Developing a Framework for Auditing and Long-term Monitoring of the Performance of Recycled Materials

Author: Atteeq Ur-Rehman

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Summary

The use of recycled materials in pavements is critical to achieving sustainability. The enhanced use of recycled materials can significantly reduce waste and emissions as well as the depletion of virgin materials. Recycled materials and products are generally required to have equivalent performance and durability characteristics as natural quarried materials. The literature review conducted as part of this project indicated that the most common recycled materials incorporated into road pavements are recycled crushed concrete, masonry, fly ash, reclaimed asphalt, glass, plastics, rubber, and end-of-life tyres. Australian road and transport agencies specify limits for the use of common recycled materials in their relevant technical documents. The performance of recycled materials, and their potential environmental impacts, have also been investigated. Specifications restrict the concentration of undesired chemicals and heavy metals in recycled materials and products.

The prediction of pavement performance is critical in estimating life cycle costs. Long-term pavement performance (LTPP) studies broadly aim to improve the characteristic of materials, and encourage the consideration of environmental effects in pavement design and performance prediction. LTPP studies also provide guidance for the selection of maintenance and rehabilitation strategies. Austroads LTPP sites were established based on the US Strategic Highway Research Program (SHRP) criteria and the pavement types examined in this project were similar to those selected in the US Long-term Pavement Monitoring (US-LTPP) program. Data collection focuses on gaining an improved understanding of pavement response, particularly in terms of the effects of climate and traffic loading.

To assist in the need to gain a better understanding of the performance of recycled materials, the NTRO engaged with Main Roads WA and selected local government agencies (LGs) in the collection of data related to road pavements incorporating recycled materials. Relevant organisations were contacted and asked to provide information using a database template. A centralised database template was then prepared and the collected data was input into the database as a pilot project. This consultation enhanced the understanding of the existing situation regarding the use of recycled materials and the availability of relevant data. An indicative cost to populate database was also provided.

In terms of pilot data capture, Main Roads provided information related to three projects only This indicated that there was currently no central database available to record information regarding the use of recycled materials in the Western Australian road network. In addition, no guidelines were in place regarding for the monitoring of the performance of recycled materials. Selected LGs were contacted and asked to provide what performance data was available. Some of the LGs provided data related to multiple projects. Engagement with relevant officers in LGs indicated that there was high interest in the use of recycled materials and their impact on long-term pavement performance, rehabilitation and whole-of-life costs. Most of the LGs contacted could only provide partial information due to the challenges associated with extracting information from project documents.

One of the objectives of the project was to prepare a framework for the monitoring of the performance of recycled materials. This framework included capturing data related to the use of recycled materials, the assessment of pavement condition, data analysis and a comparison of the performance of recycled materials with the performance of virgin materials.

Based on the project findings, it can be concluded that none of the jurisdictions contacted as a part of this project systematically record the use of recycled materials in road infrastructure. It is recommended that the use of recycled materials should be documented in a central database managed by the relevant jurisdictions. Each jurisdiction should also consider developing a LTPP monitoring program for recycled materials which includes guidance on material selection, database development, and the frequency of performance measurement.

It I recommended that Main Roads consider establishing a central database as a repository for all the information available and to be collected in the future. This would demonstrate technical leadership in and the promotion of the use of recycled materials in road pavements.

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1 Introduction

The use of reuse and recycled materials in road pavements presents a large aspect of achieving sustainability by reducing waste and emissions and transitioning towards a circular economy to reduce the need for depleting virgin materials and increase diversion from landfill rates. Australian state road and transport agencies (SRTAs) have for a long time incorporated recycled materials in road infrastructure. During 2018–19 Australia generated 61.5 million tonnes of core waste, of which 5.7 million tonnes was generated in Western Australia (WA). The resource recovery and recycling rate was 60% (Pickin et al. 2020).

Recycled materials and products are generally required to have equivalent durability characteristics when compared to natural quarried materials. The incorporation of recycled materials in the construction, rehabilitation, and maintenance of roads must deliver required levels of serviceability, functionality, durability and resilience, and meet long-term performance requirements without premature degradation and the need for costly remediation (Austroads 2022a).

Main Roads Western Australia (Main Roads) is committed to deliver sustainable road projects. Several waste streams including glass, fly ash, plastics, rubber, reclaimed asphalt, crushed rock, masonry and concrete have long demonstrated successful incorporation into roads and pavements (Lim et al. 2020a).

Long-term monitoring is critical in understanding and evaluating pavement performance. In Western Australia (WA), construction records do not record the use of recycled materials.

The objective of WARRIP Project 2022-007 was to:

- establish a database design to record type, location and quantity of recycled materials used
- develop a framework for the monitoring of the long-term performance of road pavements incorporating recycled and conventional materials.

1.1 Structure of the Report

This report presents the findings of the investigations carried out as a part of WARRIP Project 2022-007 in relation to the development of a framework for the auditing and long-term monitoring of the performance of recycled materials.

The structure and contents of the report are as follows:

- Section 1 – an overview of the project objectives and scope.
- Section 2 – a literature review to investigate the state of play of recycled materials.
- Section 3 – details of the long-term pavement performance monitoring.
- Section 4 – summary of the consultation process.
- Section 5 – details related to pilot data capture.
- Section 6 – an outline of the framework for monitoring the performance of recycled materials.
- Section 7 – key findings.
- Section 8 – conclusions and recommendations.

2 Literature Review of Current Practice

The following presents a literature review outlining the current use of recycled materials by Main Roads and other Australian SRTAs and local government. The review focuses on the usage limits, processing requirements and associated environmental and safety concerns of commonly-used recycled materials. The requirements for long-term pavement performance (LTPP) monitoring sites are also addressed.

2.1 Common Recycled Materials and Their Usage Limits in Australia

Australian SRTAs have, for a considerable time, implemented recycled materials to reduce waste and emissions and deliver sustainable transport infrastructure. Common recycled materials incorporated into road infrastructure are concrete, masonry, fly ash, reclaimed asphalt, glass, plastics, rubber, and end of life (EOL) tyres (Austroads 2022a). The allowable limits for recycled materials in the relevant specifications of Australian jurisdictions and summarised in Table 2.1 to Table 2.7.

2.1.1 Recycled Crushed Concrete and Masonry

Recycled crushed concrete (RCC) and masonry is typically derived from construction and demolition (C&D) waste. RCC is regarded as a strong and durable construction material, typically consisting of high quality aggregate coated with hydrated cement, and cementitious fines derived from cement mortar (Trochez et al. 2021; Andrews et al. 2008).

The processing of RCC and masonry before its use in road infrastructure involves the removal of contaminants such as plastics, steel, and timber in addition to crushing and screening. It should be noted that the C&D-derived materials are susceptible to asbestos contamination. Therefore, visual inspections throughout the recycling process, in accordance with an asbestos management plan by trained professionals, is required to identify and remove asbestos prior to client acceptance (Austroads 2022a). Main Roads specification 501 (Main Roads 2023a) states that RCC can only be sourced from Department of Water and Environmental Regulation (DWER)-approved suppliers in accordance with the *Roads to Reuse* (RtR) specification (Waste Authority 2021).

The *Guide to the use of recycled concrete and masonry materials* (Standards Australia 2002) suggests there are 2 classes of RCC: Class 1A – RCC composed of little or no brick, and Class 1B – RCB – composed of up to 30% brick. The RCC and masonry are generally required to meet the same specification requirements of virgin quarried materials. As a result, the allowable limits for RCC and masonry in unbound layers proposed by some SRTAs are as high as 100% and up to 45% respectively (Austroads 2022a).

RCC has been found to have equivalent or superior bearing capacity and rutting resistance qualities compared to natural aggregates, while being approximately 20% lighter than virgin aggregates (Austroads 2022a). Studies have noted that the failure of recycled materials can arise from the debonding of aggregate mortar and their residual mortar can reduce aggregate density and water absorption (Austroads 2022a; Verian et al. 2018).

Specification 501 (Main Roads 2023a) permits the use of up to a maximum of 100% RCC as subbase material; however, its use is currently limited to full depth asphalt pavement. The Department of Transport and Planning Victoria (DTP) permits the use of RCC in the pavement basecourse and subbase layers at varying proportions based on the material classes. However, masonry is classified as a supplementary material and individual limits are not generally specified (VicRoads 2016a). The *Specification of granular pavement base and subbase materials* (Transport for NSW (TfNSW) 2020a) permits 100% of RCC for basecourse and subbase materials; however, the source is dependant of traffic categories. Queensland Department of Transport and Main Roads (TMR) is the only jurisdiction to permit the use of RCC and masonry in dense-graded asphalt (DGA). The allowable limits for RCC in unbound layers are similar across the SRTAs. Table 2.1 and Table 2.2 summarise the Australian requirements for RCC and RCB.

Table 2.1: **Australian requirements for recycled crushed concrete**

Jurisdiction	Specification or Guide	Application	Allowable limit for RCC (%)
Main Roads WA	Specification 501 (Main Roads WA 2023a)	Subbase	95–100
TMR Qld	MRTS05 (TMR 2021a)	Type 2.1	100
		Type 2.2	
		Type 2.3	
		Type 2.4	
		Type 2.5	
	MRTS30 (TMR 2022a)	DGA	10
		DGA surfacing	2.5
DTP Vic.	TN107 (VicRoads 2019a)	Basecourse (Class 1)	0
		Basecourse (Class 2)	10
		Basecourse/subbase (Class 3)	100
		Subbase (Class 4)	100
		Subbase (cement treated)	100
TfNSW	D&C 3051 (TfNSW 2020b)	Unbound or modified base and subbase	100
		Bound base and subbase	100
	Supply of recycled material for pavements, earthworks and drainage (Savage 2010)	Basecourse (Class R1)	100
		Basecourse (Class R2)	100
		Fill	100
		Bedding	100
		Drainage	100
Transport Canberra and City Services (TCCS)	TCCS MITS 04 (TCCS 2019a)	Basecourse and subbase	100
DIT SA	RD-PV-S1 (DIT 2022a)	Basecourse/subbase (Class 1-3)	100
IPWEA/WALGA	*Specification for the supply of recycled road base* (IPWEA & WALGA 2019)	Basecourse	95

Table 2.2: **Australian requirements for recycled crushed brick**

Jurisdiction	Specification or Guide	Application	Allowable limit for CRC (%)
Main Roads WA	Specification 501 (Main Roads WA 2023a)	Subbase	3
TMR Qld	MRTS05 (TMR 2021a)	Type 2.2	15
		Type 2.3	20
		Type 2.4	45
		Type 2.5	45
	MRTS30 (TMR 2022a)	DGA	40
		DGA surfacing	20
DTP Vic.	TN107 (VicRoads 2019a)	Basecourse (Class 1)	5
		Basecourse (Class 2)	10
		Basecourse/Subbase (Class 3)	15
		Subbase (Class 4)	50
		Subbase (cement treated)	15

Jurisdiction	Specification or Guide	Application	Allowable limit for CRC (%)
TfNSW	D&C 3051 (TfNSW 2020a)	Unbound or modified base and subbase	20
		Bound basecourse and subbase	10
	Supply of recycled material for pavements, earthworks and drainage (Savage 2010)	Basecourse (Class R1)	20
		Basecourse (Class R2)	30
		Fill	100
		Bedding	100
		Drainage	100
TCCS ACT	TCCS MITS 04 (TCCS 2019a)	Basecourse and subbase	20
DIT SA	RD-PV-S1 (DIT 2022a)	Basecourse/Subbase (Class 1-3)	20

The *Notes to the specification for basecourse aggregate* (Waka Kotahi NZ Transport Agency 2024) permits up to 100% RCC in basecourse layers, with the requirements governed by the properties and percentage of foreign material. Similarly, The UK Department of Transport (2016) permits up to 100% crushed recycled concrete as unbound aggregates provided it meets grading requirements. The Washington State Department of Transportation (WSDOT) permits a maximum of 100% RCC (Van Dam et al. 2016). However, the regional state of practice across US Transportation agencies differs largely, with the Arizona Department of Transportation (ADOT) only permitting a maximum of 50% RCC aggregate and the New Mexico Department of Transportation (NMDOT) up to 75% (Van Dam et al. 2016).

2.1.2 Recycled Crushed Glass

Approximately 1.16 million tonnes of glass were consumed in Australia during 2018–19, with 684,000 tonnes recovered for recycling. This is equivalent to approximately 3 billion bottles diverted way from the landfill (Austroads 2022a). Recycled crushed glass (RCG) is sourced from municipal solid waste (MSW) streams comprising of post-consumer glass waste (such as bottles, jars and similar vessels) when its processing is uneconomical or it is unsuitable to be recycled back into glass (Latter & LeGrand 2020). RCG is very similar to natural or manufactured sand in terms of it physical and mechanical properties.

The *Guideline for crushing, processing and cleaning of recycled crushed glass for transport infrastructure* (Austroads 2022b) describes the processes used to convert waste glass to RCG. RCG products are produced in 3 key stages: crushing, processing and cleaning. During the crushing stage, the glass is broken down to uniform sizes for processing to separate contaminants (such as lids, corks and labels). It is then further crushed for particle size reduction and finally cleaned by washing and dewatering to eliminate contaminates that produce odours and impurities.

Use of recycled crushed glass in pavements

The use of RCG in Australia is generally limited to the substitution of fine aggregates; they are not readily accepted as coarse aggregates. Currently TMR, TfNSW, DTP and ACT permit the use of RCG in both unbound granular and asphalt applications. The use of up to 15% RCG with particle sizes less than 10 mm in granular pavements in New Zealand has shown that there are no detrimental effects on performance (Arnold et al. 2008). In the US, generally up to 20% glass is commonly permitted in granular materials applications (Austroads 2022c). The UK permits up to 25% glass in unbound mixes (Department of Transport 2016).

