heat.

CRACKSTIX are flexible & can be stretched & shaped to custom fit the repair. The rubberized compound melts/liquefies instantly & cures quickly. The self levelling sealant goes inside the crack.. not over the crack.. less waste, no tracking or unsightly residue. The multi-use formula can be used on asphalt & concrete pavements and is available in black and grey.

WHY HOT, DIRECT HEAT PROCESS?

In the past, most contractors have had no choice but to use cold pour or caulking type fillers. Cold applied products fill from the bottom up and do not permanently bond/seal to the crack sidewalls.

CRACKSTIX form a permanent bond to the sidewalls of the crack or joint and provides a (liquid rubber) 100% water tight seal. This seal will remain flexible & intact through the winter and summer expansion/contraction cycles.

3 EASY STEPS ...

CLEAN IT… Take a screwdriver & scratch out all debris from inside the crack, then take a whisk broom & sweep it clean. Crack must be dry.

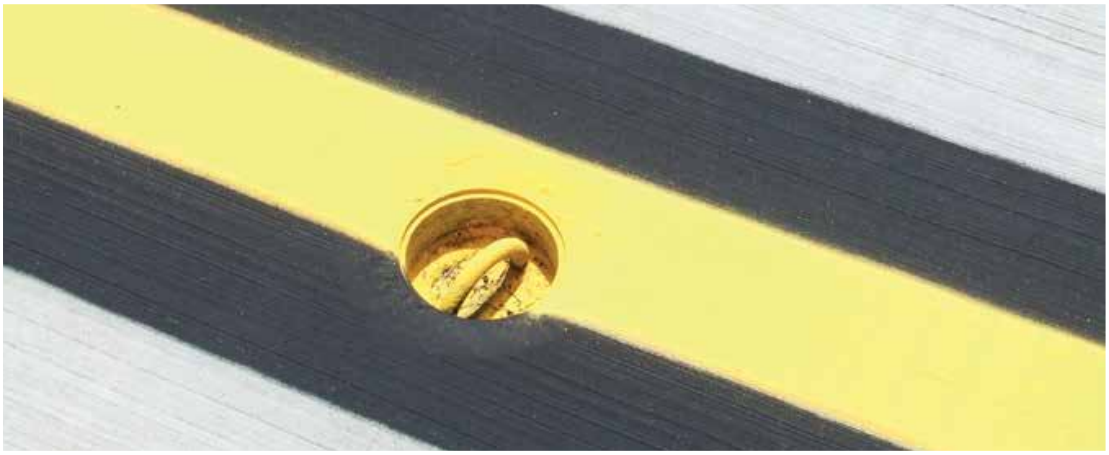
PACK IT… uncoil & cut the appropriate size & shape/pack in to crack with fingertip pressure. Using the screwdriver, press the stix into crack approximately 1.5mm to 3mm below actual pavement surface level. To achieve a neat overall appearance, do not overfill crack.
The material seals In It… Not On It.

MELT IT… take propane torch and light it. Adjust bright blue part of flame to 300mm long. Holding the flame 25mm – 40mm from stix, move the flame from side to side in a slow & even motion, heating no more than 300mm at a time (melt stick until liquid).

Item 8 / Attachment 3.

LINE MARKING

Providing guidance and information to drivers and pedestrians.



WATERBORNE PAINT

Colas specialises in the application of waterborne paint on all surfaces from asphalt and concrete on roads to airport runways.

THERMOPLASTIC

Thermoplastic is used in high wear and high traffic areas including stop lines, barrier lines, arrows, crossings and text. These can all be applied in pre-formed thermoplastic, hand screeded or via specialist equipment.

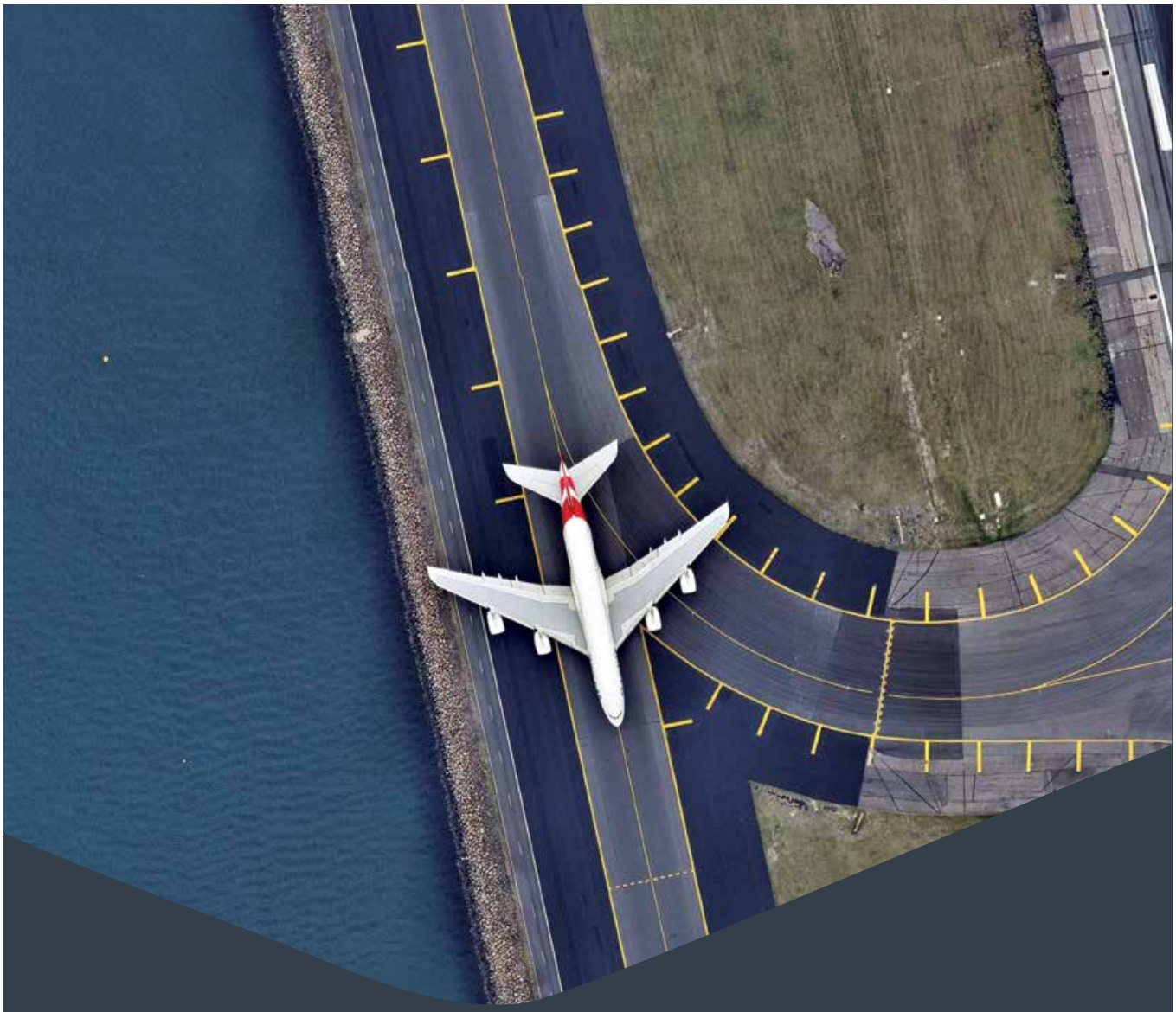
COLOURED SURFACING

Available in a wide range of colours, both paint and cold applied plastics can be used for delineation of bus, bicycle and pedestrian areas. The addition of fine aggregate can provide added skid resistance.

APPLICATIONS

- Airports
- Intersections
- Car Parks
- Temporary Construction Zones
- Warehouses

Item 8 / Attachment 3.



Downer
Relationships creating success

Product Sheet

Microsurfacing

Microsurfacing is a hard wearing, cost effective cold mix process that provides a quick set to allow traffic services to be restored, depending on weather conditions, in 15 to 45 minutes. It is ideal for restoring road profile, improving roughness, rut filling, filling surface voids and increasing skid resistance. An application of microsurfacing to older pavements stops ravelling and loss of matrix and it is an effective pavement maintenance application.

Microsurfacing is bituminous based and incorporates a polymer modified binder to improve performance characteristics including flexibility and residual softening temperature of binder.

The two generally accepted nominal sizes used for slurry mixtures are 5mm and 7mm.

5mm is the most widely used nominal size used for low to moderate traffic volume sites. 5mm is used to seal, correct surface ravelling and existing binder oxidation, restore profile, prevent loss of matrix and improve skid resistance.

7mm size aggregate is used to correct major rutting, and correct pavement profile. Applications for heavy traffic and to improve skid resistance providing surface texture greater than 1.0mm.

Process

Material is applied in a thin layer by a continuous load paver. The paver measures and proportions quantities of aggregate, bitumen emulsion, water and additives. Sufficient raw materials are carried on-board the paver to enable it to operate as a stand-alone unit for small jobs. For long road treatments requiring a join free surface, the continuous load paver is resupplied 'on the move' by custom designed feeder trucks. These restock the raw materials to the paver from strategically placed stockpiles along the road while the paver is still moving. This ensures a smooth and continuous surface which is important for pavement maintenance, lifespan and road safety.
Microsurfacing can be applied as thin as 10mm which does not alter drainage or interfere with fixed level features such as kerbs or inspection opening covers. Various spreader box designs are used to control the shape and thickness of the surfacing up to 4 metres wide. Narrower widths, especially where rut filling is required, are accommodated by speciality spreader boxes.

Microsurfacing applications include:

Urban Streets

- As a thin restorative surface course on urban roads there is no loss of curb reveal and does not alter drainage.

Rut Filling

Rut filling is critical to improve safety and the specially designed boxes deliver larger aggregate to the bottom of the rut to give maximum stability to the wheel path. Fine aggregate are moved to the edges to provide a flush finish. Specially designed rut filling mixes, used in conjunction with a purpose built rut box, can effectively fill ruts in most pavements. Microsurfacing is capable of filling wheel rut in excess of 50mm deep when the pavement has stabilised and is not subject to plastic deformation.

Shape Correction

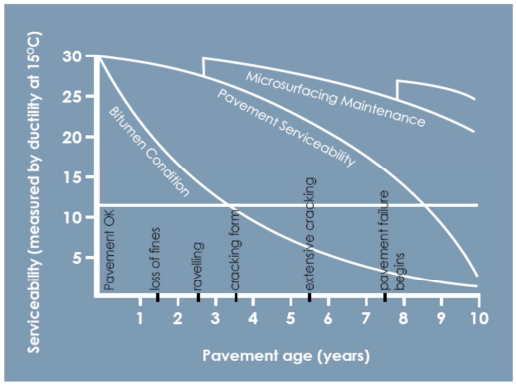
- Restores pavement profile at minimal cost, improves surface drainage.
- Provides a thin surface correction, can reduce roughness counts by up to 50 per cent in one layer of 15mm average thickness depending on roughness type.
- Can be applied in multiple layers for deep correction work.
- Suitable for heavy-traffic roadways or roads that need to be quickly reopened.
- Microsurfacing increases skid resistance, colour contrast, surface restoration and pavement service life.

Rural Airfields

- On airfields, dense graded material produces a skid resistant surface without loose stone that can damage aircraft engines.
- The product can be applied to sections of roads or runways to eliminate hydroplaning problems by restoring the proper surface profile.

Benefits

Modern continuous load pavers can lay up to 300 cubic metres or about six lane kilometres per a day without long traffic delays.
Quick traffic properties allow the product to be applied in a broad range of temperatures and weather conditions, effectively lengthening the paving season.
Applied at ambient temperature it has low energy requirements.
Life expectancy exceeding seven years
High resistance to deformation and rutting.



Cost Effective Pavement Insurance

- A planned programme of microsurfacing protects pavements and saves more than 50 per cent of the life cycle costs compared with a thin hot mix overlay.
- Microsurfacing protects the pavement from water ingress and oxidation thereby contributing to the long term integrity of the pavement.
- Microsurfacing provides a superior finish to alternative spray seal methods, with road users benefiting from smoother and safer conditions, and lower noise for nearby residents.

After specific rut correction, a full width application of surfacing can be applied to provide a uniform wearing course.

Downer
Relationships creating success

Reconophalt™

The first choice to sustainably pave Australia

Downer's Reconophalt™ is Australia's first asphalt product containing high-recycled content derived from true waste streams that would otherwise be bound for landfill.

Materials that make up our Reconophalt™ mixes include:

- Soft and scrunchable plastic bags and packaging
- Waste glass destined for landfill or indefinite stockpiling
- Waste toner from used printer cartridges
- Reclaimed asphalt pavement (RAP) from end-of-life roads
- Crumb rubber from end-of-life tyres
- Coarse aggregate and sands from street sweepings.

Materials are sourced through Downer's exclusive partnerships with Close the Loop, Repurpose It, Downer's own detritus re-purposing facilities, and other suppliers of recycled resources.

Downer is able to vary the mix constituents and proportions of Reconophalt™ to suit our individual customers and their local road surfacing needs. For example, Reconophalt™ 436 uses four recycled ingredients at 36% by weight, while Reconophalt™ 886 includes eight recycled materials making up 86% by weight.

A one-kilometre, two-lane road paved with Reconophalt™ 436 will divert from landfill:

- **101 thousand glass bottle equivalents**
- **597 thousand plastic bag equivalents**
- **17.4 thousand printer cartridges**
- **202 tonnes recycled asphalt pavement**

Creating a saving of:

- **8.08 tonnes carbon dioxide equivalent**
- **equivalent to 3 cars off the road for one year**

downergroup.com

Downer
Relationships creating success

Reconophalt™

The first choice to sustainably pave Australia

Downer's Reconophalt™ is suitable for any application where standard C170/C320 binder is specified, for underlying base layers, and non-modified wearing course asphalt.

Pavement construction using Reconophalt™ is as per traditional methodologies, using standard paving equipment, with **no increased environmental risk** compared to traditional asphalt.

Reconophalt™ mixes comply with AS2150 and standard state road authority specifications, while providing a marked increase in fatigue resistance for longer pavement life and superior resistance to deformation.

Did you know?

300,000 tonnes
of Reconophalt™ has paved roads across Australia since May 2018

Increased asset life
can be achieved, with performance better than straight-binder asphalt derivatives

Reconophalt™ is **perpetually recyclable**

The superior performance of Reconophalt™ is suitable for reduced pavement thickness **reducing cost**

Reconophalt™ Environmental Product Declaration

Downer's world-first Environmental Product Declaration (EPD) for sustainable asphalt, developed in accordance with ISO 14025 and EN 15804, is available for download at:

https://epd-australasia.com/epd/reconophalt/

downergroup.com

Product Sheet

Downer
Relationships creating success

Surface Preservation and Rejuvenation Treatments for Local Roads

Overview

Local roads account for a significant proportion of Councils' sealed road networks. The major cause of pavement distress on local roads is predominantly environmental resulting from binder oxidation.

With the growth of residential subdivisions over the last thirty years councils are now realising the full financial impact of the ongoing maintenance of their ageing local road network as a result of binder oxidation.

If left untreated binder oxidation will lead to surface defects, premature pavement failure and a reduced service life which is costly to repair and inconvenient to the local community.

The effect of oxidation on asphalt surfaces is generally evident after eight to ten years when the surface starts to lose its fine sand matrix.

After ten to 15 years, environmental cracking is generally visible and the surface texture has ravelled; exposing the larger aggregate which in time will pluck from the surface resulting in potholing and pavement failure.

On spray sealed surfaces, the first signs of aggregate loss is an indication that binder oxidation is prevalent which if not treated, could lead to extensive stripping.

Following treatment the appearance of the local roads are visually appealing, over time traffic will tend to wear the treatment off the exposed aggregate; however the long term benefit of the treatments around the aggregate continues to seal and protect the binder.

Before and After PreserveX ™ Treatment

Product Options

Since 2001 Downer has treated in excess of 13 million square metres of local roads and airfield pavements with its pavement preservation treatments. Downer offers the following surface treatment options depending on the age and condition of the bituminous surface:

- **RejuvineX ™ Rejuvenator**
- **PreserveX ™ Preservation Treatment**

Difference in the condition of the asphalt surface of local roads in Wallsend, Newcastle Council. Left photo: Claymore Close – surfaced in 1992 with Rejuvenation applied. Right photo: adjoining road Boambee Close – surfaced in 1995 and no treatments to date.

Product Sheet

Downer
Relationships creating success

Benefits of Pavement Preservation and Rejuvenation Treatments

The application of cost effective surface preservation and rejuvenation treatments on pavements in conjunction with crack sealing, will assist in protecting and preserving the bituminous surface. This will increase the life of a pavement and reduce maintenance costs over its serviceable life.

The benefits to councils of incorporating Pavement Preservation treatments in the long-term management of their local roads and shared paths include:

- The ability to extend surface life from 25 years to over 40 years, an increase of over 30 per cent before pavement requires resurfacing
- The ability to cost effectively increase the total area of pavements treated annually within budget allocation
- The ability to substantially minimise maintenance costs over the life of the pavement
- Suitable for Asphalt, Microsurfacing and Spray Sealed surfaces
- Minimal disruption to residents with no loose aggregate
- Rapid application and drying time with visible results
- Will mask unsightly cracksealing treatments
- The ability to create an even and uniform textured surface with no loose stones
- Seals and protects the surface, reducing water penetration
- Fills fine cracks, fissures and minor surface imperfections
- The ability to be reapplied to prolong the life of local roads.

When to apply Pavement Preservation Surface Treatments

Following consultation with our customers the table below has been developed to assist road asset managers in determining suitable treatment sites and most appropriate treatment option on local roads (traffic counts < 1000 AADT).

The condition triggers can also be easily implemented in most pavement management systems to assist in developing annual programmes.

To maintain the ongoing benefits and to maximise the life of the surfacing we recommend that the treatments are reapplied regularly. By tracking and maximising the actual performance across different geographic regions in Australia the frequency for reapplication varies from four to eight years.

Please also refer to Project Sheet on the long term performance of local roads treated with RejuvineX™.

Process

To assist in determining the optimum application rate for PreserveX™ and RejuvineX™, a correlation based on surface texture has been developed.

The treatments are applied during the drier warmer months with specialised spraying equipment. Following treatment, the local roads are ready to traffic usually from 30 minutes to one hour depending on the prevailing weather conditions.

Condition trigger	RejuvineX™	PreserveX™
Surface age	8-10 years	10-15+ years
Pavement condition	Good, no surface defects	Fair to good, defects account for < 2% of area
Surface texture – ravelling	Very minor loss of surface fines	Moderate to severe loss of fines
Cracking	No cracking	Minor transverse or longitudinal

OUR PURPOSE, PROMISE AND PILLARS

Downer
Relationships creating success

OUR PURPOSE

We exist to create and sustain the modern environment by building trusted relationships with our public and private sector customers.

OUR PROMISE

To work closely with our customers to help them succeed, using world leading insights and solutions.

Our business is founded on four pillars which support our Promise and our Purpose.

OUR PILLARS

Safety

Zero Harm is embedded in Downer's culture and is fundamental to the company's future success

ZERO HARM

Delivery

We build trust by delivering on our promises with **excellence** while focusing on safety, value for money and efficiency

Relationships

We **collaborate** to build and sustain enduring relationships based on trust and **integrity**

Thought leadership

We remain at the forefront of our industry by employing the best people and having the **courage** to challenge the status quo

Downer

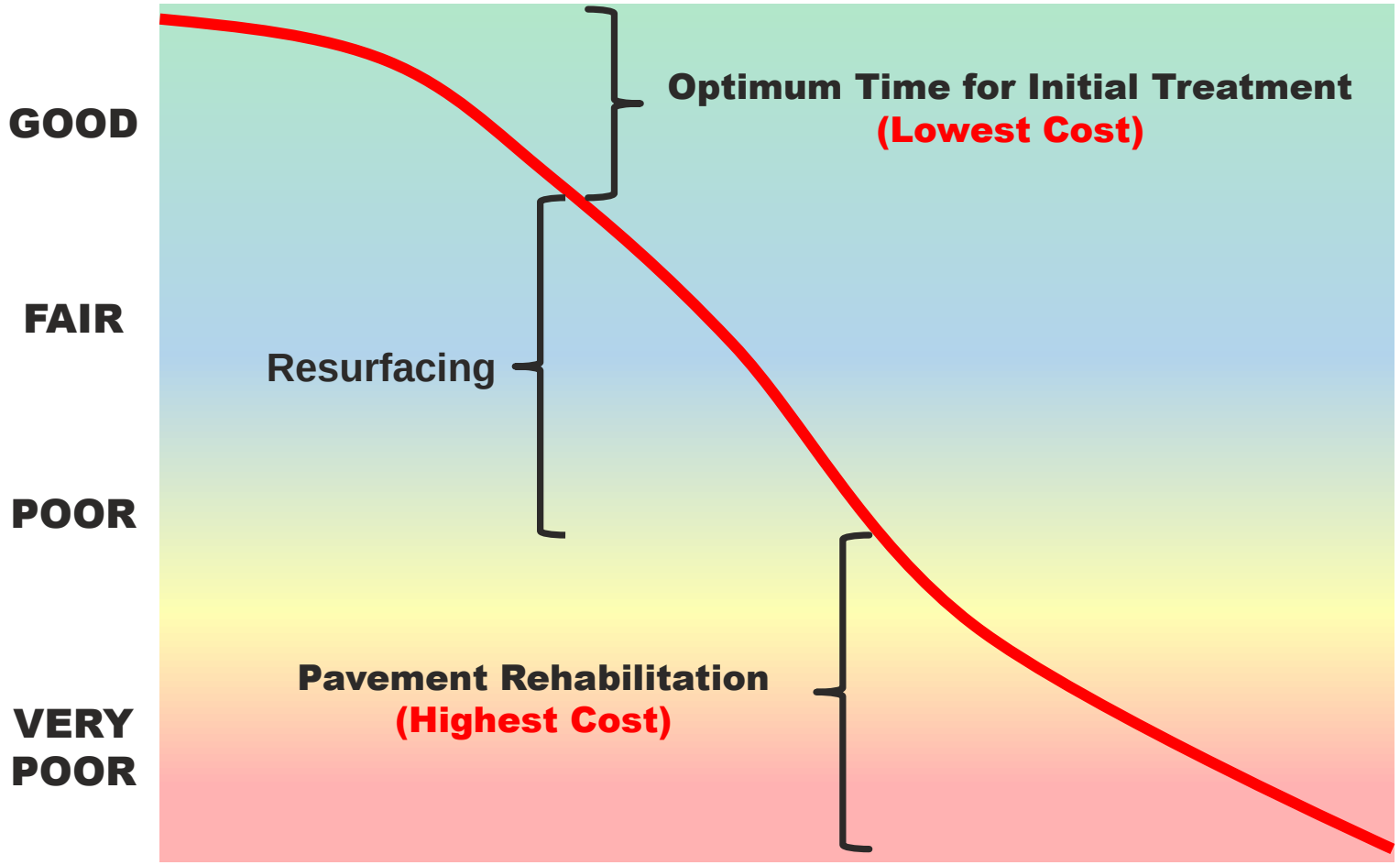

Pavement Preservation
Strategies to extend the life of pavements
without extending your budget
Downer
Relationships creating success

What is Pavement Preservation?

- A planned approach to treating existing pavements assets aimed at extending life and preserving integrity.
- All Bituminous pavements require maintenance due to traffic and environmental factors.
- Applying a surface treatment to a pavement with light to moderate distress will greatly increase the life of the pavement.
- Pavement Preservation is a maintenance/resurfacing process to assist with treatment selection and timing to provide a cost effective solution to extend pavement life.

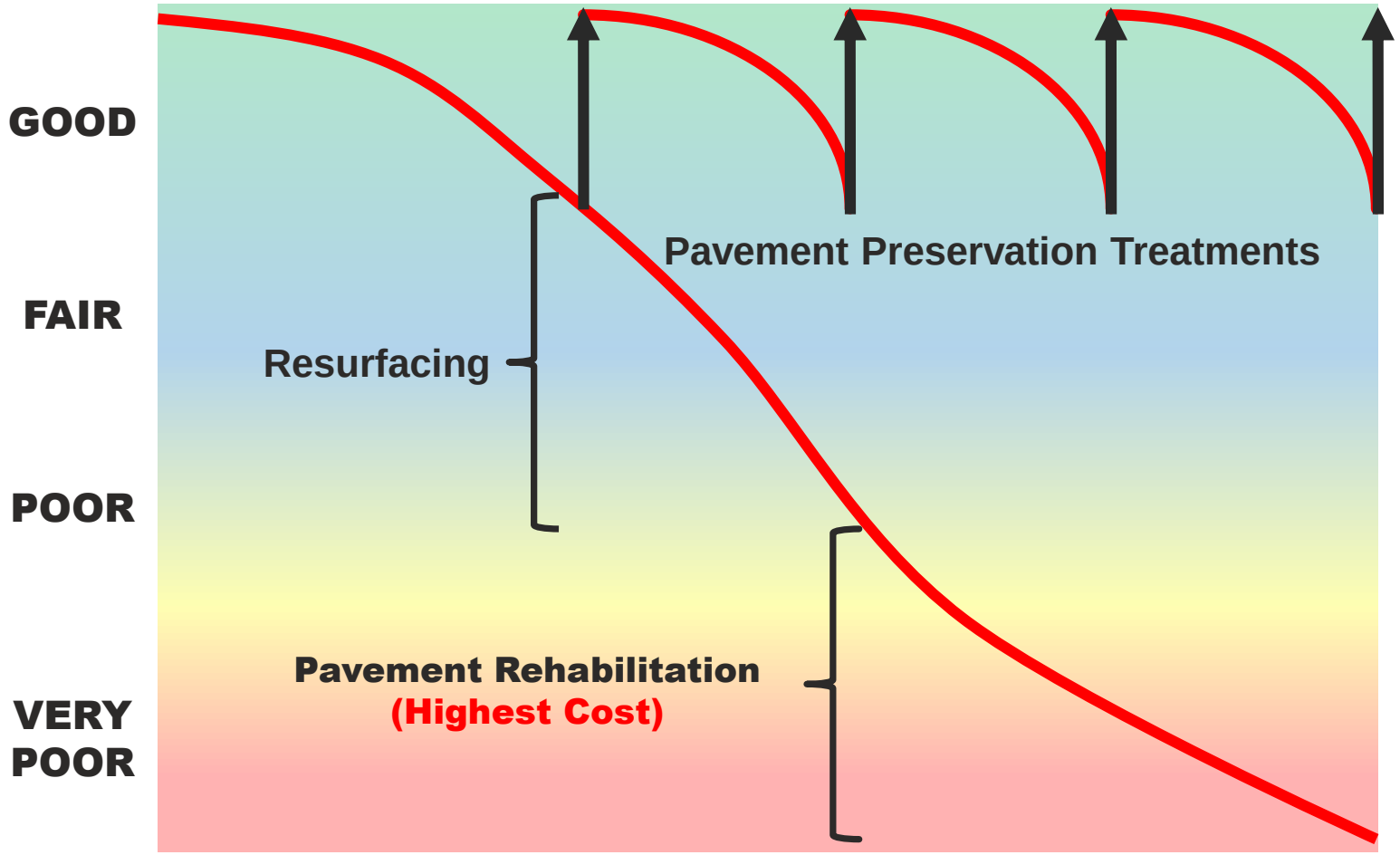
Downer

Pavement Condition Life Cycle Curve



Downer

Pavement Condition Life Cycle Curve



Downer

Local Road Pavements

Ageing local road networks are placing an ongoing strain on Councils budgets and a sustainable Road Asset Management strategy is required to maximize pavement life on constrained budgets

Local and low volume roads account for approximately 80% of the total length of sealed roads in Australia.

Local communities in metropolitan and regional centre's have come to expect smoother roads following the continued growth of new subdivisions surfaced with asphalt since the late 1970’s

Downer

Benefits of Pavement Preservation

- Lower cost over time – every additional dollar spent on preservation saves significant costs in future rehabilitation
- More predictable costs – maintained pavements provide less reactive costs and more predictable scheduled expenditure
- Fewer premature pavement failures and longer life
- Improved pavement condition across a network – scheduled monitoring and treatment provides improved overall condition of pavements
- Reduced user delay and costs – the more extensive damage a pavement has the longer the pavement repair work will take.
- Resource utilization – Scheduled maintenance allows for better use and planning of resources, saving costs.

Downer

Pavement Modelling & Program Development

Pavement Asset Management and PMS are important tools for the effective long term management of road networks and aid in implementing pavement preservation strategies.

Inputs

- Spatial asset & current condition data
- Maintenance activity and treatment history
- Intervention triggers and treatment options

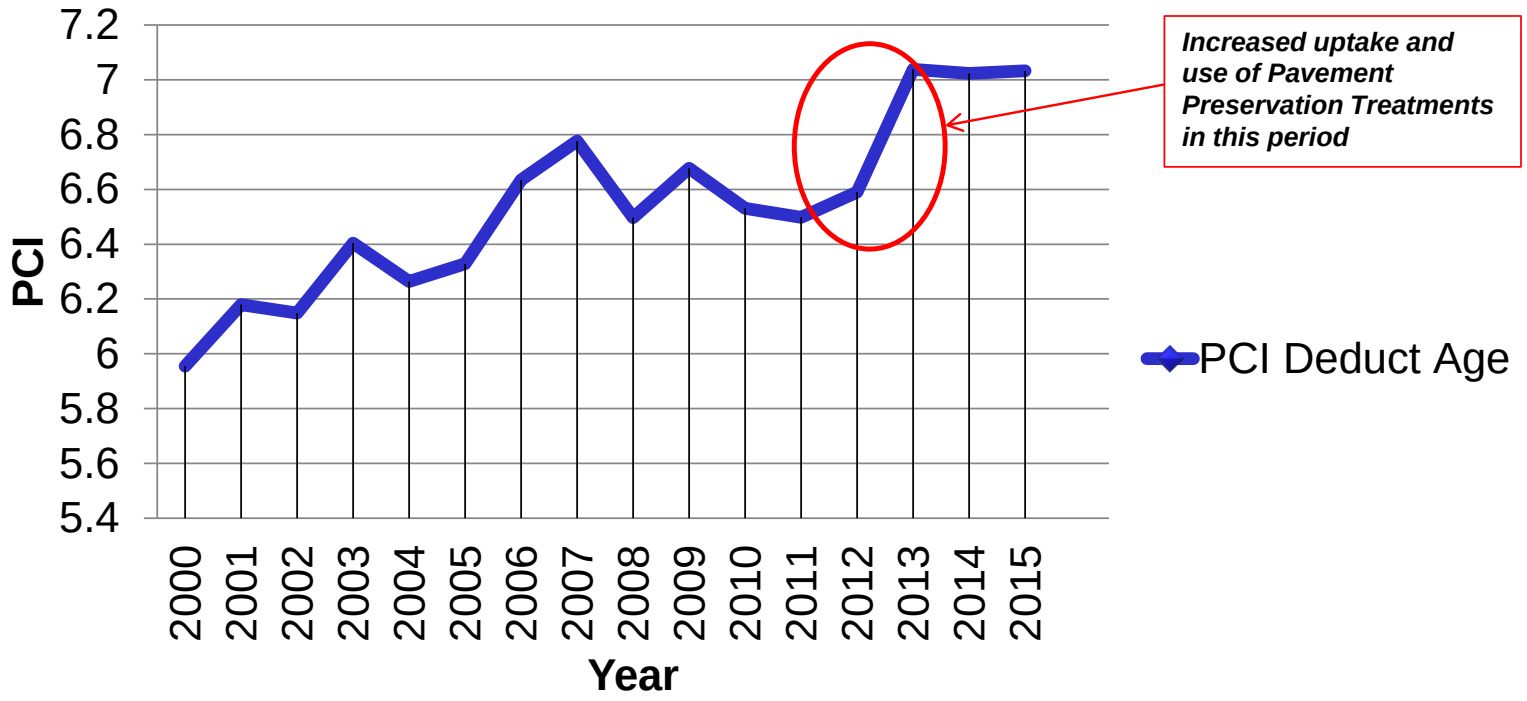
Outputs

- Trend and performance monitoring
- Program development – Short & Long Term
- Inputs for long-term Strategic Asset Management Plans

Downer

Network PCI Improvement (last 15 years)

Results below graph the overall network PCI ands the influence increased use of Pavement Preservation strategies have provided over the last decade



Downer

Intervention Triggers – Local Roads

On low volume roads triggers will be related to binder oxidization and will exhibit as;

- Surface raveling, loss of pavement matrix and fines.
- Surface cracking without loss of shape is another indicator of bitumen oxidation.
- Crocodile cracking is also a good indicator of impending pavement failure exposing sub pavement to moisture ingress and damage.

Downer

Surface Treatment Options – Local Roads

Treatment Option	Price Range (per m^2)	Expected Surface Life (years)
Asphalt	$15 – 20	12 – 18
Microsurfacing	$7 – 10	8 – 12
Hot Bitumen Spray Seal	$4 – 7	8 – 10
Surface Preservation	$3 – 4	5 – 7
Rejuvenation	< $2	4 – 6

- Designed to preserve and protect surfacing and prolong a sound pavement life.
- Do not address defects resulting from structurally deficient pavements.
- Projected life does not include further maintenance / preservation treatments.

Downer

Downer
Relationships creating success

Rejuvenation Treatments

RejuvineX™

Treatment Options – RejuvineX™

- Spray applied treatment aimed to enrich and rejuvenate bitumen binder.
- Inhibits surface reveling and oxidisation of binder.
- Acts to rehabilitate existing surface weatherproof / waterproofing
- Early life cycle intervention treatment – indicative pavement life of 6 – 8 years of age.
- Can be reapplied multiple times over life cycle

Using a wooden deck as an example, rejuvenation is a similar process to oiling the deck.

The specialty rejuvenation material should penetrate the pavement surface and rehabilitate the bitumen flexibility and elasticity, acting to prevent and delay further environmental damage.

Notably this treatment will not add any strength characteristics, merely acts to maintain the existing pavement.

Downer

Downer
Relationships creating success

Preservation Treatments

PreserveX™

Treatment Options – PreserveX™

- Spray applied treatment aimed to reseal and protect the existing bitumen surfacing.
- Inhibits surface ravelling and oxidisation of binder and acts to prevent further surface matrix loss, filling any voids.
- Provides a weatherproof and waterproofing membrane.
- Early - Mid life cycle intervention treatment – indicative pavement life of 8 – 12+ years of age.
- Can be reapplied multiple times over life cycle

Using a wooden deck as an example, preservation is a similar process to painting the deck.

The specialty preservative material should overlay the existing surface, acting to fill surface voids and lock in surface matrix applying a new final surface.

Notably this treatment will not add any strength characteristics, merely acts to maintain & extend the life of the existing pavement.

Downer

Downer
Relationships creating success

Preservation Treatments

Microsurfacing SFT

What is Microsurfacing?

Bituminous surfacing application that is manufactured onsite at the point of application comprising

- dense graded aggregates
- polymer modified bitumen emulsion

Cost effective treatment to correct defects and extend and maintain existing pavement life

Globally used extensively for

- Highways
- Residential streets
- Airports

Microsurfacing is a maintenance application of existing sound pavements, not a construction layer.

Downer

Raw Materials / Composition

RAW MATERIALS

Material components are proportioned in calibrated ratios in a similar manner to Hot Mix Asphalt designs

Two essential components are

- Crusher Sand/Aggregate

Blend mixed to gradation targets

- Polymer Modified Bitumen Emulsion

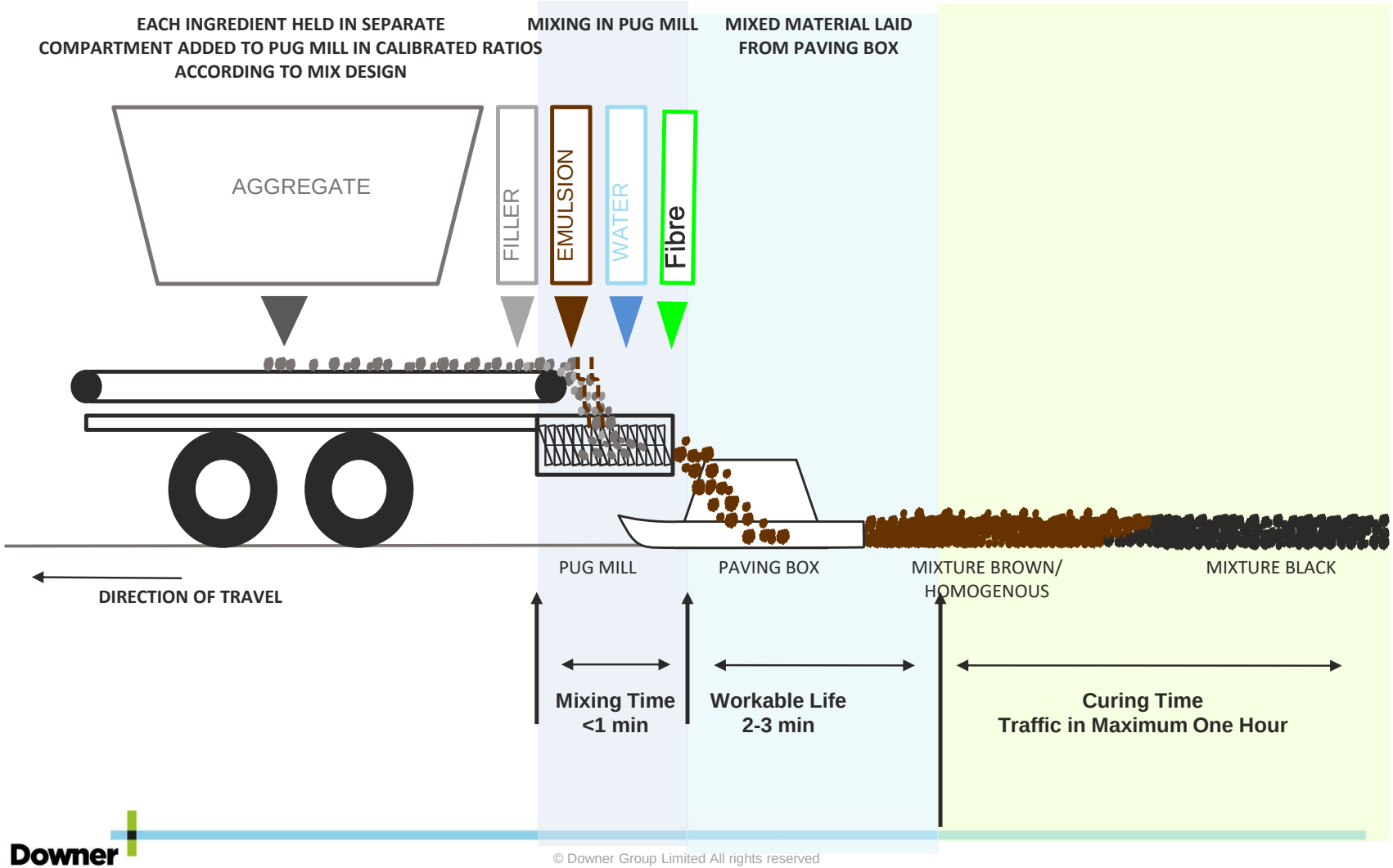
Min 62% residual binder

Additional materials may be added to the mix for workability as required

- Water
- Filler
- Set Retarding Agents
- Accelerator Setting Agents

Downer

Microsurfacing Paving Process



Downer

Microsurfacing SFT – Where it fits in

Microsurfacing for shape & ride correction

Microsurfacing is utilised extensively by State Road Authorities throughout Australia to correct pavement shape and cross fall

Downer

Applications – Residential Resurfacing

BENEFITS

Cost effective maintenance application for existing pavements

A thin restorative surface course on urban roads
- no loss of curb reveal
- no impact on existing drainage
- smooth safer surface

Durable impervious surface
- excellent skid resistance

Shape correction

Aesthetically similar to Asphalt
- lower cost based on application rate

Downer

Microsurfacing Applications – LGA - Residential resurfacing

Downer

Airfield resurfacing

BENEFITS

Smooth safer surface

Shape correction

Aesthetically similar to Asphalt
- lower cost

Durable impervious surface
- excellent skid resistance to shearing forces

Eliminates loose aggregate
- initial application and over time

Low maintenance
- no regular rolling required

Downer

Treatment Options - Microsurfacing

- Paver applied at ambient temp, dense graded bituminous mix, thin (10 -15mm) that can provide shape correction.
- Aesthetically similar to asphalt, quiet and smooth driving surface.
- Rehabilitates surface drainage and pavement shape.
- Early - Medium life cycle intervention treatment – indicative pavement life of 10 – 20 years of age.
- Can be reapplied multiple times over life cycle

An ambient temp paver applied, thin (8 – 15mm) bituminous surfacing that is manufactured onsite at the point of application comprising of;

- *dense graded aggregate blends, max size either 5mm or 7mm*
- *polymer modified bitumen emulsion*

Microsurfacing is designed as a maintenance application and will not treat pre existing pavement defects but can rehabilitate pavement shape and drainage

Downer

Life Cycle Economics - Microsurfacing

- No loss of curb reveal or impact on existing drainage
- Provides a smooth safer surface
- Durable impervious surface
- Excellent skid resistance
- Restores pavement profile and shape
- Aesthetically similar to an asphalt finish

Downer

Downer
Relationships creating success

Additional Benefits

Health, Safety, Environmental and Community Benefits

RejuvineX™, PreserveX™ and Microsurfacing are engineered treatments utilising emulsion technologies. For you this means;

- Cold / ambient temperature application
- No hazardous fumes
- Minimal odour during and after placement processes
- No VOC's or harmful chemical release to the atmosphere
- Reduced Carbon footprint
- A much safer working environment
- Fast curing and a quick return to normal use.

Downer

Strategies to treat more roads and extend pavement life

- Configure PMS to include pavement preservation treatments based on relevant condition triggers, include earlier intervention in treatments selection.

- Apply Rejuvenation treatments before surface age = 8 years and reapply at regular intervals

- Apply timely Pavement Preservation treatments to maintain surfacing in good condition and extend asset life > 35 years

- Undertake proactive routine maintenance practices

Downer

Downer
Relationships creating success

Questions


IPWEA
INSTITUTE OF PUBLIC WORKS ENGINEERING AUSTRALASIA
ipwea.org

Campbelltown City Council's (NSW) Sustainable Pavement Management Strategy

SUSTAINABILITY DIRECTOR'S CHOICE PAPER

Mahbub Hossain
–
Coordinator, Assets Services
Campbelltown City Council

INTRODUCTION

Campbelltown City Council has 718km of road infrastructure assets with a replacement cost of approximately $400 million. The rapid growth of Campbelltown City Council from 25,000 residents in 1966 to more than 150,000 today has required a significant investment in infrastructure including the road network to service the ever growing residential, commercial and industrial estates.

Due to increased financial pressure to maintain the 'smooth surface' of their urban local roads expected by their local communities, Campbelltown City Council has developed and adopted a sustainable pavement management strategy that optimizes the budget's capacity and also meets the local community's expectations for smooth and safe roads. The net benefit of the strategy is that it has resulted in an increase in the quantum of roads treated annually within existing financial constraints, whilst improving the overall condition of the road network and satisfying the community's high expectations.

Campbelltown City Council has

718km

of road infrastructure

Campbelltown City Council has seen a

500%

growth from 1966

LEVELS OF SERVICES

In council's Road Asset Management Plan, the levels of Service were developed for all classes of roads to provide the basis for the life cycle management strategies and works programs. The levels of service supported the Council's strategic goals and were based on customer expectations and statutory requirements.

The levels of services were also based on:

- Community Research and Expectations
- Information gathered from customers on expected quality and cost of services
- Strategic and Corporate Goals
- Legislative Requirements
- Environmental Standards that impact on the way assets are managed.

The council endorsed levels of services provide guidance for the scope of current and future services offered.

In determining the levels of services for road assets, the council implemented the fundamentals to the Pavement management system (PMS). In PMS, road condition is measured by Pavement Condition Index-PCI which is a range of 0 to 10. The overall condition in terms of PCI is defined as below:

- 0 to 2.5: Very Poor Condition
- 2.5 to 4: Poor Condition
- 4.0 to 5.5: Average Condition
- 5.5 to 8: Good Condition
- 8 to 10: Excellent Condition

In 2002-2003, the council decided to upgrade and maintain its whole road network at an average network PCI level of 6.75. In addition to this, the council also decided to maintain its road network on different PCI levels based on road hierarchies and urban classes as in Table 1 below.

TABLE 1: PCI LEVELS BASED ON ROAD HIERARCHIES AND URBAN CLASSES

Road class	Hierarchy	Urban class	Acceptable PCI
Road class	Hierarchy	Urban class	Acceptable PCI
Class 6	Regional road	Urban	7
Class 6	Regional road	Rural	6.5
Class 7	Collector road	Urban	6.75
Class 7	Collector road	Rural	6.5
Class 8	Residential street	Urban	6.5
Class 8	Residential street	Rural	6
Class 9	Cul de sac	Urban	6.5
Class 9	Cul de sac	Rural	6
Average for whole network	6.75		

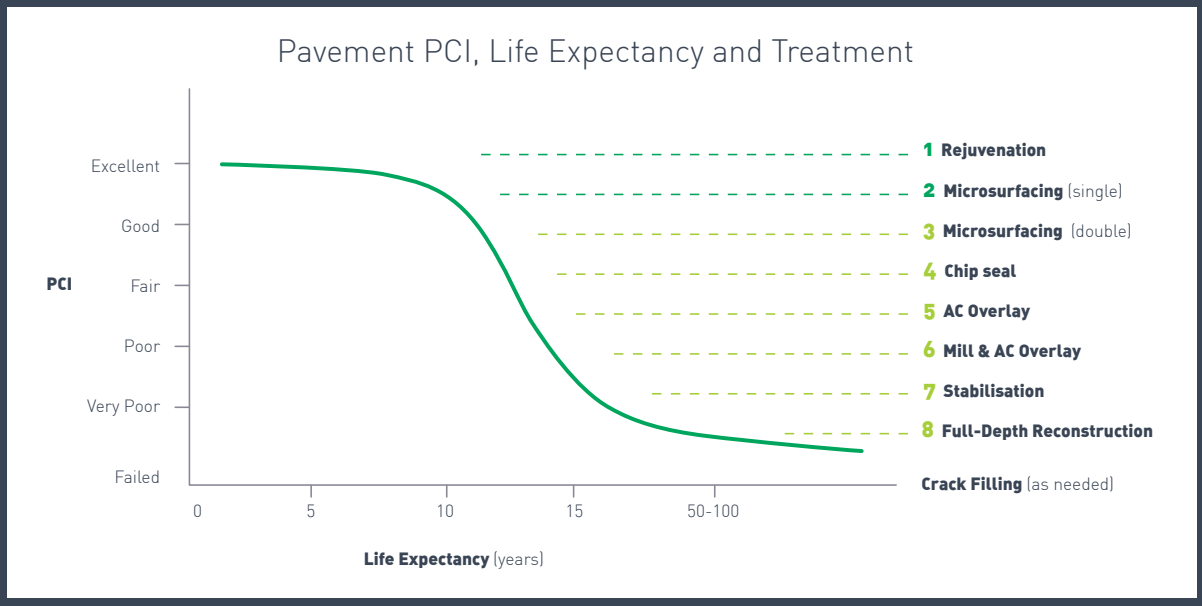
PAVEMENT MANAGEMENT STRATEGY

To achieve the above target levels of PCI, a comprehensive pavement management strategy was developed by the council.

The objective of the strategy was to maintain and improve its pavement infrastructure assets for the long term. The strategy flows through the council's Pavement Management System (PMS) and considers budget constraints, condition assessments of the network, treatment selections and suitability.

The flowchart below shows that how the PMS draws upon data such as budget constraints, condition assessments of network, treatment selections and suitability and historical recording in generating effective and prioritised works programs.

A variety of failure modes are assessed to identify each individual road segment's Pavement Condition Index (PCI) rating. This information is then utilised to identify the appropriate treatment to extend the segment's life and improve its PCI. The PCI, life expectancy and corresponding treatments are detailed below:



As demonstrated in the above chart, Campbelltown applies a broad range of pavement treatments based on PCI and life extension outcomes. The following treatments are being commonly applied based on cost benefit analysis:

01

REJUVENATION

Spray applied binder rejuvenation treatments or Polymer Modified Emulsion / Mastic preservation treatments are used as early life cycle intervention treatments on selected sites to maintain the existing PCI. These applications are limited to existing sound pavements where very minor existing failure modes are exhibited.

02 03

MICROSURFACING

Microsurfacing is used effectively on existing sound pavement where pavement shape may require correction. The final aesthetic is pleasing to residents and offers low road noise with an asphalt-like finish. Microsurfacing is also used in combination with crack sealing or spray sealing to address reflective cracking.

04

CHIP SEALING

Using either hot bitumen or emulsion technology, spray applied treatments provide improved pavement water proofing and resistance to existing surface cracking. Spray treatments are also used in combination with microsurfacing to mitigate residential complaints related to loose aggregate post surfacing and overall aesthetics of the final wearing surface. Council uilises spray applied treatments as a cost effective application on its rural road networks.

Item 8 / Attachment 8.

05 06

AC (ASPHALT) OVERLAY

Council's low PCI sites are often rehabilitated with asphalt overlays providing a cost effective preservation treatment.

07

IN-SITU STABILISATION

Sites exhibiting the lowest PCI are rehabilitated with full depth bitumen foam / cement or lime in-situ stabilisation. This process allows for full pavement rehabilitation and, once completed, allows a new life cycle to commence. Council's strategy aims to decrease the number of sites requiring full rehabilitation, preferring to increase the life expectancy of the pavement through other means prior to resorting to stabilisation works.

08

FULL DEPTH PAVEMENT RECONSTRUCTION

Full depth pavement reconstruction is the most expensive method and use only when there is no other rehabilitation option available. In this method, after milling and disposing the existing pavement materials, we reconstruct the pavement base and sub-base with new materials followed by a wearing course of asphaltic concrete or spray seal at the top.

The PMS assisted with predictive modeling including maintenance application choices, intervention triggers and life cycle costing etc. Campbelltown City Council has also integrated Pavement Preservation options in PMS to achieve longer term financial sustainability in its road network management.

In Campbelltown City Council, road-treatment selections are broken into three distinct phases based on PCI and treatment types as follows:

PHASE 1

Early Intervention
Maintenance-Preservation

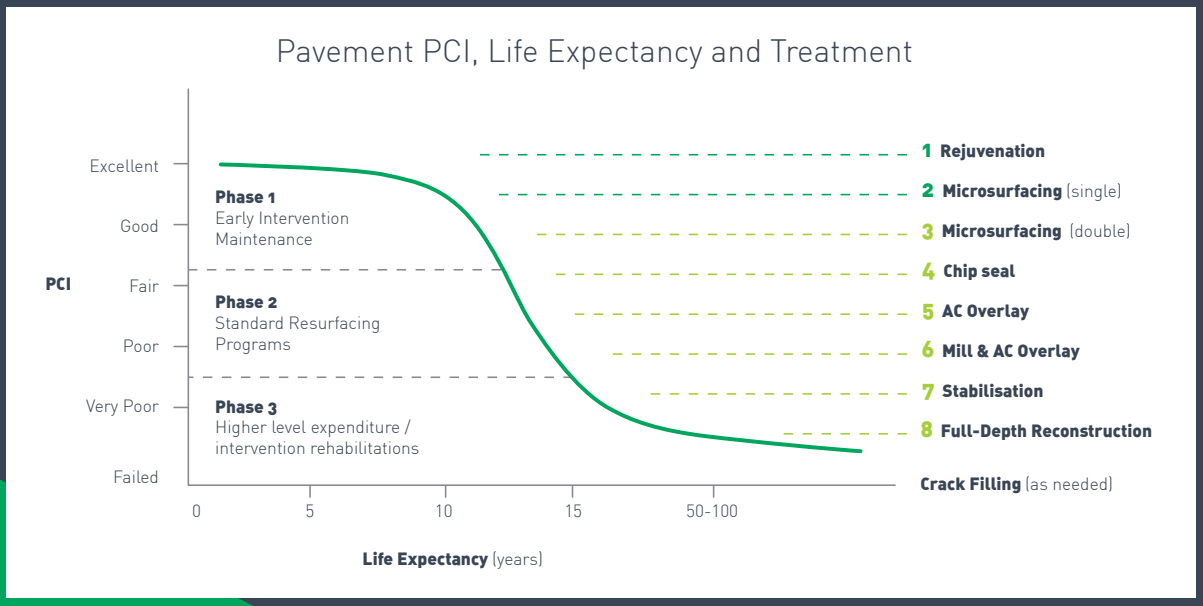
PHASE 2

Standard Resurfacing Program-
Resealing and asphalt resurfacing

PHASE 3

Higher Level Expenditure/
Intervention-Rehabilitation

The phases and corresponding treatments are detailed below:



With the help of Finance team, the asset section has also developed a funding strategy of all three phases as follows:

PHASE 1

100% funded since treatments in phase 1 are cost effective proactive maintenance and aimed to keep the good conditioned road in good condition for a long time. (Budget allocation 20%)

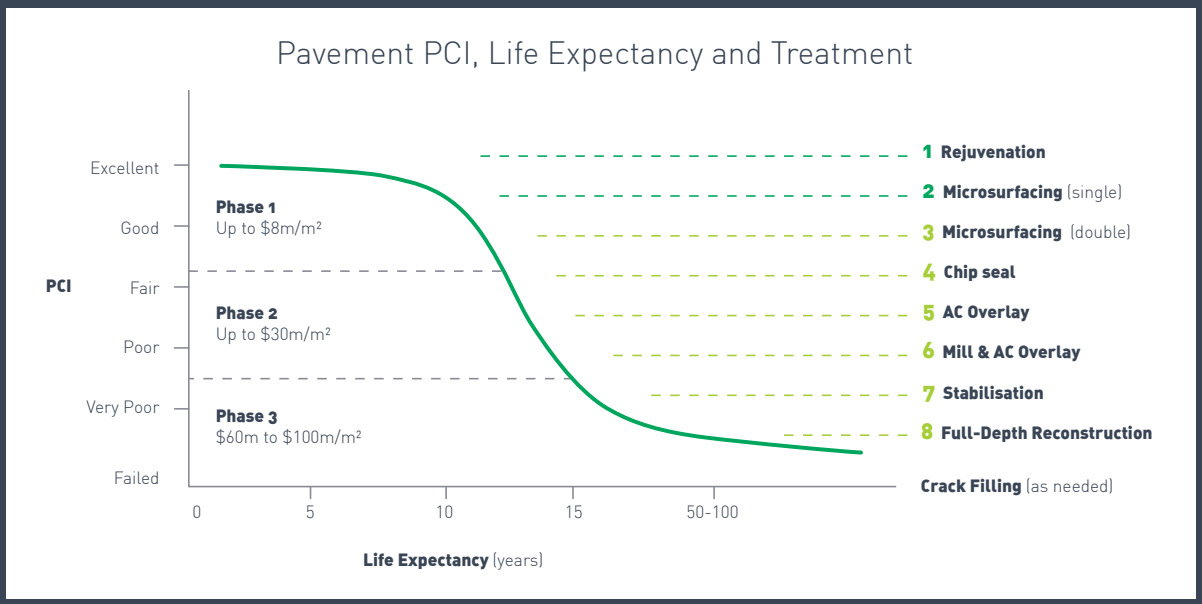
PHASE 2

Based on PCI, most of the Council's road renewal backlogs are in this phase. Council strategy is to fund the worst projects so that remaining projects do not go to Phase 3 (Budget allocation 65%)

PHASE 3

Based on current PCI, a small number of projects are only in this phase. Council decided to eliminate these in 5 to10 years. Project selections are based on asset risk score, cost benefit analysis, minimizing road user and future maintenance costs. (Budget allocation 15%)

The phases and corresponding treatments are detailed below:

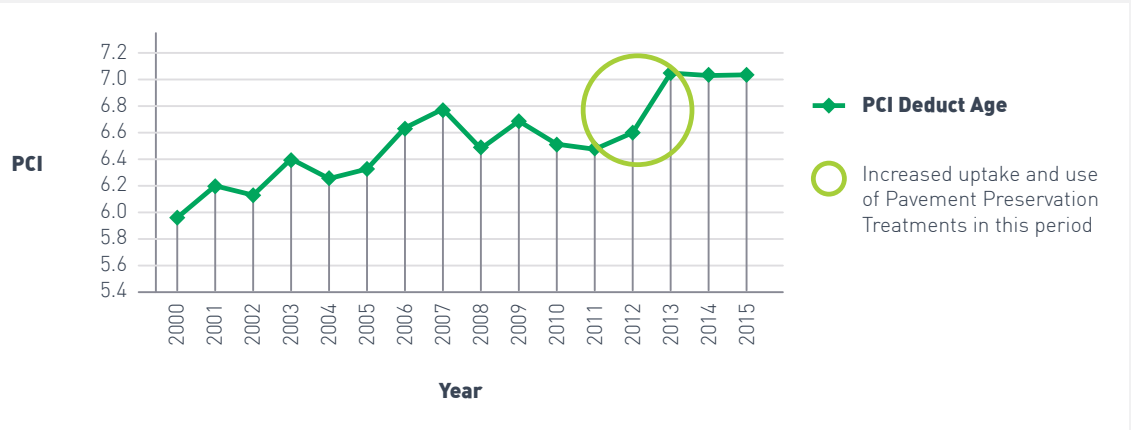


By adopting a systematic innovative approach, acting proactively and implementing a comprehensive pavement management strategy, Campbelltown City Council has managed to optimise the service levels and minimise the risk of the asset stock within budget constraint.

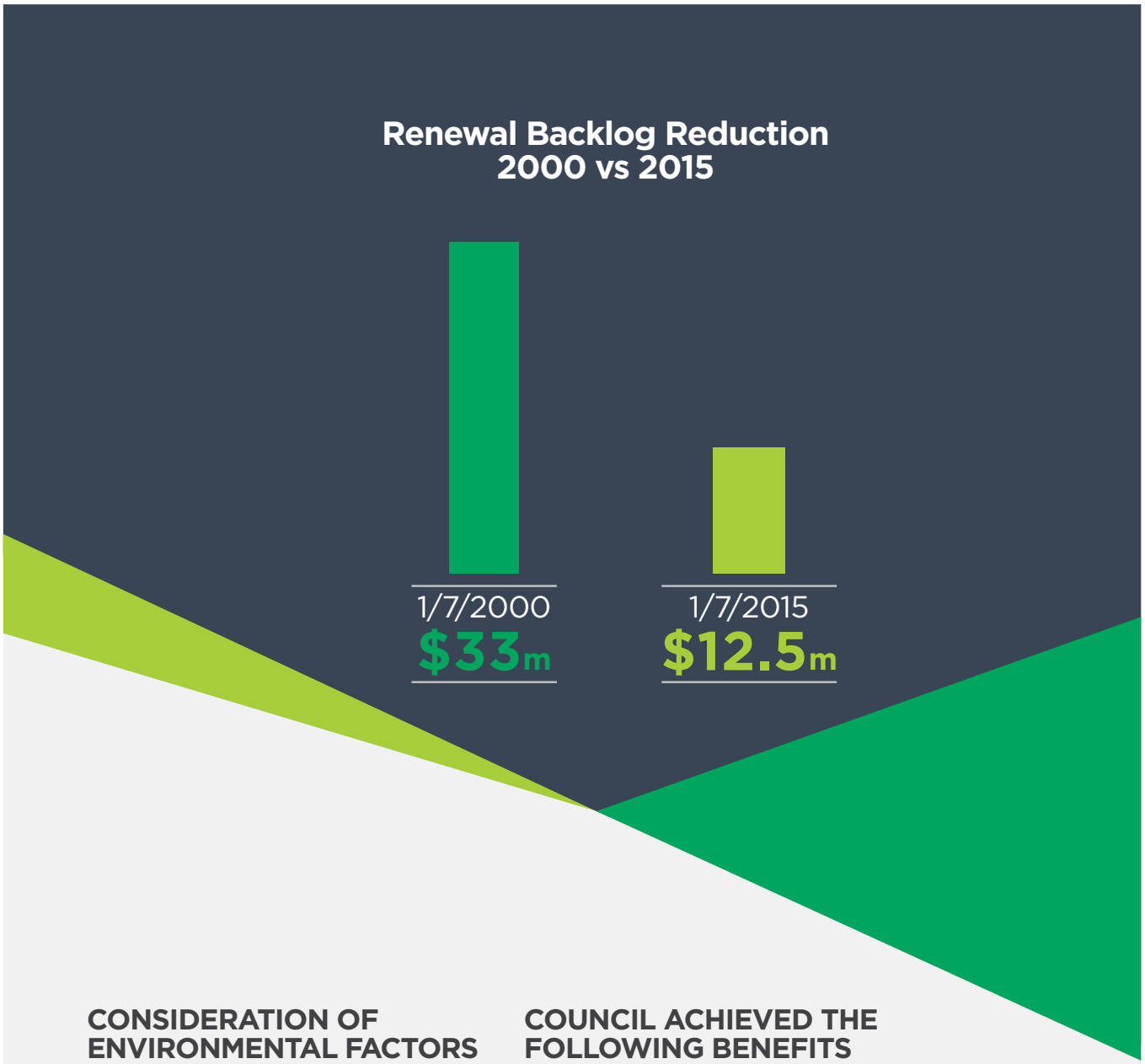
Australian Local Government Authorities should follow Campbelltown's lead in Pavement Management to realise potential improvements to their pavement infrastructure, prolong its lifespan and reduce ongoing pavement infrastructure maintenance cost.

ACHIEVEMENT

The graph below details the overall improvement in the road-network PCI due to implementation of Council's comprehensive Pavement Management Strategy over the last decade.



Financial modeling comparisons on budget costing between the Council's road renewal backlogs in Financial Year 2000 and Financial Year 2015 show a trend of decreased backlog cost required to elevate the PCI of the road-network asset. The results are direct reflection of Council's innovative approach adopted.



CONSIDERATION OF ENVIRONMENTAL FACTORS

Recycling of existing pavement materials by stabilisation is one of the main applications for Campbelltown Council's road rehabilitation processes. It enabled Council to upgrade existing roads without removal of any existing materials. Between 1991 and 2015, Campbelltown City Council successfully implemented 275 stabilisation road projects to provide sustainable outcomes for the management of its road network.

Council staff by acting proactively and utilising their comprehensive pavement management skills and sound performance results have implemented 275 stabilisation projects to minimise the deterioration of its road network assets and to optimise the service levels of the network assets within the constraint of available funding.

COUNCIL ACHIEVED THE FOLLOWING BENEFITS

- Saved 45% direct treatment costs at least of the next best alternatives
- Saved 200,000 tonnes of pavement materials from disposal
- Reduced Construction traffic
- Reduced truck generated pollution
- Reduced damage to local roads due to trucking operations
- Saved 150,000 tonnes quarried material
- Significant Energy Savings
- Drastically reduced construction time and lane closure

Doc ID No: A8086412

ITEM: 1

SUBJECT: RESPONSE TO NOTICE OF MOTION - SPRAY SEAL ROAD MAINTENANCE TREATMENTS

AUTHOR: MANAGER, CAPITAL PROGRAM DELIVERY

DATE: 30 MAY 2022

EXECUTIVE SUMMARY

This report is in response to a Notice of Motion which was raised at the Council meeting held on 19 May 2022, item number 17.4.

RECOMMENDATION/S

That this report be provided as information only to Councillors from a Notice of Motion and that it be noted that no recommendations at this time are being submitted.

RELATED PARTIES

N/A

IFUTURE THEME

Vibrant and Growing

PURPOSE OF REPORT/BACKGROUND

That a report be prepared which includes information on:

1. **The various road surface treatment options, including spray seals, available to local governments, and the relative cost and benefits of these treatments.**
2. **How Council prioritises road maintenance projects.**
3. **How Council determines when a spray seal is identified as the preferred treatment for a particular road.**
4. **The number of spray seals undertaken on council roads in the last three financial years, the number of complaints received about these treatments, and the number of complaints that required remediation.**
5. **Whether Council's use of spray seals is consistent with their use by comparable local governments.**

There are a range of options available for the surface treatments of roads across the City, however ICC predominantly uses either asphalt re-surfacing or a sprayed seal application.

ASPHALT is produced in a dedicated plant that heats, dries and mixes aggregate, bitumen and sand into a composite mix. It is then delivered to site and applied through a paving machine while hot as a solid material at a nominated or required thickness.

A **SPRAY SEAL** treatment consists of a thin layer of bitumen that is sprayed on to the existing surface as a hot liquid, that is immediately followed by the application of a single layer of crushed aggregate.
Spray seals cost approximately 40% of the cost of an asphalt surface on a direct comparison based on m2. However, this figure will change with site location, design, scale of the work and market pricing.

Due to the significant cost differential, spray seals are the predominant surfacing type in rural areas where access to batching plants are more costly. Sprayed seals account for around 70% of the total length of all surfaced roads across Australia.

In urban areas, asphalt surfaces are preferred due to their structural strength, durability, improved resistance to surface stresses, lower noise and lower maintenance.

In comparison to asphalt surfaces, the performance of spray seals deteriorates more rapidly than asphalt due to oxidation and hardening of the bitumen layer.
Over time the seal will require earlier maintenance intervention due to the loss of aggregate or minor surface cracking which may result in a weakening of the underlying pavement.

As broad indicator, spray seal surfaces are expected to require re-application after approximately 7-10 years where asphalt surfaces are expected to last approximately 15-20 years before requiring re-surfacing.

Asphalt provides a smoother and more durable asphalt road surface than a bitumen-sealed road.

Unlike sprayed seals, asphalt provides the added benefit of being a structural layer within a pavement, although thin asphalt layers, say 25–40 mm, are not considered to offer a significant structural contribution to a pavement.

The features of a spray seal surface:

- High surface texture and skid resistance
- High traffic noise
- Does not resist damage due to turning heavy vehicle traffic
- Does not contribute to structural strength of pavement
- Mainly used for rural roads

Features of an asphalt surface:

- Low traffic noise
- Resists damage due to turning traffic
- Contributes to overall pavement structural strength (particularly for depths greater than 35mm)
- Mostly used for urban roads

How Council prioritises road maintenance projects.

The road rehabilitation programs are primarily driven by inspections of existing roads, safety considerations, asset age, traffic counts, environmental conditions and forecasts of future performance.

The current level of service provided by a road can be quantitatively measured through a range of indicators based on road characteristics and surface defects such as:

- roughness
- edge breaks
- shoving
- rutting of the seal surface
- loss of seal texture
- percentage of cracking
- percentage of potholes.

Future road performance modelling then uses a range of predictive data including:
- current and historical road condition and maintenance costs
- the age of overall pavement and the surfacing materials
- traffic volumes
- other road details to project road conditions

The modelling system used in Council to carry out this evaluation and generate future works programs is the SMEC Pavement Management System (PMS). The PMS has been in use in Council for more than twenty years and the parameters used in its operation are regularly reviewed and outputs validated through design.

The most recent review was undertaken for the 2021-2022 capital budget inputs.

ROAD CONDITION ASSESSMENTS:
Every three to four years Council has a full condition assessment undertaken of the entire sealed road network, capturing data on all road segments. Council's asset register of all sealed road pavements contains approximately of 1,550 km of Council owned roads – which is growing each year.

The condition assessment is performed utilising a vehicle fitted with technology to measure and record the surface defects and/or roughness. Other more specific road testing is also performed from time to time to provide additional information on the pavement characteristics and underlying subgrade to address particular problems.