The major application for RCG is basecourse and subbase layers, asphalt wearing courses and earthwork backfill. *Specification 501 pavements* (Main Roads 2023a) does not specifically permit RCG; however, it limits the allowable inert material in RCC materials. *Specification 302 Earthworks* (Main Roads 2020) permits 100% RCG in backfill applications. TMR permits up to 20% of RCG in subbase applications. TMR limits the use of RCG in DGA applications. The RCG aggregate material requirements for TMR are defined in MRTS36 (TMR 2021b). The Australian SRTA's requirements for RCG are summarised in Table 2.3.

Concerns associated with adhesion is a key limiting factor regarding the increased usage of RCG in asphalt applications. However, limiting particle sizes to below 5 mm were found to alleviate these effects. Austroads (2022a) reported that asphalt mixes containing RCG are more sensitive to moisture as compared to equivalent mixes composed of natural aggregates. This sensitivity may lead to stripping of asphalt mixes. Research suggests that the increased use of hydrated lime can significantly reduce the stripping propensity in asphalt layers and stripping tests should be considered at the mix design stage (e.g. ATM 232-22). Similarly, concerns have been raised regarding the glass market, with supply exceeding demand (Austroads 2022d).

Table 2.3: Australian requirements for recycled crushed glass

Jurisdiction	Specification or Guide	Application	Allowable limit for CRC (%)
Main Roads WA	Specification 302 (Main Roads 2020)		100
	Specification 501 (Main Roads 2023a)	Subbase CRC	3[1]
TMR Qld	MRTS04 (TMR 2021c)	Backfill	100
	MRTS05 (TMR 2021a)	Type 2.3	20
		Type 2.4	
		Type 2.5	
	MRTS07B (TMR 2021d)	Foamed bitumen	Not specified
	MRTS09 (TMR 2021e)		
	MRTS30 (TMR 2022a)	Dense-graded asphalt	10
		Dense-graded asphalt (surfacing)	2.5
	MRTS101 (TMR 2021f)	Asphalt	✓
DTP Vic.	Section 204 (VicRoads 2015)	Earthworks	✓
	Section 702 (VicRoads 2019b)	Drainage	100
	TN107 (VicRoads 2019a)	Basecourse (Class 1)	5[1]
		Basecourse (Class 2)	10[1,2]
		Basecourse/subbase (Class 3)	15[1]
		Subbase (Class 4)	50[1]
		Subbase (cement treated)	15[1]
TfNSW	Specification D&C R116 (TfNSW 2021a)	Wearing course	2.5
	Specification D&C R117 (TfNSW 2022)		
	Specification D&C R121 (TfNSW 2020c)		
		Other wearing course	10
	Specification D&C 3051 (TfNSW 2020b)	Unbound or modified base and subbase[3,4]	10
		Bound basecourse and subbase[4]	10
	Specification 3201 (TfNSW 2021b)	Slab replacement work for concrete pavements	15
	Specification for supply of recycled material for pavements, earthworks and drainage (Savage 2010)	Basecourse (Class R1)	10

Jurisdiction	Specification or Guide	Application	Allowable limit for CRC (%)
		Basecourse (Class R2)	10
		Fill	10
		Bedding	50
		Drainage	50–100
TCCS	TCCS MITS 04 (TCCS 2019a)	Basecourse and subbase	10
DIT SA	RD-LM-S1 (DIT 2019a)	Pavement marking	✓
DIPL NT	*Standard Specification for Roadworks v5.1* (DIPL 2022a)	Bedding and drainage	100
		Pavement marking	✓
IPWEA/WALGA	Supply of recycled road base 2016 (IPWEA & WALGA 2019)	Basecourse	95

1. Recycled material (including RCB, RCG and RAP) are supplementary materials and individual limits are not specified.
2. Light duty pavements.
3. For unbound or modified base materials for Traffic Categories A and B, RCC must be sourced on structural concrete.
4. For unbound or modified base materials for Traffic Categories C and D and unbound subbase, bound base and bound, RCC from structural and non-structural concrete are acceptable.

The UK Department of Transport allows up to 25% glass in recycled coarse aggregate and recycled concrete aggregate products in type 1, 2 and 4 unbound pavement mixtures. The NMDOT permits up to 15% RCG in basecourses and up to 30% in subbase and embankments. Similar to the Australian practice in non-structural and drainage layers up to 100% RCG is permitted. The WSDOT permits up to 15% in unbound aggregates (Van Dam et al. 2016). The State of Connecticut specifies that aggregate used for roadway embankments may contain up to 25% by weight of cullet smaller than 25 mm (Van Dam et al. 2016). These allowable limits from the US jurisdictions closely align with Australian specifications. The *Notes to the specification for basecourse aggregate* (Waka Kotahi ZN Transport Agency 2024) allow up to 5% cullet of glass in recycled layers.

Performance and environmental issues

Recycled glass powder is pozzolanic and will react with lime to form stabilised materials. Moreover pozzolanic reactions between glass particles and alkalis in the cement could enhance the compressive strength of concrete (Kazmi et al. 2020). Austroads (2022a) reported that alkali-silica reactions as a result of glass reacting with the cement products lead to swelling and expansion of the glass particles, resulting in cracking of the stabilised layers. In asphalt which includes RCG, greater susceptibility to water-induced stripping and poor skid resistance has been reported (Austroads 2022a; Austroads 2022b).

The high concentration of chemicals and heavy metals in RCG products may cause ecological harm and contaminate groundwater or cause human health issues. Therefore, each SRTA specifies the acceptable limit of contaminants in RCG. The *Specification for recycled glass aggregate* (TMR 2021b) specifies the material requirements and maximum concentration limits for chemicals and other attributes. Concerns are further mitigated by eliminating the contact between RCG and water by placing RCG below the sealed surfaces and away from elevated water-tables. Moreover, there are respiratory concerns around the use of fine RCG where fine particles may become airborne. Appropriate personal protective equipment (PPE) should be worn when handling RCG products (Austroads 2022a).

2.1.3 Recycled Plastics

The use of recycled plastics in road applications is currently an emerging trend. Plastics have been used as a component for manufacturing modified bitumen for asphalt and sprayed seals for a number of years. Post-consumer plastic waste is a diverse group of materials with differing chemical compositions and physical properties. Therefore plastic wastes, derived from commercial and industrial (C&I) waste, has been the focus in recycled plastics research (Austroads 2022a; California Department of Transportation (Caltrans) 2020). Additionally, C&I plastic waste has a lower contamination which facilitates cleaning, sorting and processing. Mechanical recycling which repurposes plastic waste into secondary raw materials is widely used in Australia and New Zealand. The process involves collection, sorting, shredding, washing or decontamination, extrusion, quenching and pelletisation (Austroads 2021a).

The *Guide to pavement technology part 4e: recycled materials* (Austroads 2022a) describes the processes for the use of recycled plastics and performance- and cost-related issues of recycled plastic.

Mixing processes

Recycled plastic wastes are utilised primarily through three mixing processes: dry method, wet method, and mixed method. The dry method involves adding solid recycled plastics directly in the mix chamber or the asphalt plant. The wet method introduces recycled plastic to bitumen, creating a plastic modified binder. The mixed method combines aspects of the both the wet and dry methods.

Use of recycled plastics in pavements

Recycled plastics have potential applications as aggregate substitute, binder modification and geosynthetics and geogrids in pavements (Trochez et al. 2021). Recycled plastics are used to modify bitumen to manufacture polymer modified bitumen (PMB) binders and there are a range of specifications available for guidance in Australia (e.g. Austroads ATS3110 (Austroads 2020)). New Zealand utilises the Superpave Performance Grading System developed in the USA; it covers both neat and PMB binders. The selection and use of a PMB to satisfy the required binder grade for a given application is the responsibility of designers and contractors.

Another application of recycled plastics is inclusions of polymer granules in subbase and lower subbase layers. Research-based investigations carried out overseas showed that the polymer granules' inclusions at less than 5% with particle size no greater than 10 mm do not significantly impact bearing capacity. It should be noted that polymers generally have far lower strength than natural aggregates and their use in large quantities may adversely impact deformation characteristics in granular pavements. Therefore, care must be taken and only limited volumes of natural aggregates must be substituted for polymer granules. This application may have a high potential for release of polymer particles from the pavement into the environment and this can pose challenges due to the processing required to segregate polymer and conventional aggregate.

In addition to the applications mentioned above, recycled plastic is re-manufactured and used as discrete fibre or continuous fibre mesh as geotextile reinforcement for the purpose of material separation of unbound granular layers and interlayer tensile reinforcement of asphalt. Proprietary recycled plastic geotextile products exist but their mechanical properties need to be tested in the laboratory to ensure their compliance with Australian and New Zealand specifications for geotextiles.

The use of recycled plastics in India is well established, with plastic concentrations of 6–8% by binder weight (typically 0.3–0.4% of the total mix) are permitted (Austroads 2022c).

The use of recycled plastics in pavements is still an emerging trend and researched is being conducted. A limited number of US states such as California and Australian regional councils such as the City of Mitcham in South Australia, and South African cities have trialled plastics in asphalt layers.

Performance of recycled plastics in pavements

Plastic-modified bitumen can be regarded as a type of PMB. Bitumen-plastic blends are prone to phase separation similar to that of crumb rubber. Asphalt mixes modified with plastics are reported to have increased moisture sensitivity (Austroads 2022a). Moreover, the long-term durability of waste plastics in pavements has not been validated. As a result, at present there are no specifications covering the use of waste plastics in road pavements or surfacing applications in Australia or New Zealand. However, commercially available proprietary products are available.

Recycled plastics can be used to replace a portion of aggregate in asphalt mixes. Huang et al. (2007) suggested that 15–30% of aggregates can be replaced with plastics to improve rutting, cracking and ageing performance, while up to 8% plastic in binder can increase the Marshall Stability.

There are a number of perceived occupational health and safety (OHS) concerns related to the use of recycled plastics in road infrastructure. Recycled plastics have the potential to release volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) under thermal degradation, but it can be mitigated by lower temperature applications. Moreover, dry methods of mixing may result in chemical leaching or dispersion in road pavement layers.

Cost-related issues

Cost is a significant barrier to the use of recycled plastics, with the cost of recycled plastics comparative to that of virgin materials. Moreover, there is an additional cost of incorporating plastic wastes with varying processing methods. However, recycled plastic potentially offers key economic benefits such as improved engineering properties including stripping and rutting resistance, resistance to fatigue damage, reduction in air voids, and improved workability when used in bitumen (Austroads 2022a).

2.1.4 Crumb Rubber

Crumb rubber (CR) is derived from recycling EOL tyres. EOL tyres consist of natural and synthetic rubber, carbon black, metal, zinc oxide and sulphur. However, the composition of synthetic and natural rubber varies between truck and passenger car tyres (Harrison et al. 2019). EOL tyres are processed in 3 stages:

- shredding the tyres to small particles of rubber
- removing the fibres and steel through the use of suitable separators
- grinding to produce a finer size and mixing with different reclaiming agents.

The use of CR as a recycled material in pavements can be divided into 2 categories:

- bitumen modifiers in the manufacturing of PMB for sprayed sealing
- asphalt mix applications.

PMB binders are frequently used for sprayed sealing applications in Australia.

Mixing processes

CR is generally incorporated into asphalt using 2 approaches: the ‘wet mix’ process and the ‘dry mix’ process. During the ‘dry mix’ process rubber crumbs are incorporated directly into the hot aggregates prior to the addition of the binder. They are a substitution of a proportion of fine aggregates, resulting in underutilisation of rubber modification. On the other hand, during the ‘wet mix’ process rubber crumbs are blended into the binder as a modifier to produce crumb rubber-modified (CRM) binder. This process maximises the benefit of crumb rubber and permits greater control. CR has commonly been used in modified asphalt pavements across Europe and USA (Rice & Harrison 2021; Harrison et al. 2021).

Use of crumb rubber in pavements

In Australia, CR used by SRTAs must:

- comply with the requirements of AGPT/T190 (Austroads 2019a). the use of uncured or de-vulcanised rubber is not permitted
- be processed from EOL tyres generated in Australia and processed by a Tyre Stewardship Australia accredited supplier

- be a uniform material consisting of synthetic rubber or natural rubber from car or truck tyres, or a mixture of both, and free from cord, wire, fluff and other deleterious materials
- meet the specified particle size distribution requirements.

Main Roads uses S45R as a sprayed seal binder with 15% CR in C170. The allowable limit increases to 18% in open-graded asphalt mixes. TMR allows 18% CR in C170 bitumen sprayed seals while DTP permits 9% in high-stress seals. DIT have conducted CR field trials containing 15% rubber. Currently, there are no material or NZTA construction specifications that either prohibit or permit the use of crumb rubber (Wu et al. 2020). Table 2.4 summarises the Australian SRTA's requirements for CR.

Table 2.4: Australian requirements for crumb rubber

Jurisdiction	Specification or Guide	Application	Allowable limit for CR
Main Roads WA	Specification 503 (Main Roads 2018a)	Sprayed seal (GRS)	5% rubber
	Specification 509 (Main Roads 2018b)	Sprayed seal	15%
	Specification 517 (Main Roads 2023b)	Asphalt	18%
TMR Qld	MRTS11 (TMR 2019a)	Sprayed seals	5% (unmodified seals) 9% (high stress seals) > 15% (extreme stress seal)
	MRTS18 (TMR 2019b)	PMB	✓
DTP Vic.	Section 408 Sprayed bituminous surfacing (VicRoads 2022)	Sprayed seals	5% (unmodified seals) 9% (high stress seals) > 15% (extreme stress seal)
	Section 421 (VicRoads 2020)	Crumb rubber binder	2.5–3%
	Section 422 (VicRoads 2019c)		✓
TfNSW	D&C Specification 3256 (TfNSW 2020d)	Crumb rubber	✓
	QA specification R118 (TfNSW 2020e)	Crumb rubber asphalt	✓ 2% minimum
	QA specification 3252 (TfNSW 2020f)	PMB	10–16% minimum Based on treatment
DIT SA	RD-LM-S1 (DIT 2019a)	Pavement marking	✓

Many US state transportation agencies have evaluated the use of crumb rubber in bitumen used to manufacture asphalt, resulting in differing states of practice (Van Dam et al. 2016). The Caltrans) standard specifications (Caltrans 2018) and ADOT (2008) state that crumb rubber modifier should be added at 20%. The NMDOT standard specification (2019) allows a minimum of 5% crumb rubber content for polymer-modified asphalt (NMDOT 2019). The Texas Department of Transportation (TxDOT) specification (2014) specifies graduation requirements along with a minimum of 5% crumb rubber for rubber-asphalt crack sealing and asphalt-rubber binders. CR binders produced in South Africa typically contain 18–24% crumb rubber but the allowable limits are not specified (Austroads 2021b).

The incorporation of CR in asphalt increases viscosity and elasticity to improve rutting resistance and fatigue cracking in pavements. Moreover, CR-modified binders in sprayed seals are readily used in applications subject to heavy turning loads (Austroads 2022c). Crumb rubber modified (CRM) binders have effectively been used to mitigate reflective cracking of failed and damaged pavements (Austroads 2022c; COLAS 2020; GeoPave Materials Technology 1997). In concrete applications, incorporation of CR using the dry process has been found to increase ductility and impact resistance. However, it is generally weaker than traditional concrete due to poor bonding between rubber and cement (Austroads 2022c; Lim et al. 2020a).

The implementation and performance of CR in roads is dependent on the compatibility between the rubber and bitumen. It is influenced by (Harrison et al. 2019):

- processing variables such as temperature, mixing time and process
- base binder properties
- recycled tyre rubber properties including processing methods, particle size, natural and synthetic content.

Environmental issues

According to the Tyre Stewardship Australia (2022), CR, in comparison to conventional bitumen, introduces a minor increase in risk to the surrounding environment, During asphalt construction there is a minor to moderate fuming risk for construction workers. However, fumes and airborne particles from CR were not above SafeWork Australia standards and would not result in carcinogenic or negative symptoms for asphalt construction workers. Similarly, a CRM binder field trial in Western Australia demonstrated that the levels of airborne contaminants (e.g. PAH and VOC) at the work site were below exposure limits and standards (Middleton 2022). Moreover, there are leaching concerns associated with the release of metals such as zinc into the surrounding environments from CR. However, Gheni et al. (2018) found that the CR combined with bitumen can reduce leaching of metal by up to 50%.

There are concerns associated with the segregation and degradation of crumb rubber binders. Degradation is addressed by limiting the storage time between the binder manufacture and use, and/or storing and transporting the binder at the lowest practicable temperature (Austroads 2021b). Moreover, segregation is addressed by equipping storage tanks or trucks with augers or paddles so that the crumb rubber remains dispersed in the binder (Austroads 2021b).

Due to economic and processing costs and the recycling rate, the availability of CR is not consistent, and this can limit greater use of CR in road applications. Despite this, over the long term a significant cost saving is expected from the reduced amount of bituminous binder and enhanced performance.

2.1.5 Reclaimed Asphalt Pavement

Recycled or reclaimed asphalt pavement (RAP) is derived from milling old asphalt pavements. RAP material is classed as either ‘Class 1’ or ‘Class 2’ (Austroads 2022a). Class 1 RAP consists solely of asphalt and is generally used in ‘new’ asphalt to reduce the use of virgin aggregates and bitumen. Class 2 RAP comprises asphalt and contaminants such as unbound granular material, As such, it is deemed unsuitable for use in ‘new’ asphalt pavements.

Post milling, RAP material is generally stockpiled, crushed, graded and tested before being recycled into new hot mix asphalt or used in cold in situ recycling applications (Bressi et al. 2021). It is noted that the milling and crushing can cause aggregate degradation. In cold recycled RAP, the mixing is achieved through the incorporation of emulsified or foamed bitumen with 1–2% cementitious additive to improve early strength and moisture resistance. In hot recycled RAP, the mixing occurs at high temperatures with fresh bitumen, aggregate and rejuvenators or softening agents. Hot recycled RAP mixes have superior mechanical properties when compared with cold recycled RAP mixes (Austroads 2022c).

Use of reclaimed asphalt in pavements

Whilst RAP is preferably used in the production of new asphalt layers, it has been reported that RAP is often used in Europe in unbound granular layers, up to 60% in some countries due to the excess supply of RAP (Austroads 2022c). RAP is also blended with other recycled materials as virgin aggregate replacement. RAP in foamed bitumen-stabilised (FBS) pavements has been investigated with results showing no noticeable difference in rutting between FBS pavements with 50% RAP and 0% RAP (Austroads 2019c). For use as bituminous sealing aggregate, RAP meets the material property requirements for virgin aggregates, with improved workability due to the residual binder (Austroads 2022c; Federal Highway Administration (FHWA) 1997). Consequently, there is improved bonding of RAP in sprayed seals when compared to virgin aggregates.

RAP technology is well established and regarded as a standard practice among SRTAs. The usage limits, specifications and guidance on the use of RAP vary between Australian SRTAs. Generally, RAP contents of less than 15% have marginal effects on mix properties. Currently, Australian SRTAs typically permit between 15 to 25% RAP in surface layers and 15 to 50% in basecourse layers. In New Zealand, up to 15% RAP can be added to all DGA mixes, with higher RAP contents being permitted provided quality control and suitable manufacturing procedures are demonstrated (Austroads 2016a and 2022b; Waka Kotahi NZ Transport Agency 2024; NZTA 2020). TMR permits up to 20% RAP in DGA wearing courses, up to 40% in DGA in other applications, and up to 15% in high modulus asphalt (EME2). In Western Australia, up to 10% RAP is permitted in basecourse applications for Class 1 materials and up to 15% for Class 2 materials (IPWEA & WALGA 2019). Main Roads allows 0–10% and 11–25% RAP for level 1 and level 2 usage.

The FHWA defines a 'high' RAP content as over 25% (FHWA 2020). US transportation agencies generally permit high percentages of RAP (25% or greater) in pavement layers; however, fewer than 50% of states use more than 20% RAP (Van Dam et al. 2016). Caltrans allows up to 25% RAP in all pavement layers. The maximum allowable RAP content used by NMDOT (2014) is 35%; however, where the RAP content is greater than 15%, asphalt binder properties are required to be investigated. TxDOT (2014) permits up to 10% RAP in DGA wearing course, 30% in intermediate course, and 40% in basecourse layers. The *Specification for highway works* (UK Department of Transport 2021) allows RAP to be used in bituminous wearing courses, binder courses, regulating courses and basecourses. Its use in unbound layers it is limited to 50% for type 1 and 2 mixtures; however, 100% is permitted in type 4 mixes. The permitted RAP limits between Australian and US practices are generally similar. Jayakody et al. (2021) found that increasing RAP proportions in granular blends increased the rapid settlement of the material during initial loading during repeated load triaxial (RLT) testing.

The Australian SRTA's requirements for RAP are presented in Table 2.5.

Table 2.5: Australian requirements for RAP

Jurisdiction	Specification or Guide	Application	Allowable limit for RAP
Main Roads WA	Specification 501 (Main Roads 2023a)	Subbase(1) CRC	15%(1)
	Specification 504 (Main Roads 2021a)	Wearing course	Not Permitted
	Specification 510 (Main Roads 2021c)	Asphalt intermediate course	Level 1 ≤ 10%, Level 2 ≤ 25%, Level 3 ≤ 40%
	Specification 515 (Main Roads 2021d)	Base and subbase	10%
TMR Qld	MRTS30 (TMR 2022a)	Dense-graded asphalt	30% (base, intermediate and corrector courses)
		Dense-graded asphalt (surfacing)	20% (surfacing) 15% (DGA with PMB and multigrade bitumen)
	MRTS32 (TMR 2022b)	EME2	15%
	TN 183 (TMR 2019c)	Dense-graded asphalt (high percentage RAP)	40%
DTP Vic.	Section 405 Regulation Gap Graded Asphalt (VicRoads 2014a)	Gap-graded asphalt	10%
	Specification 407 (VicRoads 2021a)	Dense-graded asphalt	25% (Level 1) 40% (Level 2)
	Section 802 (VicRoads 2014b)	Bituminous cold and warm mixes	✓
	TN 107 (VicRoads 2019a)	Base/subbase (Class 3)	15%
		Subbase (Class 4)	40%
	Section 813 (VicRoads 2021b)		20% (base) 50% (subbase)

Jurisdiction	Specification or Guide	Application	Allowable limit for RAP
TfNSW	Specification D&C R116 (TfNSW 2021a)	Wearing course (heavy duty)	20% (wearing course) 40% (other than wearing course in heavy duty DGA)
	Specification D&C R117 (TfNSW 2022)	Wearing course (light duty)	25% (wearing course) 40% (other than wearing course in heavy duty DGA)
	Specification D&C R121 (TfNSW 2020c)	Stone mastic asphalt	Not permitted
	Specification D&C 3051 (TfNSW 2020b)	Unbound or modified base and subbase(2,3)	40%
		Bound base and subbase(3)	40%
DIT SA	RD-BP-S2 (DIT 2022b)	Asphalt	10% (course wearing course) 20% (fine dense mix asphalt) 50% (other than wearing course)
	RD-PV-S1 (DIT 2022a)	Base/Subbase (Class 1–3)	20%
DIPL NT	*Standard specification for roadworks v5.1* DIPL (2022a)	Asphalt	10% (wearing course)
		Base	15%
IPWEA and WALGA	*Specification for the supply of recycled road base* (IPWEA & WALGA 2019)	Base	10% (Class 1) 15% (Class 2)

1. Foreign material in RCC.
2. For unbound or modified base materials for Traffic Categories A and B, RCC must be sourced on structural concrete.
3. For unbound or modified base materials for Traffic Categories C and D and unbound subbase, bound base and bound, RCC from structural and non-structural concrete are acceptable.

Environmental and cost-related issues

There are no reported health, safety and environmental risks associated with RAP. However, consideration should be made where RAP contains previously-recycled material. Austroads (2022c) reported that incorporation of 25% to 50% RAP can decrease overall material costs by 20 to 35%. This represents a cost savings throughout the asset's lifecycle. It is noted the economic benefits will vary between projects, location, material availability and application.

2.1.6 Fly Ash

Fly ash is an industrial by-product of coal combustion in power plants. It is widely used in construction materials due to its non-hazardous nature in terms of corrosivity, ignitability and reactivity. There are toxicity concerns associated with fly ash with potential heavy metal leaching. Dust hazards can result from fly ash due to its low density and particle size; however, this is suitably managed by keeping the material moist and covered during storage.

Fly ash is a fine non-plastic material with pozzolanic properties. The amount of calcium in the fly ash is an indicator of its behaviour. Fly ash is classified as either Class F or Class C depending on the calcium oxide content (Austroads 2022a). Class F fly ash is derived from black coal and has lime content of less than 7%. Class C, on the other hand, is derived from brown coal and has a greater lime content, ranging from 15 to 30%. The compliance requirements of fly ash are defined in AS/NZS 3582. Its products are defined by fineness, loss on ignition, moisture content, SO_3 content, and aggregate applications.

Use of fly ash in pavements

Fly ash is a widely used additive used in cement to improve workability, strength and durability. Currently, Australian SRTAs permit the use of fly ash as a supplementary cementitious material in concrete and pavements, with limits not defined for application in asphalt.

TfNSW and TMR permit up to 40% fly ash in concrete pavement basecourse layers and 75% in lean mix concrete subbases.

Main Roads permits the use of fly ash as a filler in micro-surfacing. In blended cements it permits up to 25% fly ash for concrete structures and culverts.

Fly ash has also been used in the cementitious stabilisation of granular pavements (American Coal Ash Association 2003). For stabilisation works Austroads specifies a maximum fly ash limit depending on the binder mix, ranging from 40 to 75%. Generally, Australian SRTAs only specify fly ash limits when used as a supplementary cementitious material.

The FHWA (1997) reported that fly ash can be added up to 5% by aggregate weight for use as a filler in asphalt pavements. Similarly, the *Specification for highway works* (UK Department of Transport 2021) allows fly ash to be utilised as a filler in bituminous materials. Fly ash reduces the moisture susceptibility of the binder and stripping potential due to its pozzolanic nature and act as a bitumen extender. However, asphalt pavements with fly ash have had compaction issues related to inconsistent softened bitumen. In subbase and basecourse stabilisation applications high volumes of fly ash are reported to lead to erodibility issues.

ADOT (2008) allows up to 20% of the Portland cement to be replaced with fly ash for lean mix concrete basecourses. Caltrans (2018) and NMDOT (2019) specifications do not permit fly ash as a filler in hot mix asphalt (HMA); however, as a supplementary cementing material (SCM) in concrete there is an allowable limit of 50%. The Southern African Bitumen Association permits fly ash to be used as a filler in asphalt (SABITA 2022).

Table 2.6 summarises the Australian SRTA's use of fly ash.