The most recent condition assessment was carried out during the period October 2019 to April 2020.

ROAD REHABILITATION MODELLING:

In developing the future works program, the PMS uses the historic, current and predicted pavement conditions and maintenance costs for each road section. The current sealed road

rehabilitation program has been based on minimising Council costs for the network over the full life cycle of the pavement.

How Council determines when a spray seal is identified as the preferred treatment for a particular road.

The initial determination of whether a spray seal is identified as the preferred resurfacing option is based on the following initial assessment:

1. What is the current surface type?
2. Has current surface type performed as expected/planned?

If yes to Q2, then re-apply a like-for-like surface treatment
If no to Q2, then identify cause of under-performance and determine appropriate pavement solution.

The consequence of this initial like-for-like assessment is that older, urban areas of Ipswich will continue to have a spray seal applied to the road network by default while newer areas will automatically have asphalt overlays applied.

The recommendation to move from an existing spray seal treatment to an asphalt surface is usually only identified if there has been a significant increase in traffic load or if turning and/or braking traffic is damaging the spray seal.

At this stage there is no program in place to improve the service level standard to that which an asphalt overlay provides in urban areas.

The number of spray seals undertaken on council roads in the last three financial years, the number of complaints received about these treatments, and the number of complaints that required remediation.

The number of spray seals undertaken over past 3 financial years is as follows:

Financial Year	2019-2020 FY					
Finished Surface Treatment / #'s/ m2 /$	Reseal (Spray Seal) m2	No. of Streets Spray Sealed	Asphalt Resurfaced m2	No. of Streets Asphalt Resurfaced	Total Area - m2 Resurfaced (Combined Spray Seal & Asphalt)	Total Number of streets Resurfaced
Division						
Division 1	1,403	1	1,736	1	3,139	2
Division 2	20,529	9	0	0	20,529	9
Division 3	53,038	5	12,594	5	65,632	10
Division 4	35,638	10	3,685	2	39,323	12
Division 5	67,068	20	1,220	1	68,288	21
Division 6	28,892	9	0	0	28,892	9
Division 7	39,691	15	18,360	8	58,051	23
Division 8	15,060	4	581	1	15,641	5
Division 9	0	0	0		-	0
Division 10	122,864	11	5054	3	2,399	14
Total in FY	**384,183**	**84**	**43,230**	**21**	**301,894**	**105**

Financial Year	2020-2021 FY	2020-2021 FY	2020-2021 FY	2020-2021 FY	2020-2021 FY	2020-2021 FY
Finished Surface Treatment / #'s/ m2	Reseal (Spray Seal) m2	No. of Streets Spray Sealed	Asphalt Resurfaced m2	No. of Streets Asphalt Resurfaced	Total Area -m2 Resurfaced (Combined Spray Seal & Asphalt)	Total Number of streets Resurfaced
Division / Area / Suburb						
Division 1	65,921	14	1,880	2	67,801	16
Division 2	29,923	11	1,440	2	31,363	13
Division 3	134,055	62	19,962	11	154,017	73
Division 4	175,688	49	1,815	3	177,503	52
Total in FY	405,587	136	25,097	18	430,684	154

Financial Year	2021-2022 FY	2021-2022 FY	2021-2022 FY	2021-2022 FY	2021-2022 FY	2021-2022 FY
Finished Surface Treatment / #'s/ m2	Reseal (Spray Seal) m2	No. of Street Spray Sealed	Asphalt Resurfaced m2	No. of Streets Asphalt Resurfaced	Total Area -m2 Resurfaced (Combined Spray Seal & Asphalt)	Total Number of streets Resurfaced
Division / Area / Suburb						
Division 1	1,225	3	12,519	8	13,744	11
Division 2	23,597	13	41,089	13	64,686	26
Division 3	75,307	36	40,702	13	116,009	49
Division 4	88,582	29	13,443	9	102,025	38
Total in FY	188,711	81	107,753	43	296,464	124

The number of complaints received for spray seal road rehabilitation works have been collated below.

It should be noted that there are a number of different reporting mechanisms that residents can utilise to lodge complaints, and as such the information provided may not be complete.

Complaints can be received via the CES system, as direct calls or emails to the Project Manager listed on the works notifications or through complaints lodged with Divisional offices.

From the information available we have been able to provide the following analysis:
CES Data

- Road resurfacing complaint register – there are 9 streets that have complaints recorded against them from the 2021-2022 resurfacing program
- Sealed road maintenance requests – there are 45 requests generated in the last 3 FYs related to recently constructed sealed roads

On Site Data – Sealed Road Defects Spreadsheet

- 2019-2020 FY
    - Approx. 88 seals completed
    - Approx. 44 roads identified with defects requiring repairs
    - 50% intervention rate – **this ranges from small defect (i.e. sweeping) to significant bleeding**

- 2020-2021 FY
    - Approx. 167 seals completed
    - Approx. 155 roads identified with defects requiring repairs
    - 93% intervention rate - **this ranges from small defect (i.e. sweeping) to significant bleeding**
- 2021-2022 FY
    - Approx. 71 roads completed (not all asphalt projects have been removed from this list)
    - Approx. 18 roads identified with defects requiring repairs
    - 25% intervention rate - **this ranges from small defect (i.e. sweeping) to significant bleeding**
    - Failures are all identified in streets completed prior to summer. This indicates that an increase is expected when roads recently completed go through their first summer cycle.
- Summary
    - Approx. 326 seals completed
    - Approx. 217 roads identified with defects
    - 67% intervention rate
- Qualifications
    - Most defects are isolated failures, typically bleeding
    - Not all defects will require rectification
- Defect rectifications
    - Costs have not been clearly captured as some of the issues are under normal Defects Liability Periods and the contractor is responsible
    - One standalone project to address defect precinct (Thomas/Mary/Eileen St, Flinders View) at cost of $177,177.34 excl. GST. Rectification was asphalt overlay on the seal.
    - Maintenance team did undertake some intervention during last summer, the extent and cost of this is unknown.
    - Additional costs incurred due to additional sweeper requests to address customer complaints

Other Data/discussion points

- Most complaints are not captured in CES and are directly responded to via the stakeholder or project management team
- Most seal complaints occur during summer months due to high temperature ranges
- Limited cost effective and timely options to respond to these complaints
- Many complaints received immediately following work to remove loose stone, which is essential to creating a good seal
- Loose stone has also had an impact in claims to contractor's insurance department (broken windscreens)
- Many complaints received about perceived poor quality work due to comparisons with asphalt or previous surface (likely a well bedded seal)
- Many complaints regarding tracking of seal onto driveways or footpaths
- Limited season to complete works, restricting ability to deliver
- Expertise in the industry relating to seals is significantly harder to find than asphalt experience

- One significant cost is the man hours from the construction team/stakeholder team put in to dealing with complaints
- In addition, there is a knock of effect on normal capital delivery program when contractor has to stop program to return/revisit site to deal with defects

Whether Council's use of spray seals is consistent with their use by comparable local governments.

It is the opinion of the Capital Delivery Branch that the use of spray seal surface treatments within the City of Ipswich is higher than that of comparable local governments.

When compared to the local government areas of Moreton Bay, Redland and Logan it can be determined that those other local Councils separate the surface treatments into the categories of spray seal for rural or semi-rural areas and asphalt is used for urban areas.

This can be evidenced by their respective 'Annual Contracts' for bitumen re-surfacing that have separable portions for asphalt and spray seal surfacing. The listing of roads for each separable portion can then be located as urban or rural/semi-rural.

It is uncommon for established urban communities to have on-going spray seal rehabilitation programs.

LEGAL/POLICY BASIS
This report and its recommendations are consistent with the following legislative provisions:
Not Applicable

RISK MANAGEMENT IMPLICATIONS

Not applicable

HUMAN RIGHTS IMPLICATIONS

HUMAN RIGHTS IMPACTS
RECEIVE AND NOTE REPORT
The Recommendation states that the report be received and the contents noted. The decision to receive and note the report does not limit human rights. Therefore, the decision is compatible with human rights.

FINANCIAL/RESOURCE IMPLICATIONS

Not applicable

COMMUNITY AND OTHER CONSULTATION

Not applicable

CONCLUSION

This information provided is a response to the Notice on Motion.

Graeme Martin
MANAGER, CAPITAL PROGRAM DELIVERY

I concur with the recommendations contained in this report.

Sean Madigan
GENERAL MANAGER - INFRASTRUCTURE AND ENVIRONMENT

"Together, we proudly enhance the quality of life for our community"

5th September 2022

Boral Resources (Qld) Pty Ltd
ABN 13 008 421 761
119 Cullen Avenue West
Eagle Farm, QLD 4009

PO Box 227
Hamilton Central, QLD 4007

T: +61 (07) 3268 8011
F: +61 (07) 3268 8077

boral.com.au

Ipswich City Council
PO Box 191
Ipswich QLD 4305

Attn: Brett McGrath
cc: Graeme Martin

Boral Asphalt – Thin Asphalt Surfacing For Residential Overlays

Dear Brett,

Find enclosed supporting details and relevant referenced documentation regarding Boral's product offering for thin asphalt resurfacing, that we believe best suits the needs and requirements of the council for this application, while also considering the broader community expectations with respect to recycling, safety, environmental and durability / life cycle benefits.

Product Overview / Summary

- Nominal 5mm size proprietary thin asphalt surfacing, designed for placement at 15-25mm depth.
- Suitable for residential pavements in good condition, requiring only re-surfacing treatment.
- Sustainable product with increased life cycle benefits for end user / asset owner.

Constructability / Manufacturing Considerations

- Conventionally manufactured asphalt with no specialised production runs or times.
- Conventionally laid asphalt with no specialised preparation or paving requirements.
- Ability to manufacture and place product all year round and is suitable for winter paving.
- Demonstrated capability to deliver technology (Boral delivery of 1st CR project to TMR pilot spec).

Sustainability / Environmental / Technical Aspect

- Incorporates local (Australian) waste tyre derived rubber into the asphalt mixture design.
- Approx. 28 equivalent passenger tyres recycled in every tonne of asphalt produced / laid.
- Warm mix additive incorporated into the asphalt mixture design.
- Reduces emissions (promotes worker safety) and energy usage (by approx 15-20 degrees).
- Allows for greater manufacture and placement windows (all year round paving for Ipswich).
- Up to 66% reduction in virgin materials compared to AC7 mix at 25mm depth.
- Increased life cycle (potential for up to 3x service life), compared to AC7 mix at 25mm depth*.
- Provides enhanced crack reflection / resistance – due to high binder content.
- Crumb rubber modified binder retards oxidisation / environmental cracking and ageing.
- Improved waterproofing / impermeable surfacing layer.

Commerical Considerations

- Anticipate 33% increase in cost [20mm depth] vs C320 AC7 asphalt at 25mm depth.
- Cost neutral to 10% increase in cost [15mm depth] vs C320 AC7 asphalt at 25mm depth.

Local Availability

- Asphalt manufacturing facility located in Ipswich City Council at Redbank Plains.
- Contracting office with local paving crew based out of the same site.

Boral looks forward to any opportunity to further explore this unique product offering with ICC, and I can also be contacted further in regards (details undersigned) to review / discuss further details.

Regards,

Carl Topp
National Technical Manager – Asphalt
0401 892 156

Appendix Summary

A – Boral "Innovo" range of recycled products.
B – Boral "WarmPave" brochure for warm mix technology
C – AfPA Tech Talk 2019 – Durable regional & LG roads
D – RMIT paper – Reduced UV ageing rubber
E – TSA fact sheet – Crumb Rubber Roads

based on outcome of fatigue testing performed on CR/DGA mixes 2021.

BORAL™

INNOVO™

SUSTAINABLE PAVEMENT SOLUTIONS

Boral Australia is committed to delivering innovative, high-performing and sustainable products and solutions that respond to a changing world and better meet our customers' needs.

INNOVO™ is Boral Australia's new system offering customers an asphalt containing alternative materials of their choice that can contribute to meeting their sustainability requirements. These materials are gaining a new life through incorporating them into our asphalt manufacturing and paving operations.

ENVIRONMENTAL SUSTAINABILITY

CHOICE OF RECYCLABLES

UPCYCLED ASPHALT PRODUCTS

PRODUCT OF AUSTRALIA

INNOVO™

RECYCLED ASPHALT PAVEMENT (RAP)

RAP is recycled asphalt from existing highways and freeways. Asphalt is 100 per cent recyclable and the most reused construction material in the world. Reuse of asphalt can reduce the demand for imported bitumen and replaces new high-quality aggregate raw materials that can then be used for other projects.

CRUMB RUBBER

Crumb rubber is a by-product of used tyres that have been shredded, ground or cryogenically processed. When blended with bitumen, the material behaves like an elastic polymer suitable for spray seal and asphalt solutions. Crumb rubber provides exceptional performance in inhibiting environmental cracking with many clients using it on roads on expansive clay soils.

RECYCLED GLASS

Recycled crushed glass can be used to replace sand in the manufacturing process of asphalt. With a similar particle density, using crushed glass to replace some of the natural sand in asphalt reduces the need for this raw material, which can then be used in other projects. Glass can also increase luminescence and reflectivity of the asphalt surface.

RECYCLED PLASTICS

Plastics can be a substitute for the fine aggregates or in addition to the binder used in asphalt production. They can also improve asphalt performance properties when included as part of an INNOVO design.

STEEL SLAG

Adding slag to asphalt can improve the skid resistance of the asphalt. The by-product of iron ore processing can provide increased resistance to abrasion and polishing of the asphalt surface and can be used where high levels of surface friction are required.

TONER

The toner from used printer toner cartridges can be added to asphalt. This can provide a stiffer binder and help with the oxidisation of the bitumen through the addition of carbon black.

Toner is often combined with soft plastic to make a composite additive for asphalt.

www.boral.com.au/innovo

CONTACT US

Visit **www.boral.com.au/asphalt** for more information about Boral's range of asphalt products. For orders and enquiries please call our office:

1300 132 964

PRODUCT OF AUSTRALIA

BORAL™

WarmPave

Applications

WarmPave asphalt can directly replace hot mix asphalt in many applications and is ideal for use on municipal roads, parking areas, side walks and driveways where community concerns for the environment are most prevalent. It can be produced in all structural forms of hot mix asphalt including dense graded, stone mastic, open graded or Novachip.

Results of performance testing WarmPave against hot mix asphalt reveal that (shown previous page) the viscosity of the binder in WarmPave is lower and so very likely less aged. Furthermore, there is little difference in resilient modulus (see graph) and supports adding recycled asphalt to achieve additional stiffness.

Special Applications

WarmPave asphalt can be customised to meet specific client requirements for grading and binder content for special applications. Boral Asphalt technologists can assist with the modification of WarmPave so customers may meet community needs for sustainable technologies and the specific demands of road performance.

Availability

WarmPave is widely available from Boral Asphalt locations around Australia. Unlike hot mix, WarmPave asphalt can be transported much longer distances due to its ability to be placed at lower temperatures. Contact your local Boral Asphalt office to find out more.

Achieving Carbon Neutral

Warm mix asphalt can reduce green house gases by up to 15% compared to hot mix, so helping the journey to net zero carbon.

There are many examples of where Boral has placed WarmPave including:

Road Projects	Jurisdiction	Location	State
Great Eastern Highway	Main Roads Western Australia	Sawyers Valley	WA
Franki Avenue	Hunters Hill Council	Woolwich	NSW
Queens Street	City Of Parramatta	Granville	NSW
Deer Park Bypass	VicRoads	Deer Park	VIC
Norris Road	Shire Of Yarra Ranges	Lilydale	VIC
Gallipoli Grove	DTEI & City Of Port Adelaide Enfield	South Road Superway	SA
Carina Hockey Pitch	McIlwain Civil	Carina Hockey Pitch	QLD

Reference (1) Warm-Mix Asphalt: European Practice, FHWA, 2008

www.boral.com.au/asphalt

CONTACT US

Visit **www.boral.com.au/asphalt** for more information about Boral's range of asphalt products. For orders and enquiries please call our office:

1300 132 964

WarmPave

WARM MIX ASPHALT

Building more systainable roads

Paving the way towards a more sustainable future

New developments in asphalt production technology have led to a reduction in the amount of energy used and green house gases emitted as compared to hot mix asphalt. As an industry leader in the manufacture and application of construction materials, Boral is committed to providing sustainable asphalt technologies and superior pavement performance for a better future.

A Better Planet with Warmpave Asphalt

WarmPave is specially designed around the latest innovations in asphalt performance and application with sustainability practices and technologies to reduce carbon emissions and lower embodied energy of asphalt roads.

This is primarily achieved by reducing the temperature of the asphalt in manufacturing and application, using a proven warm mix technology and optimising the use of reclaimed asphalt pavement (RAP) in the mix.

Warmpave Innovation

WarmPave technology is an innovation that allows asphalt to be produced and placed at lower temperatures compared to traditional 'hot mix'. This process reduces energy consumption and carbon emissions resulting from asphalt production and application, and also allows greater quantities of recycled asphalt to be used in the mix than ever before.

Consistent with international developments in warm mix technology, WarmPave is the result of many years of research and reflects a commitment to biosphere friendly technologies sought throughout the world by road authorities and communities in their efforts to preserve and sustain the environment for future generations.

Boral has adopted both additive and foam methods of producing WarmPave asphalt. Experience with the rheological modifier or organic additive called Sasobit dates back to 2006 while foaming systems have been installed in both double drum and batch plants. In fact Boral is the first to install a WarmPave foaming unit to a batch plant in Australia.

WarmPave

Recycled Asphalt (RAP) and Reduced Waste

WarmPave asphalt uses reclaimed asphalt pavement (RAP) in the mix, avoiding waste asphalt going to landfill. Although recycling aged asphalt (removed from existing roads during reconstruction and maintenance) is not new, the advent of warm mix technology allows RAP to be more effectively used to manufacture a product with sustainable qualities that performs comparably with hot mix asphalt.

Processed reclaimed asphalt pavement (RAP).

Preserving Resources

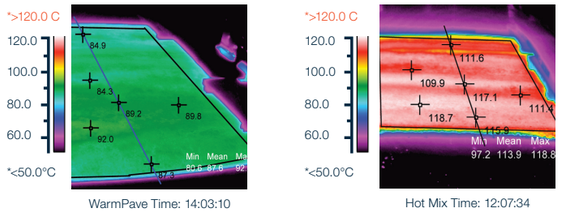
Using larger quantities of RAP in the production of WarmPave proportionately reduces the demand for virgin materials (bitumen and aggregates) in the asphalt mix and preserves these valuable resources for future use. The aggregates in recycled asphalt are generally of the same high quality as virgin aggregates specified for new asphalt and can be directly substituted to achieve similar asphalt performance.

When RAP is added, the bitumen coating on the RAP aggregate is usually reactivated by the heat from the virgin aggregates during mixing. This means that the amount of new bitumen can also be reduced – so preserving another valuable natural resource.

WarmPave asphalt with 15% RAP being paved on the Superway project in South Australia.

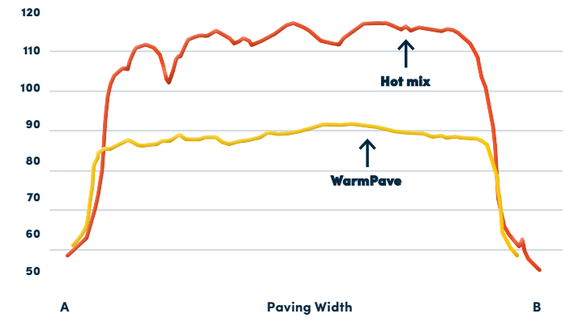
Temperature Profile

When thermographic images that capture the heat distribution using infrared cameras were taken of the completed mat immediately behind the paver in recent works, they clearly demonstrated that a more uniform temperature distribution was achieved on the surface of the newly placed mat with WarmPave.

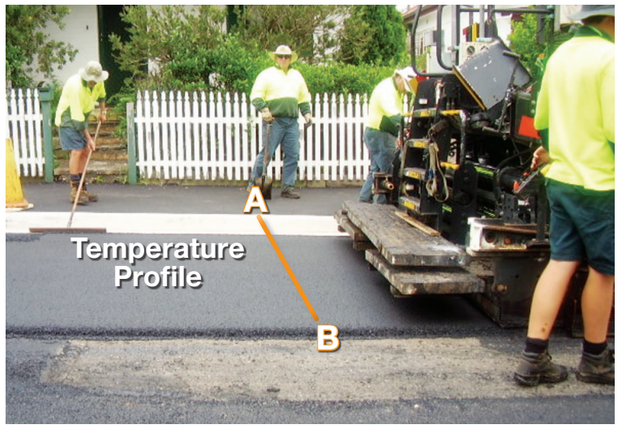


Temperature Profile. Extract from Boral field test, Granville, NSW 2010

Temperature Profile (ºC)



Temperature Profile. Extract from Boral field test, Granville, NSW 2010



Temperature Profile. Extract from Boral field test, Granville, NSW 2010

Work benefits with Warmpave Asphalt

As well as environmental benefits, WarmPave asphalt has additional advantages such as reduced handling temperatures and greater workability. This enables the asphalt to be handled and placed with even greater safety and ease. Reductions in smoke, fumes and odours also results in cleaner air around road works to the significant benefit of both workers and the communities in which asphalt roads are being paved.

WarmPave asphalt combining recycled asphalt (RAP) and warm mix asphalt technology provides high value benefits compared to hot mix asphalt.

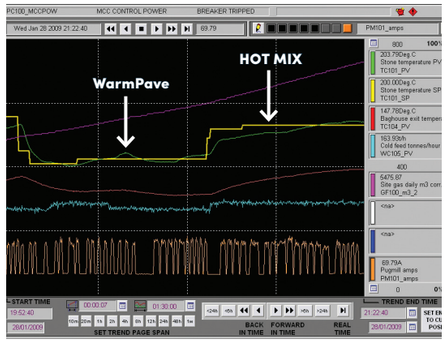
Benefits of WarmPave are[1]:

- Reduces emissions (CO^2 ~ 10% – 15%, CO ~ 10% – 25%, NO ~ 15% – 20%)
- Can reduce energy and fuel consumption by up to 30%
- Reduces production and placement temperatures by up to 25°C compared to HMA
- Increases the ability to use recycled asphalt
- Can reduce the consumption of non renewable materials
- Reduces smoke, fumes and odours thereby reducing the impact on neighbours living in vicinity of asphalt plants

WarmPave asphalt being discharged into the tipper from the pug mill after mixing. Note the absence of any fumes.

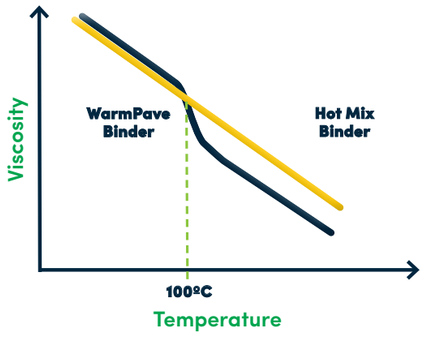
- Enables easier compaction that can lead to improved density control and increased service life
- Allows multiple layers of asphalt to be placed more quickly
- Offers a wider compaction window allowing more time required to achieve specified density
- Increases the opportunity for improved compaction of joints
- Allows asphalt applications previously not possible such as hand work
- Improves working conditions for laying crew that results when temperature and emissions are reduced
- Leads to higher production rates by virtue of lower production temperature
- Extends the paving season in colder climates due to a wider band of compaction temperatures.
- Allows newly placed asphalt roads to be opened to traffic sooner due to lower compaction temperature.
- Lower mixing temperatures reduce the binder ageing thus contributes to longer pavement and service life.
- Field observations supports rutting resistance and crack inhibition is equivalent to hot mix asphalt.
- Laboratory tests indicate that required key asphalt performance properties are met.

Fuel usage comparison



Drop in fuel usage during WarmPave asphalt production. Boral Deer Park Plant Trial, January 2009

Binder viscosity comparison



Change in binder viscosity at paving and mixing temperature using an organic additive. Extract, NCAT, USA Presentation 2006

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

TechTalk: Durable regional and local government roads

Townsville

June 2019

TyreStewardship AUSTRALIA

TechTalk Outline

- **Topic 1: Crumb rubber modified bitumen for sprayed seals and asphalt**
- **Topic 2: Surface preservation for low volume roads**
- **Topic 3: SMA7**

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

Crumb Rubber Modified Bitumen

For sprayed seals and asphalt

April 2018

TyreStewardship AUSTRALIA

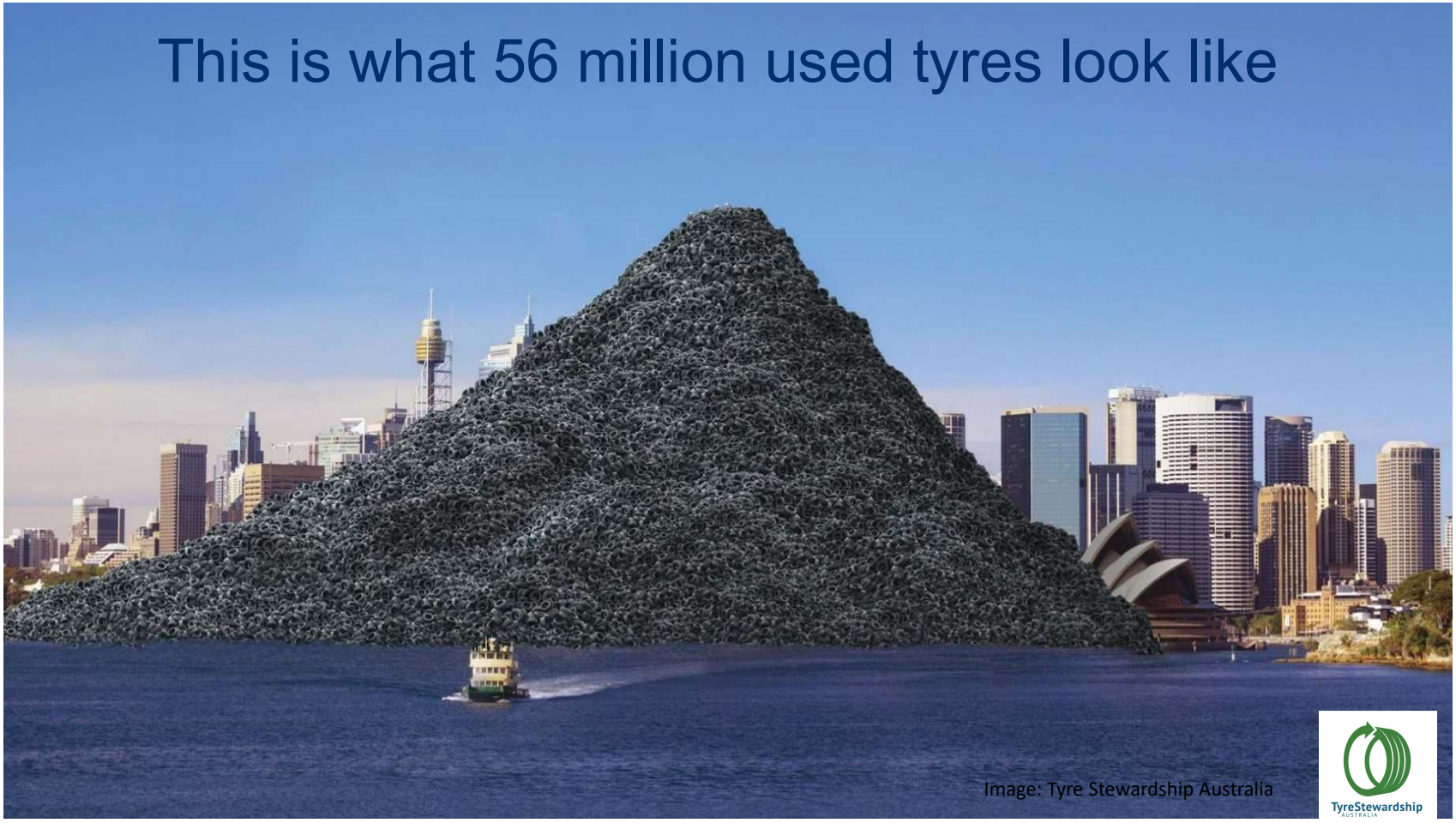
Outline

- **Background**
- **Benefits of crumb rubber modification**
- **Crumb rubber manufacture**
- **Crumb rubber modified binder**
- **Sprayed seals**
- **Asphalt**
- **Emission Control**

Background

End of life tyres

- More than two equivalent passenger tyre units scrapped per Australian per year
- A high-value application of these materials is as elastomeric crumb rubber modifier (CRM) in bitumen
- Tyres are processed to crumbs and digested into bitumen at a high temperature.


This is what 56 million used tyres look like
Image: Tyre Stewardship Australia
TyreStewardship
AUSTRALIA

Background

End of life tyres

- CRM binder has enhanced elastic properties
- results in more durable asphalt and sprayed seal surfacings
- CRM binder has a long history of use in Australia
- Potential for use on a larger scale

7


AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
Benefits of rubber modification
ED
TyreStewardship AUSTRALIA
8

Benefits of rubber modified bitumen

Improved performance of bitumen in sprayed seals

- Service life significantly increased
  - Delays oxidization cracking and stone loss
- Superior resistance against reflective cracking
  - Good as a strain alleviating membrane interlayer
- Improvement in waterproofing the road surface
- Competitive with other polymers such as SBS and PBD
- Early aggregate retention

9

Benefits of rubber modified bitumen

Improved performance of bitumen in Asphalt

- Allows higher binder application rates due to higher viscosity (reduced drain down and bleeding)
  - Higher film thickness retards oxidative aging in OGA
  - Minimises raveling
  - More durable
- Improved elastic properties
  - Resistant to reflective and fatigue cracking

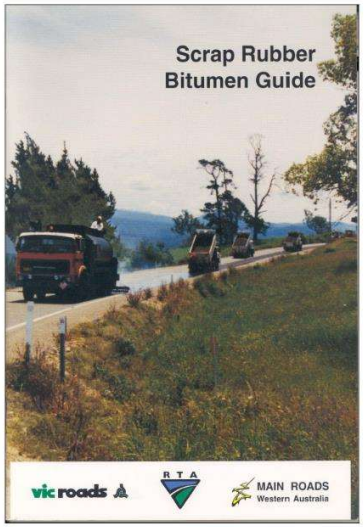
10

Benefits of rubber modified bitumen

Improved performance of bitumen in Asphalt

In 1995 a joint VicRoads/RTA/MRWA report cited benefits of CRM binder in asphalt as

- Cost effective because of increased pavement life
- Increased shear resistance, i.e. less rutting and shoving
- Increased resistance to fatigue and reflective cracking



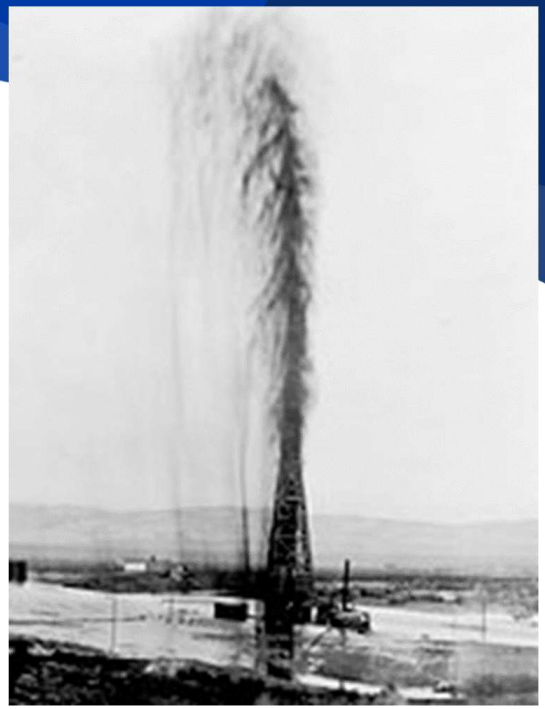
Source: Vicroads, RTA, MRWA 1995

11

Benefits of rubber modified bitumen

Bitumen extender

- Crude oil is a finite resource
- Consideration of crumb rubber as a bitumen extender may be an attractive option



Easily accessible crude oil, Source unknown

12

Environmental benefits

Reduction of tyre stockpiles

- Stockpile fires can release toxic gasses
- Tyre stockpiles provide breeding habitats for pests, e.g. mosquitos risk spreading dengue fever in Australia
- Reduction in landfill
  - Currently 66% of EoL tyres go to landfill or are illegally dumped

Source: East Bay Times

Mammoth effort to remove Stawell's toxic tyre mountain

Rex Martinich

Victoria's Environmental Protection Authority is tackling the removal of a toxic mountain of tyres from a site in western Victoria like a military operation.

A week after taking control of the Stawell Tyre Yard, which poses a potentially "catastrophic" fire risk, the agency has described the mammoth clean-up process as a marathon rather than a sprint.

The site on the western side of Stawell holds an estimated nine million tyres.

For the first time, the EPA has used specific clauses in legislation to take full control of a site after the deadline for the owners to act on fire hazard notifications expired.

"EPA used the powers under section 55 and 62 of the Environmental Protection Act to access and take control of the site in order to clean up and reduce the very high fire risk that was imposed on the community," Danny Childs, the agency's project manager at the site, said. "If the tyres were to go up in flames, it would have huge impacts on society, the economy and the environment," he said.

Excavators chip away at the stockpile at Stawell Tyre Yard. Photo: Rex Martinich

"It would be catastrophic. This has been an unacceptable risk to the Stawell community for far too long now, and that's part of the reason the EPA has taken action."

The tyre yard has sat mostly idle for the past decade, with increasing numbers of Stawell residents objecting to the site.

The saga took a bizarre turn this month when Fairfax Media revealed that the site's owner, Used Tyre Recycling Corporation, had "gifted" the property to a mysterious company registered in Panama, which then tried and failed to get a Supreme Court injunction against the EPA.