Table 2.6: Australian requirements for fly ash

Jurisdiction	Specification or Guide	Application	Allowable limit for FA
Main Roads WA	Specification 302 (Main Roads 2020) Specification 820 (Main Roads 2023c)	Select fill Concrete structures	25%
	Specification 410 (Main Roads 2021e)	Backfill	Not specified
	Specification 507 (Main Roads 2017a)	Microsurfacing	Not specified
	Specification 515 (Main Roads 2021d)	Base and subbase	Not specified
TMR Qld	MRTS07B (TMR 2021d)	In situ stabilisation	Not specified
	MRTS07C (TMR 2021g)	Foamed bitumen (in situ)	Not specified
	MRTS08 (TMR 2021h)	Plant-mixed heavily-bound (cemented) pavements	Not specified
	MRTS09 (TMR 2021e)	Foamed bitumen (plant-mixed)	Not specified
	MRTS10 (TMR 2021i)	Plant-mixed lightly-bound pavements	Not specified
	MRTS39 (TMR 2018a)	Lean mix concrete subbase for pavements	Not specified

Jurisdiction	Specification or Guide	Application	Allowable limit for FA
	MRTS40 (TMR 2018b)	Concrete pavement base	40%
DTP Vic.	Section 306 (VicRoads 2019d)	SCM in blended cement – cement-treated subbase	30%
	Section 307 (VicRoads 2008)	SCM in blended cement	30%
	Specification 407 (VicRoads 2021a)	Dense-graded asphalt(3)	Not specified
	Section 520 (VicRoads 2018)	Compacted concrete pavement courses	Not specified
	Section 815 (VicRoads 2016b)	SCM in blended cement – cement-treated subbase	30%
TfNSW	Specification D&C 3051 (TfNSW 2020b)	Unbound or modified base and subbase(1,2)	10%
		Bound base and subbase(2)	10%
	Specification D&C 3211 (TfNSW 2020a)	SCM in blended cement – concrete pavement base	40%
		SCM in blended cement – lean mix concrete subbase	75%
TCCS	TCCS MITS 04 (TCCS 2019a)	Base and subbase	Not specified
	TCCS MITS 02C (TCCS 2019b)	Subgrade	Not specified
DIT SA	RD-PV-S1 (DIT 2022a)	Base/subbase (Class 1-3)	67% (3% consisting of 2% fly ash and 1% lime)
	RD-PV-S2 (DIT 2019b)	Plant mixed stabilised pavement	Not specified
DIPL NT	*Standard specification for roadworks v5.1* DIPL (2022a) DIPL (2022b)	Stabilisation	Not specified
Austroads	AGPT4L-09 (Austroads 2009)	Binder (in cement) blends)	50%
		Binder (in lime) blends)	75%
		Binder (in lime-fly ash GGBFS) blends)	50%
		Binder (in cement-fly ash GGBFS) blends)	40%

1. For unbound or modified base materials for Traffic Categories A and B, RCC must be sourced on structural concrete.
2. For unbound or modified base materials for Traffic Categories C and D and unbound subbase, bound base and bound, RCC from structural and non-structural concrete are acceptable.
3. Intermediate and basecourse.

Quality and viability related issues

Risks associated with the fly ash include product variability (chemical and physical) and quality control due to the composition of coal and combustion process. Quality control of fly ash applications can be maintained by ensuring that the source materials do not vary. Moreover, the location of the coal combustion power plants relative to the site are vital in the economic viability of using fly ash.

2.1.7 Slag

Slag is a by-product from manufacturing process of steel and iron. It is commonly grouped into 4 categories: ground granulated blast furnace slag (GBFS), blast furnace slag (BFS), basic oxygen steel slag (BOS) and electric arc furnace slag (EAF). Slag is an acceptable alternative to natural aggregates (Austroads 2022c). DTP recognises the potential use of slag in roadworks, however VicRoads (2011) refers the user to contact DTP for technical advice for specific requirements.

Use of slag in pavements

Slag has been widely used throughout Australia and New Zealand as aggregate in engineering fill, unbound granular materials, asphalt and sprayed seals and stabilisation applications. The Australasian Slag Association (ASA) has published several guidelines for the use of slag in road infrastructure.

In the USA, slag is typically used as aggregate for the construction of concrete and pavements. (Austroads 2022c). Slag materials in granular pavements enhance the strength due to its pozzolanic properties, if activated.

According to the ASA (2002) slag aggregates can potentially improve constructability in wet climates due to their reduced moisture sensitivity compared to virgin aggregates and also to enhance uniaxial compressive strength (UCS). In asphalt and sprayed seal applications, steel slags have superior performance characteristics, including enhanced skid resistance and crushing compared to traditional aggregates. Ground GBFS is commonly utilised as a cement substitute.

BOS and EAF slags generally contain free lime. When exposed to water, the reaction induces aggregate swelling. TfNSW specifies that slag derived from the BOS process is not permitted for use in pavements (upper zone of formation (TfNSW 2020g). Similarly, the VicRoads (2011) cautions its use in unbound aggregates unless it has undergone a hydration program. Leaching of heavy metals is generally associated with slags, but these are typically below environmental limits. However, slags potentially create alkali leachate which can impact the surrounding environment. The weathering of steel slag in a controlled environment can minimise the leachate potential.

Australian SRTAs typically permit 50 to 90% slag as a SCM material. TfNSW allows up to 100% slag in unbound, modified and bound basecourse and subbase layers, while other SRTAs, including Main Roads, do not indicate allowable limits. The NZTA notes the modification to sealing using slag aggregate chip seals but does not define allowable limits. Sabita (2022) permits slag to be used as a filler and aggregates in asphalt.

Table 2.7 summarises the Australian SRTA's requirements for slag.

Table 2.7: Australian requirements for slag

Jurisdiction	Specification or Guide	Application	Allowable limit for Slag
Main Roads WA	Specification 302 (Main Roads 2020)	In situ stabilisation	60%
	Specification 410 (Main Roads 2021e)	Backfill	Not specified
	Specification 507 (Main Roads 2017a)	Microsurfacing	Not specified
	Specification 515 (Main Roads 2021d)	Base and subbase In situ stabilisation	60%
	Specification 820 (Main Roads 2023c)	Concrete structure	65%
TMR Qld	MRTS07B (TMR 2021d)	In situ stabilisation	Not specified
	MRTS08 (TMR 2021h)	Plant-mixed heavily-bound (cemented) pavements	Not specified
	MRTS10 (TMR 2021i)	Plant-mixed lightly-bound pavements	Not specified
	MRTS39 (TMR 2018a)	Lean mix concrete subbase for pavements	Not specified
	MRTS40 (TMR 2018b)	Concrete pavement base	65%
DTP Vic.	Section 306 (VicRoads 2019d)	SCM in blended cement – cement-treated subbase	90%

Jurisdiction	Specification or Guide	Application	Allowable limit for Slag
	Section 307 (VicRoads 2008)	SCM in blended cement	50%
		Cementitious binder in a slag-lime blend	90%
	Specification 407 (VicRoads 2021a)	Dense-graded asphalt(3)	Not specified
	Section 815 (VicRoads 2016b)	SCM in blended cement – cement-treated subbase	50%
		Cementitious binder in a slag-lime blend	90%
TfNSW	Specification D&C 3051 (TfNSW 2020b)	Unbound or modified base and subbase(1,2)	100%
		Bound base and subbase(2)	100%
	Specification D&C 3211 (TfNSW 2020a)	SCM in blended cement – concrete base	65%
		SCM in blended cement – lean mix concrete subbase	50%
		Stabilisation of earthworks	Not specified
TCCS	TCCS MITS 02C (TCCS 2019a)	Subgrade	Not specified
DIT SA	RD-PV-S1 (DIT 2022a)	Base/subbase (Class 1–3)	67% (3% consisting of 2% fly ash and 1% lime)
	RD-PV-S2 (DIT 2019b)	Plant mixed stabilised pavement	Not specified
DIPL NT	*Standard specification for roadworks v5.1* DIPL (2022a) DIPL (2022b)	Stabilisation	Not specified
Austroads	AGPT4L-09 (Austroads 2009)	Binder (in cement) blends)	60%
		Binder (in lime) blends)	70%
		Binder (in lime-fly ash GGBFS) blends)	50%
		Binder (in cement-fly ash GGBFS) blends)	40%

1. For unbound or modified base materials for Traffic Categories A and B, RCC must be sourced on structural concrete.
2. For unbound or modified base materials for Traffic Categories C and D and unbound subbase, bound base and bound, RCC from structural and non-structural concrete are acceptable.
3. Intermediate and basecourse.

2.1.8 Municipal Solid Waste Incineration

Municipal solid waste incineration (MSWI) with energy recovery is a preferred option in dealing with municipal solid waste (MSW) (Poulikakos et al. 2017). The incineration reduces the volume of waste up to 80% to 90%. Fly ash and bottom ash are the resulting residues from the incineration of MSW. The fly ash is largely used in partial replacement of Portland cement. The bottom ash has courser dimensions, with a lower hazardous content compared to fly ash due to a number of inert materials (Poulikakos et al. 2017). MSWI bottom ash is an atypical granular material that can be used as a partial substitution of natural aggregates.

Use of municipal solid waste incineration in pavements

MSWI bottom ash tends to satisfy the requirements as an unbound material. TfNSW (2020f) permits bottom ash (derived from coal combustion furnaces) in public road related infrastructure however does not specify any limits or requirements.

A number of field studies summarised by Lynn et al. (2017) have evaluated MSWI bottom ash. The results showed it has 70% of the strength of crushed rock. In bound layers, MSWI bottom ash demonstrated encouraging crack resistance properties. At low contents, it can be used in the bituminous-bound basecourse and wearing course layers. Higher bitumen contents are required with MSWI bottom ash to satisfy the design limits. MSWI in asphalt results in increasing skid resistance with no significant effect on susceptibility; however, there is an increase in rutting deformation (Lynn et al. 2017).

The Netherlands, Denmark and Canada re-used over 90% of MSWI bottom ash in subbase and fill applications, while other European countries are further investigating its suitability for use (Lynn et al. 2017; Reid 2001).

2.2 Documentation of Recycled Materials Usage

Documentation of the usage of recycled materials in road infrastructure are not widely accessible/available in Australia with only limited road trials reported. The reference guide for *Recycled and sustainable materials at main roads* (Main Roads 2022a) describes the recycled materials that have been used and the trial sites. However, consultation with key Western Australian stakeholders have highlighted that the documentation of recycled material usage in road pavements, and the associated construction records of assets built with recycled materials, are not kept in a centralised database. However, Main Roads do liaise with projects and suppliers and collect quantities used for annual reporting.

Based on discussion with Main Roads, the following can be concluded:

- Main Roads does not capture the location of RAP for several reasons.
  - Up to 10% RAP may be used in all asphalt intermediate course (AIC) layers without advising Main Roads.
  - Level 2 (11–25%) may be placed in AIC layers. If, for example, L2 was only placed in one of 4 AIC layers, it is too complex to capture where RAP may be incorporated and no benefit is expected from recording that data.
  - There is expectation that RAP will behave the same as AIC with virgin material. The location of RAP is not recorded as its performance is not monitored.
- Main Roads have good Integrated Road Information System (IRIS) records of rubber use in wearing course layers (OGA, GGA and spray sealing):
  - When construction data is updated the drop-down menus capture all the rubber surfacing treatments.
  - Main Roads do not monitor S45R in sprayed seals, but can easily do so if required using condition data collected using the Traffic Speed Deflectometer (TSD).
- Main Roads may use glass as subsoil drainage material or bedding material but construction data does not drill down to that level of detail in IRIS. There is no plan to use it in asphalt due to cost-related issues and in concrete due to alkali-silica reaction (ASR) issues.
- CRC in subbase under FDA is captured in IRIS.
- Main Roads routinely reuse redundant material in the highest level application possible but this is not captured and monitored.

Other Australian SRTAs, including TMR and DTP, have published technical notes (e.g. TN193 (TMR 2020) and TN107 (VicRoads 2023)) which identify permissible recycled materials without documenting the sites and records where these recycled materials were previously used. It supports the idea of having a centralised database located at Main Roads which documents the use of recycled materials on the Western Australian road network in order that their performance can be monitored.

3 Long-term Pavement Performance Monitoring

Performance prediction of pavement behaviour is critical in estimating life cycle costs. Long-term pavement performance (LTPP) monitoring seeks to better understand pavement performance under various traffic loading and environmental conditions (Austroads 2019b).

The LTPP monitoring program was first established in 1987 in the USA to study the rapid deterioration of the US highway network and to gain a better understanding of pavement performance. The US-LTPP program, which originally formed part of the Strategic Highway Research Program (SHRP) has to date involved the monitoring of over 2,500 asphalt and Portland cement concrete (PCC) pavement test sections across the USA and Canada, covering a wide range of climatic and soil conditions. Austroads developed its own LTPP monitoring program in 1994–95 in order to calibrate Australian pavements (traffic and climate) against the US-LTPP.

The LTPP programs broadly aim to (Austroads 2019c; FHWA 2015):

- improve traffic prediction and characterisation
- improve the characterisation of materials
- enhance the consideration of environmental effects in pavement design and performance prediction
- evaluate and use the pavement condition data for asset management
- evaluate existing and/or develop new pavement response and performance models
- provide guidance for maintenance and rehabilitation strategy selection and performance prediction
- quantify the performance impact of specific design features (e.g. presence or absence of positive drainage, differing levels of pre-rehab surface preparation, etc.)
- prepare guidelines for LTPP which focus on both site establishment and data collation.

3.1 Australian Long-term Pavement Performance Monitoring

The establishment of the Austroads LTPP sites was based on the SHRP criteria, with pavement types similar to those selected in the US-LTPP program selected (Section 3.1.2). Following the Austroads LTPP study, guidelines for the establishment of LTPP sites were developed using the following site selection criteria (Clayton 2000):

- consideration of pavement composition and type of pavement surfacing
- availability of materials testing information
- availability of construction and maintenance history
- suitability of vertical and horizontal alignment (i.e. no sharp curves and no grades steeper than 2%)
- minimum section length of 200 m
- consistency of subgrade conditions
- availability of traffic volume and composition information
- practicality and safety issues
- availability of information allowing estimation of the local climate of the road segment
- availability of road use data.

3.2 International Long-term Pavement Performance Monitoring

3.2.1 United States

The US-LTPP sites are generally about 150 m in length. They are monitored at about 15 m intervals with a 15.2 m (about 50 feet) material sampling section at the end of the monitoring segment (FHWA 2021). The test section is preceded by a 152 m (about 500 feet) long maintenance control zone and immediately followed by a 76 m (about 250 feet) long control zone.

Two types of pavements were examined in the US-LTPP studies: General Pavement Studies (GPS) and Specific Pavement Studies (SPS) (FHWA 2015). The GPS investigates in-service pavement sections to evaluate general performance, while the SPS investigate the influence on performance of specific features such as drainage, layer thickness and maintenance or rehabilitation treatments.

A number of US state highway agencies formed part of the US-LTPP program including:

- Arizona Department of Transportation (ADOT)
- Colorado Department of Transportation (CDOT)
- Texas Department of Transportation (TxDOT)
- Minnesota Department of Transportation (MnDOT)
- Pennsylvania Department of Transportation (PennDOT)
- New Jersey Department of Transportation (NJDOT)
- Kansas Department of Transportation (KDOT).

Table 3.1 shows the LTPP pavement study types.

Table 3.1: US-LTPP pavement study types

Type	Description	Type	Description
GPS1	Asphalt concrete[1] pavements on granular base	SPS1	Strategic study of structural factors for flexible pavements
GPS2	Asphalt concrete pavements on bound base	SPS2	Strategic study of structural factors for rigid pavements
GPS3	Jointed plain concrete pavements	SPS3	Preventive maintenance effectiveness of flexible pavements
GPS4	Jointed reinforced concrete pavements	SPS4	Preventive maintenance effectiveness of rigid pavements
GPS5	Continuously reinforced concrete pavements	SPS5	Rehabilitation of asphalt concrete pavements
GPS6	Asphalt concrete overlay of asphalt concrete pavements	GPS6	Rehabilitation of jointed Portland cement concrete pavements
GPS7	Asphalt concrete overlay of Portland cement concrete pavements	SPS7	Bonded Portland cement concrete overlay of Portland cement concrete pavements
GPS8	Bonded Portland cement concrete overlay	SPS8	Study of environmental effects in the absence of heavy loads
GPS9	Unbonded Portland cement concrete overlay or Portland cement concrete pavements	SPS9	Validation of strategic highway research program asphalt specification and mix design
		SPS10	Warm mix asphalt overlay of asphalt pavements

Source: FHWA (2015).

1 The term 'asphalt concrete' used in the USA is the equivalent to the use of the term 'asphalt' in Australia and New Zealand.

In the US context, the LTPP studies have been evaluated by comparing the recycled materials mixes versus virgin aggregates. The LTPP program applied the US-LTPP protocols to study RAP in flexible pavement rehabilitation. The results from the study indicated that the recycled materials performed equally or outperformed virgin materials (Chow & Badra 2018; FHWA 2011).

Measuring the deflection, rutting, roughness and cracking at the LTPP sites is important if pavement performance, and road asset management generally, is to be properly assessed. LTPP sections in Australia with recycled materials are scarce in comparison to the US-LTPP program. However, some local governments (LGs) in the USA have access to the Accelerated Loading Facility (ALF) as an alternative test to the LTPP program (Lim et al. 2020b).

3.2.2 New Zealand

The New Zealand LTPP program involves 145 LTPP sites throughout the country (Neaylon et al. 2017). The sites were divided into two groups based on the maintenance requirements: no maintenance is allowed other than pothole patching and more extensive maintenance such as resealing and pavement strengthening.

The selection criteria for the New Zealand LTPP sites include:

- climate based on 4 moisture sensitivity conditions

- traffic volume classifications
- pavement strength determined from pavement thickness and adjusted structural number
- pavement condition expressing condition and age
- geometric criteria.

The New Zealand LTPP program has been benchmarked against the Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) accelerated pavement testing programs.

3.2.3 South Africa

LTPP studies were first initiated in South Africa in 1991 to investigate the relationship between LTPP and heavy vehicle simulations (Anochie-Boateng et al. 2015). The selection of the LTPP sites by the Western Cape Government (WCG) was based on similar pavement types and environments, where detailed traffic count data and traffic characteristics affecting the performance of the pavement could be obtained.

The WCG LTPP program included (Anochie-Boateng et al. 2015):

- traffic counts
- visual assessments
- field data collection
- sampling and testing of asphalt
  - coring at distressed sites
  - laboratory testing on asphalt cores and extracted binders
- analysis of stiffness, permanent (plastic) deformation, strength, and moisture sensitivity tests results for asphalt layers
- evaluation of ageing models for the bituminous binder
- development of stiffness and performance models for asphalt materials.

The South African LTPP program has benchmarked against the Heavy Vehicle Simulator (HVS) programs (Jones & Paige-Green 2003).

3.3 Long-term Pavement Performance Data Collection

The monitoring of LTPP sites focuses on understanding the pavement response primarily from the effects of climate and traffic loading. The integrity of the data collection process and monitoring is pivotal to its success. The Austroads guideline stipulates that the data collection regime adopted should be uniform and consistent to ensure the success of long-term pavement performance monitoring (Austroads 2019b). Some Australian LTPP trial sites have monitoring frequency of once every 5 to 6 years for strength testing and every 2 years for a functional condition survey (Clayton 2000). For weaker pavements, such as the additional LTPP sites, a full annual monitoring survey is required. The US-LTPP program, however, stipulates that data be collected at least annually (FHWA 2015).

Generally, data collection at LTPP sites is divided into a number of categories as shown in Table 3.2. Key performance parameters monitored include strength, rutting, cracking, roughness, gravel loss and loss of shape.

Table 3.2: LTPP data collection

Category	Purpose
Administration	
Automated Weather Station (AWS)	Understand the influence of environmental conditions on performance by collecting site-specific information, e.g. air temperature, humidity, precipitation, solar radiation, wind direction and wind speed.
Climate	Understand the influence of environmental conditions where AWS was not used. Climate data includes precipitation, temperature, wind, and humidity.
Dynamic load response	Measure the response of the pavement under controlled loading conditions.
Ground Penetrating Radar	Evaluate the pavement structure and record layer thickness data.
Inventory	Collect inventory data, including location, pavement type, layer thickness, material properties data and information regarding previous treatments.
Maintenance and rehabilitation	Successful data analysis requires maintenance and rehabilitation data is to be collected for each LTPP site.
Materials testing	Sampling and testing at all sites in order to determine pavement cross-sections and layer thicknesses.
Monitoring	To evaluate pavement performance including deflection, distress, drainage, distress, friction, roughness and rutting. This data is collected at given intervals and frequencies.
Deflection	Use the FWD to measure the deflection response of the LTPP sites to assist in pavement life prediction.
Distress	Document surface conditions including cracking, deformation and rutting using visual inspection and photos.
Drainage	Provide information of drainage features and their possible influence on the condition of the pavement.
Friction	Perform friction tests.
Profile	Measure the pavement roughness which is used to indicate the level of service.
Rutting	Measure rutting in the wheelpaths.

Source: FHWA (2015) and Austroads (2019b).

It is worth noting that distress surveys in US state highway agencies are based on the procedures presented in Miller and Bellinger (2014).

3.3.1 Arizona Department of Transportation

The ADOT LTPP study (FHWA 2015) focused on distress, longitudinal profile and FWD deflection data. Distress was tracked over time and grouped according to failure mechanism (i.e. traffic/load-related and climate/materials-related) into structural and environmental damage. The results indicated that roughness and roughness progression alone could not be used to represent the condition as several test sections did not exhibit changes in roughness in proportion to the amount of fatigue cracking. Moreover, the sections that had reached the end of their service lives did not necessarily have roughness values that would trigger rehabilitation (FHWA 2015).

3.3.2 Colorado Department of Transportation

The CDOT LTPP program (FHWA 2015) included instrumentation (e.g. dial gauges, thermocouples, and surface-mounted strain gauges) to measure the temperature and load-induced deflections and strains. The effectiveness of various sealant materials, methodologies, and the effects of sealed versus non-sealed joints on the performance of rigid pavements was monitored (FHWA 2015).

3.3.3 Texas Department of Transportation

The TxDOT LTPP (FHWA 2015) program involved an evaluation of the effectiveness of typical and promising maintenance treatments for asphalt pavements. The sites were inspected at 6 months and annually for 8 years. The pavement distress surveys were conducted in accordance with Miller and Bellinger (2014) for cracking, patching and potholes.

TxDOT used the LTPP program to develop guidelines for local calibration of the Mechanistic-empirical Pavement Design Guide (MEPDG) (FHWA 2015). The pavement test section followed the typical layout of US-LTPP site. Additionally, the LTPP sites served as ongoing reference source and diagnostics for engineers and transportation professionals (FHWA 2015).

3.3.4 South Africa

The South African LTPP program (Anochie-Boateng et al. 2016) included the monitoring and laboratory evaluation of field samples to develop a comprehensive database. Monitoring of 6 sites was performed biannually. However, the South African LTPP program only ran for a relatively short period of time. The data collected included a visual assessment and measurement of rut depth, pavement temperature, density, moisture content and deflection. The results showed similarities between the HVS and LTPP rutting data in a heavily-trafficked section although for low trafficked sections greater rutting was observed in HVS compared to LTPP (Anochie-Boateng et al. 2016).

3.3.5 Austroads

Austroads (2019a) funded a LTPP and LTPP maintenance study of over 30 sites across Australia covering a large range of traffic and climatic conditions. The LTPP sites were set up on pavements with thick asphalt or a bound base overlying a bound subbase. The site monitoring involved roughness, rutting and pavement strength measurements in addition to recording visual surface conditions and maintenance treatment activities. The sites were initially monitored annually; however, following a review of the performance of each site, monitoring was revised to make more effective use of the budget. The sites with low distress were monitored once every 5 to 6 years for strength testing and every 2 years for a functional condition survey, while sites with faster rate of deterioration were still monitored annually (Austroads 2019c).

3.4 Comparison of Long-term Pavement Performance Programs

Flexible pavements previously used in the Australian LTPP monitoring program were equivalent to the US GPS1 and GPS2 sites, while the US LTPP focuses on a number of pavement structures. The New Zealand and South African LTPP programs do not define pavement types and site establishment; instead, they focus on the availability of level of traffic, age of the road and layout data. The climate data in the Australian LTPP is measured using the Thornthwaite Moisture Index (TMI) while freezing index is used across the US-LTPP program. Table 3.3 presents a comparison of the LTPP protocols.

Table 3.3: Comparison of the LTPP programs

Monitoring module	Australian LTPP	US-LTPP	New Zealand LTPP	WCG LTPP
Site length	150–200 m	152 m	Not defined	Not defined
Pavement type	Flexible	Flexible Rigid	Not defined	Not defined
Climate	TMI Rainfall and temperature	Freezing Index		Pavement temperature
Profile	Walking Profiler Multi-laser Profilometer	String line method/algorithm Automated transverse profiling		
Deflection	FWD (40, 53, 70 kN) 10 m intervals OWP and BWP	FWD (26, 40, 53, and 71 kN) 15.2 m intervals IWP, OWP and BWP	FWD	FWD (40 kN) 50 m interval
Traffic	AADT	AADT		

Monitoring module	Australian LTPP	US-LTPP	New Zealand LTPP	WCG LTPP
Surface distress	Visual Digital imaging or by automatic distress detection devices	Visual Digital imaging	Visual Imagery	Visual
Data collation		Drainage, GPR, automated weather station	Maintenance details	

4 Consultation – Road Asset Audit

Discussions were held with Main Roads and selected local government agencies (LGs) to gather data related to road assets incorporating recycled materials. A communication strategy was prepared and the relevant organisations were contacted via email or telephone. The intent of this task was to:

- evaluate the existing situation
- investigate what type of recycled materials are incorporated into road pavements
- explore to what extent the use of recycled materials is recorded
- identify if performance monitoring is in place.

A data collection template (see Appendix A) was prepared to ensure that all the required information was collected and documented. Main Roads' relevant staff were asked to fill in the template for those projects where recycled materials were used.

The National Transport Research Organisation (NTRO) project leader and Main Roads project manager jointly selected 10 LGs, and the NTRO project leader coordinated with those LGs to request data related to the recycled materials.

The following challenges were faced during data collection:

- There was no contact list of the people available who were involved in the use of recycled materials in their respective organisations. Therefore, inquiries were directed to their general inquiry phone numbers or emails which was a time-consuming process.
- There was no central database in each organisation to record the use of recycled materials; as a result, there was an uncertainty regarding of data availability and responsibility.
- Generally, the LGs considered it an external request and data availability was not certain. Therefore, in addition to the long waiting time for responses, the data provided was incomplete for most of the LGs.

4.1 Main Roads

The NTRO project leader held meetings with Main Roads' relevant staff identified as the source of information by the Main Roads' project manager. After discussions regarding the project objectives and the nature of the data required, the data collection template was distributed for completion.

Main Roads provided data related to recycled materials for 3 projects only. The templates were only partially completed as some information could not be retrieved. Moreover, the information provided may not have been complete as the Main Roads' IRIS database does not cater for all possibilities; for example, if a RAP level 2 mix was used, the database only reported that a dense-graded 20 mm (DG20) mix was used.

IN terms of the performance monitoring of the recycled materials, Main Roads has no performance monitoring in place or relevant field trials except for the Kwinana Freeway trial.

The data collected from Main Roads is attached in Appendix B.

4.2 Local Government

Selected LGs were asked to share information related to the use of recycled materials in their relevant jurisdictions. Table 4.1 summarises the information collected.