Mr Childs estimated that it would take another 12 to 18 weeks to complete the project. "We're currently working Monday to Saturday ... from 6.45am to 6pm," he said. "It really depends on the weather, what we find in the stockpile itself, and on how quickly we can process them. It's not a sprint, it's a marathon."

The site has two new large polyethylene tanks to hold water for the firefighting trucks that have been placed on standby. New drainage channels are being built and an erosion management plan will be put in place for the bare ground left behind when the tyres are removed.

Portable pumps are being used continuously at the site to remove water that has built up underneath the tyre piles. Security guards now patrol temporary fences and the EPA has set up a time-lapse camera to document the process.

One EPA worker described the seized tyre yard as a miniature army base, with temporary offices shipped to the site.

"At this stage the project is progressing well and as planned," Mr Childs said. "We have removed 550 tonnes of tyres. They have been taken to Somerton in Melbourne to be processed by Tyrecycle."

Tyrecycle's plant can process 10.5 million tyres a year. Between 100 and 150 tonnes of tyres from Stawell have been shredded and processed so far.

The Stawell Times News

BA NATAGE A009

'The site on the western side of Stawell holds three million tyres'

'A potentially catastrophic fire risk'

'If the tyres were to go up in flames, it would have huge impacts on society, the economy and the environment'

Source: The Age, 18 Aug 2017


AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
Crumb rubber manufacture
TD
TyreStewardship AUSTRALIA
15

Crumb Rubber Manufacture

Terminology

Three main types of tyres used in Australia:

- Passenger tyres
- Truck tyres
- Off-road tyres

Source: Sustainability Victoria 2014

Crumb Rubber Manufacture

Terminology

Equivalent Passenger Units

EPUs

Rubber and carbon black represent approximately 70% of the weight of a tyre.

EPUs for reporting by TYRE IMPORTERS, VEHICLE MANUFACTURERS and MINERS	
Type of Tyre	**EPU Ratio**
Motorcycle	0.5
Passenger Car 1	1
Light Truck/SUV/RV	2
Truck small (17.5" & 19.5")	3
Truck large (20" & 22.5")	5
Small Specialty/Ag (skid steer, forklift 8"-15", front tractor & backhoe 15" to 18")	3
Medium Specialty/Ag (20" – 30")	5 to 8
Large Specialty Ag (32" and above)	20 to 30
Small Earthmover (24" – 25")	50
Medium Earthmover (29" – 35")	100
Large Earthmover (above 35")	200

EPUs for reporting by RECYCLERS	
Type of Tyre	**EPU Ratio**
Motorcycle	0.5
Passenger	1
Light Truck	2
Truck	5
Super Single	10
Solid small (up to 0.3m high)	3
Solid medium (>0.3m up to 0.45m)	5
Solid large (>0.45 m up to 0.6m)	7
Solid extra large (> 0.6m)	9
Tractor small (up to 1m high)	15
Tractor large (>1m up to 2m)	25
Fork lift small (up to 0.3m high)	2
Fork lift medium (>0.3m up to 0.45m)	4
Fork lift large (>0.45m up to 0.6m)	6
Grader	15
Earth mover small (up to 1m high	20
Earth mover medium (>1m up to 1.5m)	50
Earth mover large (>1.5 up to 2m)	100
Earthmover extra large (>2m up to 3.0m)	200
Earthmover giant (>3 up to 4m)	400
Bobcat	2

Image: Tyre Stewardship Australia

17

Crumb Rubber Manufacture

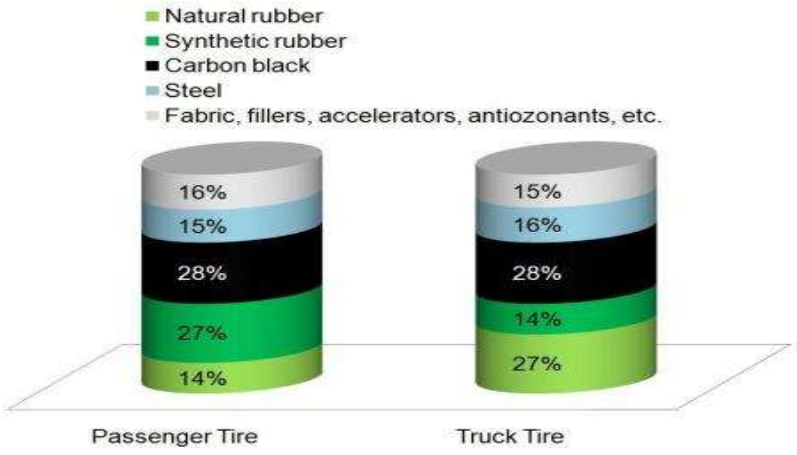
Sorting

Car Tyres

- Use SBR, and are recycled into tyre derived fuel
- Used in furnaces as a coal substitute
- Used in bitumen and adhesives

Truck Tyres

- Higher percentage of natural rubber
- Recycled into crumbs and powder
- Used in bitumen and adhesives



18

Crumb rubber manufacture routes

1. Ambient mechanical grinding

- Tyres are shredded by rotating blades, at ambient or room temperature
- Fibers and metal are extracted
- Shredded rubber is mechanically ground
- Produces irregularly shaped, torn particles with a relatively large surface area

19

Crumb rubber manufacture routes

2. Cryogenic grinding

- Uses liquid nitrogen to freeze the rubber
- Brittle rubber then shattered in a hammer mill
- Produces smooth particles with relatively smaller surface area
- Cryogenic manufacture is not used in Australia
- Some international specifications prohibit the use of cryogenically derived crumb rubber in bitumen

Sources: Denneman et al 2015; Neaylon 2013

CR Manufacture - delivery

Photographs: Kym Neaylon 21

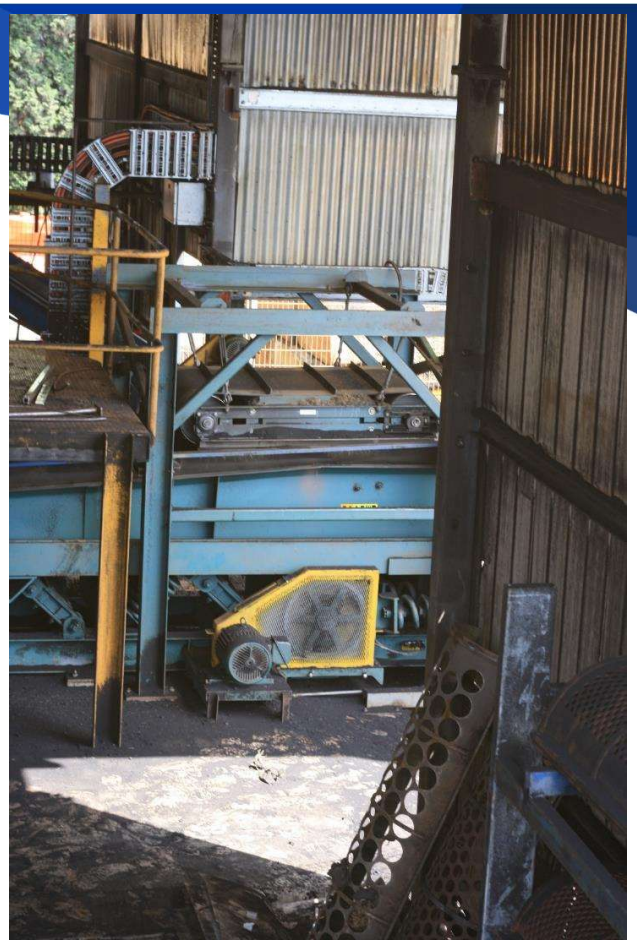
CR Manufacture - Shredding

22

CR Manufacture - Shredding

Electromagnets

Electromagnets at several stages to remove wire



23

CR Manufacture – Granulating & Grinding

CR Packing

25

CR manufacture

Final Grading

Road surfacing	8 mesh to 40 mesh (sieve size 2.36mm to 425µm)
Tile adhesives	30 mesh to 40 mesh
Playground and sporting surfaces	4, 12 & 16 mesh crumbs, 2, 4, 15 mm granules

mesh = number of wire mesh openings per lineal inch

Uses

At present, recycled tyre uses include…

- Adhesives
- Athletics tracks
- Brake pads
- Building insulation
- Civil Engineering
- Conveyor belts
- Explosives
- Furnace fuel (TDF)
- Industrial and commercial flooring & mats
- Marine nonslip surfaces
- Road surfacing

Source: http://www.tyrecycle.com.au/why-recycle

27

AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

Crumb rubber modified binder

TD

TyreStewardship AUSTRALIA

28

Binder blending

Dry process (in Asphalt)

- Part of the aggregate is substituted by crumb rubber
- Aggregate and rubber mixed thoroughly before bitumen is added
- Most appropriate for gap graded mix designs
- Not constrained by binder storage time and phase separation
- Has successfully been used in Australia on a regular basis

29

Binder blending

Wet process, with agitation (high shear, high viscosity)

- Modifies bitumen with crumb rubber before being used in asphalt or sprayed sealing
- Greater interaction between crumb rubber and bitumen
- Extensive modification of bitumen is achieved
- Crumb partially digested

Binder blending

Wet process (high shear, high viscosity)

- Oils in the bitumen enter into and swell the crumb rubber
- Requires constant agitation to keep particles well distributed

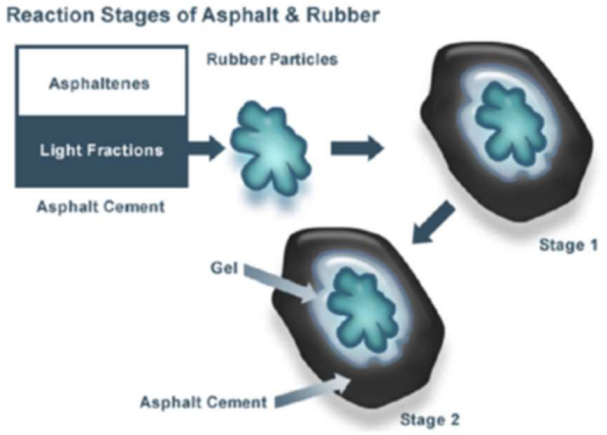


Image: Jansz 2012

Binder blending

Wet process (high shear, high viscosity)

Digestion occurs in different stages

1. Light phase of bitumen is adsorbed. Increases resilience of the binder
2. Rubber changes into a gel. Increases viscosity
3. Rubber changes into an oil. Increases durability of binder

Source: Lo Presti 2013

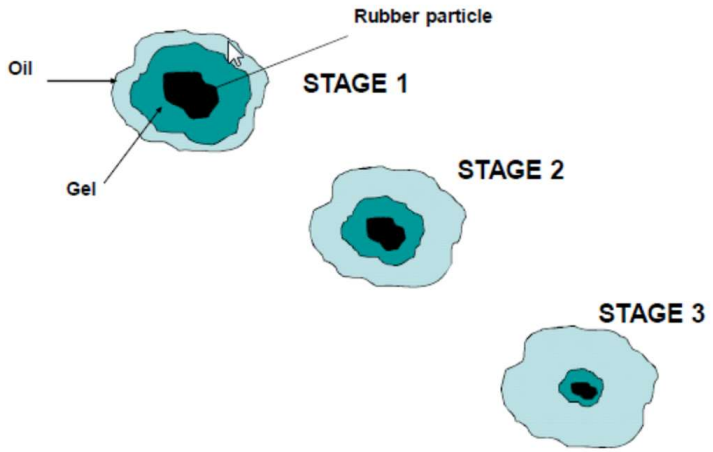
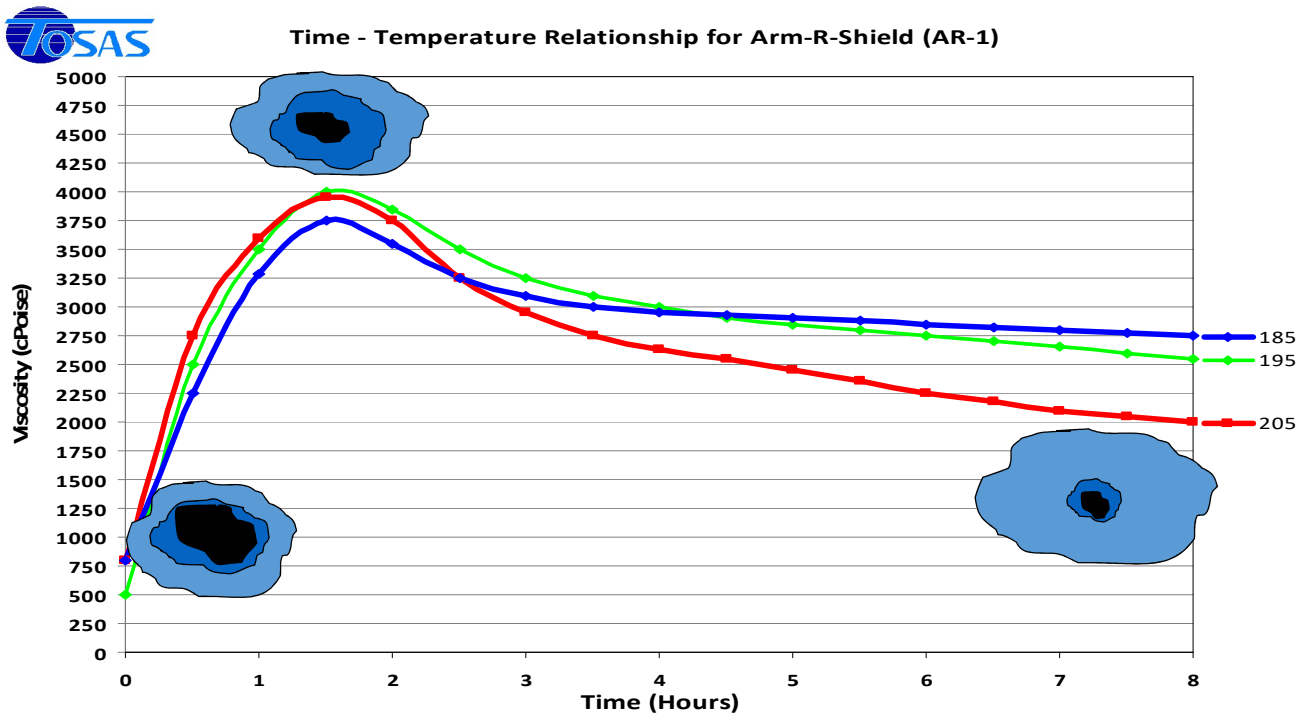


Image: SABITA 2016

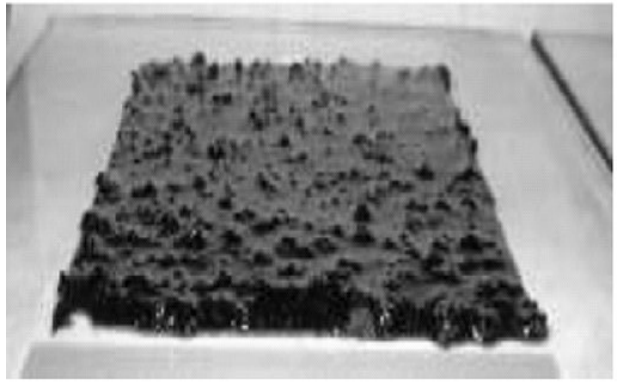

Time - Temperature Relationship for Arm-R-Shield (AR-1)
Viscosity (cPoise)
5000
4750
4500
4250
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
Time (Hours)
185
195
205

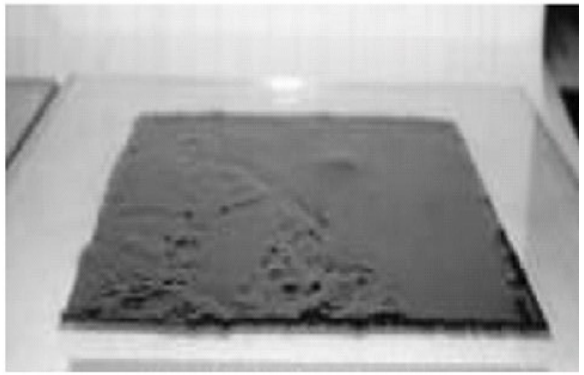
Binder blending

Wet process, no agitation (Terminal Blend)

- Blended at high shear stresses and temperature
- Crumb rubber highly digested
- Storage-stable product that does not need agitation
- Were typically produced at a refinery or bitumen terminal (hence the name)
- Not currently used in Australia

Wet blend vs terminal blend





Site blending

Rubber crumbs from hopper

Bitumen from bulker

CR Binder to sprayer

Mixing box

Photographs: Robert Busuttil 36

Site blending (sprayed sealing)

VicRoads

Another mixing box at a very small job

Photograph: Kym Neaylon 37

Site blending (sprayed sealing)

Introduction of site blending into South Australia, 2007

- Old VicRoads method was not encouraged
- Factory blends at the time were too unstable to travel long distances

Photograph series: Kym Neaylon 38

Site blending (sprayed sealing)

Equipment

39

Site blending (sprayed sealing)

Rubber

40

Site blending (sprayed sealing)

41

Site blending (sprayed sealing)

Site Blending (sprayed sealing)

43

Site Blending (sprayed sealing)

44

Site blending (sprayed sealing)

An off-the-shelf Californian machine, 2012

Source: Janz 2012

CRM Binder specification

Austroads Test Method AGPT-T190-14

Table 5.4 Properties of crumb rubber

Test	Method	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		–	20 max.
Particle length (mm) max.	AGPT/T143	3	3
Bulk density (kg/m^3)	AGPT/T144	Report	Report
Water content (%) max.	AGPT/T143	1	1
Foreign materials – other than iron (%) max.	AGPT/T143	0.1	0.1
Foreign materials – metallic iron (%) max.	AGPT/T143	0.1	0.1

CRM Binder specification

Austroads Test Method AGPT-T190-14
Requirements for plant and field produced spray grades

Property	S45R	S15RF	S18RF
Blending	Plant	Field	Field
Rubber, % min	10	15	18
Softening Point, °C	55 - 65	55 min	62 min
Torsional recovery, %	25 - 55	25 min	30 min
Viscosity @ 165°C, Pa.s	4.5 max	NA	NA
Frequency testing	each batch	Weekly	

47

CRM Binder specification

AAPA model specification for CRM OGA and GGA

Property	Test method	Reaction time (from incorporation of rubber into the binder)				
		60 mins	120 mins	240 mins	360 mins	TBN[2]
Penetration @ 4°C, 200 g, 60 sec, 0.10 mm, minimum	AS 2341.12	15	-	15	-	15
Penetration @ 25°C, 100 g, 5 sec, 0.10 mm, minimum	AS 2341.12	TBR[1]		TBR[1]		TBR[1]
Resilience @ 25°C, percent rebound, minimum	ASTM D5329	20	-	20	-	20
Torsional recovery at 25°C 30 s, %	AG:PT/T122	TBR[1]	-	TBR[1]	-	TBR[1]
Softening point, °C, minimum	AG:PT/ T131	55	-	55	-	55
Viscosity at 175°C, Pa.s	AG:PT/T111	1.5–4.0	1.5–4.0	1.5–4.0	1.5–4.0	1.5–4.0

48

CRM sprayed seal

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

ED

TyreStewardship AUSTRALIA

49

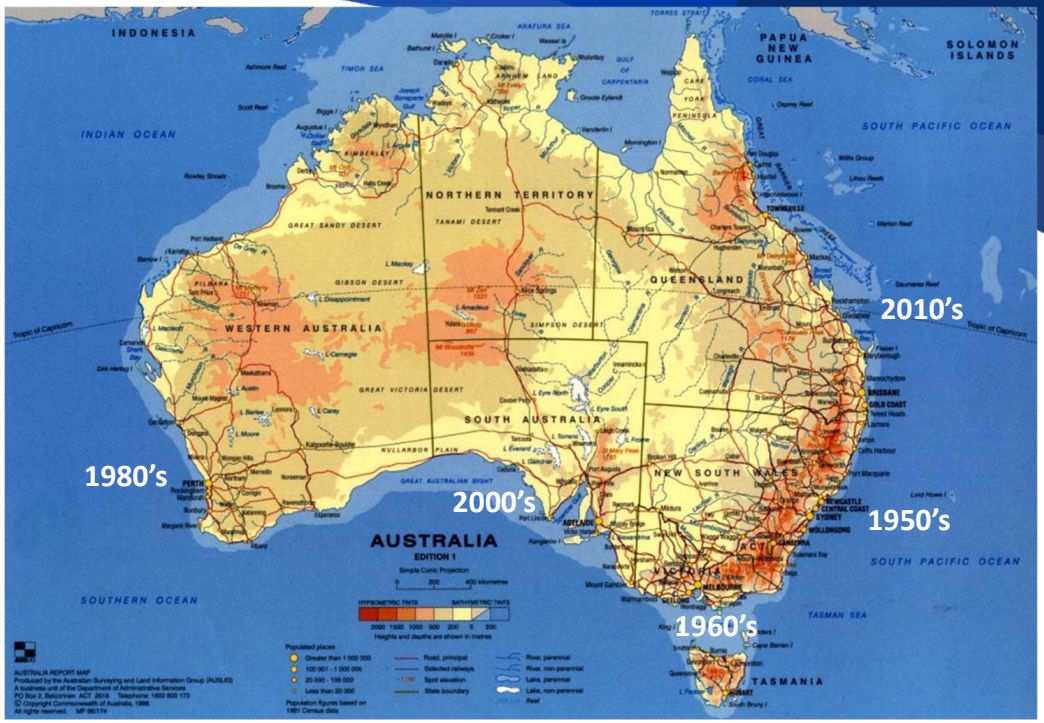

Conventional Seal
• Binder: C170, C320
• Single/single – Low stress
• Double/double – Low to moderate stress

First National Specification 1992

Sprayed sealing

Australian CRM use

1950s – NSW
1960's – Vic
1980's – WA
1992 – First national spec
2000's – SA
2010's - Qld



Base image: AUSLIG

Sprayed sealing

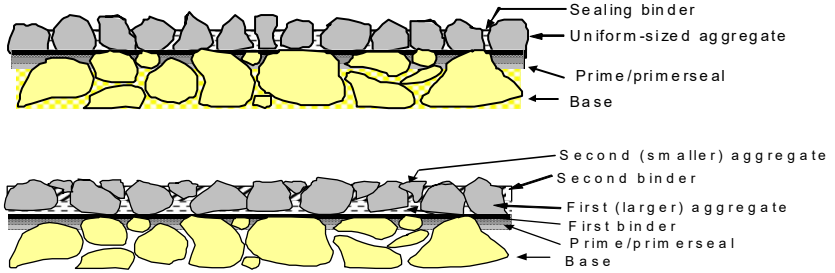
Crumb rubber in Australia

- 5% - 18% crumb rubber by mass of binder
- >13% rubber binder (S45R, S15RF, S18RF) used nationally for seals in high demand situations; heavy traffic, or over cracked pavement
- 5% rubber used in Victoria as tough resilient seal on light trafficked roads and to improve aggregate retention on heavy traffic roads

52

Types of sprayed seal

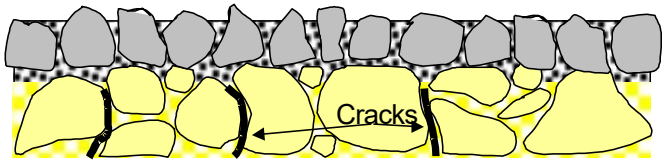
- Identified by number of layers of binder and aggregate
  - Single/single (s/s)
  - Double/double (d/d)



- Combine with binder types to
  - produce different treatments
  - suit range of conditions

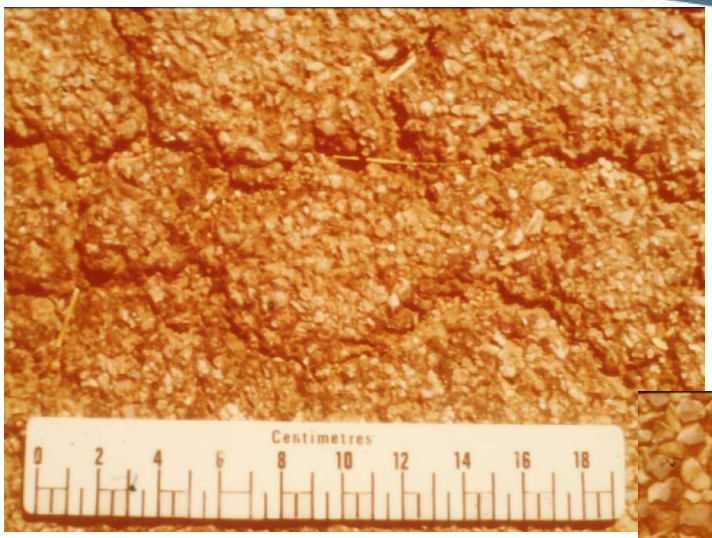
53

Strain Alleviating Membrane (SAM)



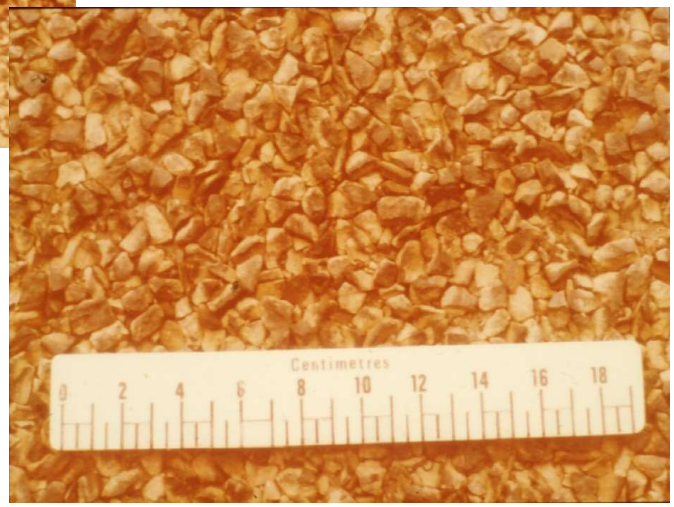
Use:	To minimize reflection cracking Provide a more waterproof surface on roads constructed with moisture sensitive pavement material or subgrades
Type:	Preferably single/single, but may use double/double
Binder:	Low to medium modified PMB
Aggregate:	10 and 14 mm (single/single), 14/7 & 10/5 (double/double)
Design:	Minimum **desirable** binder rate **1.5 L/m²** for effectiveness

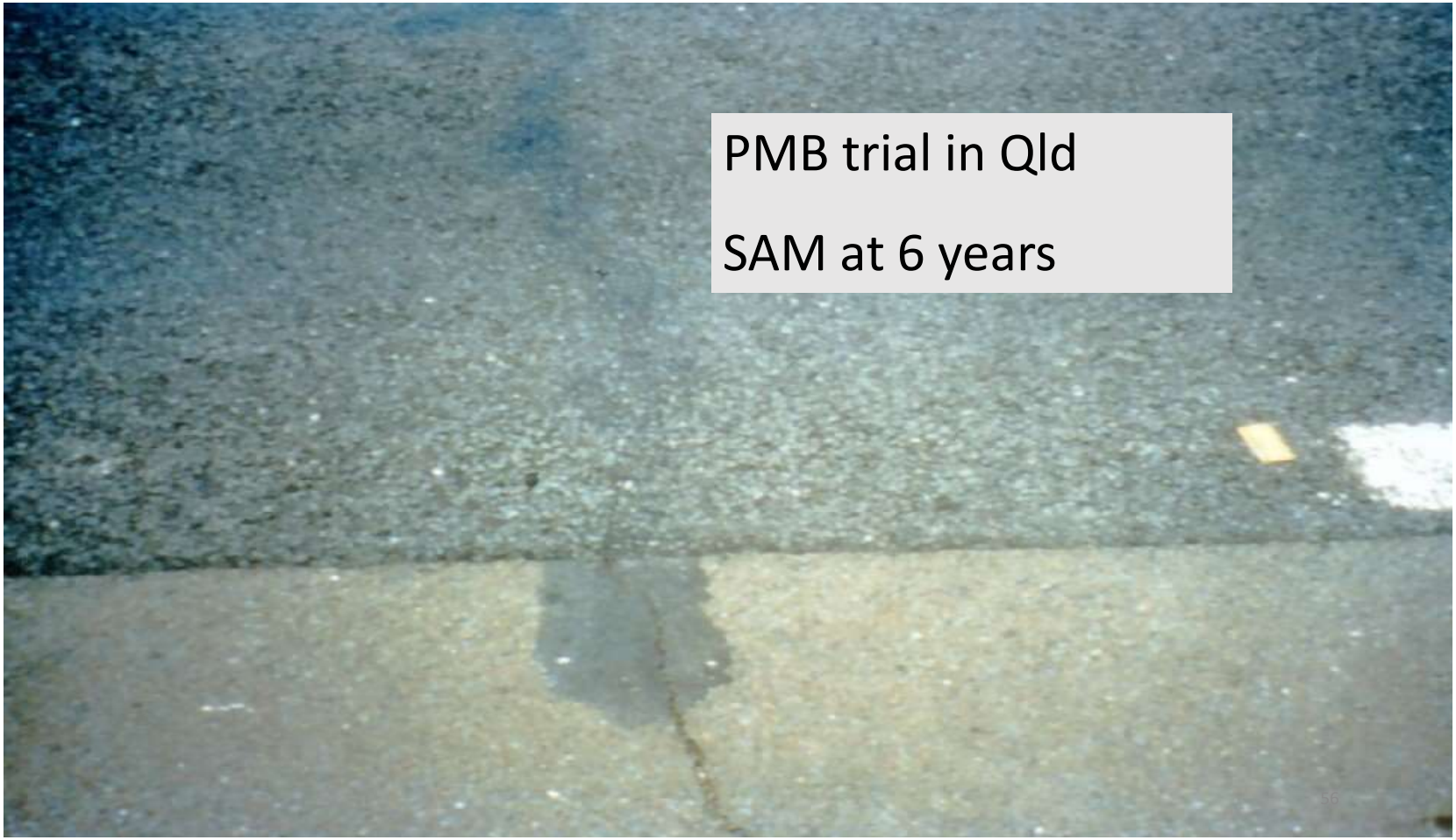
54



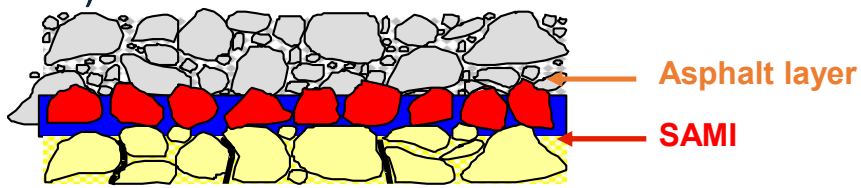
Fatigued pavement – badly cracked, slow movement

Same location - 12 months old SAM 14 with S15RF binder




PMB trial in Qld
SAM at 6 years

Strain Alleviating Membrane Interlayer (SAMI)

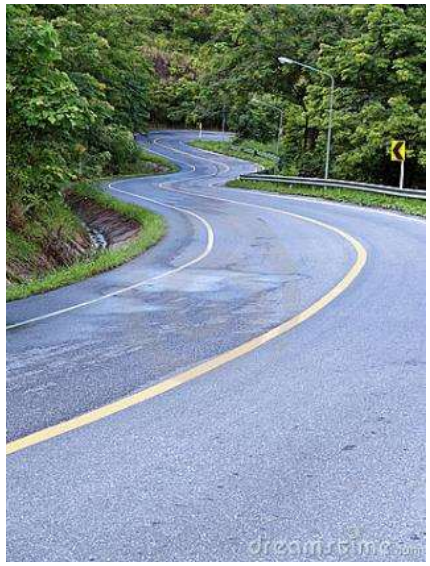


Use:	**Minimise reflection cracking into an asphalt overlay; Provide very waterproof membrane under open grade asphalt**
Type:	**Single/single 10mm or 14mm (do not use a D/D for SAMI)**
Binder:	**Highly modified PMB (S25E or S18RF)**
Design:	**Minimum desirable binder rate of 1.8 L/m²**

57

High Stress Seals (HSS)

- All aggregate sizes
  7, 10 and 14mm
- HSS1 Single/single
- HSS2 Double/double
- Binder
  - Multigrade M500
  - PMB binders all grades

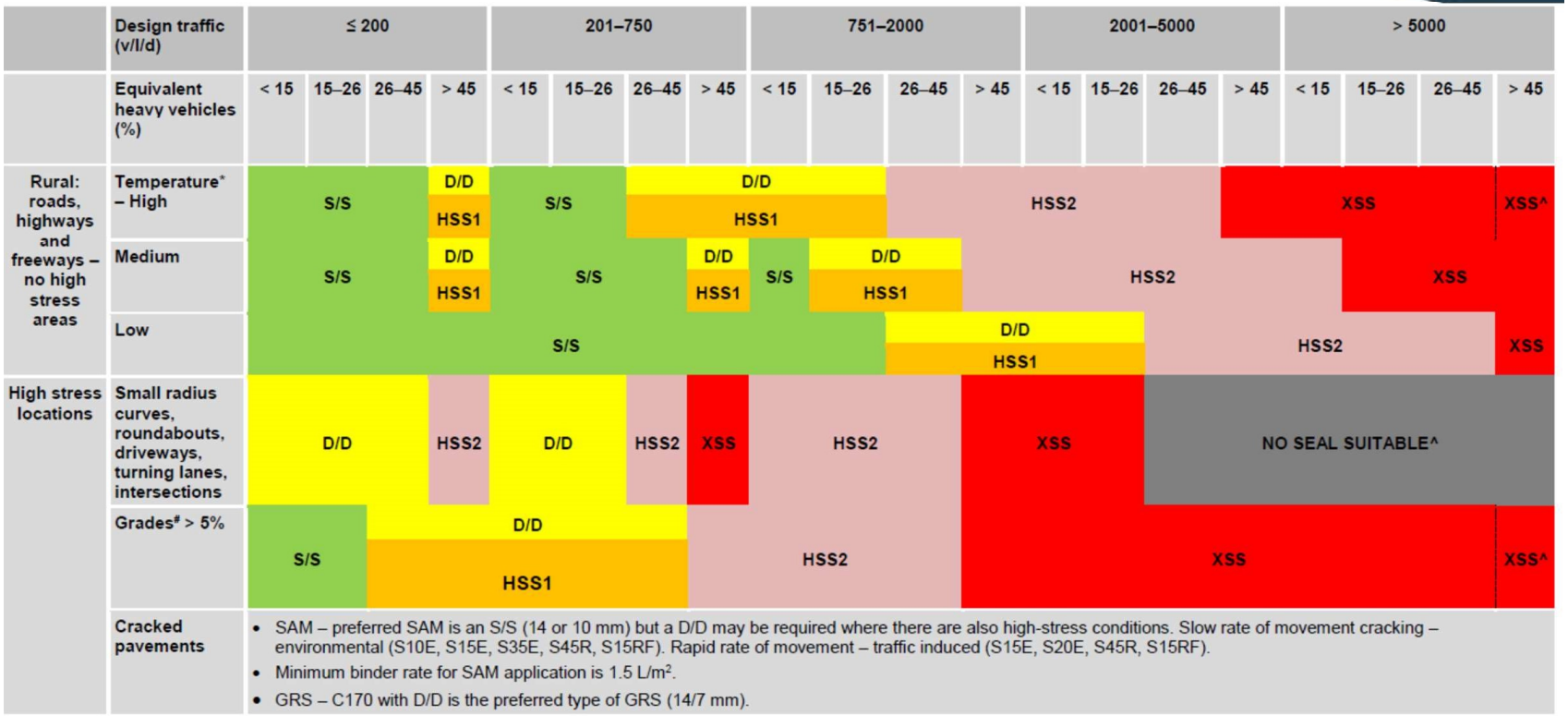


58

Extreme Stress Seals (XSS)

- **Double/double seal**
- **PMB – high modification S20E or S45R/S15RF**
  - **For rural highways with high numbers of heavy vehicles**
  - **Extreme stress e.g. long/steep climbing lanes > 5%**
  - **High Pavement Temperatures**

59



	Design traffic (v/l/d)	≤ 200				201–750				751–2000				2001–5000				> 5000			
	Equivalent heavy vehicles (%)	< 15	15–26	26–45	> 45	< 15	15–26	26–45	> 45	< 15	15–26	26–45	> 45	< 15	15–26	26–45	> 45	< 15	15–26	26–45	> 45
Rural: roads, highways and freeways – no high stress areas	Temperature* – High	S/S			D/D HSS1	S/S			D/D HSS1					HSS2				XSS			XSS^
	Medium	S/S			D/D HSS1	S/S			D/D HSS1	S/S			D/D HSS1	HSS2				XSS			
	Low	S/S				S/S				S/S				D/D HSS1				HSS2			XSS
High stress locations	Small radius curves, roundabouts, driveways, turning lanes, intersections	D/D			HSS2	D/D			HSS2	XSS	HSS2			XSS				NO SEAL SUITABLE^			
	Grades# > 5%	S/S	D/D HSS1							HSS2				XSS				XSS^			
	Cracked pavements	• SAM – preferred SAM is an S/S (14 or 10 mm) but a D/D may be required where there are also high-stress conditions. Slow rate of movement cracking – environmental (S10E, S15E, S35E, S45R, S15RF). Rapid rate of movement – traffic induced (S15E, S20E, S45R, S15RF). • Minimum binder rate for SAM application is 1.5 L/m^2. • GRS – C170 with D/D is the preferred type of GRS (14/7 mm).																			