Table 4.1: Summary of LGs

LGs	Response	Template filled	Recycled materials reported	Source of recycled material	Comments
City of Bayswater	Yes	Yes	CR, RAP	Unknown	• Used in basecourse and wearing course • 20% RAP
City of Swan	Yes	Yes	CR, plastic (plastiphalt)	Recycled tyres	• Provided data related to 2 projects • CR consumed in binder
City of Kalamunda	Yes	Yes	CR	Not provided	• CR consumed in binder • Recycled material data provided for four projects
City of Canning	Yes	Partially	CRC	Construction and demolition (C&D) waste	• Used in basecourse and subbase layers • Testing indicated that CRC basecourse material was at least as strong as conventional material
City of Perth	Yes	–	–	–	• No records of recycled materials exist.
City of Wanneroo	Yes	No	–	–	• Talked to the responsible person over the phone and shared the template, however, no response received.
City of Cockburn	No	–	–	–	• Responded the general inquiry stating that the request will be forwarded to the engineering department. No response despite multiple reminders.
City of Sterling	No	–	–	–	• Contacted City of Sterling over the phone and submitted an online inquiry as directed. No response despite multiple reminders.
City of Subiaco	Yes	Yes	CR	–	• CR consumed in binder • Performance monitored by regular inspection
City of Cambridge	Yes	Yes	CR, CRC	• CRC – Crushed demolition • CR – Recycled tyres	• CR – used in binder • CRC – used in basecourse

Key: CR = crumb rubber, RAP = recycled asphalt pavement, CRC = crushed recycled concrete.

The data collected from the LGs is presented in Appendix C.

4.3 Other Stakeholders

Other stakeholders include prominent material suppliers, private road operators (e.g. mine sites) and key industry or recycling bodies (e.g. Tyre Stewardship Australia). At this stage only Main Roads and selected LGs were contacted for data collection.

4.4 Benefits of Consultation

The benefits of the consultation with Main Roads and LGs were as follows:

- The outcome of the consultation resulted in an enhanced understanding of the existing situation regarding the use of recycled materials and availability of the data.
- The consultation process provided an opportunity to collaborate with LGs and develop relationships.

- Useful information regarding the use of recycled materials in different LGs was collected, including types of materials, quantity and challenges.

5 Pilot Data Capture

5.1 Database Development

A pilot database was developed to enable the collation of data related to local and state-wide road assets incorporating recycled materials. The database template was developed in the form of a simple Excel spreadsheet so that the data could be transferred to a new database template or software in the future if required.

Data from different organisations (Main Roads, LGs) was summarised in separate spreadsheet tabs. Some LGs provided data for a single project whereas others provided data for multiple projects. All projects of an organisation were populated in the same tab. Note that the Main Roads tab presents all data supplied as a part of this project.

The following details related to recycled materials were summarised in the database:

- Organisation or department responsible for the project where recycled material was used.
- Is the use of recycled materials properly documented?
- Location and brief introduction to the project.
- Dimensions of the road assets (sections) incorporating recycled materials.
- Date and contact details of the person who filled out the template.
- Date when the pavement was constructed or opened to traffic.
- Pavement type and configuration/structure.
- Type of surfacing.
- Rehabilitation and/or maintenance status.
- When last rehabilitated and details of rehabilitation.
- Existing pavement condition.
- Type and severity of pavement distress.
- Details of the conventional and recycled materials used.
- Indication of the pavement layers where recycled material was used.
- Application of recycled materials (e.g. replaced of fine aggregate, consumed in binder, etc.).
- Percentage and quantity/volume of recycled materials used.
- Maximum allowable usage limit and specification requirements.
- Source of the recycled material(s).
- Recycled materials' mixing process.
- Details of any processing required and laboratory testing conducted to evaluate the recycled materials.
- Challenges faced and the response or strategy to manage those challenges.
- Cost issues related to recycled materials procurement, processing, transportation, handling, testing, placement and construction.
- Is the performance of the recycled materials being monitored?
- If performance is being monitored, then what is the overall performance of recycled materials to date?
- Environmental risks identified and how those risks were managed.

The pilot database is presented in Appendix D.

5.2 Database Update

After the pilot data capture, the project team continued to follow up with the LGs and Main Roads to capture more data regarding the use of recycled materials in their relevant jurisdictions. Data for additional projects were added in Table 3.1 and populated in the database.

Guidelines for further updates to ensure up-to-date information include:

- Liaise with LGs to collate information for existing projects where recycled materials are being used.
- Follow up with the LGs on a weekly basis to ensure the data has been captured.
- Invite LGs to provide future projects and give them a suitable timeframe to capture data for the completed projects.
- Share the central database with the LGs and Main Roads regional staff.

Main Roads has provided quite limited information related to the use of recycled materials. They need to record missing details regarding their use of recycled materials used on its network.

5.3 Indicative Cost to Populate Database

At this stage, only a very rough estimate (Table 5.1) could be made of the cost of populating the database based on the following assumptions:

- one data entry operator
- data collection related to 50 projects
- data analysis
- monthly newsletter/communication with the stakeholders.

As just discussed, LGs and Main Roads staff will be invited to populate the database with additional projects. During this data collation phase, costs to provide the data will be recorded in order that the Table 5.1 estimates can be refined.

Table 5.1: Indicative cost to populate recycled materials database for 50 projects

Action	Units	Unit price ($)	Cost ($)	Comments
Enter and maintain database (hours)	50	250	12,500	
Request, follow up and collect data (hours)	110	250	27,500	Data collection
Purchase of database software (item)	1	10,000	10,000	If required
Software annual maintenance (lump sum)	1	1000	1000	If applicable
Material testing in the field and laboratory (items)	50	750	37,500	If required (limited testing)
Data analysis and monthly newsletter (hours)	24	250	6,000	12 updates during a year
Total estimated cost ($)			**94,500**	

6 Framework for Monitoring Performance of Reused and Recycled Materials

6.1 Framework for Performance Monitoring

The framework for monitoring recycled materials is based on in situ performance monitoring of pavements incorporating recycled materials. The Austroads *Guide to pavement technology part 4E* (Austroads 2022a) provides a recycled materials assessment framework for the selection and evaluation of appropriate recycled materials in terms of their technical, economic and environmental suitability for a particular project. It should be noted that the framework described in this report addresses the performance monitoring of recycled materials in pavements: it does not cover the evaluation and selection framework for recycled materials.

Monitoring of the performance of recycled material is critical if overall performance and lifecycle costs are to be estimated and the use of recycled materials in pavements enhanced. The objectives of the monitoring are to:

- evaluate existing practices related to the use of recycled materials in pavements
- improve design methods, mix and blending practices and the processing of recycled materials
- develop and implement a laboratory testing program
- improve construction practices for pavements incorporating recycled materials
- determine the effect of recycled materials on overall pavement performance, including material properties and durability, pavement response to loading, environment, construction quality, pavement distress patterns and maintenance requirements.

This framework for monitoring performance of recycled materials can be divided into the following parts:

- capturing data related to the use of recycled materials
- assessment of pavement condition and defects
- data analysis
- comparison of the performance of recycled materials compared conventional or virgin materials
- reporting and documentation.

6.1.1 Capturing Data Related to the Use of Recycled Materials

A fundamental step in the monitoring of recycled materials is data collection. This data should be kept in a database in a computer-based environment. The collected data should be documented in a systematic approach to provide input to data analysis work. Climate and traffic loading are two primary factors affecting a pavement structure's performance. Climate affects mainly the properties of the materials in the pavement. Therefore, climate- and traffic loading-related data should be an integral part of data collection process.

The key data collection activities that should be conducted are as follows:

- Develop and maintain data collection procedures and protocols.
- Ensure different LGs follow the same data collection procedures.
- Document problems to provide input for future data analysis.
- Ensure data collection quality by checking and inspecting as required.

The data collection template prepared and used as a part of this project divides the data into 3 major categories:

- Basic information related to the project (e.g. location, length, timing) and contact details of the organisation responsible for data collection.
- Pavement details, including pavement composition and surfacing type, overall current condition and rehabilitation details, if any.

- Details of recycled materials, including types and quantities of the conventional and recycled materials used, source of the recycled materials, specification limits, and any laboratory testing and processing involved.

In addition, the data collection template also requires project-specific information, e.g. environmental impact, challenges faced as a part of their procurement, sourcing, processing, usage in construction, and the operating environment. Data should be collected for each project separately and kept in a central database for future reference.

Details of the data to be collected are summarised in Section 4 and a sample data collection template is presented in Appendix A.

6.1.2 Assessment of Pavement Condition and Defects

The assessment of pavement condition is based on factors such as structural integrity, roughness, skid resistance, rate of deterioration and maintenance operations. Some distress types such as cracking, ravelling, weathering, and polished aggregates may not result in decreased structural capacity but may restrict functional usage. Recycled materials are used in pavements in 2 scenarios:

- as a part of maintenance and/or rehabilitation of existing pavements
- construction of new pavements.

If the recycled materials are used in an existing pavement as part of repairs or rehabilitation, the performance monitoring of the recycled materials involves pavement condition assessment before and after their incorporating into the pavement. The condition of the pavement before the incorporation of recycled materials will be compared with the condition data collected after the incorporation of the recycled materials to evaluate any change in pavement performance.

The performance factors to be measured in the existing pavement prior to incorporating recycled materials include:

- visual assessment
- evaluation of the existing pavement strength and structural adequacy (deflection testing)
- determination of the structure of the existing pavement through ground penetration radar (GPR) measurements
- measurement of roughness, texture, rutting and crack detection using network survey vehicle (NSV).

If the new pavement is designed and constructed with recycled materials, the pavement condition and defects assessment may include:

- visual assessment
- the collection of field data, e.g.
  - deflection (FWD or TSD) (Test Method WA 326.2 for FWD (Main Roads 2017b) and Austroads Test Methods AG:AM/T006 for FWD (Austroads 2011) and AG:AM-T017-16 for TSD (Austroads 2016b))
  - crack detection (Austroads Test Method AG/T018 (Austroads 2016c))
  - rutting measurement (Austroads Test Method AGAM-T009-16 (Austroads 2016d))
  - roughness (Austroads Test Method AG:AM/T001 (Austroads 2016e))
  - surface texture (Austroads Test Method AGAM-T013-16 (Austroads 2016f))
  - skid resistance (Test Method WA 310.1-2022 (Main Roads 2022b))
- coring of distressed sites (if required)
- laboratory testing, which may include:
  - testing of asphalt cores for modulus, density, binder content and particle size distribution
  - permeability (Test Method WA 117.3 (Main Roads 2012))
  - moisture sensitivity testing for asphalt (Austroads Test Method AG:PT/T232-07 Austroads (2007))
  - environmental impact testing (e.g. microplastics, leaching, emissions, minimum concentration of chemicals).

The scope of the assessment should be tailored to suit the expected failure mode. A reasonable timeframe for the assessments should be maintained. For an existing pavement, an assessment should also be performed before incorporating recycled materials for comparison. For new pavement, an assessment should be conducted immediately after construction and then at specific intervals. Visual inspections could be carried out every 6 or 12 months as deemed appropriate. Visual assessments may be conducted more frequently than deflection testing (if applicable).

6.1.3 Data Analysis

The collected data should be analysed in order to establish, if possible, the causes of any observed distress. It should be noted that the distress may or may not be related to the recycled materials; therefore, a careful analysis is required.

A comparison of the performance of the recycled materials with the virgin material can contribute to an improved optimisation of the use of recycled materials in pavements. Data analysis should be conducted and reported, including any lessons learnt.

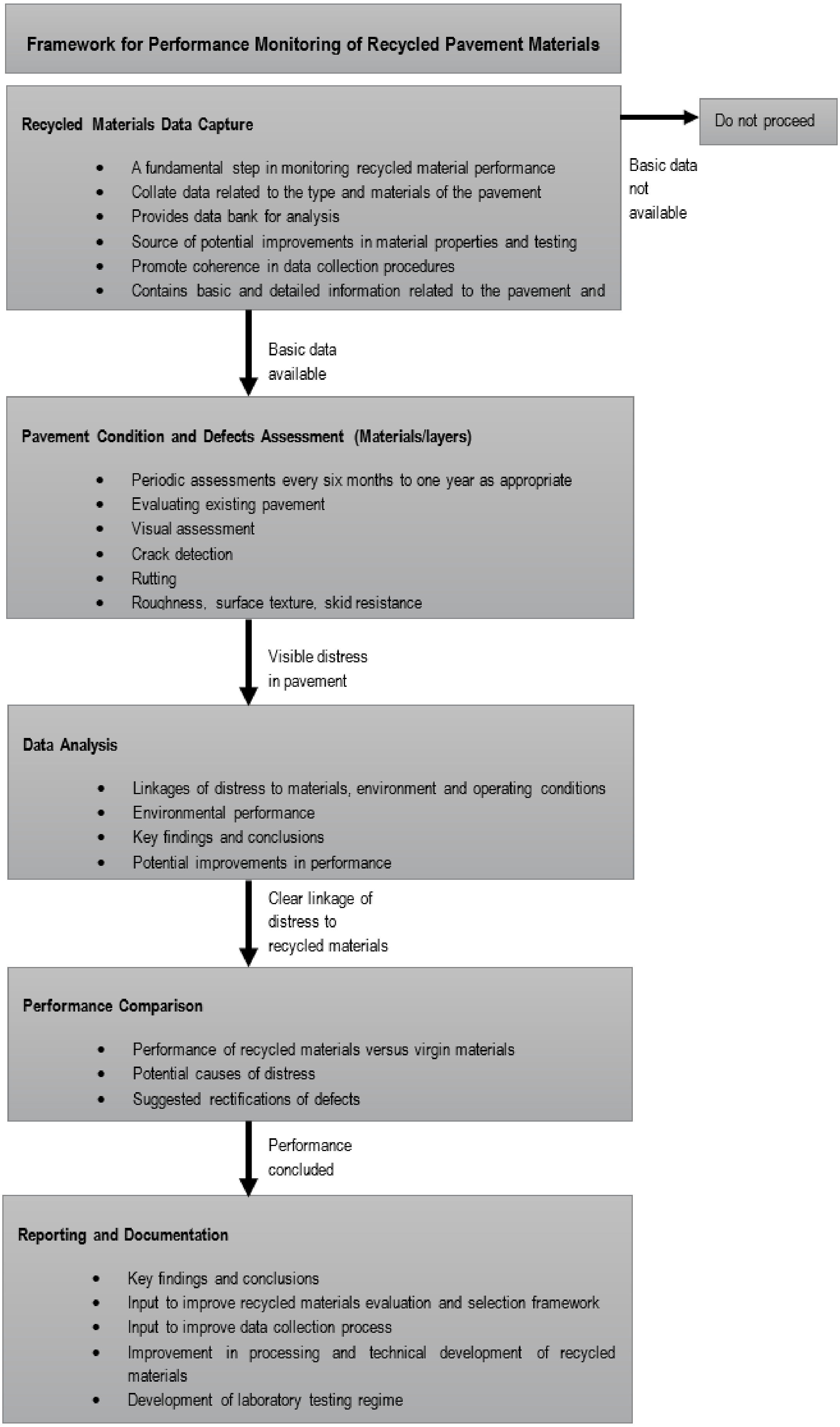
6.1.4 Reporting

Reporting of the performance monitoring should be completed at every stage of the monitoring process.

The outcome of the implementation of this framework will not lead to an improved understanding of recycled materials practice but also the refinement of the framework for the evaluation and selection of recycled materials for road pavements.

A flowchart for the monitoring of recycled materials is presented in Figure 6.1.

Figure 6.1: Framework for performance monitoring of recycled pavement materials



6.2 Indicative Costs of Long-term Regular Monitoring

It is not possible to estimate the exact cost of monitoring the performance of recycled materials due to variations in pavement materials, construction practice, project-specific conditions and the operating environment. The indicative costs presented in Table 6.1 are estimates for annual monitoring based on experience with similar testing. The monitoring is likely to be required over a number of years.

Table 6.1: Indicative cost for monitoring performance of recycled materials (Year 2024)

Action	Unit price ($)	Units	Cost ($)	Comments
Recycled materials data capture (hours, database software price)	250	1	250	Estimated cost as per Table 5.1
Pavement condition and defects assessment				
Coring				If required.
Visual assessment	875	1	875	Include traffic management cost of $175/hr
Rutting	250	1	250	If any
Deflection (TSD or FWD)	3,000	1	3,000	
Crack detection	200	1	200	
Roughness, surface texture and skid resistance	600	1	600	
Laboratory testing	2,250	1	2,250	
Data analysis	350	1	350	
Comparison of performance of recycled materials versus virgin materials	300	1	300	
Environmental performance assessment	750	1	750	Testing and reporting
Key findings and conclusions	350	1	350	
Project management	100	1	100	
Total ($)			**9,275**	

Note: Cost estimate is based on monitoring 1 km section of the road for single data collection.

7 Key Findings

The government and SRTAs' focus on a circular economy have promoted strategies that have increased the utilisation of a wide range of recycled materials in road infrastructure. There is no consistent approach regarding the usage of different recycled materials in different pavement layers and their relevant allowable limits. Key findings following a review of Australian and international practice are as follows:

- The requirements for the consumption of RCC are governed by its properties and the percentage of foreign materials. SRTAs in Australia and overseas specify different allowable limits of RCC in different pavement layers. For example, Australian SRTAs permit 100% RCC in unbound pavement layers, NZTA and WSDOT permit up to 100% RCC in basecourse layers, and TMR allows up to 10% RCC in DGA.
- The major application of RCG is basecourse and subbase layers, asphalt wearing courses and earthwork backfill. Main Roads permits up to 3% RCG in subbase layers and 100% in earthworks applications, whilst TMR permits up to 2.5% in wearing courses and 10% in DGA. TfNSW, on the other hand, allows up to 2.5% of RCG in DGA and SMA, with increased limits for other wearing courses. The allowable limits specified by US DOTs are closely aligned with Australian specifications.
- Crumb rubber is commonly adopted in sprayed seals in Australia. Main Roads allows 15% CR in sprayed seal and 18% in asphalt, TMR allows 18% in C170 bitumen sprayed seals, while DTP permits 9% in high-stress seals. On the other hand, CRM binders produced in South Africa typically contain 18 to 24% CR.
- RAP is largely used in the construction of new asphalt pavements. TMR, DTP and TfNSW permit up to 30 to 40% RAP in different pavement applications. TMR allows up to 10% RAP in basecourse applications for Class 1 and up to 15% for Class 2 materials whereas RAP is not permitted in asphalt wearing courses. Main Roads specifications for RAP are conservative compared to other SRTAs as the impact of the RAP on the binder is generally negligible below 15%. Main Roads allows 10% RAP in asphalt intermediate courses; this increases to 11–25% and 26–40% for level 2 and level 3 respectively. The US road agencies permit a high percentage of RAP (25% or greater); however, it has been reported that the blends incorporating RAP are increasingly susceptible to poorer early permanent strain performance when the RAP exceeds 15% of the blend's proportion.
- Fly ash is widely used as an additive in cement to improve workability, strength and durability and as a supplementary cementitious material in concrete and pavements. Slag is recognised as an acceptable alternative to natural aggregates. Generally, SRTAs do not specify allowable limits for slag with the exception of TfNSW, which permits up to 100% in unbound or modified and bound base and subbase layers. As SCM material, all SRTAs typically permit 50–90% slag.
- Recycled plastic in pavement applications is currently an emerging trend. It is currently being trialled and allowable limits have yet to be set by SRTAs.
- The prediction of pavement behaviour is critical in estimating life cycle costs. Long-term pavement performance (LTPP) trials are being used to gain a better understanding of pavement performance under various traffic loading and environmental conditions (Austroads 2019c). Documentation of the usage of recycled materials in road infrastructure is not widely accessible/available in Australia with only limited road trials reported. None of these road trials are LTPP sections.
- The Australian LTPP program has generally focused on flexible pavements. It was developed from the US-LTPP program which covers a wide range of climatic and soil conditions in the USA and Canada. In general, LTPP site establishment considers a number of basic criteria and information such as pavement composition and type of surfacing, availability of material information and construction history, traffic volume information and climate.
- The monitoring of Australian LTPP trial sites occurs once every 5 to 6 years (structural condition) and every 2 years (functional condition), whereas, and depending on budgetary constraints, data on US-TPP sites is collected at least annually. It should be noted that only limited LTPP monitoring has occurred for sites incorporating recycled materials.

In terms of data capture, Main Roads provided information related to three projects only. This is partly due to the lack of a central database to record the use of recycled materials. In addition, there is no mechanism for the performance monitoring of recycled materials. Some LGs provided data related to multiple projects. Conversation with the responsible officers in LGs indicated that there is high interest in the use of recycled materials and their impact on long-term pavement performance, rehabilitation and whole-of-life costs. Most of the LGs contacted supplied partial information due to challenges in extracting information from the project documents. Engaging with project managers post-construction is difficult because staff move to other projects/roles and they have to try and access relevant information from project records.

A database was developed to capture the information required for analysis related to the use and performance of recycled materials. Based on this information a framework for the performance monitoring of recycled materials was developed as well as indicative costs of monitoring the performance of recycled materials.

8 Conclusions and Recommendations

Based on the project findings, it can be concluded that none of the jurisdictions contacted as a part of this project systematically record the use of recycled materials in road infrastructure. It is recommended that the use of recycled materials be documented in a central database managed by the relevant jurisdictions. Each jurisdiction should consider developing a LTPP monitoring program for recycled materials which includes guidance on site selection, database development and the frequency of performance measurement.

A lesson learned from the consultation with Main Roads and LGs is that it will be more effective if stakeholders such as LGs and material suppliers are involved in the project as research partners. In the end, they are beneficiaries of the outcome of the project and their early involvement would be helpful in shaping the project and facilitating the data collection process.

Based on the outcomes of this stage of the project, the following recommendations are suggested:

- Develop a research proposal for Stage 2 of the project focussing on:
  - Data collection from Main Roads and LGs related to recycled materials.
  - The analysis of the data collected and the sharing of the key findings with the stakeholders.
  - Conduct a virtual workshop at the start of stage 2, just after the inception meeting, to: discuss the findings of stage 1, invite LGs to discuss the scope of stage 2, and get them involved in the data collection process.
    WA Local Government Association (WALGA) staff need to be engaged from the start of the next stage to enhance communication and collaboration in order to maximise the benefits of the project outcome.
  - Use the results of the data analysis to address the issues related to the environmental impacts of incorporating recycled materials in pavements and the effects of recycled materials on pavement rehabilitation.
  - Develop a best practice guide which addresses the selection, use and management of recycled materials in pavements.
- Main Roads and LGs should amend their inventory database to include all reused/recycled materials and products to ensure that the data is routinely captured.
- Establish a central database at Main Roads to demonstrate technical leadership in the documentation and promotion of the use of recycled materials in road pavements.
- Share the key findings of the data analysis and lessons learned with all stakeholders on an annual or biannual basis. This will enhance their knowledge and enable them to make more informed decisions related to recycled materials.

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Appendix A Recycled Materials Data Collection Template

The first section of the data collection spreadsheet includes basic information, such as the organisation, project, name of the person who has filled out the template and size of the project. The second section contains information related to the pavement, including pavement construction date, type, surfacing and configuration and rehabilitation status. The third section captures details related to the conventional and recycled materials used, location, quantity, source, and percentage of the recycled materials as well as specification requirements, testing and processing requirements, environmental, performance monitoring and cost-related issues.

The template was shared with Main Roads and LGs staff involved in data collection related to recycled materials.

Recycled Materials Data Collection

Organisation	
Total Projects	

Project	

Basic Info

LG/Organisation *(eg. City of Perth, Main Roads)*			
Project *(eg. White Road Rehab.)*			
Project location *(eg. Coordinates, SLK, Side streets etc.)*			
Project length *(m or kms)*		Who filled in this template *(Name, position)*	
Contact details *(Mobile, email)*		Date filled in *(dd/mm/yyyy)*	

Pavement Details

Date of pavement constuction or opened to traffic *(dd/mm/yyyy)*		Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	
Surfacing type *(eg. sprayed seal, thin asphalt, none)*		Rehab status (e.g. once, twice)	
When last rehabilitated?		Details of rehabilitation *(e.g. type, material used)*	
Overall current pavement condition *(eg. poor, fair, good)*		Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate, severe)	

Recycled Materials Details

Conventional material used *(eg. crushed aggregate, asphalt etc.)*		Recycled material used *(e.g. RCC, RCG, CR, RAP)*	
Pavement layers where recycled material was used *(eg. basecourse, subbase, fill)*		Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used *(e.g. 20%, 2.5%, 15%)*	
Was any processing required/done at the site before use?		Total quantity or volume used in the project *(e.g. tonnes, m3)*	
Maxium allowable usage limit *(eg. 3.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(eg. MRWA Spec. 501)*		Any lab testing performed on the recycled material and what was the result?	
Challenges faced and how those challenges were tackled?		Cost issues	
Recycled materials performance		Environmental issues and risks identified and how those risks were managed?	
Is the recycled materials used documented? (if yes, where?)		Is performance of the recycled materials being monitored? (if yes, how?)	

Overall Comments

Abbreviations
RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Appendix B Main Roads Data

Organisation	Main Roads Western Australia
Total Projects	3

Project 1	Kwinana Freeway Trial

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Main Roads		
Project *(e.g. White Road Rehab.)*	Kwinana Fwy Trial Mile		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	H015, SLK 56.38 - 56.48		
Project length *(m or kms)*	100m	Who filled in this template *(Name, position)*	zak birchall
Contact details *(Mobile, email)*	zak.birchall@mainroads.wa.gov.au	Date filled in *(dd/mm/yyyy)*	22/03/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	2009	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	258mm CRC 150mm CLS Yellow Sand
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	30mm OGA 30mm DGA	Rehab status (e.g. once, twice)	zero
When last rehabilitated?	n/a	Details of rehabilitation *(e.g. type, material used)*	n/a
Overall current pavement condition *(e.g. poor, fair, good)*	fair/good	Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate, severe)	Minor cracking and minor ravelling

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	OGA, DGA, ES, CLS, Yellow Sand	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CRC
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Basecourse	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Basecourse Material
Source of Recycled Material *(where the material derived from?)*	All Earth Recyclers	Percentage of recycled material used *(e.g. 2.0%, 2.5%, 15%)*	100% of basecourse
Was any processing required/done at the site before use?		Total quantity or volume used in the project *(e.g. tonnes, m3)*	
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*	n/a	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	MRWA Spec. 501	Any lab testing performed on the recycled material and what was the result?	PSD, LS, LL, CBR, MDD, OMC, LA Abrasion All Passed
Challenges faced and how those challenges were tackled?		Cost issues	
Recycled materials performance		Envronmental issues and risks identified and how those risks were managed?	
Is the recycled materials used documented? (if yes, where?)		Is performance of the recycled materials being monitored? (if yes, how?)	Yes, Trials conducted every 6 months

Overall Comments

Project 2	Armadale Road to North Lake Road Bridge

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Main Roads		
Project *(e.g. White Road Rehab.)*	Armadale Road to North Lake Road Bridge Project		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	H023, SLK15.81-16.06		
Project length *(m or kms)*	250m	Who filled in this template *(Name, position)*	zak birchall
Contact details *(Mobile, email)*	zak.birchall@mainroads.wa.gov.au	Date filled in *(dd/mm/yyyy)*	22/03/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	2021	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	288mm Asphalt 150mm CRC
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	40mm AIC	Rehab status (e.g. once, twice)	zero
When last rehabilitated?	n/a	Details of rehabilitation *(e.g. type, material used)*	n/a
Overall current pavement condition *(e.g. poor, fair, good)*	fair/good	Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate, severe)	Minor Cracking, some curvature

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CRC
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Subbase	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Subase for FDA
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used *(e.g. 2.0%, 2.5%, 15%)*	100% of subbase
Was any processing required/done at the site before use?		Total quantity or volume used in the project *(e.g. tonnes, m3)*	≈19,000-29,000 tonnes
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*	n/a	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	MRWA Spec. 501	Any lab testing performed on the recycled material and what was the result?	
Challenges faced and how those challenges were tackled?		Cost issues	
Recycled materials performance		Environmental issues and risks identified and how those risks were managed?	
Is the recycled materials used documented? (if yes, where?)	Yes, Roads to Reuse: economic benefits case study, Government of Western Australia 2021	Is performance of the recycled materials being monitored? (if yes, how?)	