Summary guide to selection of PMB's

Application	Service condition				Binder class							
	Cracking activity	Width severity	Site severity	Traffic loading	M500/ 170	S10E	S15E	S20E	S25E	S35E	S45R S15RF	S18RF
HSS1	NA	NA	Moderate	Medium	■	■	■			■	■	
				Heavy			■			■	■	
			Severe	All				■			■	
HSS2(1)	NA	NA	Severe	Medium	■	■				■	■	
				Heavy		■	■	■		■	■	
XSS(2)	NA	NA	Severe	All			■	■			■	
SAM	Slow	All	NA	All		■	■			■	■	
	Rapid	Low	NA	All			■	■			■	
		High	NA	All				■				■
SAMI	All	All	NA	All					■			■

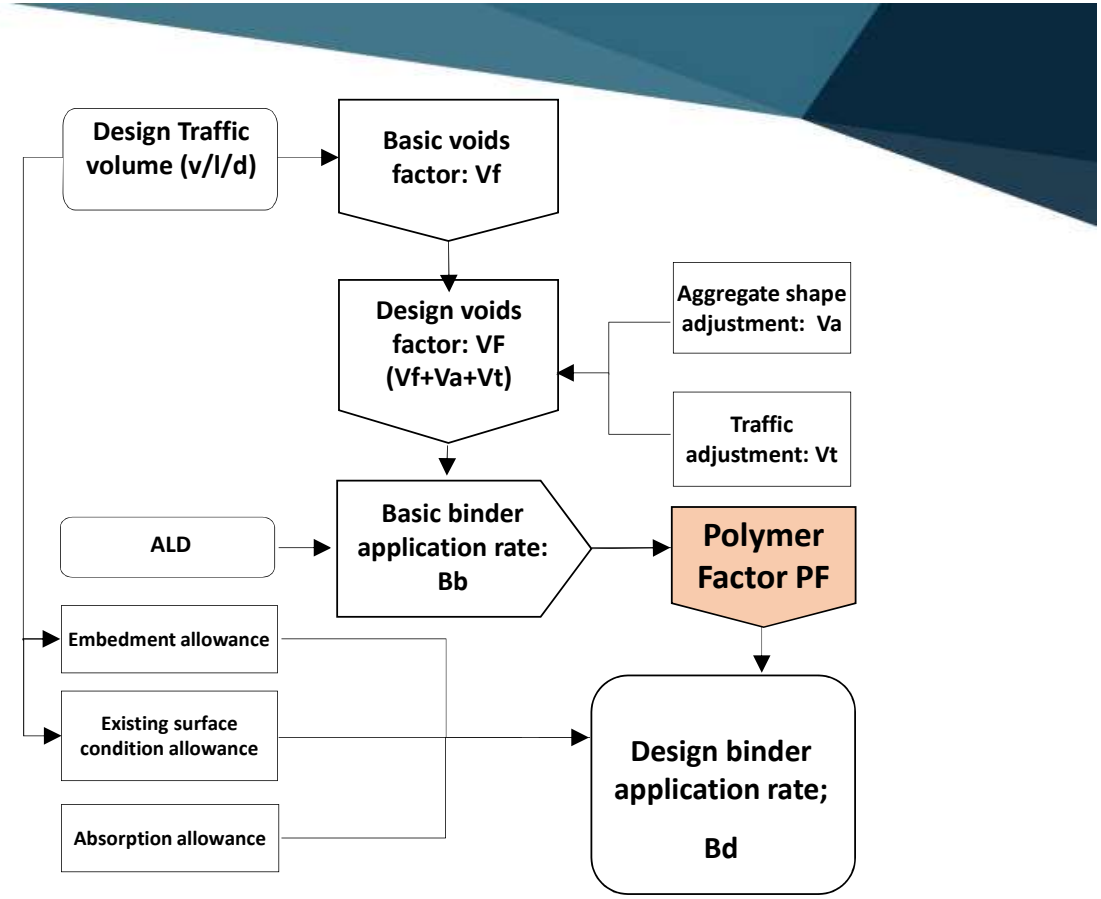
61


AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
CRM sprayed seal design
ED
TyreStewardship AUSTRALIA
62

Item 8 / Attachment 10.

DESIGN FLOW CHART

Single/Single PMB Seals



63

Design of PMB seals

Same design philosophy

Modified binder design rate:

$$Bd\ (L/m^2) = (Bb \times \mathbf{PF}) + Allowances$$

- Bb = Basic Binder Application Rate
- PF = PMB factor for SAM, HSS, SAMI ….
- Bd = Design Modified Binder Application

Allowances as normal

Note – PMB factor is multiplied not added

64

PMB factors - HSS

High Stress Seal (HSS)		
S10E **S35E**	**1.0**	**Generally these factors should not be adjusted** **They may be reduced, if required, by 0.1 on very high traffic applications and/or hot to very hot locations to minimise flushing or binder pick-up**
S15E **S20E** **S45R** **S15RF**	**1.1**	
M500	**1.1**	

PMB factors - SAM

Strain Alleviating Membrane (SAM)		
S10E	1.2	The SAM factors are designed to optimise resistance to reflective cracking and waterproof the pavement They may be reduced by 0.1 on very high traffic applications and/or hot locations to minimise flushing or binder pick-up Do NOT use these factors in other PMB applications
S15E S20E	1.3	
S35E	1.2	
S45R S15RF S18RF	1.4	

Minimum recommended Bd = 1.5 L/m² where possible

PMB factors – other applications

Class of PMB	PMB factor	Type of treatment
Aggregate retention (AR)		
S10E	1.1	The factors for AR may be increased by 0.1 on low traffic applications, but reduced by 0.1 on high to very high traffic applications and/or high temperature locations in order to minimise flushing.
S35E	1.1	
Holding treatment (HT)		
S10E	1.2	The factors for HT may be increased by 0.1 on low traffic applications, but reduced by 0.1 on high to very high traffic applications and/or high temperature locations in order to minimise flushing.
S35E	1.2	
S45R/S15RF	1.3	
Weak pavements (WP)		
S15E, S20E	1.3	The factors for WP may be increased by 0.1 on low traffic applications where maximum waterproofing is desired and the potential for flushing is low, but reduced by 0.1 on very high traffic volume applications.
S45R/S15RF	1.3	
As a waterproofing seal under OGA (not a SAMI)		
S10E, S35E	1.3	Being placed under open graded asphalt, there is little risk of bleeding and the factors should not require further adjustment, although they may be increased, if required, by 0.1 to provide maximum waterproofing.
S45R, S15RF	1.4	
High Stress Seal (HSS)		
S10E, S35E	1.0	Generally these factors should not be adjusted.
S20E, S45R, S15RF	1.1	
Strain Alleviating Membrane (SAM)		
S10E	1.2	The SAM factors are designed to provide the maximum practicable binder application rate to optimise resistance to reflective cracking and to waterproof the pavement. They may be reduced, if required, by 0.1 on very high traffic applications and/or hot to very hot locations to minimise flushing or binder pick-up.
S15E, S20E	1.3	
S35E	1.2	
S45R, S15RF	1.4	
Strain Alleviating Membrane Interlayer (SAMI)		
S25E	1.6	The SAMI factors are designed to optimise the resistance to reflective cracking under Dense Graded Asphalt. The factors may be increased by as much as 0.5 when the SAMI is designed to minimise reflective cracking under open graded asphalt.

PMB seal - Aggregate spread rates for 10mm and larger

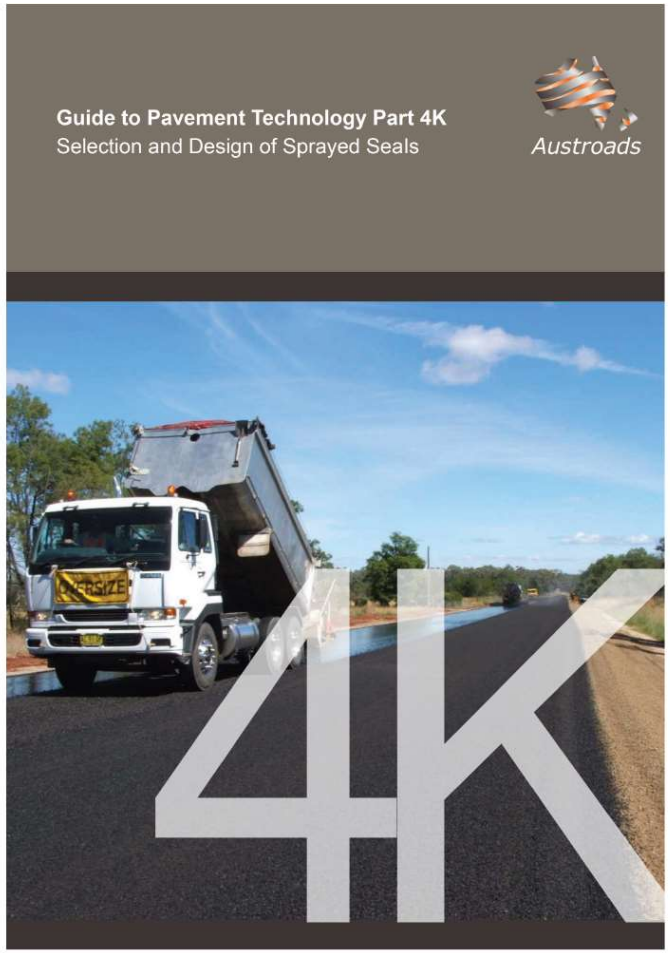
Traffic (v/l/d)	Aggregate spread rate (m^2/m^3)
< 300	750 / ALD
≥ 300	800 / ALD
SAMI	1000 / ALD

Sprayed seal design

Single seals

Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals

- Design rubber seals as all other Polymer Modified Binder seals
- PMB factors for S45R/S15RF or S55R/S20RF



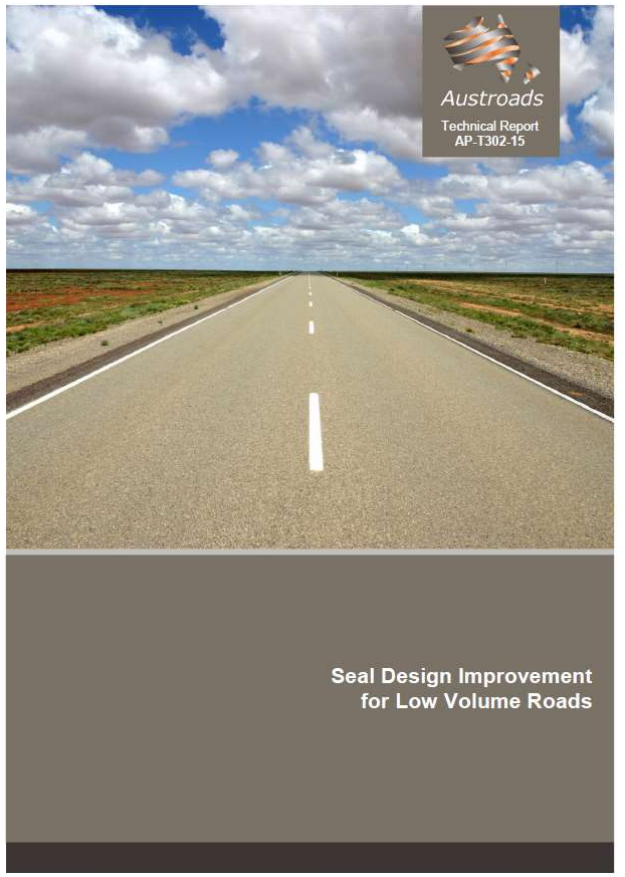
69

Sprayed seal design

Low Volume Road Single seals

Use AP-T302-15 ‘Seal Design Improvement for Low Volume Roads’ with the new basic voids factor (Fig. 5.2)

Then use AP-T68-06, ‘Update of the Austroads Sprayed Seal Design Method’ with §4 ‘Polymer Modified Binder’ as before



70

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

CRM sprayed seal construction

TD

TyreStewardship AUSTRALIA

71

CR Binder supply

CRBs are produced by one of the wet processes

As discussed earlier…..

- Mobile, on-site
- Fixed factory location, and transported to site

72

CR Binder supply

How should CRM binders be handled

- Sprayed seal binders are produced by one of the wet processes
- Controlling viscosity by managing temperature is important
  - Bitumen may be heated to 200 °C to enable mixing
  - Transfer temp should be 190 – 195 °C
  - A large in-line strainer mesh is recommended
- Larger spray nozzles (Copley B6) should be used

Sources: Jud et al. 2008; Vicroads 2004; Wu et al 2015 73

CR Binder supply

Storage of binder

Field produced: keep binder agitated

Factory produced: some do not need constant agitation

The distinction above has become blurred – check the manufacturers recommendation

Sprayed seal construction

A subset of polymer modified binders

- Placement of crumb rubber binders is basically the same as for any Polymer Modified Binder, except for some individual tweaks
- Refer to AAPA sprayed sealing course/notes for general seal construction

Construction

- Pavement temperature > 20^{o}C and rising
- Cutback CRB in sprayer with 4% kerosene and add 1% adhesion agent
- Circulate and heat binder to 190 - 200^{o}C before spraying
- Use precoated aggregates
- Chip spreading tippers to follow directly behind sprayer
- Use pneumatic tyred rollers to orientate stone on ALD and form stone matrix
- Sweep off loose stone same day before opening to traffic
- Use of adhesion agent is recommended to ensure minimal chip loss



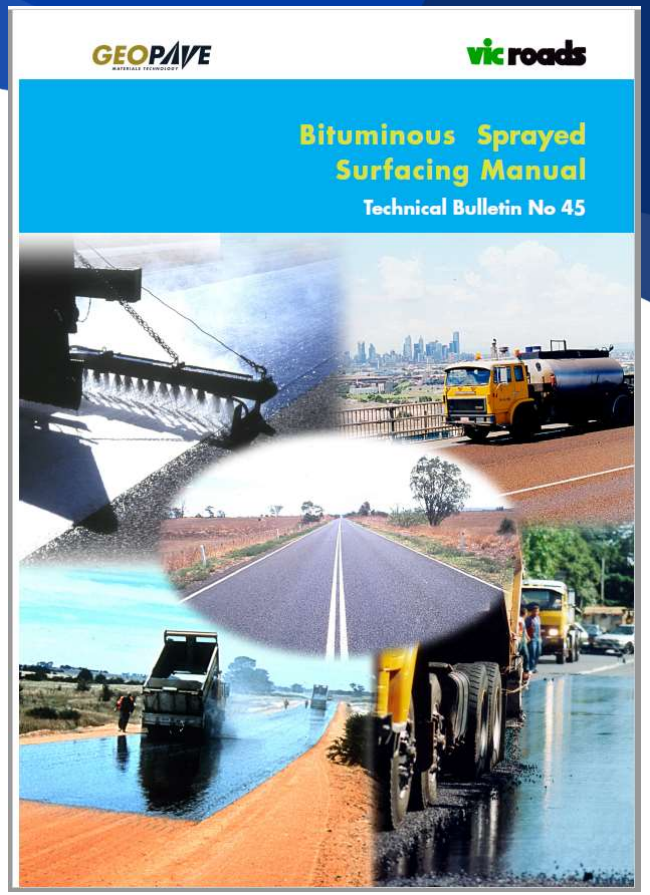

76

CR Binder placement

Victoria

VicRoads 2004, Bituminous sprayed surfacings manual, Technical Bulletin No 45, VicRoads, Melbourne.

https://www.vicroads.vic.gov.au/~/media/files/technical-documents-new/technical-reports-and-bulletins/technical-bulletin-tb-45--bituminous-sprayed-surfacing-manual.pdf



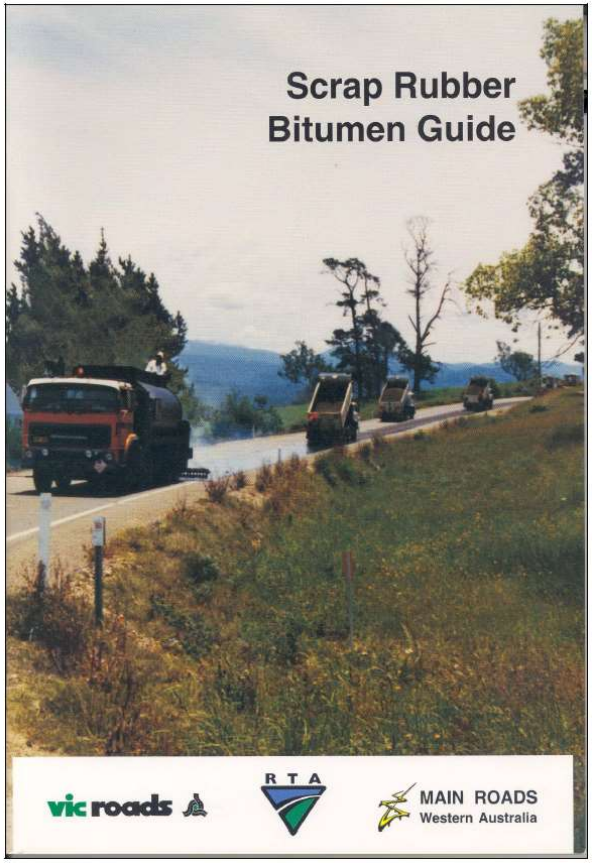
77

CR Binder placement

Victoria, NSW, WA, 1995

VicRoads, Roads and Traffic Authority, Main Roads Western Australia,1995, Scrap Rubber Bitumen Guide.

https://www.mainroads.wa.gov.au/Documents/ScrapRubberBitumenGuide.pdf



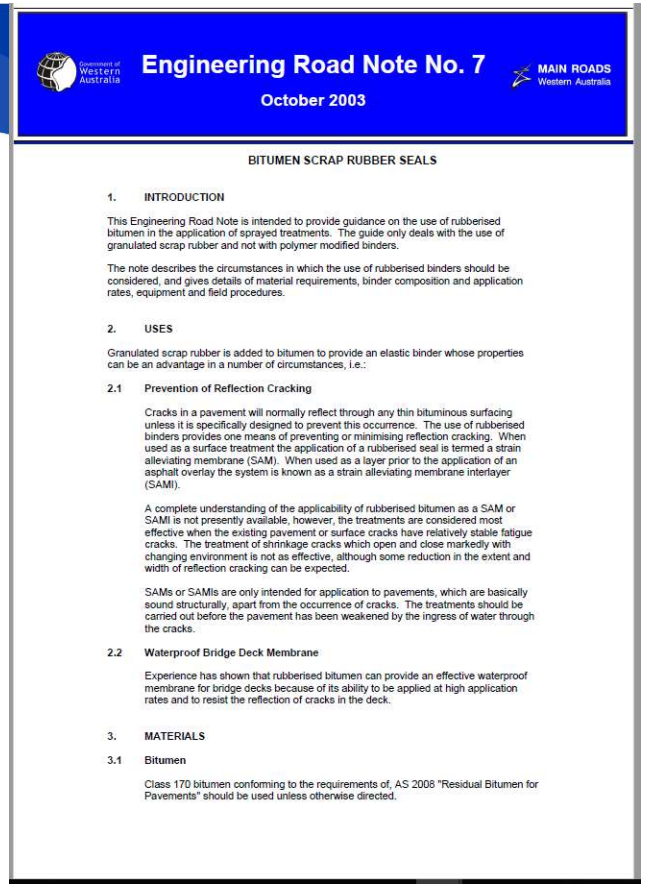
78

CR Binder placement

Western Australia

Main Roads Western Australia 2003, Bitumen Scrap Rubber Seals, Engineering Road Note 7, MRWA, Perth.

https://www.mainroads.wa.gov.au/Documents/EngineeringRoadNote7final_08102003_9999991.pdf



Engineering Road Note No. 7

October 2003

MAIN ROADS Western Australia

BITUMEN SCRAP RUBBER SEALS

1. INTRODUCTION

This Engineering Road Note is intended to provide guidance on the use of rubberised bitumen in the application of sprayed treatments. The guide only deals with the use of granulated scrap rubber and not with polymer modified binders.

The note describes the circumstances in which the use of rubberised binders should be considered, and gives details of material requirements, binder composition and application rates, equipment and field procedures.

2. USES

Granulated scrap rubber is added to bitumen to provide an elastic binder whose properties can be an advantage in a number of circumstances, i.e.:

2.1 Prevention of Reflection Cracking

Cracks in a pavement will normally reflect through any thin bituminous surfacing unless it is specifically designed to prevent this occurrence. The use of rubberised binders provides one means of preventing or minimising reflection cracking. When used as a surface treatment the application of a rubberised seal is termed a strain alleviating membrane (SAM). When used as a layer prior to the application of an asphalt overlay the system is known as a strain alleviating membrane interlayer (SAMI).

A complete understanding of the applicability of rubberised bitumen as a SAM or SAMI is not presently available, however, the treatments are considered most effective when the existing pavement or surface cracks have relatively stable fatigue cracks. The treatment of shrinkage cracks which open and close markedly with changing environment is not as effective, although some reduction in the extent and width of reflection cracking can be expected.

SAMs or SAMIs are only intended for application to pavements, which are basically sound structurally, apart from the occurrence of cracks. The treatments should be carried out before the pavement has been weakened by the ingress of water through the cracks.

2.2 Waterproof Bridge Deck Membrane

Experience has shown that rubberised bitumen can provide an effective waterproof membrane for bridge decks because of its ability to be applied at high application rates and to resist the reflection of cracks in the deck.

3. MATERIALS

3.1 Bitumen

Class 170 bitumen conforming to the requirements of, AS 2008 "Residual Bitumen for Pavements" should be used unless otherwise directed.

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

International practice

TD

TyreStewardship AUSTRALIA

80

Sprayed sealing

South Africa

2011+2018 AAPA study tours

- South Africa had used CR for since the 1980s
- Specialised sprayers used
  - Larger nozzles
  - Stronger pumps
  - Agitation
- Also had equipment to blend on site

81

Sprayed sealing

South Africa

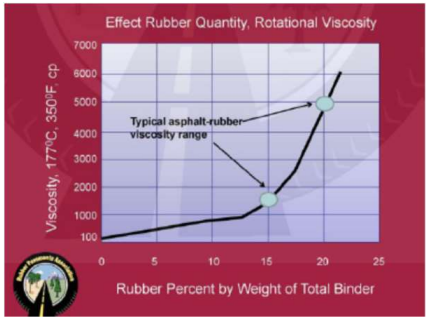
2011+2018 AAPA study tours

- Field blended >20% crumb rubber used as a heavy duty seal
- Large projects enable portable blending sites to be established
- New crumb rubber technology: low temperature, storage stable, no cutter

Photographs: Kym Neaylon 82

Field blend ratios

	Component	Bitumen	Rubber	Oil	Cutter	Adhesion agent
	Australia	82 – 85%	15 & 18%	nil	> 4%	1%
	South Africa	76%	20 – 22%	2%	Nil	nil
		Plant blending			Sprayer blending	



Field vs factory blended

Field 

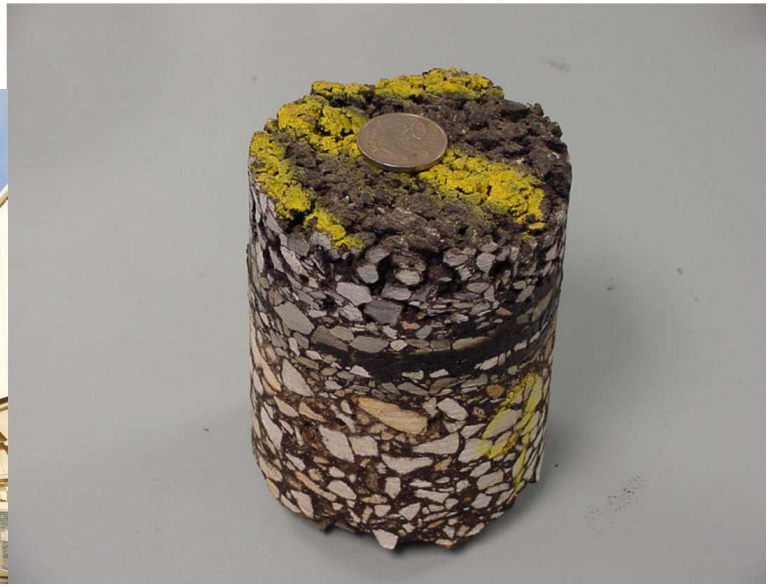
- Higher rubber content
  - more effective for demanding applications
  - not suitable for extended transport and storage
  - higher risk of rubber degradation & settlement

Factory 

- Lower rubber content
  - more stable for transport and storage
  - easier to spray (less viscous)
  - no site establishment required
  - opportunities to use higher rubber content stabilised CRB


AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
CRM Asphalt
ED
TyreStewardship AUSTRALIA
85

Crumb rubber in asphalt



Crumb rubber modified asphalt

Australia

- Dry process used for decades by some Australian jurisdictions.
- Dry process: proportion of aggregate replaced by rubber
- Used in gap graded surfacing layers
- Limited market penetration

Source: AAPA 2010

87

Asphalt

Australia recent developments

- Crumb rubber modified open graded asphalt (OGA) and gap graded asphalt (GGA)
- Wet process

Source: AAPA 2010

88

Asphalt

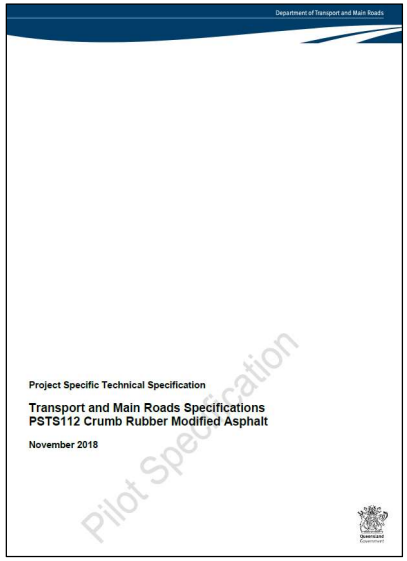
Crumb rubber modified asphalt

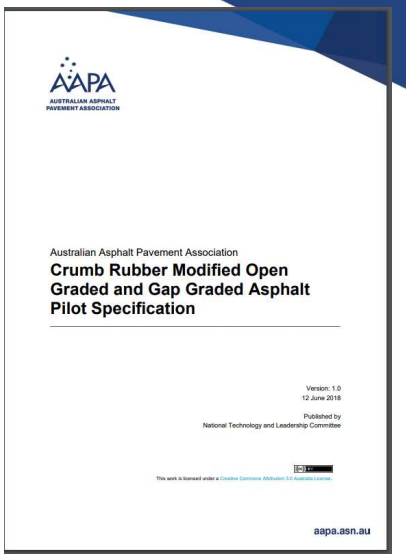
- High viscosity ➔ high binder content without drain down or bleeding
- High film thickness ➔ improved durability
- High binder + elastomeric properties ➔ improved cracking resistance and aggregate retention

Asphalt

Developing a CRM OGA and GGA specification

- Based on Arizona/California technology
- >18 % rubber by mass of binder
- MRWA,TMR,AAPA,TSA
- Use of **warm mix** mandatory
- Mixing temperature ≤ 165 ^{o}C





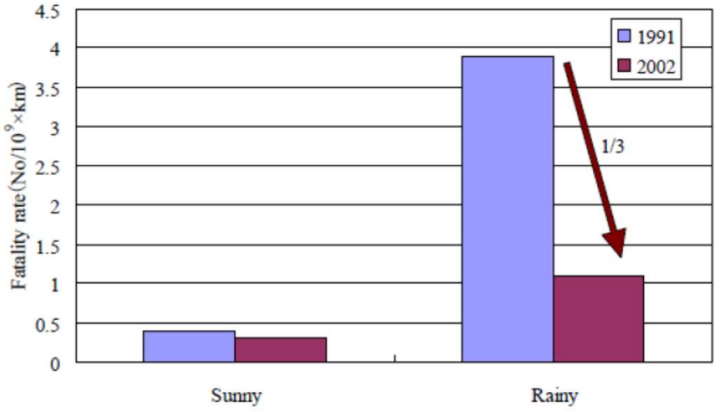
www.aapa.asn.au/aapa-national-model-specifications/

90

Potential uses

Open graded asphalt

- Benefits:
  - Safety
  - Noise reduction
- Limited use in Australia due to reduced service life
- CRM OGA more durable



Crumb rubber open graded asphalt (OGA)

First application

Bli-Bli trial

Objectives

- Validate specification
- Monitor harmful emissions

Method

- Hot mix rubber OGA10
- Warm mix rubber OGA10
- SBS modified OGA10 (control)

Demonstration successful, performance being monitored

Potential uses

Gap graded asphalt

- Fatigue resistant layer
- Surfacing on granular pavement
- Overlay cracked pavement

Potential uses GGA

Overlay over cracked pavement

- Superior resistance against reflective cracking based on years of experience in US
- Significant thickness reductions possible
- Main consideration for introducing CRM GGA technology to Australia

Crumb rubber Gap Graded asphalt (GGA)

First application

Gold Coast trial (June 2018)

Objectives

- Validate specification
- Monitor harmful emissions

Method

- Warm mix rubber GGA14
- AC14 with SBS
- AC14 with C320

Demonstration successful, performance being monitored

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

Emission monitoring

ED

TyreStewardship AUSTRALIA

96

Emission monitoring

Sprayed seal

Emission monitoring OGA

Emission monitoring

Loose asphalt mix:

- 2 flux chambers
- Temperatures same as at start of paving (130 – 155 °C)
- Sampled:
  - Polycyclic aromatic hydrocarbons (PAHs)
  - Volatile organic compounds (VOCs)
  - Total suspended particles (TSPs)

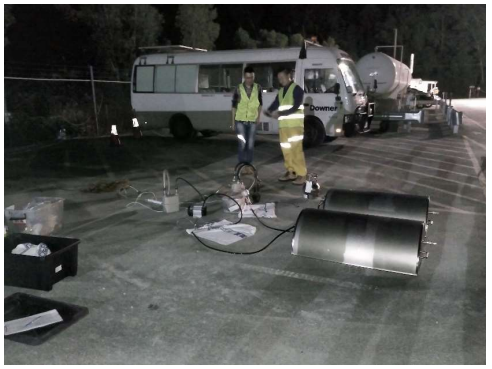
Worker exposure:

- Personal monitoring devices
- Paver operator and asphalt delivery supervisor

Emission monitoring OGA

Emission monitoring

- No significant difference TSPs different mixes
- Compounds vary between binder types
- Temperature is the dominant factor in emissions
- Use of warm mix mandated in specifications



Emission monitoring GGA

Emission monitoring

- Investigation of paver crew exposure using personal monitoring devices

Emission monitoring

Findings

Temperature dominant factor in emissions

Worker exposure study did not identify harmful emissions above recommended exposure limits

Lowering asphalt can reduce risk of exposure to emissions – lowering asphalt temperatures (<145°C) is the way forward

Warm mix specified

Way forward

Wider use of crumb rubber modified binder in Australia

- Clear sustainability benefits
- CRM sprayed seal technology mature and now applied in more states
- Few, technical challenges remaining for wider use in asphalt
- Emission assessment to continue

AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

Topic 2: surface preservation

TD

104

Surface preservation

Preventative maintenance practice on low volume roads

105

Surface preservation

How to prevent 50 shades of grey

106

Presentation overview

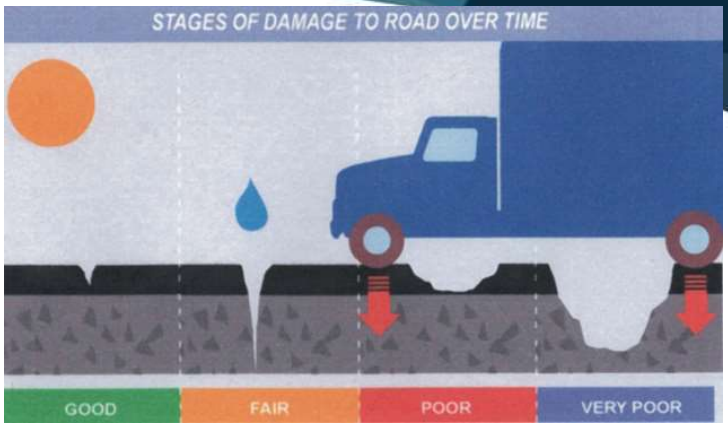
- Introduction
- Bitumen hardening
- Strategies to reduce bitumen hardening
- What preservation treatments to use
- Case study
- Sustainability aspects of emulsion based techniques
- Conclusion

Introduction

- Australia has approx 394,000 km of surfaced roads of which the majority are lightly trafficked
- > 80% of surfaced road network is sealed with sprayed seals
- Hot binders cutback with kerosene are used in these spray seals
- Hot bitumen modified with SBS, PB and crumb rubber are also used
- Limited use of emulsions in surface dressing mainly due to long haul distances

Introduction

- The deterioration of the low trafficked roads is **mainly from oxidisation of the bitumen** in the surfacing and not from traffic
- The presence of oxygen and ultra violet causes the properties of the bitumen to harden
- This can result in premature cracking and stone loss during in-service life
- Traffic on the other hand can have the benefit of closing micro cracks constraining oxidation

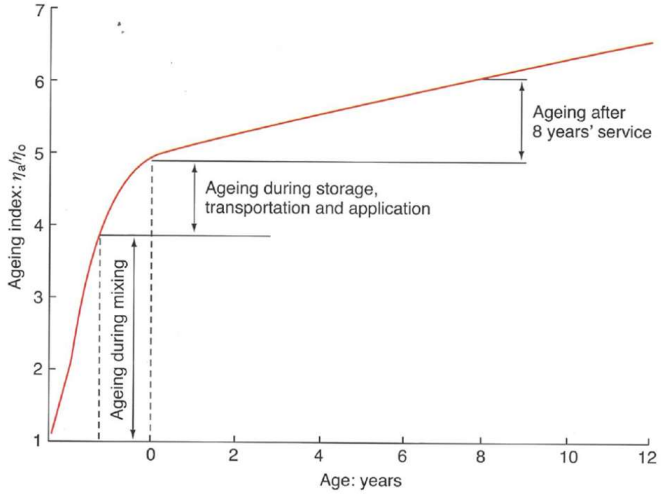


Cause	Effect	Consequence
Environment effect	Oxidation UV radiation from sun	Loss of volatile and oils in the bitumen
Binder	Hardening Loss of adhesion	Fatigue cracking Aggregate loss
Surfacing	Surface cracks	Leads to water entering and weakening the base
Pavement	Potholes	Expensive repairs

109

Bitumen hardening

- Bitumen hardens during different stages of its life
  - Handling in hot liquid form
  - In-service life on the road
- Bitumen hardening is desirable for heavily trafficked road to prevent rutting and increase stiffness of asphalt



110

Strategies to reduce bitumen hardening

- The ideal resealing frequency for rural road network is between 10 – 12 years with a sprayed seal
- Most of our surfaced network is under the control of Councils who have limited funding for road maintenance
- We need maintenance strategies than will extend the life of these low trafficked urban roads to prevent them deteriorating from oxidation and not traffic
- In other words we need to defy the ageing process – retard oxidation of the bitumen

111

Strategies to reduce bitumen hardening

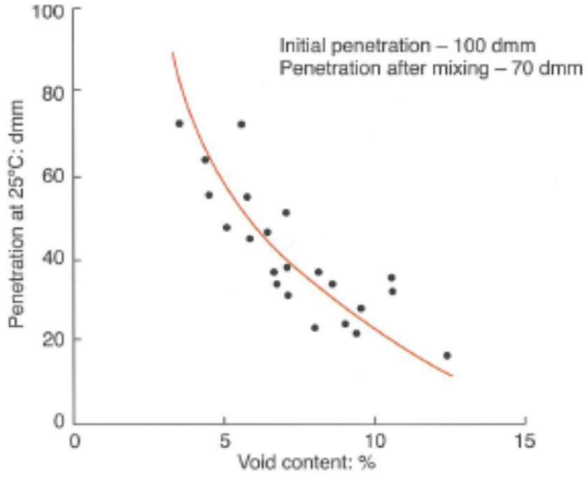
- Change elements in the design and construction of new surfacings
  - Sprayed seals
  - Asphalt
- Change maintenance philosophy from reactive to preventative maintenance
  - Timeous intervention during the service life
  - Make use of more cost effective surface preservation techniques to extend surface life and increase network coverage of financial spend

112

Strategies to reduce bitumen hardening

Asphalt

- SRA's specifications are focussed on preventing rutting under heavy traffic conditions
- Change asphalt specifications to accommodate low traffic conditions:
  - Increase the bitumen content
  - Use softer bitumen
  - Compact to lower insitu air voids
- Make use of warm mix technologies
  - Reduce binder ageing during mixing

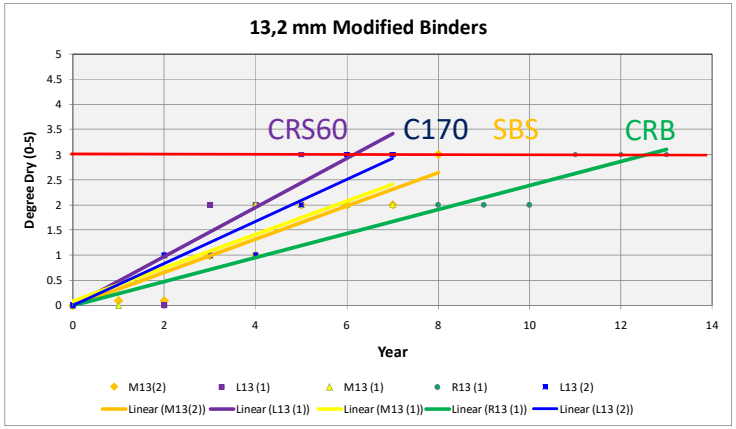


113

Strategies to reduce bitumen hardening

Spray seals

- Increase bitumen applicate rate without risk of increasing bleeding by:
- Using larger aggregate size
- Modifying bitumen with rubber
  - Increases viscosity of the binder
  - Carbon black in the rubber acts as an antioxidant

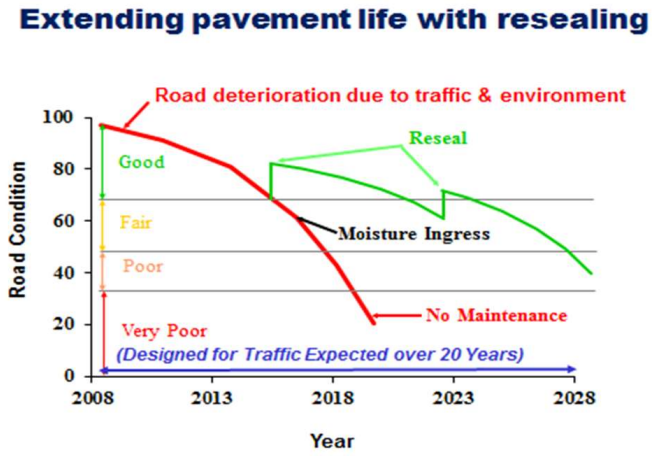


Service life of single seals with different binders

(South African data)

Strategies to reduce bitumen hardening

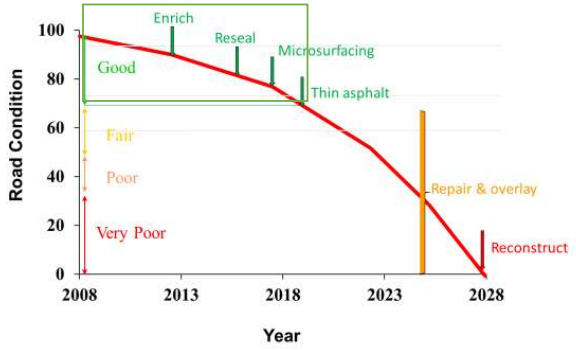
- Traditional approach is timeous intervention during in-service life to extend the pavement life



115

Strategies to reduce bitumen hardening

- Make use of more cost effective surface preservation techniques to extend surface life and increase network coverage of financial spend
- Cold emulsion
  - Spraying dilute bitumen emulsions (DE)
  - Spraying mineral filled polymer modified bitumen emulsions (PME)
  - Paving microsurfacing (MS)
- Hot binder
  - Cut-back C170 enrichment
  - Spray a crumb rubber modified binder single seal with large aggregate



Cost 1X

Cost 6x

Cost 18x

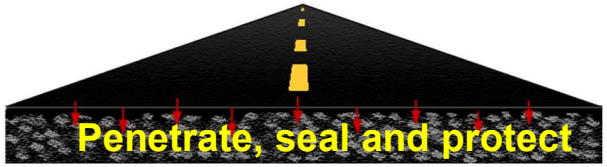
Extending pavement life with rejuvenating

116

What preservation treatment to use

The decision on which **surface enrichment treatment** to use will depend on:

- Condition of existing pavement
  - Must be structurally sound
- Type of surface distress
  - No active cracking only aged cracking
  - Binder brittleness
  - Stone loss



- Having sufficient surface texture in the surfacing to accommodate DE without increasing risk of vehicles skidding in wet weather
- Time required to open the surface to traffic
- Gradient and cross fall of the surfacing

117

Before **After**

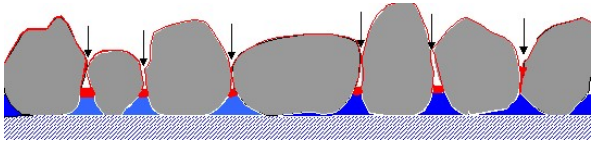
Cutback bitumen surface enrichment at 0.7L/m²

118

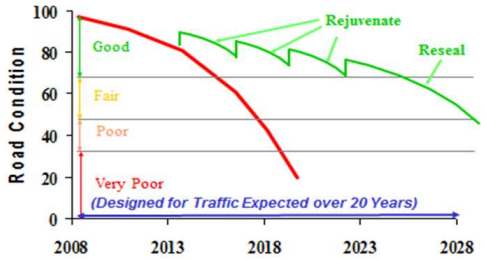
Surface Enrichment

- Binder without aggregate
- Used to
  - waterproof
  - extend life
- Existing surface MUST have texture
- May be repeated if texture is adequate
- Low traffic or where easily detoured/kept off
- Take several hours to dry
- Life expectancy - 4 to 6 years

When to use …



Extending pavement life with rejuvenating

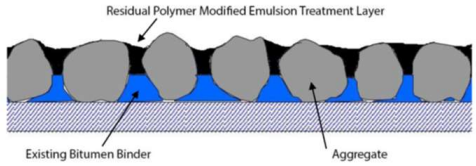


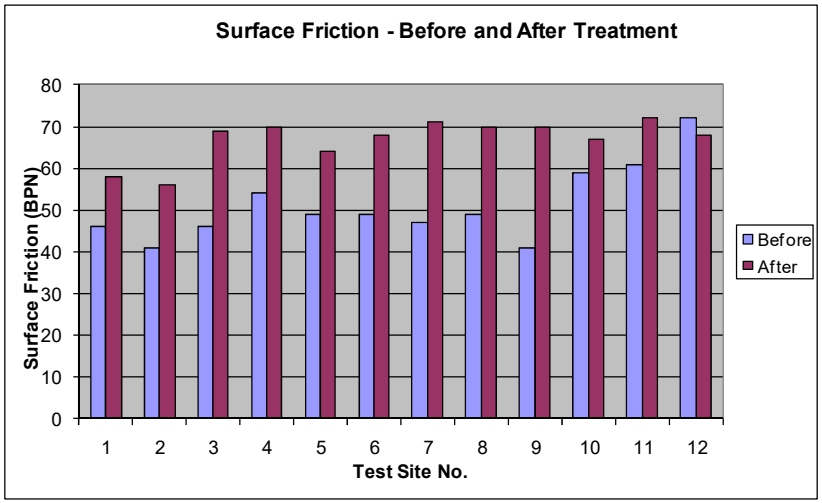
- Dilute Bitumen Emulsions:
  - Will help enrich an ageing spray seal thereby help improve the aggregate retention and waterproof the base.
  - Typically CRS30 or proprietary emulsion is sprayed with a conventional sprayer at a net bitumen application rate of 0.15 l/m2 for this purpose.
  - The application rate will depend on the existing surface texture.
  - This can best be determined beforehand by carrying out small trail sections by hand applying different DE rates to the candidate surface.
  - Ideal surfaces are road shoulders, runways and low volume rural roads
  - Can be applied a number of times before resealing is required

When to use …

Polymer Modified Emulsions:

- Allows application rate of the mineral filled binder to be increased up to 1 l/m2 without increasing the risk of skidding
- Will extend the life of the existing surfacing substantially longer than DE because of the incorporation of polymer and higher bitumen application rate
- Will reduce permeability whilst increasing surface friction
- Applied with purpose built sprayers and are sold under brand names



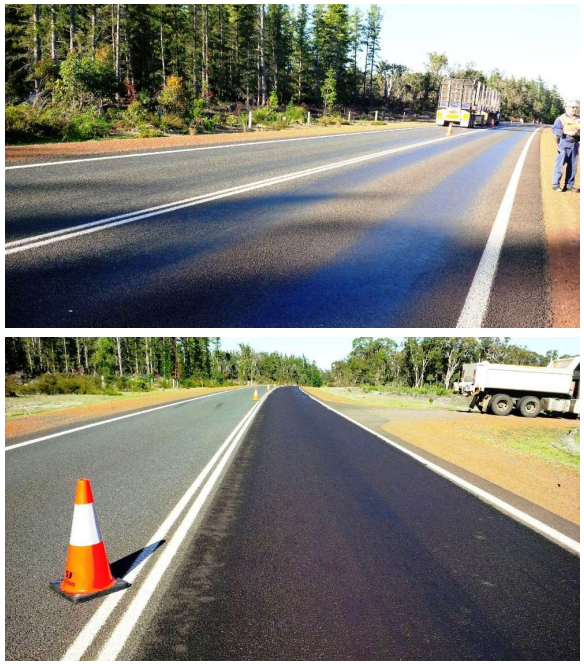


121

When to use …

Microsurfacing:

- Can be used where:
  - The existing surface requires an improvement in profile correction
  - The ruts are > 6mm then the MS needs to be applied in two applications.
- A special rut filling box can be used to restore profile in a single pass with if rut depth is <15 mm
- Treatment thickness can vary between 5 - 20mm
- When rut filling make sure that the deformation is not in the surfacing layer but is from the consolidation of the under lying layers
- Is mixed and laid with a special machine in a one pass application



122

When to use …

Microsurfacing is effective for:

- **improving durability** by preventing further oxidation of aged binder in existing surface
- **preventing the ingress of water** into the underlying layers by filling in micro cracks and voids of existing surface
- **improving the skid resistance** by increasing the micro texture of the surfacing
- **improves the rideability** by filling the undulations in the existing surface

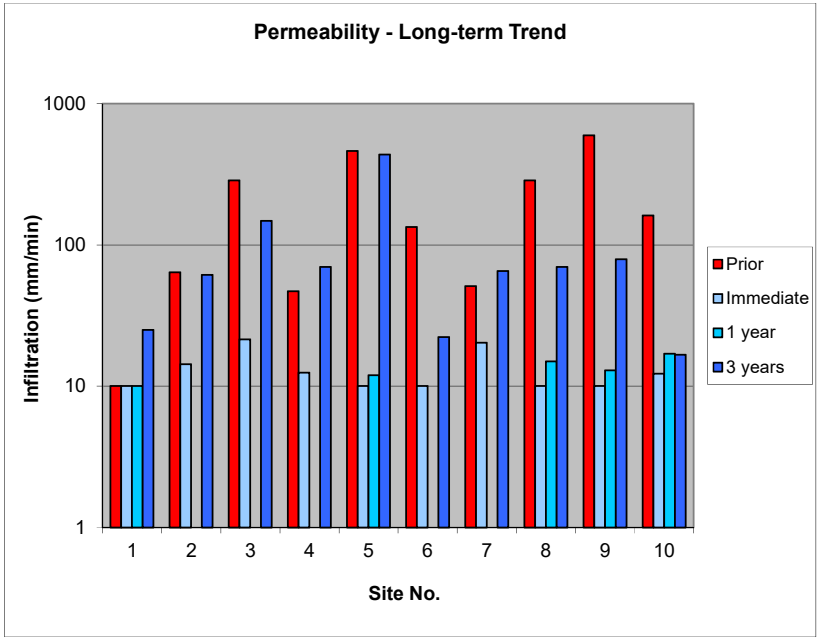
But not for stopping large reflective cracking

- Localised fatigue cracking must be repaired prior to placing of Colmat
- Cracks in the aged existing surface caused from binder ageing will not reflect through Colmat

123

Case study : Penrith Council

- Situated due west of Sydney
- Since 2000 has been applying between 100,000 to 150,000 m2 of PME's per annum
- Permeability tests showed that it gave them addition 3 to 4 years life
- With same financial budget it freed up 20% more funds for expensive repairs
- Use PMS system to identify roads for enrichment
- Need to treat every surface between 3 – 7 years



124

Sustainability aspects of preservation treatments

- Extending the life of the pavement and thereby reducing the demand for non-renewable materials like aggregates which would normally be used in the construction of reseals and asphalt overlays
- The use of **surface enrichment techniques** make the maintenance of road pavements more sustainable by:
  - Reducing energy consumption in the manufacturing and application process
  - Reducing GHG emissions
  - Improving worker health and safety by reducing exposure to harmful fumes and risk of hot bitumen burns
  - Minimises the number of construction vehicles used per unit area

125

Summary surface preservation

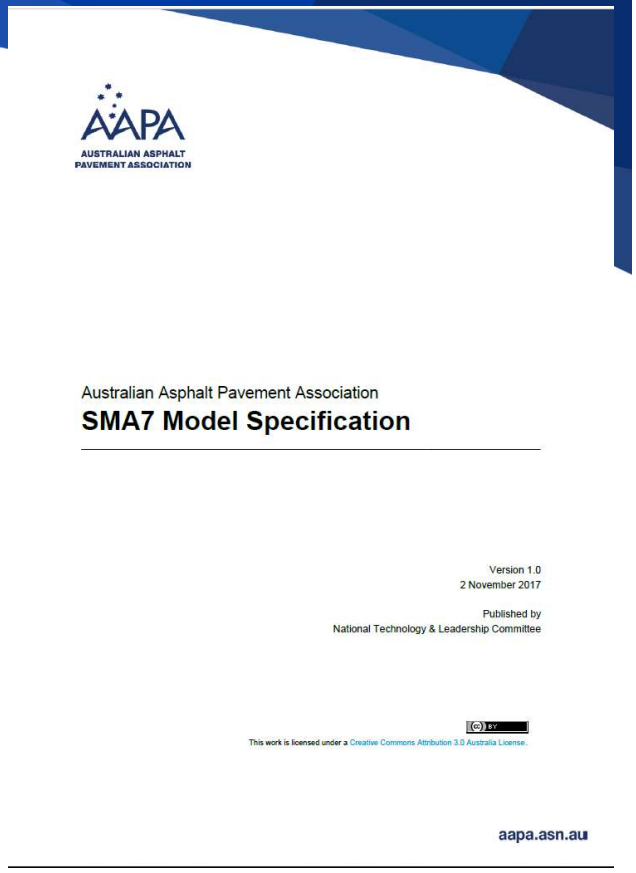
- There are a number of strategies to extend the life of bituminous surfacings in low trafficked environments from the **harmful effects of bitumen hardening**
- Measures can be taken in the **selection, design and types of materials used** in the bituminous surfacings that can increase the durability of spray seals and asphalt
- **Timeous application of preservation treatments** can be a very cost effective tool to allow Council's to ensure that they can maintain their road network in a good condition
- Emulsion based treatments in the form of **dilute emulsions, mineral filled polymer modified bitumen emulsions and microsurfacing** can be applied to retard binder ageing and prolong the road surface life before more expensive periodic maintenance is required in the form of a spray seal or asphalt overlay
- The **use of these cold applied treatments** help improves the sustainability of road pavements by conserving scarce non-renewable aggregates which would normally be used in road maintenance, protecting the environment and improving worker health and safety
- The **reuse rubber** to modify bitumen helps keep old tyres out of land fills and increases the durability of sprayed seals


AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
Topic 3: SMA7
ED
127

7mm Stone Mastic Asphalt

SMA7 National Model Specification

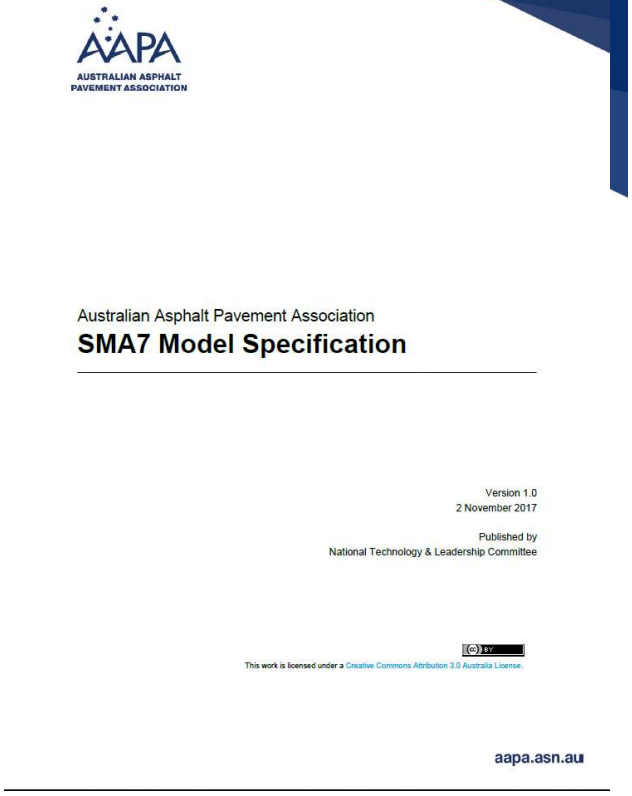
- Developed by AAPA members to reflect national best practice
- Makes cost effective thin surfacing available to every road agency in the country
- Use PMB where traffic > 100 commercial vehicles per day



SMA7

Benefits

- 25mm – 35mm thickness
- Durable, rut resistant surfacing
- Easy matching of existing levels
- Lower m^2 cost




AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION
2/20 Sabre Drive
Port Melbourne, VIC 3207
Telephone (03) 8416 4509
aapa.asn.au

Abstract submission for the 18th AAPA International Flexible Pavements Conference & Exhibition NOW OPEN!!!

Call For Abstracts

Abstracts are invited on following themes:

- Circular Economy
- Preservation and Rehabilitation
- Roads as a Service
- Continual improvement

Abstract Submissions

Abstracts are invited for two types of submissions:

1. Full peer reviewed paper
2. Presentation only

Timeline

Final deadline for abstract submission (early submission encouraged)	31/10/2018
Deadline for full papers	31/01/2019
Deadline for presentations (without paper)	31/01/2019
Final papers	31/05/2019
Final presentations (without paper)	30/06/2019

For more information, or to submit your abstract, visit https://www.conference.aapa.asn.au

Journal of Cleaner Production 348 (2022) 131372

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Exposure of crumb rubber modified bitumen to UV radiation: A waste-based sunscreen for roads

Muhammad Jamal [a], Michele Lanotte [b], Filippo Giustozzi [a,*]

[a] Civil and Infrastructure Engineering, RMIT University, Melbourne, VIC, 3000, Australia
[b] Civil Infrastructure and Environmental Engineering, Khalifa University, PO Box, 127788, Abu Dhabi, United Arab Emirates

ARTICLE INFO

Handling Editor: Zhen Leng

Keywords:
UV Ageing
Bitumen
Glover-rowe parameter
Crumb rubber
Recycling
Asphalt

ABSTRACT

The degradation of asphalt roads due to heat and moisture is well studied, but very little focus has been given to the effects of high energy transmitted by sunlight UV radiations. This study aims to investigate the effect of UV radiations on the chemo-mechanical properties of neat and modified bitumen with different concentrations of crumb rubber and compare it to that of thermal ageing. Samples were aged in the Q-Lab weatherometer for 869 h at 0.89 Wm^{-2}, equivalent to one year of UV radiations energy in the city of Melbourne, Australia, in 2019. Fourier transformation infrared (FTIR) spectroscopy was used for analysing the changes of chemical bonds before and after ageing. It was found that thermal ageing results in the development of carbonyl and sulfoxide oxides while evaporates the volatile components as depicted from the decreasing value of aliphaticity index. On the other hand, UV ageing mainly targets components with bond energy lower than 413 kJ/mol, i.e., C–C, C–O and C–H that usually consist of aliphatic chains of hydrocarbons. The rheological test results revealed that both thermal and UV ageing produce stiffer materials as depicted from the upward shift of the master curves. However, this shift reduces with the increase in CR concentration. All unaged samples were found to lay well below the Glover-Rowe onset damage envelope, however, as the samples underwent thermal ageing, they moved towards the onset damage zone. With the addition of UV ageing, the standard bitumen was only 13.2 kPa away from the 'onset damage' threshold while crumb rubber modified bitumen was almost 60 kPa away from the damage zone. Moreover, if neat bitumen is to be modified with 22.5% of CR, it can reduce the damage produced by UV and thermal ageing by approximately 50%, hence showing greater resistance to the thermal and solar radiation degradation.

1. Introduction

Just like many other materials, bitumen is also susceptible to degradation over time and the factors contributing to its ageing include oxygen present in the air, radiations coming from the sun, moisture in the form of precipitation or humidity in the air, and temperature variations (Menapace et al., 2018b). These environmental factors alters the chemical composition of the binder by increasing the polar components and inducing brittleness, thus making the binder susceptible to fatigue and thermal cracks, especially at low and intermediate temperatures (Gamarra and Ossa, 2018; Lu and Isacsson, 2002). Therefore, understanding and characterising the effect produced by ageing has practical implications on the durability of the road infrastructure. Bitumen undergoes short term ageing during the production process at the plant and consequent long-term ageing during its service life. Several ageing methods have been developed to simulate field ageing in the laboratory. The most common methods to simulate short and long term ageing are the rolling thin film oven (RTFO) and pressure ageing vessel (PAV) equipment under the guidelines of ASTM D2872-19 (ASTM, 2019a) and ASTM D6521-19 (ASTM, 2019b), respectively. The shortcomings of these methods are related to their consideration of the effect of heat and oxygen while moisture and solar radiations are commonly neglected; this aspect limits the scope of these methods and cannot accurately captures the fields condition. The American Society for Testing and Materials (ASTM) has developed some test methods to measure ageing produced by solar radiations (Table 1), although none of them is relevant to asphalt binders for paving applications. ASTM D4799 (ASTM, 2017a) seems relevant to bituminous materials but its scope is limited to bituminous roofing and waterproofing materials to be used in combination with ageing conditions mentioned in ASTM G151 (ASTM, 2019c)

* Corresponding author.
E-mail address: filippo.giustozzi@rmit.edu.au (F. Giustozzi).

https://doi.org/10.1016/j.jclepro.2022.131372
Received 6 December 2021; Received in revised form 5 March 2022; Accepted 12 March 2022
Available online 16 March 2022

Table 1
ASTM standards relevant to ageing due to solar (UV) radiations.

ASTM Designation	Standard Description
G151-19(ASTM, 2019c)	Standard practice for exposing non-metallic materials in accelerated test devices that use laboratory light sources
G154-19(ASTM, 2016)	Standard practice for operating fluorescent ultraviolet (UV) lamp apparatus for exposure of non-metallic materials
D4799-17(ASTM, 2017a)	Standard practice for accelerated weathering test conditions and procedures for bituminous materials (fluorescent UV, water spray, and condensation method)
D4587-11(ASTM, 2017b)	Standard practice for fluorescent UV-condensation exposures of paint and related coatings

and G154 (ASTM, 2016).

Moreover, the climatic conditions (precipitation, temperature, solar radiations) around the globe vary. In Australia, due to very harsh climatic conditions, the ageing phenomenon of the pavements in the field is significantly different from other temperate-climate regions even if the pavement is constructed with the same material. Therefore, a more precise and accurate estimate of the conditioning parameters is required to simulate field ageing. Various researchers tried to develop UV conditioning method to predict ageing with more accuracy. Recently, Crucho et al. (2018) proposed a new laboratory approach for the simulation of UV radiations and precipitation from the Solargis maps and meteorology department data, respectively. This approach was recently adopted by Menapace et al. (Menapace et al., 2018a, 2018b) for the study of environmental factors affecting ageing of bituminous binders. However, there are limitations with this approach as the Solargis maps plot global horizontal irradiation (GHI) and Crucho et al. (2018) used a factor of 3.14% for the conversion of GHI into UV radiations; however, this conversion factor is not universal but rather geographically dependent. According to Hu et al. (2018), bitumen ageing due to UV radiations is thickness dependent. Researchers have used various ageing depths as shown in Table 2 without achieving any consensus on what thickness is to be used. This emphasises that no standard procedure exists for the UV ageing of bituminous samples in terms of what UV intensity is to be set inside the chamber for a targeted ageing effect, or the process duration to generate correlation with field data, and optimal sample size and weight. In summary, there are four main challenges with regard to the UV ageing of bitumen; i) the wavelength that should be used to best correlate with the outdoor UV radiations, ii) the exposure time a sample should be kept inside the machine for to provide a meaningful relation with field ageing, iii) the sample size and iv) the distinction between the ageing occurred due to UV and heating.

In recent years, there is a growing trend towards sustainable construction and significant focus is given to the recycling of pavement material (Jamal Hafeez et al., 2018), waste plastics (Giustozzi et al., 2019; Joohari and Giustozzi, 2020; Nizamuddin et al., 2020) and end of life tyres (EOLTs) (Joohari and Giustozzi, 2021). In a recent report (Baker et al., 2020; TSA, 2019) published by Tyre stewardship Australia (TSA), it was found that a total of 465,218 tonnes of EOLTs are generated in Australia annually. EOLTs in the form of crumb rubber (CR) gives it a safer way of disposal and is beneficial for a circular economy approach (Dehghani et al., 2013; Giustozzi et al., 2012). The addition of CR to bitumen provides various advantages to asphalt pavements as it improves the high temperature stiffness and elastic response, also improving the fatigue resistance of the binder (Wang et al., 2020b). CR absorbs the maltenic fraction of bitumen during the blending phase and consequently changes the fractional composition of CRMB (Ghavibazoo and Abdelrahman, 2013); in turn, this should also provide a change in the response to UV exposure. Various studies (Hu et al., 2018; Wu et al., 2010, 2008; Zhen-gang et al., 2016) conducted on the UV ageing of neat bitumen showed that UV radiations also add to the brittleness of the binder, thus reduces the durability and long term performance of the pavement. Wang et al. (2017), in their review of chemical characterization of rubberized asphalt, reported several studies that recently investigated the ultraviolet aging of CRMBs. Although the final claim is that traditional CRMB (Arizona wet-process) does not act as a shield to UV light, it is worth mentioning that none of the supporting references have actually reported results on CRMB. Hence, the declared non-shielding effect remains unproved. It is therefore important to explore the durability of CRMB when exposed to UV radiations.

The objective of this study was to propose a methodology that could account for the UV exposure at a specific location and consequently simulate it in the laboratory on bituminous specimens. The innovative aspect of the study relies on separating the ageing mechanisms of thermal and UV ageing and comparing their respective effects on the performance properties of the binder. Benefits associated with different concentrations of CR on CRMB are also explored in the current study. In addition, 869 h of UV exposure where tested in this study – the longest ageing period if compared to the previous studies in Table 2.

2. Material & methods

2.1. Bitumen C320

C320 bitumen (equivalent to pen grade 50/70) was used as the base binder for CR modification. Its penetration (ASTM D5), softening point (ASTM D36), and viscosity (ASTM D4402) at 135 °C were 59.3 (0.1 mm), 48.0 °C and 0.62 Pa s, respectively.

2.2. Crumb rubber

CR particles were collected from a local tyre recycling plant in Victoria (Australia). According to the supplier, the CR powder is derived from the recycling of truck tyres only (i.e., no passenger car tyres) using the ambient grinding process of manufacturing. The CR powder was made of 90% of the particles being below 600 μm in size (i.e., #30 mesh) and showed a polymer content (natural rubber plus synthetic rubber) of 57.7% with 29.3% of carbon black. The detailed composition, gradation curve and SEM images are provided in a previous study of the authors (Jamal and Giustozzi, 2020) to which the reader is referred.

Table 2
UV ageing conditions and sample thicknesses used by previous studies.

UV Ageing Conditions					Sample thickness	Reference
Equipment	Wavelength (nm)	Intensity	Temperature (°C)	Duration		
UV irradiation Oven, Model LHX-205	UVA-365	1200 μW/cm^2	60	6, 12, 24 and 48 h	0.1 mm	Zhen-gang et al. (2016)
Q-Sun Xe1, weathering chamber	UVA-340	0.35 W/m^2	60	50, 100, 150 and 200 h	0.6 mm	Araujo et al. (2015)
UV Irradiation Oven	UVA-365	800 μW/cm^2	60	6 days	2 mm	Feng et al. (2013)
UV Irradiation Oven	UVA-340	9.5, 13.9, 17.3, and 20.0 mW/cm^2	45, 65 and 80	48 h	50, 100, 150 and 200 μm	Wu et al. (2010)
UV Irradiation Oven	UVA-360	20 W/m^2	60	432 h	50, 100, 200 and 500 μm	Wu et al. (2008)

2.3. Sample preparation

Bitumen was heated up to 177 ± 10 °C and then CR was added at three different concentrations, 7.5% (Low), 15.0% (Medium) and 22.5% (High) (by weight of bitumen). Silverson L5M-A high shear mixer was used to uniformly disperse CR particles into the bitumen. The shear mixer speed was kept at a constant rate of 700 rpm, and the materials blended for a duration of 60 min. To maintain the same thermal history in all samples subjected to further tests, the sole C320 bitumen was also mixed for 60 min at 177 °C. The shear mixer speed and blending duration was optimized in another study of the authors (Jamal and Giustozzi, 2021). The samples prepared were named as 'Unaged'.

2.4. Experimental program

2.4.1. Ageing of samples

A Q-Lab QUV weatherometer reproduces the damage caused by the sunlight (radiations and temperature), rain and dew by generating one or a combination of the following: UV rays, moisture, temperature. In a few days or weeks, the QUV tester can reproduce the damage that occurs over months or years outdoors (Menapace et al., 2018a). When providing UV radiations, the UV lamps produce heat along with the radiations and the minimum temperature in the machine cannot be set below 50 °C. To distinguish among the two types of ageing (thermal and UV related), one set of samples was aged under both UV radiations and heating (50 °C) while the other one was covered with aluminium trays to hinder the penetration of UV radiations into the sample. The first set is labelled as 'UV + Thermal' while the second set as 'Thermal' throughout this paper. The ageing conditions inside the chamber were set after calculating the equivalent one-year UV exposure of the material in the city of Melbourne (Victoria, Australia). One of the approaches used by Crucho et al. (2018) was through the utilization of Solargis Maps. These maps plot the total Global Horizontal Irradiation (GHI) in a colour gradient pattern as shown in Fig. 1.

From these maps, the GHI values for any region of the world can be extracted. According to Miguel et al. (2019), on average, UV radiations correspond to 3.14% of the total GHI. Based on this assumption, the total UV radiation energy in Melbourne for the years 2017, 2018 and 2019 is approximately 184, 196, and 202 MJ, respectively. However, the 3.14%-factor may not be applicable at the global level. In fact, the thinner the ozone layer at any precise location around the world, the higher the intensity of UV rays that will reach the earth surface. Therefore, a more practical approach was adopted in this study for the estimation of total UV radiations reaching the earth surface in Melbourne, Australia. UV radiations data was collected from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) for the last ten years (2009–2019). The Agency has several UV sensors installed at various locations across Australia that collects data at intervals of 10 min all year round. Raw data was in the form of UV intensity (watts per square meter) recorded at 10-min intervals for the entire year. The trend of UV radiations (UV-A and UV-B) for 2019 in Melbourne is shown in Fig. 2.

It may be noted from Fig. 2 that the intensity of UV radiations is the lowest in the period of March to July - which corresponds to the winter season in the southern hemisphere - while it is highest during the summer months (October to February). It should also be observed that the intensity of UVB is significantly smaller compared to UVA and is mostly neglected in the simulation of laboratory based UV ageing of bitumen.

The raw data was then converted into *Exposure* (total UV energy per square meter) for one year using the following equation.

$$E = \sum_{i=1}^{n} (It)_i \quad (1)$$

where: 'E' is total UV energy per square meter for one year, 'I' is the UV radiations' intensity in watts per square meter during the ith interval, 't' is the time interval between the consecutive data recording readings in 'seconds', and 'n' is the total number of readings taken for any period of time. Melbourne's *Exposure* to the UV radiations in the last ten years is listed in terms of total UV energy in Table 3.

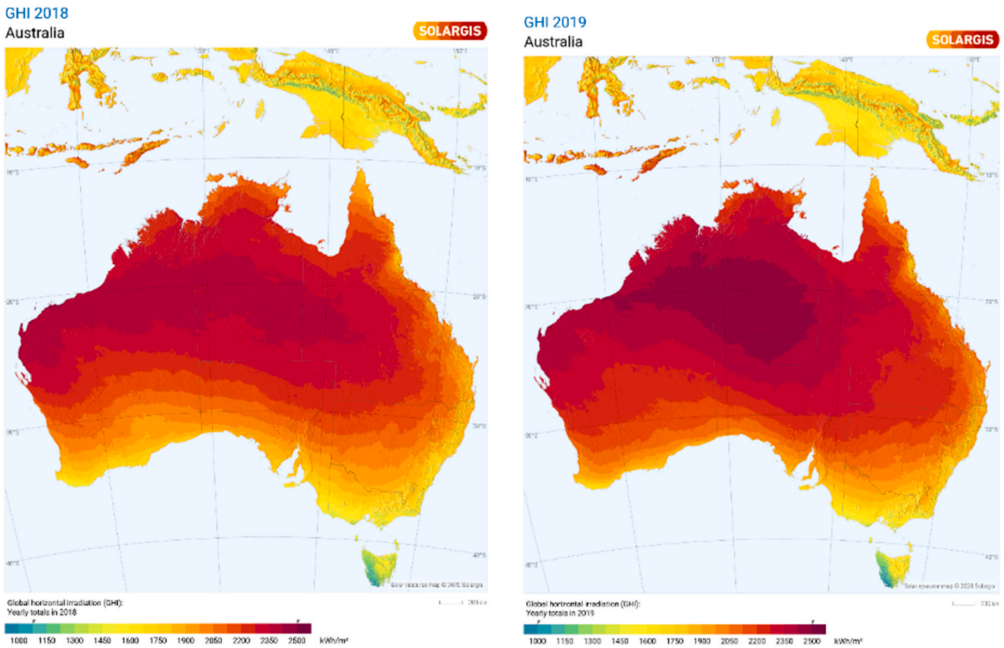


Fig. 1. Solargis maps of Australia for year 2018 and 2019.

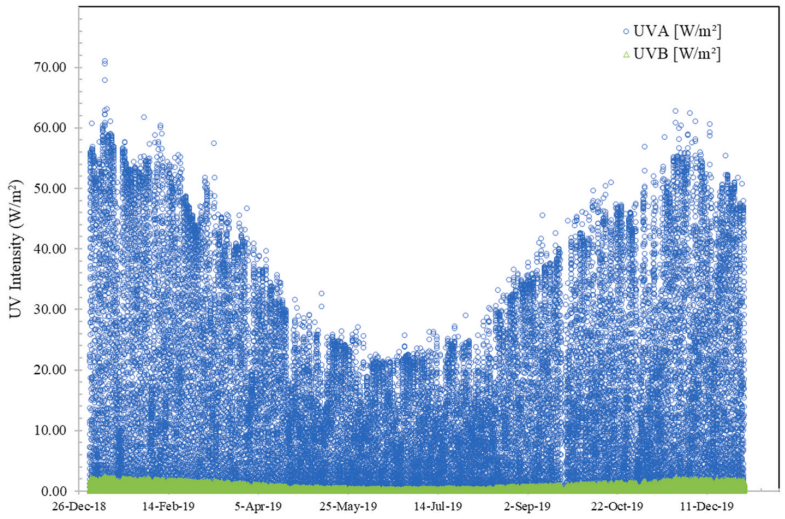


Fig. 2. Variations in the UV intensity for the city of Melbourne in 2018–2019.

Table 3
UV exposure of Melbourne in 2009–2019.

Year	Based on Solargis Maps		Based on ARPANSA	
	Exposure (MJ)	Duration (hours)	Exposure (MJ)	Duration (hours)
2009			244	762.47
2010			247	771.04
2011			249	778.02
2012			233	726.78
2013			291	907.09
2014			312	975.17
2015			303	944.73
2016			297	928.31
2017	184	574.72	284	887.40
2018	196	613.03	286	891.90
2019	**202**	**632.19**	**278**	**869.18**

According to ASTM G154-19, UVA-340 nm bulbs create the best correlation with the outdoor exposure, as they have the closest wavelengths to the damaging natural light from 295 to 365 nm (Menapace et al., 2018a).To subject the laboratory specimens to the same amount of (outdoor) energy, UVA-340nm lamps were used. According to the ATLAS weathering guidebook (ATLAS, 2018), the energy contained in the 340 nm wavelength is approximately one percent of the 295–385 nm range. Using this conversion factor, if the UVA-340nm lamp's intensity is set to 0.89 W/m^2, the durations required to produce the same level of exposure registered for Melbourne are listed in Table 3. By comparing the amount of UV radiations with the Solargis maps, it can be noted that the 3.14%-factor underestimates the total amount of solar radiations in Melbourne by a factor of 1.5 or, on average, by 88 $\pm$ 12 MJ. Therefore, the ARPANSA data sets were used as they are based on precise 10-min recordings and, overall, they represent a more conservative approach towards the ageing conditioning of the samples.

In this study, the samples were aged in the QUV weatherometer to simulate the radiation over the entire year of 2019, which means samples were put inside the machine for approximately 869 h (Table 3). This duration may be reduced by half if the intensity is doubled, although the damaging extent is not necessarily linearly correlated with the intensity of radiations (Araujo et al., 2015). Therefore, the 0.89 W/m^2 intensity value recommended by ASTM G154-19 (ASTM, 2016) was used in the laboratory ageing process.

Ageing of bitumen is commonly evaluated using FTIR analysis and rheological tests. Traditional short- and long-term ageing processes are conducted through standard RTFO and PAV ageing of samples. Once ageing is completed, samples are reheated, stirred and poured in the silicon moulds of 8 mm and 25 mm diameter and tested for rheology (ASTM, 2019b). Both standard procedures are applied on thin films of bitumen (RTFO) or homogenously throughout the mass of the samples (PAV) due to heating and pressure; this theoretically ensures a homogeneous ageing effect is provided to the entire mass of bitumen. The same approach cannot be used for UV ageing because the impact of UV radiations is thickness dependent and UV lamps are commonly located on top of the samples; some research reports UV light can only penetrate a few millimetres (Hu et al., 2018). The bitumen was initially poured into the 8 mm and 25 mm standard silicon moulds commonly used for preparing rheometer samples and subsequently placed inside the QUV machine. The aged samples were then characterised using chemo-rheological parameters and comparisons were made with the un-aged samples.

2.4.2. *FTIR spectroscopy*

PerkinElmer Spectrum 100 FTIR spectrometer was used to get the bitumen spectrum in the range of 650–4000 cm^{-1} wavenumber. Tests were run in attenuated total reflectance (ATR) mode at a resolution of 2 cm^{-1}. A total of 32 scans were collected for each sample and the average of 32 spectra is reported in this article. As FTIR only captures the molecular compounds on the surface of the sample, the top surface of the aged samples (i.e., the one that was directly exposed to UV radiation) faced towards the lens of the Spectrum 1000 equipment.

2.4.3. *Frequency sweep*

Bitumen is sensitive to both loading time and temperature. The time and temperature dependent properties are termed as rheological properties. Anton Paar MCR702 rheometer was deployed to run the frequency sweep tests at 5-15-25-40-60-80 °C on all samples. The loading frequency varied from 0.1 to 15 Hz keeping the strain in linear viscoelastic range. The 8 mm diameter parallel plate geometry with 2 mm gap was used for temperatures between 5 and 25 °C, while the 25 mm diameter plate with 1 mm gap was used from 25 to 80 °C. Data obtained from the frequency sweep tests was analysed using master curves. Shift factors were calculated using regression analysis and all data sets were shifted to a reference temperature of 25 °C and fitted using a symmetrical sigmoidal model (*Guide for Mechanistic–Empirical Design of New and*

Rehabilitated Pavement Structures. NCHRP 1-37A Final Report, 2004).

$$\log\left|G^*\right| = \delta + \frac{\alpha}{1 + e^{\beta+\gamma(\log\ \omega_r)}} \quad (2)$$

where: G* is the predicted complex modulus, δ is the minimum complex modulus, and α, β, and γ are the fitting parameters of the master curve.

Another important aspect related to ageing of the binder is its performance at low temperatures as it is commonly acknowledged that oxidised bitumen is more susceptible to cracking at low temperature due to embrittlement. The Glover Rower (G-R) parameter was developed as a possible indicator for field cracking. To plot the G-R parameter, only the 8 mm rheological data was considered. In this method, the 8 mm data was fitted to master curve at 15 °C and the obtained rheological parameters were used to calculate the G-R parameter at a frequency of 0.005 rad/s using the following equation.

$$G - R = \frac{G^* \cos(\delta)^2}{\sin(\delta)} \quad (3)$$

where G* and δ are the complex shear modulus and phase angle at 15 °C and 0.005 rad/s, respectively.

3. Results & discussion

3.1. Ageing mechanism of thermal & UV ageing

FTIR data of C320 and CRMBs in the unaged, thermal and UV + thermal aged conditions are presented in Figs. 3–6, respectively. For bitumen, the peaks in the range of 2990–2850 cm^{-1} are commonly recognized as C–H symmetric and anti-symmetric vibrations in the $–CH_3$, CH_2 aliphatic compounds while 2850-2700 cm^{-1} are due to the C–H stretching of CH_3 attached to –O or –N. Medium intensity peaks in the range of 1870–1650 cm^{-1} are the C═O stretches and are also called as Carbonyl compounds. Peaks in the range of 1640–1540 cm^{-1} are the C═C bonds in the aromatic compounds of bitumen. Strong intensity peaks in the range of 1475–1400 cm^{-1} are the CH_2 scissors vibrations and the anti-symmetric deformations of CH_3 in the aliphatic compounds. Similarly, the CH_3 deformations in the aliphatic compounds are observed in the form of a strong peak in the range of 1400–1350 cm^{-1}. Medium peaks in the range of 1280–1240 cm^{-1} are the C–O functional groups in esters while 1170-1140 cm^{-1} and 1130-1070 cm^{-1} are the C–O in aliphatic ethers. 1040-990 cm^{-1} are the C═S in aromatic sulphur and S═O groups. Peaks in the range of 900–840 cm^{-1}, 870-770 cm^{-1} and 750-670 cm^{-1} are the CH_2 polyaromatics in the vinylidenes, primary amines and in benzene rings.

It may be noted from Fig. 3 that C320 in the unaged state has higher carbonyl compounds than CRMBs; this shows that the blending process affects the neat C320 binder more as compared to CRMBs (Jamal and Giustozzi, 2020). The thermal ageing of the samples did not generate any new peak (compared to CRMB) except it decreased the intensity of $–CH_3$, $–CH_2$ peaks and increased the intensity of the sulfoxide peak. The UV + thermal ageing method shows that the CH_3 and CH_2 peaks in the range of 2990–2850, 2850–2700, 1475–1400, 1400-1350 cm-1 are almost nil; this shows that these peaks are seriously affected by the UV ageing. Similarly, it is important to understand the ageing mechanism behind UV ageing. The most vulnerable components to be damaged by the UV radiations in bitumen are the Carbon–Carbon (C–C), Carbon–Hydrogen (C–H), and Carbon–Oxygen (C–O) bonds. In fact, UV radiations generate energy in the range of 427–299 kJ/mol, which is higher than the bond energy of C–C, C–O and C–H that is 332 kJ/mol, 358 kJ/mol and 414 kJ/mol, respectively (Zhen-gang et al., 2016). The breaking of side chains from the aliphatic and branched compounds pushes the carbon atoms to make pair with the similar unpaired carbon atoms and increases the C═C bonds. Moreover, peaks at 1700 cm-1 are also observed showing the oxidation of the binder. Differences between the thermal and UV ageing are more prominently observed in CRMB - Figs. 4–6 show a decrease in the absorbance intensity of peaks in the sulfoxide region meaning UV also damages peaks in that region. Although the bond energy of S═O is 522 kJ/mol, this value is still close to the energy contained in UV radiations. To quantify the ageing, the following indices have been calculated using a baseline method.

$$CI = \frac{A_{carbonyl(1870-1650)}}{\Sigma A} \quad (4)$$

$$SI = \frac{A_{sulphoxide(1040-990)}}{\Sigma A} \quad (5)$$

$$AI = \frac{A_{aliphatics\ (2990-2850,\ 2850-2700,\ 1475-1400,\ 1400-1350)}}{\Sigma A} \quad (6)$$

$$A_rI = \frac{A_{romatics\ (1640-1540)}}{\Sigma A} \quad (7)$$

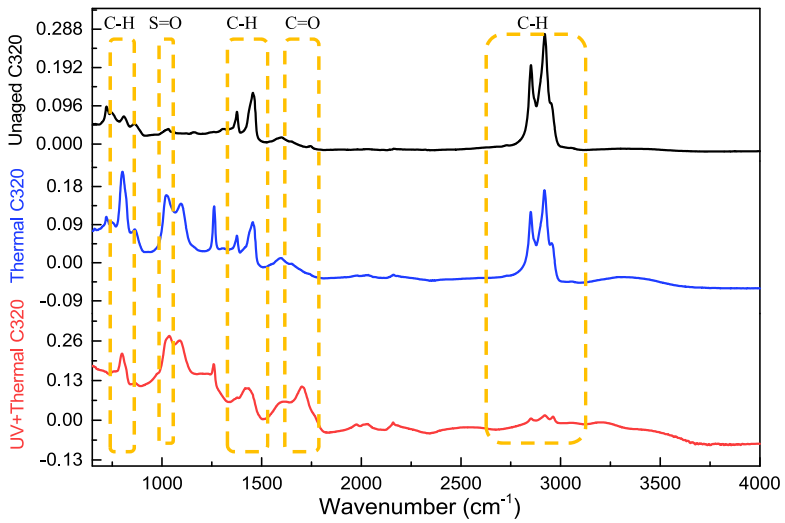


Fig. 3. FTIR spectra of C320 bitumen at different ageing conditions.

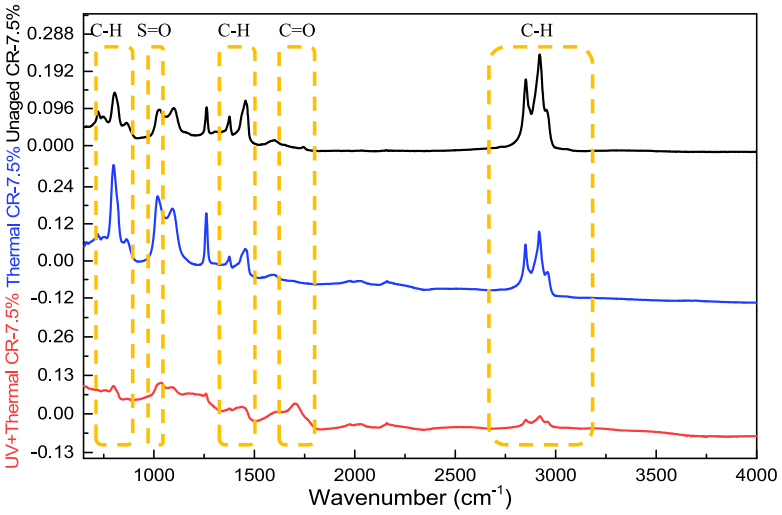


Fig. 4. FTIR spectra of CR-7.5% bitumen at different ageing conditions.

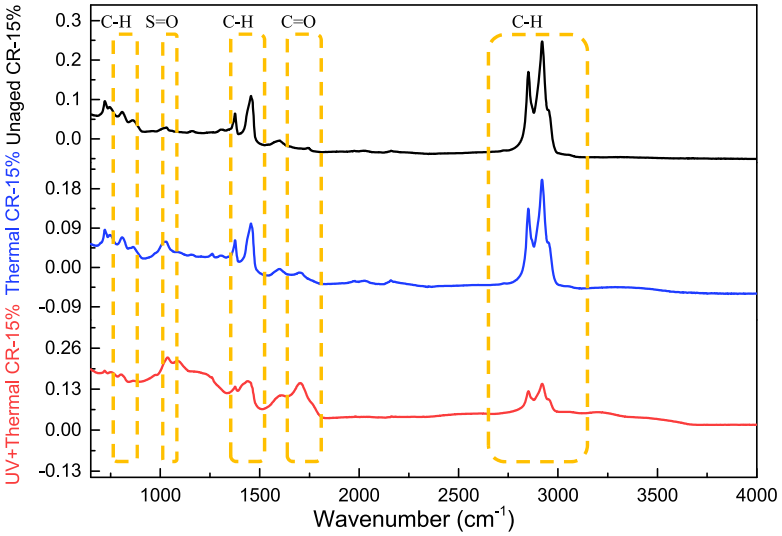


Fig. 5. FTIR spectra of CR-15% bitumen at different ageing conditions.

where 'CI' is the carbonyl index, 'SI' is the sulphoxide index, 'AI' is the aliphatic index, 'A_rI' is the aromatic index and 'A' is the area under the relative peaks mentioned in the subscript. ΣA is the summation of areas of all the peaks (2990–2850, 2850–2700, 1870–1650, 1640–1540, 1475–1400, 1400–1350,1280-1240, 1170–1140, 1130–1070, 900–840, 870–770, 750–670) in a spectrum for normalization purposes. The areas under the peaks were calculated using *Spectragryph Optical Spectroscopy* software. The indices are calculated and presented in the following section.

3.2. *Effect of Thermal and UV ageing on the chemical ageing indices*

The ageing indices calculated for all samples based on FTIR peaks are presented in Fig. 7.

It is noted from Fig. 7a that CI of all blends increased under both thermal and UV ageing while the CR addition seems to resist to the formation of carbonyl compounds. Thermal ageing increased CI from 0.005 to 0.076 while, when the thermal ageing was coupled with UV radiations, CI increased by almost three times - i.e., 0.231. Thermal ageing also increased CI of all CRMBs, although its value is still lower than C320 and reduces with increased CR concentration. Ageing with the addition of UV radiations impacted all mixes. Among CRMBs, 7.5% CR blend showed the greatest UV ageing effect and 22.5% the least.

SI (Fig. 7b) increased with both the addition of CR into C320 bitumen and thermal ageing, while it decreased with UV ageing. SI of C320 bitumen at unaged state is 0.015, the addition of 7.5% CR raised this to 0.061 which is four times that of C320. When the CR content is further increased to 15% and 22.5%, the SI value increased by five and six times, respectively. As the same mixing duration was applied to all blends, the increase in SI at unaged state with the increasing amount of CR can be

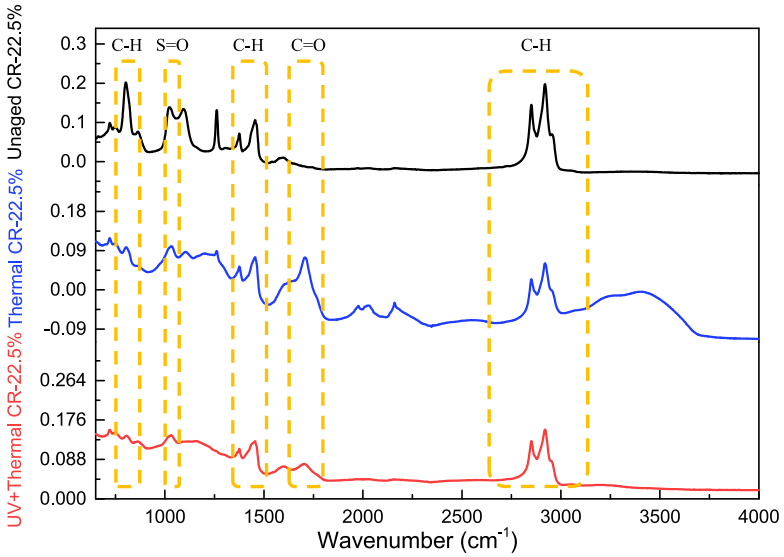


Fig. 6. FTIR spectra of CR-22.5% bitumen at different ageing conditions.

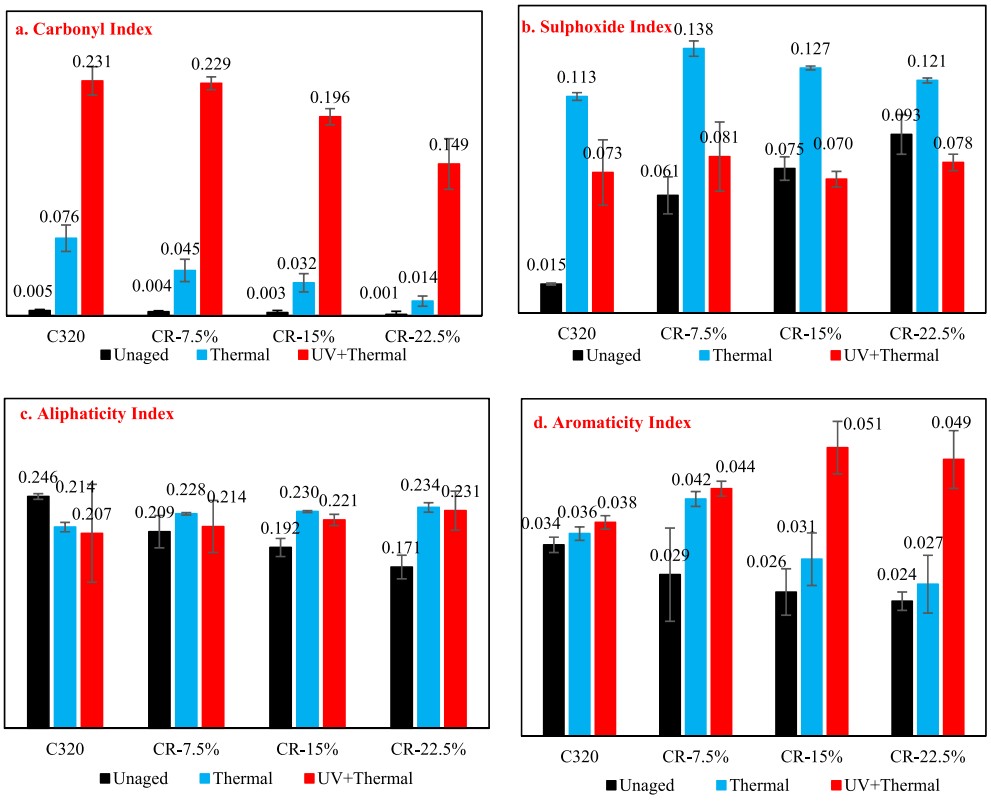


Fig. 7. Effect of Thermal and UV ageing on the chemical ageing index of binders.

linked to the sulphur present in the CR. According to Masad (Menapace et al., 2018a, 2018b, 2018a), the peak at 1030 (which is usually assigned to S═O) is C═S (aromatic sulphur). However, that study was conducted under moisture conditioning and it was reported that S═O was washed off by water during the experiment. Nonetheless, the tests in this study are not conducted under any moisture condition, and both bonds exist at the described range of peaks. Hence, the SI index reported in Fig. 7b is the combination of both S═O and C═S peaks. The bond energy of S═O and C═S is 522 kJ/mol and 573 kJ/mol, respectively. The sulphoxide bond is therefore more susceptible to be damaged by the UV radiations and a decrease in the SI value was anticipated and confirmed in Fig. 7b.

AI mostly shows the saturates or oily parts of the binder. During prolonged thermal ageing, the oily part or the volatile components of the bitumen tend to evaporate. With UV ageing, UV radiations degrade the C–H, C–C and C–O bonds. Accordingly, the initial value of AI for C320 bitumen (0.246) was then reduced to 0.214 and 0.207 after thermal and thermal-UV ageing, respectively. The addition of CR into C320 bitumen also resulted in a decrease of AI, which can be linked to the diffusion process that occurs as a result of the swelling of CR particles in bitumen (Artamendi et al., 2006; Ghavibazoo et al., 2015). Therefore, for unaged CRMB, AI values are lower than unaged C320 bitumen. As the concentration of CR particles increases, more oily components are absorbed by CR particles and a decrease in AI is observed. Thermal ageing of CRMB gradually increased the AI value, however, a reduction in AI was observed for CRMBs when subjected to UV radiations.

In the unaged state, A_rI decreased from 0.034 to 0.024 with the addition of 22.5% CR to C320 bitumen. The decrease of A_rI with addition of CR can be linked to the maltenic part also containing aromatic fractions that, due to swelling during the blending, cause rubber particles to absorb the oily components. Upon thermal ageing, volatile components from C320 bitumen evaporate, however, in case of CRMBs, the thermal part of the ageing makes the rubber release back the absorbed oils (Wang et al., 2020a)while the UV radiations degrade the aliphatic chains. The broken components, mainly from iso-paraffins, alkyl-naphthenes and some alkyl-aromatics (Zhen-gang et al., 2016), can diffuse together and add to the rise in A_rI values. Therefore, the combined effect of UV and thermal ageing generates more evident effects than the thermal ageing alone, hence the importance of UV ageing cannot be neglected in the assessment of the durability of bituminous binders.

3.3. Effect of ageing on bitumen rheological properties

Complex shear modulus master curves of C320 and CRMBs before and after thermal and thermal-UV ageing are compared in Figs. 8 and 9-11, respectively. In the previous section, it was observed that C320 bitumen is significantly affected by both thermal and UV ageing. This effect also appeared in the form of increased complex shear modulus of the bitumen, which is related to the evaporation of volatile components and increase of the polar components as reported in the FTIR section of this study. UV ageing further increased |G*| of C320 as UV radiations were proved to specifically target the branched components within the bitumen. This effect is more pronounced at the lower reduced frequencies (high temperatures) while all curves converge towards the glassy modulus of 1 GPa at the higher reduced frequency range (low temperatures).

The ageing effect is evident for 7.5% CRMB as it was for C320 bitumen but the relative difference between the thermal and UV + Thermal ageing curves decreased compared to C320. Similarly, binders produced with 15% and 22.5% CR also showed an influence under both ageing conditions but the relative difference between the thermal and UV ageing master curves is smaller than for C320 and 7.5% CRMB. This means the increase in CR content into the neat bitumen gradually decreased the impact of both thermal and UV + Thermal ageing.

3.4. G-R parameter & black space diagram

According to Mensching et al. (2016), G-R parameter has showed good relation with the pavement cracking in the field and are therefore calculated and presented in the following table.

A G-R value of 180 kPa is considered as the threshold between satisfactory performance against cracking and the onset damage. It may be noted from Table 4 that all the binders in the unaged state are well below the 180 kPa limit. Interestingly, it can be noticed that the addition of CR is also resulting to an increase in the G-R value, and this can be linked to the greater relaxation times. A greater relaxation times means the binder is not able to release the applied stresses quickly and results in the accumulation of residual stresses.

When these binders underwent thermal ageing, the G-R value of neat bitumen increases by 13.5%, however, CRMB showed a moderate to steady change in the G-R values as the CR concentration increase from 7.5% to 22.5%. When the thermal ageing was coupled with UV ageing, G-R of neat bitumen further increased to a value of 162.8 kPa from

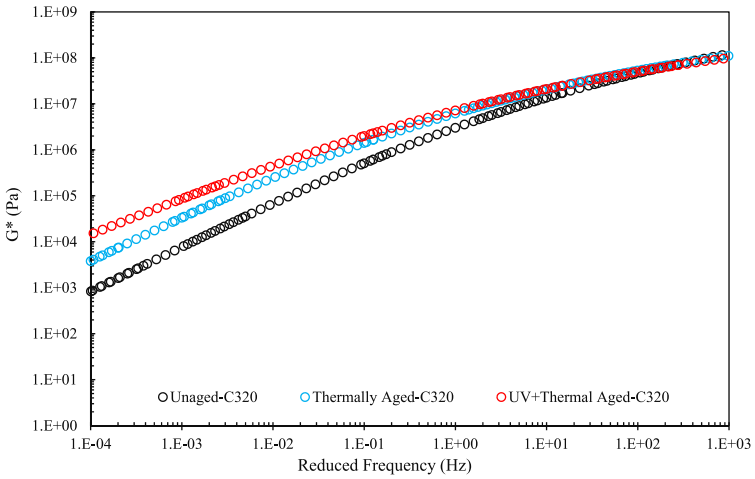


Fig. 8. |G*| master curve of C320 bitumen at different ageing conditions.

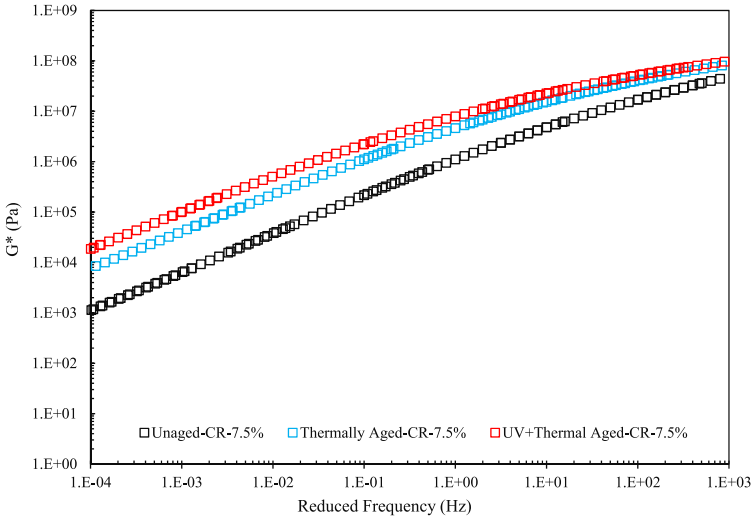


Fig. 9. |G*| master curve of CR-7.5% bitumen at different ageing conditions.

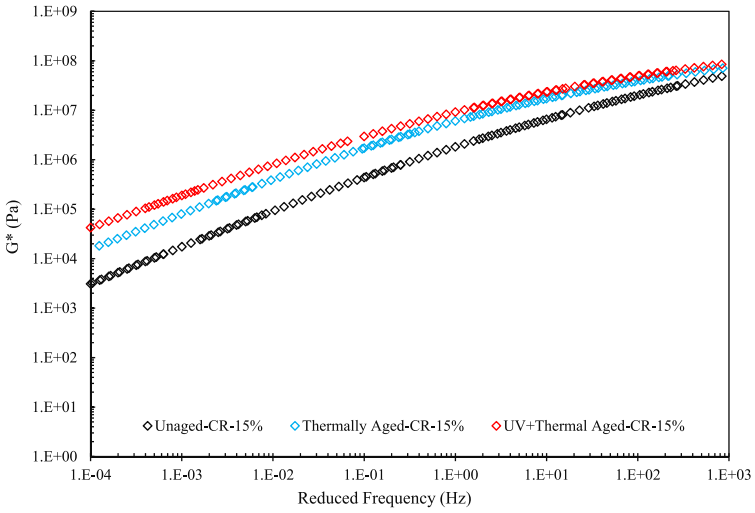


Fig. 10. |G*| master curve of CR-15% bitumen at different ageing conditions.

101.3 kPa; this value being just 13.2 kPa away from the 'onset damage' zone, i.e., 180 kPa. On the other hand, CRMB showed greater resistance towards the thermal as well as UV ageing. It can be observed from the Table 4 that the bitumen resistance to UV + Thermal ageing can be improved by 26.7%, 40.2%, and 46.6%, if the neat bitumen is modified with 7.5, 15 and 22.5% of CR, respectively. For visual presentation, a black space diagram is usually plotted to show the G-R values together with the 'onset damage' (180 kPa) and the 'significant cracking' envelope (450 kPa). A black space diagram for unaged and aged binders of this study is presented as Fig. 12.

It may be noted from Fig. 12 that the unaged binders are clearly well below the onset damage envelope. As the binder undergoes thermal ageing, all binders shifted upward and get closer to the onset damage zone. This means that thermal ageing has significant impact on the cracking performance of the binders. UV radiations further push the binders towards the onset damage zone, where the neat bitumen was the one being affected the most. The magnitude of the shift from the satisfactory performance zone towards the significant cracking zone due to thermal and UV ageing is more noticeable for C320 and decreases with the greater CR concentration.

4. Conclusions

The aim of this study was to evaluate the impact of UV ageing and compare it with thermal ageing to assess their effects on the chemo-rheological performance of crumb rubber modified bitumen. FTIR spectroscopy of the unaged and aged samples was conducted to understand the ageing mechanism while the rheological tests were conducted

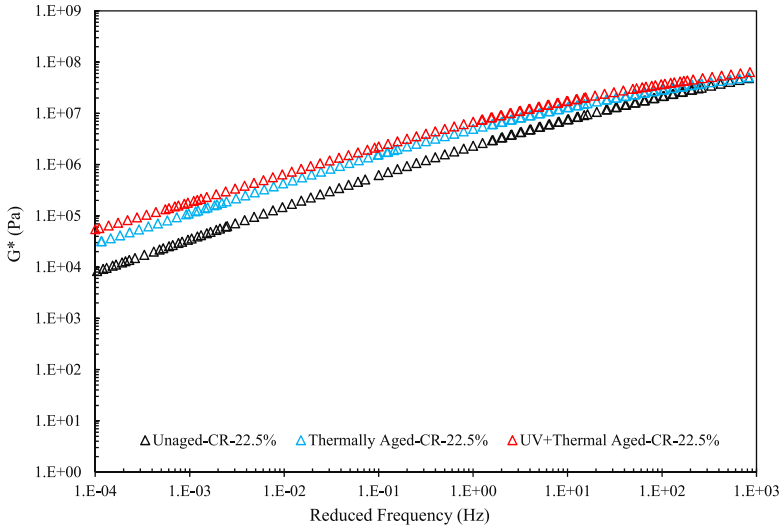


Fig. 11. |G*| master curve of CR-22.5% bitumen at different ageing conditions.

Table 4
G-R parameter (kPa) of binders at 15 °C and frequency of 0.005 rad/s.

Ageing condition	Binder type			
	C320	CR-7.5%	CR-15%	CR-22.5%
Unaged	7.5	11.9	17.5	42.4
Thermal	101.3	94.1	72.2	77.4
UV + Thermal	162.8	119.3	97.4	87.0

to evaluate the stiffness and cracking performance. The following conclusions can be drawn from this study.

- The magnitude of total UV radiations falling on the earth surface varies across the world and depends on the ozone layer. The use of the commonly used '3.14%' conversion factor for the calculation of UV radiations from the total GHI value obtained from Solargis maps may lead to the underestimation of the UV radiations.
- FTIR spectroscopy and rheological investigations revealed that both thermal and UV radiations have significant impact on bitumen ageing. However, their ageing mechanism and magnitude are different and dependent on the binder type.
- FTIR suggests that thermal ageing is oxidative in nature and creates carbonyl and sulfoxide compounds while contributing to evaporating the binder's volatile components. UV radiations target the weak chains with a lower bond energy, i.e., C–C, C–H, C–O. In contrast to thermal ageing, the degradation of sulfoxide compounds was observed as a result of exposure to UV radiations.
- The addition of crumb rubber to C320 bitumen partially absorbs the oily components of the bitumen and acts as a 'sunscreen' for the saturates when subjected to UV radiations. Furthermore, the

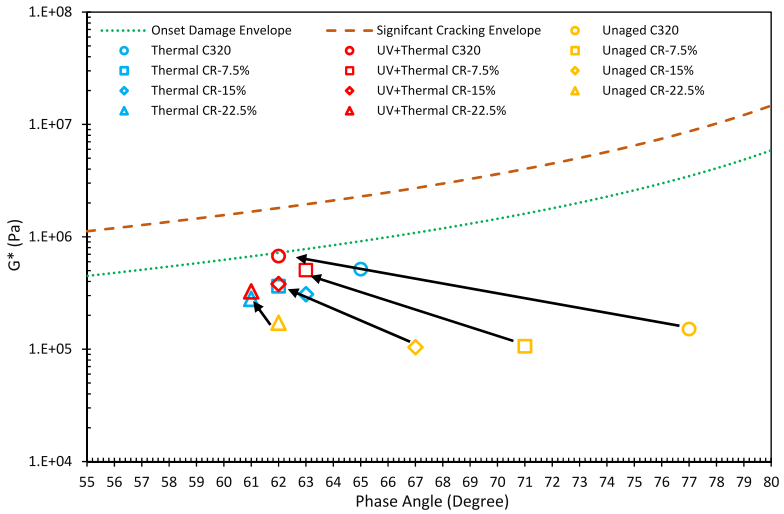


Fig. 12. Black Space Diagram of C320 and CRMBs at different ageing states.

presence of carbon black in CR also acts as a UV blocker. Increasing the concentration of CR further lowers the impact of UVs.
- Both thermal and UV ageing decrease the cracking resistance of the binders, with the neat C320 bitumen being the most impacted compared to CRMB.

CRediT authorship contribution statement

Muhammad Jamal: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Michele Lanotte:** Conceptualization, Writing – review & editing. **Filippo Giustozzi:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Project administration, Funding acquisition, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The Authors would like to acknowledge the support given by Tyre Stewardship Australia under the scholarship "Crumb rubber asphalt binder characterization and specifications for road pavement applications". The UV radiation data is provided by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

References

Araujo, M. de F., Oliveira, A.A. da S., Pasa, V.M.D., Lins, V. de F.C., 2015. Weathering degradation effect on chemical structure of asphalt binder. Int. J. pavement Res. Technol. 8, 7. https://doi.org/10.6135/ijprt.org.tw/2015.8(1).23.

Artamendi, I., Khalid, H.A., Page, G.C., Redelius, P.G., Ebels, L.J., Negulescu, I., Kennepohl, G., 2006. Diffusion kinetics of bitumen into waste tyre rubber. Asph. Paving Technol. Assoc. Asph. Paving Technol. Tech. Sess. 75, 133–164.

ASTM, 2019a. ASTM D2872-19 Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test). https://doi.org/10.1520/D2872-19.2.

ASTM, 2019b. ASTM D6521-19 Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV). https://doi.org/10.1520/D6521-19A.1.

ASTM, 2019c. ASTM G151 − 19 Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources. https://doi.org/10.1520/G0151-19.2.

ASTM, 2017a. ASTM D4799-17 Standard Practice for Accelerated Weathering Test Conditions and Procedures for Bituminous Materials (Fluorescent UV , Water Spray , and Condensation Method). https://doi.org/10.1520/D4799.

ASTM, 2017b. Standard Practice for Fluorescent UV-Condensation Exposures of Paint and. https://doi.org/10.1520/D4587-11.2.

ASTM, 2016. ASTM G154-16 Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials. https://doi.org/10.1520/G0154-16.2.

ATLAS, 2018. Weathering Testing Guidebook.

Baker, B., Farrell, K.O., Farrell, K.O., 2020. USED TYRES SUPPLY CHAIN AND FATE ANALYSIS.

Crucho, J., Picado-santos, L., Neves, J., Capitão, S., Al-Qadi, I.L., 2018. Tecnico accelerated ageing (TEAGE) – a new laboratory approach for bituminous mixture ageing simulation. Int. J. Pavement Eng. 21, 753–765. https://doi.org/10.1080/10298436.2018.1508845.

Dehghani, M.S., Giustozzi, F., Flintsch, G.W., Crispino, M., 2013. Cross-Asset Resource Allocation Framework for Achieving Performance Sustainability 16–24. https://doi.org/10.3141/2361-03.

Feng, Z.-G., Yu, J.-Y., Zhang, H.-L., Kuang, D.-L., Xue, L.-H., 2013. Effect of ultraviolet aging on rheology , chemistry and morphology of ultraviolet absorber modified bitumen. Mater. Struct. 46, 1123–1132. https://doi.org/10.1617/s11527-012-9958-3.

Gamarra, A., Ossa, G.A., 2018. Thermo-oxidative aging of bitumen. Int. J. Pavement Eng. 19, 641–650. https://doi.org/10.1080/10298436.2016.1199876.

Ghavibazoo, A., Abdelrahman, M., 2013. Composition analysis of crumb rubber during interaction with asphalt and effect on properties of binder. Int. J. Pavement Eng. 14, 517–530. https://doi.org/10.1080/10298436.2012.721548.

Ghavibazoo, A., Abdelrahman, M., Ragab, M., 2015. Evaluation of oxidization of crumb rubber-modified asphalt during short-term aging. Transport. Res. Rec. 2505, 84–91. https://doi.org/10.3141/2505-11.

Giustozzi, F., Crispino, M., Flintsch, G., 2012. Multi-attribute Life Cycle Assessment of Preventive Maintenance Treatments on Road Pavements for Achieving Environmental Sustainability 409–419. https://doi.org/10.1007/s11367-011-0375-6.

Giustozzi, F., Crispino, M., Toraldo, E., Mariani, E., 2019. Mix Design of polymer-modified and fiber-reinforced warm-mix asphalts with high amount of reclaimed asphalt pavement: achieving sustainable and high-performing pavements. Transp. Res. Rec. J. Transp. Res. Board 2523, 3–10. https://doi.org/10.3141/2523-01.

Hu, J., Wu, S., Liu, Q., Hernández, M.I.G., Zeng, W., Nie, S., Wan, J., Zhang, D., Li, Y., 2018. The effect of ultraviolet radiation on bitumen aging depth. Materials 11. https://doi.org/10.3390/ma11050747.

Jamal Hafeez, I., Yaseen, G., Aziz, A., 2018. Influence of Cereclor on the performance of aged asphalt binder. Int. J. Pavement Eng. https://doi.org/10.1080/10298436.2018.1542694.

Jamal, M., Giustozzi, F., 2021. Chemo - rheological investigation on waste rubber - modified bitumen response to various blending factors. Int. J. Pavement Res. Technol. 1–20. https://doi.org/10.1007/s42947-021-00045-x.

Jamal, M., Giustozzi, F., 2020. Low-content crumb rubber modified bitumen for improving Australian local roads condition. J. Clean. Prod. 271, 1–13. https://doi.org/10.1016/j.jclepro.2020.122484.

Joohari, I.B., Giustozzi, F., 2021. Waste tyres crumb rubber as a sustainability enhancer for polymer-modified and hybrid polymer-modified bitumen. Int. J. Pavement Eng. 1–15. https://doi.org/10.1080/10298436.2021.1943745.

Joohari, I.B., Giustozzi, F., 2020. Chemical and high-temperature rheological properties of recycled plastics-polymer modified hybrid bitumen. J. Clean. Prod. 276, 1–17. https://doi.org/10.1016/j.jclepro.2020.123064.

Lu, X., Isacsson, U., 2002. Effect of ageing on bitumen chemistry and rheology. Construct. Build. Mater. 16, 15–22. https://doi.org/10.1016/S0950-0618(01)00033-2.

Menapace, I., Masad, E., Masad, E., 2018a. The influence of moisture on the evolution of the microstructure of asphalt binders with aging. Road Mater. Pavement Des. 21, 1–16. https://doi.org/10.1080/14680629.2018.1491882.

Menapace, I., Yiming, W., Masad, E., 2018b. Effects of environmental factors on the chemical composition of asphalt binders. Energy Fuel. https://doi.org/10.1021/acs.energyfuels.8b03273.

Mensching, D.J., Jacques, C.D., Daniel, J.S., 2016. Applying the glover-rowe parameter to evaluate low-temperature performance of hot mix asphalt LTPP sections. J. Mater. Civ. Eng. 28, 1–9. https://doi.org/10.1061/(ASCE)MT.1943-5533.0001606.

Miguel, J., Crucho, L., Manuel, J., Dias, S., 2019. Evaluation of the durability of asphalt concrete modified with nanomaterials using the TEAGE aging method. Construct. Build. Mater. 214, 178–186. https://doi.org/10.1016/j.conbuildmat.2019.04.121.

Nizamuddin, S., Jamal, M., Gravina, R., Giustozzi, F., 2020. Recycled plastic as bitumen modifier : the role of recycled linear low- density polyethylene in the modification of physical , chemical and rheological properties of bitumen. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.1219880959-6526.

TSA, 2019. TSA Annual Report 2018/2019.

Wang, H., Liu, X., Apostolidis, P., van de Ven, M., Erkens, S., Skarpas, A., 2020a. Effect of laboratory aging on chemistry and rheology of crumb rubber modified bitumen. Mater. Struct. Constr. 53 https://doi.org/10.1617/s11527-020-1451-9.

Wang, H., Liu, X., Ven, M. Van De, Lu, G., Erkens, S., Skarpas, A., 2020b. Fatigue performance of long-term aged crumb rubber modified bitumen containing warm-mix additives Fatigue performance of long-term aged crumb rubber modified bitumen containing warm-mix additives. Construct. Build. Mater. 239, 117824 https://doi.org/10.1016/j.conbuildmat.2019.117824.

Wang, S., Cheng, D., Xiao, F., 2017. Recent developments in the application of chemical approaches to rubberized asphalt. Construct. Build. Mater. 131, 101–113. https://doi.org/10.1016/j.conbuildmat.2016.11.077.

Wu, S., Pang, L., Liu, G., Zhu, J., 2010. Laboratory study on ultraviolet radiation aging of bitumen. J. Mater. Civ. Eng. 22, 767–772. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000010.

Wu, S., Pang, L., Mo, L., Qiu, J., Zhu, G., Xiao, Y., 2008. Uv and thermal aging of pure bitumen-comparison between laboratory simulation and natural exposure aging. Road Mater. Pavement Des. 9, 103–113. https://doi.org/10.1080/14680629.2008.9690161.

Zhen-gang, F., Hui-juan, B., Xin-jun, L., Jian-ying, Y., 2016. FTIR analysis of UV aging on bitumen and its fractions. Mater. Struct. 49, 1381–1389. https://doi.org/10.1617/s11527-015-0583-9.

THE BENEFITS OF SURFACING ROADS WITH TYRE DERIVED CRUMB RUBBER

FINDINGS AND FACTS

CRUMB RUBBER: DURABLE, FLEXIBLE AND RECYCLABLE

FIRST REPORT
V2. May 2022

TyreStewardship AUSTRALIA

Australian Government Accredited Product Stewardship Scheme

Crumb Rubber in road surfacing applications

This fact sheet provides a snapshot of the initiatives and the activities of Tyre Stewardship Australia (TSA) in relation to use of tyre derived Crumb Rubber in road surfacing applications. It also provides attributes, statistics, linkages and references to the various projects funded by TSA on the use of Crumb Rubber Modified Bitumen and Asphalt in road surfacing applications.

This document can also be accessed on our website: Click here

TyreStewardship AUSTRALIA

Australian Government Accredited Product Stewardship Scheme

TSA's purpose is to drive sustainable outcomes for end-of-life tyres (EOLT).

Our vision is a circular economy for EOLT which contributes to a sustainable society.

Our mission is to collaboratively ensure the sustainable management, recycling and productive use of EOLT.

Crumb Rubber in road surfacing applications

1

Crumb Rubber (CR), derived from end-of-life tyres, has been utilised in road surfacing applications since 1975, with its first use in Victoria. Progressively, CR was then used in NSW and Western Australia. Recently the uptake has spread nation-wide, while also increasing the types of road surfacing applications that it can be utilised in.

Since its inception, Tyre Stewardship Australia (TSA) has played an important part in better understanding the sustainability and performance value contributed by the use crumb rubber. Various projects supported by TSA in creating demand by overcoming barriers, demonstrating benefits and enabling supply have been instrumental in this regard.

Create demand

- Research & Development into use and benefit
- Specification alteration and creation

Demonstrate benefit

- State authorities: Dept of Transport VIC, Transport and Main Roads QLD, Main Roads WA
- Local Government: Logan City Council, City of Mitcham

Enable supply

- Infrastructure procurement

Advantages of Crumb Rubber when compared to neat Bitumen

2

- Elimination of waste, supports recycling and sustainability principles and improves the environment from less landfill.
- Higher resistance to deformation at increased road temperature, reduced degree of rutting, improves driving comforts even on higher axle loads.
- Crumb rubber bitumen has enhanced engineering properties
- Improved adhesion and bonding with aggregates, less windscreen damage and improves safety.
- Higher softening point, high flow resistance and higher impact resistance, takes heavy vehicular traffic.
- Increased viscosity avoids bitumen softening and flushing onto the surface of the sprayed seal.
- Improved skid resistance, better road grip and smoother vehicle break application, which reduces chances of accident.
- Higher elongation and tensile strength, increases elasticity. Reduced thermal sensitivity, which avoids all types of cracks under stress. Excellent ability to resist reflection cracking.
- Anti-stripping properties. High resistance to moisture/water absorption hence reduction to damage to roads during rains.
- Improved durability through the ability to use higher binder film thickness in sprayed seals.
- Cost effective binder relative to other polymer modified bitumen, crumb rubber pricing is at par or below that of bitumen.
- Longer road pavement life and lesser maintenance.

Demonstrated benefits of using Crumb Rubber Modified (CRM) binder

3

3.1 Performance benefits of CRM binder in Sprayed Sealing

In sealing, CRM binder with high rubber content can be applied at a higher spray rate than bitumen without flushing (fattening-up of the road surface under traffic) occurring. The higher spray rate, in combination with the improved elastic, viscous and ductile properties of the binder, leads to benefits of CRM binder seals compared to seals with neat bitumen. These benefits include:

Service life is significantly increased

The higher spray rate and increased binder film thickness lead to later onset of oxidation cracking and stone loss. The carbon black component of the tyres working as an antioxidant is also believed to contribute to the superior longevity of CRM binder seals (Hoffmann & Potgieter 2007).

Durability of skid resistance is improved

The higher viscosity of the CRM binder leads to reduced stone embedment, and as a result, the seal maintains its texture depth (Hoffmann & Potgieter 2007).

Resistance against reflective cracking

There is superior resistance against reflective cracking (California Department of Transportation, 2003). CRM binder use originated from a desire to create a durable seal over cracks in asphalt roads. Its ability to arrest cracking is still one of the main reasons why CRM binder technology is used in sprayed seals. CRM binder seals are used as a maintenance action over cracked road surfaces. They are also used in specialised applications to insulate new pavement layers placed over existing pavements from cracks reflecting up from underlying layers. This application is known as a strain alleviating membrane interlayer. (Austroads 2013).

Improvement in waterproofing

Improvement in waterproofing of the road surface (Hoffmann & Potgieter 2007). One of the main functions of a sprayed seal is to keep water out of the pavement. The high spray rate of a CRM binder seal leads to a durable waterproof surface, which protects the underlying material.

3.2 Performance benefits of CRM binder in Asphalt

In asphalt, the use of CRM binder allows higher binder application rates in certain asphalt types without excessive drain down or bleeding due to the high viscosity of the binder (Lo Presti, 2013). The higher binder film thickness comes with considerable durability benefits. High binder film thicknesses retard oxidative aging, which is especially important in open grade (porous) asphalt (OGA) mixes.

In OGA mixes oxidation eventually leads to raveling of the material, which is the main mode of failure for such asphalt. In Gap Graded Asphalt (GGA) mixes, the high binder film thickness, in combination with the improved elastic properties of CRM binder, results in much improved resistance to reflective and fatigue cracking (California Department of Transportation 2003). This was also verified in laboratory tests on Australian mixes (Austroads Pavements Research Group 1999).

Accelerated pavement testing conducted by the University of California has shown that GGA CRM binder asphalt placed at half the thickness of conventional asphalt over concrete outperforms the conventional asphalt in terms of resistance to reflective cracking (Jones, Harvey & Monismith 2007). This has led the California Department of Transportation to implement the rule that for overlays over concrete, conventional dense-graded asphalt may be substituted with CRM binder gap graded asphalt at onehalf the intended dense-graded mix thickness (California Department of Transportation 2003). Note that this half- thickness rule is relevant to resistance to crack reflection only, it does not pertain to the asphalt design thickness required to protect underlying layers.

Long-term pavement performance monitoring in Arizona has shown that CRM binder GGA outperformed conventional* asphalt in terms of cracking, maintenance costs, ride quality and resistance and rutting (Way, Kaloush & Biligiri 2011). Other studies have found CRM binder asphalt to have rut resistance like conventional asphalt, although there are indications that CRM gap-graded asphalt may be more susceptible to rutting than conventional asphalt (Jones, Harvey & Monismith 2007). In Australia, the reported benefits of using CRM binder in asphalt mixes over standard bitumen are (Roads and Traffic Authority 1995):

- Cost-effectiveness due to increased pavement life.
- Increased shear resistance including resistance to permanent deformation (rutting and shoving).
- Increased resistance to fatigue and reflective cracking.
- The use of an otherwise waste material.

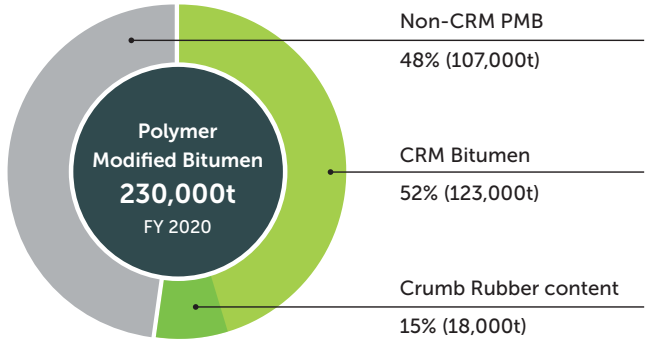
**Conventional asphalt refers to non polymer modified asphalt*

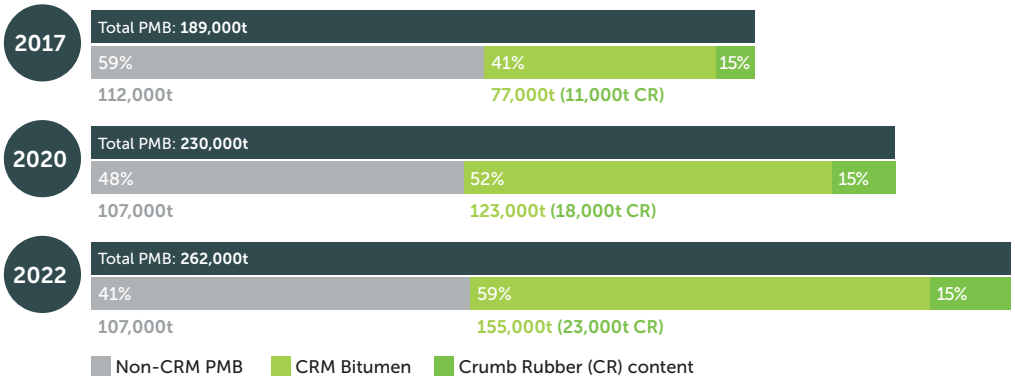
Statistics

4

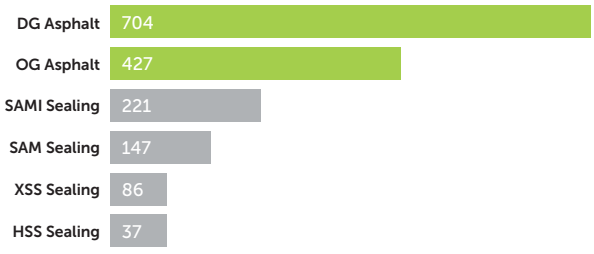
It is estimated that in 2020, 230,000 metric tonnes of Polymer Modified Bitumen (PMB) was used in Australia out of which Crumb Rubber Modified Bitumen was ~123,000 metric tonnes, 52% of the total modified bitumen market.

At an average of 15% crumb rubber content, this equates to 18,000 metric tonnes of crumb rubber or 3 million Equivalent Passenger Units (EPUs).





The volume of crumb rubber is likely to increase sharply due to the recent uptake of crumb rubber in asphalt application. This application uses the most amount of crumb rubber per Lane Kilometer constructed. In a positive development, most states in Australia are now moving towards the use of crumb rubber in various road surfacing applications.



EPUs per Lane Kilometer against treatment type

TSA initiatives

5

TSA identified three areas of support needed to utilise crumb rubber in road surfacing applications. These are creating demand by overcoming barriers, demonstrating benefits and enabling supply.

5.1 Overcoming barriers and creating demand

Significant barriers have been overcome with specifications on crumb rubber modified bitumen in National (Austroads) and State Road Authorities specifications. Furthermore, TSA is actively working with academic and research institutions, state road authorities, statutory organisations and industry bodies in technology transfer, specification developments, performance assessments and training in the use of crumb rubber for road surfacing applications.

Jurisdiction	Relevant Guidelines, Codes and Specifications
International	ASTM D6114 / D6114M Standard Specification for Asphalt-Rubber Binder provides a standard approach to crumb rubber asphalt recommending a minimum 15% of rubber by weight of the total blend
National	Austroads Technical Specification ATS 3110 outlines the requirements for polymer modified binders, including crumb rubber, in BCRA and rubber modified spray seal applications.
NSW	Specification and DC3256 (22/06/2020) R118 Crumb Rubber Asphalt provides a dedicated specification for use of BCRA. Specification R107 Sprayed Bituminous Surfacing provides guidance for use of polymer modified binders including rubber modified spray seals.
Victoria	Section 421 Bitumen Crumb Rubber Asphalt and Section 522 (26/11/2019) Code of Practice RC500.01 set allowances and provisions for use of crumb rubber asphalt in Victoria. Bituminous Sprayed Surface Manual and Technical Note TN14 provide guidelines and requirements for rubber modified spray seals.
Queensland	Technical Specification MRTS 11 – Sprayed Bituminous Surfacing provides guidance and procedures for use of crumb rubber binder in spray seals Technical Specification MRTS18 - Polymer Modified Binder provides guidance and requirements for use of crumb rubber binder in BCRA
WA	MRWA Specification 516 - Crumb Rubber Open Graded Asphalt and Specification 511 – Materials for Bituminous Treatments provides some information related to crumb rubber treatments for bitumen products such as BCRA and rubber modified spray seals.
SA	RD-BP-S1 Supply of Bituminous Materials and Part R25 Supply of Bituminous Materials and Part R26 Guidelines provide guidance on the blending and application of crumb rubber binders for asphalt and spray seal.
NT	Standard Spec for Civil Maintenance V9.0 (FEB 2021), Spray Seal Surfacing – Selection of Binder Type and Standard Specification for Roadworks contain some requirements and details regarding use of crumb rubber binders.
Tasmania	Sprayed Bituminous Surfacing and Guidance Notes for Bituminous Surfacing Specifications provide broad guidelines for road construction, including use of crumb rubber binders.
ACT	The following general specifications refer to crumb rubber: ACT Trunk Road Infrastructure Technical Specification No. 04 – Flexible Pavement

5.2 Demonstrating benefits

While there is already widespread use of crumb rubber in road surfacing applications, there are still applications where it has been necessary to demonstrate the benefits; a major one being in the application of hot mix asphalt. TSA has provided significant support to various collaborations with the road authorities, local government and industry in placement and monitoring of road surfacing demonstration projects. Projects supported to date have provided valuable learnings.

TSA Initiatives to promote benefits of CRM binder in Asphalt

Case Study: City of Mitcham (South Australia)

In partnership with Tyre Stewardship Australia, the City of Mitcham developed a crumb rubber asphalt mix for application in a local road test environment to demonstrate the improved crack resistance and longevity that could be achieved through the addition of waste tyres.

Asphalt mix type	Fatigue Cycles to failure	Moisture sensitivity Tensile strength ratio	Rutting Wheel tracking deflection
Conventional Asphalt (C320)	116,868	77%	7.5mm
Crumb Rubber GGA	498,805	87%	3.6mm

The results demonstrated outstanding properties with regards to **fatigue** failure through the addition of crumb rubber in the binder mix, with the CRM binder sample lasting close to 4 times longer than the C320 mix. The results are a good indicator that the CRM mix is more resilient to fatigue cracking in the field than a normal C320 mix and shows a significant increase in performance.

Moisture sensitivity testing is undertaken by comparing the loss of tensile strength of the asphalt after saturating the sample with water, with the CRM asphalt demonstrating better cohesion and aggregate bonding properties than the standard C320 mix and would be indicative of improved crack resistance and moisture performance over typical asphalt.

Predictions of the performance of an asphalt mix in the field with regards to **rutting** and repeated loading over time can be estimated using the wheel tracking test, where a set load is applied over the sample, which in this case was 10,000 times. The CRM mix produced significantly better results and it could be expected that excellent performance could be achieved in a local road setting, as can be seen in the table above. This shows that conventional AC14 C320 mix deflect more than twice as much as CRM mix.

--ooOOoo--

5.3 Enabling supply

The use of crumb rubber involves either pre-blending the crumb rubber with bitumen at a centralised plant and then transporting to the jobsite or having the mixing equipment onsite for blending 'just in time'. This is designated as a "wet process". Alternatively, in asphalt applications the crumb rubber can be directly introduced during the manufacture of the hot mix, this is designated as a "dry process". In either case of the process, the blending or the introduction of the crumb rubber requires additional and sometimes specialised equipment to ensure better dispersion, thus providing a consistent quality outcome.

- **TSA has supported the enhancement and the expansion of the blending capacities by supporting industry partners in the set up of improved processes and procurement of specialised equipment.**
- **Click here to see road projects funded by TSA:** https://www.tyrestewardship.org.au/handbooks/tsa-funded-projects-brochure/

5.4 Supply Chain

Click here to visit TSA's Source Recycled Page for a list of Crumb Rubber suppliers:

- https://www.tyrestewardship.org.au/product/crumbrubber/

Links and references 6

https://www.ipwea.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=321ffd79-d989-8584-93c0-bbd50a202722&forceDialog=0

http://nacoe.com.au/wp-content/uploads/2017/10/P31-P32-Optimising-the-use-of-crumb-rubber_Yr1-2014-15-Final.pdf

Hoffmann, P & Potgieter, C 2007,
'Bitumen rubber chip and spray seals in South Africa', Southern African transport conference, 26th, Pretoria, University of Pretoria, South Africa.

Austroads 2013,
Guide to the selection and use of polymer modified binders and multigrade bitumens, APT235-13, Austroads, Sydney, NSW.

Lo Presti, D 2013,
'Recycled tyre rubber modified bitumens for road asphalt mixtures: a literature review', Construction and Building Materials, vol. 49, pp. 863-81.

California Department of Transportation 2003,
Asphalt rubber usage guide, Caltrans, Sacramento, California, USA

Austroads Pavements Research Group 1999,
The use of recycled crumb rubber, APRG technical note 10, Austroads, Sydney, NSW.

Jones, D, Harvey, J & Monismith, C 2007,
Reflective cracking study: summary report, research report UCPRC-SR-2007-01, University of California Pavement Research Center, Davis, USA.

Way, G, Kaloush, K & Biligiri, K 2011,
Asphalt-rubber standard practice guide, Rubber Pavements Association, Phoenix, Arizona, USA

Roads and Traffic Authority1995,
Scrap rubber bitumen guide, VicRoads, Main Roads Western Australia & Roads and Traffic Authority, NSW.