Overall Comments

Project 3	Wanneroo Road / Beach Road

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Main Roads		
Project *(e.g. White Road Rehab.)*	Wanneroo Rd / Beach Rd		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	H035, SLK11.59-12.35		
Project length *(m or kms)*	760m	Who filled in this template *(Name, position)*	zak birchall
Contact details *(Mobile, email)*	zak.birchall@mainroads.wa.gov.au	Date filled in *(dd/mm/yyyy)*	22/03/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1977	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	150mm Crushed Rock
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	30mm GGAR	Rehab status (e.g. once, twice)	
When last rehabilitated?	2020	Details of rehabilitation *(e.g. type, material used)*	Resurfacing, GGAR
Overall current pavement condition *(e.g. poor, fair, good)*	Fair/Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate, severe)	moderate cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	Crushed Rock, Granite Aggregate	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	GGAR, CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Wearing Course, Binder Modifier	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in Binder
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used *(e.g. 2.0%, 2.5%, 15%)*	
Was any processing required/done at the site before use?		Total quantity or volume used in the project *(e.g. tonnes, m3)*	
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	MRWA Spec. 517	Any lab testing performed on the recycled material and what was the result?	
Challenges faced and how those challenges were tackled?		Cost issues	
Recycled materials performance		Environmental issues and risks identified and how those risks were managed?	
Is the recycled materials used documented? (if yes, where?)		Is performance of the recycled materials being monitored? (if yes, how?)	

Overall Comments

Abbreviations

RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Appendix C LG Data

Organisation	**City of Canning**
Total Projects	**1**

Project 1	**Upgrade of Welshpool Road**

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	City of Canning		
Project *(e.g. White Road Rehab.)*	Upgrade of Welshpool Road		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From a point west of Sevenoaks St to Leach Hwy in Welshpool		
Project length *(m or km)*	850m	Who filled in this template *(Name, position)*	Keith M - ARRB professional
Contact details *(Mobile, email)*		Date filled in *(dd/mm/yyyy)*	

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	Late 2020 - Late 2022	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*		Rehab status (e.g. none, twice)	
When last rehabilitated?		Details of rehabilitation	
Overall current pavement condition *(e.g. poor, fair, good)*		Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate,	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*		Recycled material used *(e.g. RCC, RCG, CR, RAP)*	Construction and demolition material (CRC)
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Road Base Sub-base	Application of recycled material *(e.g. replacement of fine aggregate, component in binder)*	
Source of Recycled Material *(where the material derived from)*	Construction and demolition waste	Percentage of recycled material used	
Was any processing required/done at the site before use?	Yes	Total quantity or volume used in the project *(e.g. tonnes, m3)*	2000m3
Maxium allowable usage limit *(e.g. 5.5%, 10%, 25%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	IPWEA-WALGA Recycled base spec	Any lab testing performed on the recycled material and	
Challenges faced and how these challenges were tackled?		Cost issues	
Recycled materials performance	Testing indicated that the road pavement produced using recycled material was at least as strong, and possibly stronger, than conventional roadbase. Further testing over time has shown that the recycled product gains considerable strength with curing and is now	Environmental issues and risks identified and how these risks were managed?	
Is the recycled materials used documented? (if yes, where?)		Is performance of the recycled materials being monitored? (if yes, how?)	

Overall Comments

Abbreviations

RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Organisation	**City of Swan**
Total Projects	**2**

Project 1	**Talbot Road Resurfacing**

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	City of Swan		
Project *(e.g. White Road Rehab.)*	Talbot Rd Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	-Entire project length (Dongara Cir (N) SLK 1.90 - O'Connor Rd SLK 2.25)		
Project length *(m or km)*	350m	Who filled in this template	Michael Newman, Asphalt and Seal Engineer
Contact details *(Mobile, email)*	0400 700 386 michael.newman@swan.wa.gov.au	Date filled in *(dd/mm/yyyy)*	29/11/2022

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	19/11/2019	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	-Existing surface: old asphalt surface (with gravel basecourse underneath) -Asphalt overlay completed with a seal (SAMI) laid prior to new asphalt layer
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	-Seal (SAMI) then asphalt	Rehab status (e.g. never, twice)	Never
When last rehabilitated?	-Never, only crack sealing has been completed as a maintenance item	Details of rehabilitation *(e.g. type, materials used)*	-SLK 1.90 - 2.25 (full width) -7mm granite SAMI S45R (crumb rubber) -SLK 1.90 - 2.25 (southbound) -40mm DGA10/75 -SLK1.90 - 2.25 (northbound) -40mm Plastiphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Fair	Distress type and severity (e.g. cracking, ravelling, potholes & minor, moderate,	-Medium severity stable environmental cracking (managed by the crack sealing) -Low severity shoving at Dongara Cir (S) intersection (managed by an asphalt patch)

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	Asphalt	Recycled material used *(e.g. RCC, RCB, CR, RAP)*	Plastic (plastiphalt)
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Asphalt	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from)*	Recycled plstic bags	Percentage of recycled material used *(e.g. 2.8%, 2.5%, 15%)*	-Approx 1%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project *(e.g. tonnes, m3)*	820t of asphalt used for the entire project, 370t of sustainable trial asphalt
Maxium allowable usage limit *(e.g. 5.5%, 10%, 20%)*	-Not defined	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	-Combination of IPWEA/AAPA Asphalt Spec, MRWA Spec 501, MRWA Spec 509 and MRWA Spec 511	Any lab testing performed on the recycled material and what was the result?	Standard asphalt samples and coring occurring, at higher frequency than usual. All results complied
Challenges faced and how these challenges were tackled?	Day of the trial ambient tempatures reached 43 degrees, so very hot and not ideal conditions for the trial. Compaction rolling was required to be delayed more than usual, otherwise pick up of the	Cost issues	Open tender via WALGA eQuotes completed for competitive rates
Recycled materials performance	-Performing well, no reflective cracking, shoving or potholes/ deformation	Environmental issues and risks identified and how these risks were managed?	Nil
Is the recycled materials used documented? (if yes, where?)	-Contained within asphalt delivery dockets	Is performance of the recycled materials being monitored? (if yes, how?)	-Yes, biannual (or less) visual inspections

Overall Comments

-Swan typically prefer to completed these trials using a 'sample area' rather than the whole road and this was the case on this project too. 1 lane of the project was completed using the standard treatment, whilst the other lane was completed using the trial asphalt. By laying a standard and trial section adjacent to each other performance can be directly compared to standard treatment, whilst maintaining identical geographical, temporal, geometric and traffic conditions.

Project 2	West Swan Road Surfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Swan		
Project *(e.g. White Road Rehab.)*	West Swan Rd Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	-Entire projet length (Millhouse Rd SLK 1.10 - Leake Pl SLK 1.86) -Length of sustainable asphalt - SLK 1.31 - 1.61 (300m)		
Project length *(m or kms)*	760m	Who filled in this template	Michael Newman, Asphalt and Seal Engineer
Contact details *(Mobile, email)*	0488 700 386 michael.newman@swan.wa.gov.au	Date filled in *(dd/mm/yyyy)*	23/11/2022

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	19/11/2019	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	-Existing surface: old bitumen seal (with gravel basecourse underneath) -Asphalt overlay completed
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Asphalt	Rehab status (e.g. once, twice)	Once, likely the original seal or may have had a reseal completed at some stage but data unknown. Some isolated maintenance patching completed in 2018 and early 2019
When last rehabilitated?	Unknown. Maybe never likely the original seal or may have had a reseal completed at some stage but data unknown	Details of rehabilitation *(e.g. type, material used)*	-Asphalt overlay: -SLK 1.10 - 1.31 and SLK 1.61 - 1.86 -Asphalt shoulders: 40mm DGA10/75+A15E+2%ROX -Asphalt running lanes: 40mm DGA14MRWAINT+A15E -SLK1.31-1.61 -Asphalt shoulders: 40mm DGA10/75+A15+2%ROX -Asphalt running lanes: 40mm crumb rubber (gap graded, 14mm aggregate)
Overall current pavement condition *(e.g. poor, fair, good)*	Fair	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	-Low severity potholing (addressed by the isolated maintenance patching) -Low severity stable environmental cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR (crumb rubber)
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Asphalt	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Recycled tyres	Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	-Approx 1.5%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	776t of asphalt used for the entire project, 215t of sustainable trial asphalt
Maxium allowable usage limit *(e.g. 3.5%; 10%; 20%)*	-Not defined	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	-Combination of IPWEA/AAPA Asphalt Spec, MRWA Spec 501, MRWA Spec 509 and MRWA Spec 511	Any lab testing performed on the recycled material and	Standard asphalt samples and coring occuring, at higher frequency than usual. All results complied
Challenges faced and how those challenges were tackled?	-Due to high traffic counts, project completed on nightshift so sustainable trial mix needed ot be appropriate for nightshift which it was	Cost issues	Open tender via WALGA equotes completed for competitive rates
Recycled materials performance	-Performing well, no reflective cracking showing or potholes/ deformation	Envronmental issues and risks identified and how those risks	Nil
Is the recycled materials used documented? (if yes, where?)	-Contained within asphalt delivery dockets	Is performance of the recycled materials being monitored? (if yes, how?)	-Yes, biannual (or less) visual inspections

Overall Comments

-Swan typically prefer to completed these trials using a 'sample area' rather than the whole road and this was the case on this project too. 2/3 of the project was completed using the standard treatment, whilst 1/3 was completed using the trial asphalt. By laying a standard and trial section adjacent to each other performance can be directly compared to standard treatment, whilst maintaining identical geographical, temperal, geometric and traffic conditions.

Abbreviations
RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Organisation	**City of Bayswater**
Total Projects	**1**

Project 1	**Vidgee Road Resurafcing**

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	City of Bayswater		
Project *(e.g. White Road Rehab.)*	Widgee Road - Road Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From Alexander Dr to Camboon Road		
Project length *(m or km)*	375m	Who filled in this template *(Name, position)*	Tina Hoang (Technical Officer)
Contact details *(Mobile, email)*	Anthony Clarke (Anthony.Clarke@bayswater.wa.gov.au)	Date filled in *(dd/mm/yyyy)*	28/02/2025

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	7/04/2022	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	mill & fill 50mm - 20mm SSMA CR - 30mm 10AC 75MD 20% RAP
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	asphalt	Rehab status *(e.g. new, twice)*	
When last rehabilitated?		Details of rehabilitation	
Overall current pavement condition *(e.g. poor, fair, good)*		Distress type and severity *(e.g. cracking, ravelling, potholes & minor, moderate,*	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR RAP
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	basecourse & wearingcourse	Application of recycled material *(e.g. replacement of fine aggregate, an additive in binder)*	
Source of Recycled Material *(where the material derived from)*	unknown	Percentage of recycled material used *(e.g. 2.5%, 5.5%, 15%)*	20% RAP
Was any processing required/ done at the site before use?	no	Total quantity or volume used in the project *(e.g. tonnes, m3)*	577t of SSMA CR 824t of 10AC 75MD 20% RAP
Maxium allowable usage limit *(e.g. 5.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*		Any lab testing performed on the recycled material and	no
Challenges faced and how these challenges were tackled?		Cost issues	no
Recycled materials performance	no issues so far.	Environmental issues and risks identified and how these risks were	
Is the recycled materials used documented? (if yes, where?)		Is performance of the recycled materials being monitored? (if yes, how?)	

Overall Comments

Abbreviations
RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Organisation	City of Kalamunda
Total Projects	4

Project 1	Arthur Road Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	City of Kalamunda		
Project *(e.g. White Road Rehab.)*	Arthur Road Lesmurdie Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Between Silverdale RD and Allbrett RD Lesmurdie; SLK 0 - SLK 205		
Project length *(m or kms)*	205	Who filled in this template	Shaphal Subedi
Contact details *(Mobile, email)*	892579950; Shaphal.Subedi@kalamunda.wa.gov.au	Date filled in *(dd/mm/yyyy)*	2/02/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1/03/1965	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	Laterite
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Asphalt	Rehab status (e.g. once, twice)	once (01/01/1983)
When last rehabilitated?	18/11/2022 (CR)	Details of rehabilitation *(e.g. type, material used)*	Asphalt install of 30mm 10 DG Crumbed Rubber 75 MB
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt etc.)*	Asphalt, crushed aggregate	Recycled material used *(e.g. RCG, RCG, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Wear Course	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	18%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	7 m3
Maxium allowable usage limit		Recycled material mixing process	
Specification/Guide *(e.g. MRWA Spec. 501)*		Any lab testing performed on the recycled material and	Futon Hogan hasn't provided us any information
Challenges faced and how those challenges were tackled?	No	Cost issues	No
Recycled materials performance	Good	Envronmental issues and risks identified and how those risks were	No
Is the recycled materials used documented? (if yes, where?)	No	Is performance of the recycled materials being monitored? (if yes, how?)	No

Overall Comments

Project 2	Wittenoom Road Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Kalamunda		
Project *(e.g. White Road Rehab.)*	Wittenoom Road, High Wycombe Road Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Wittenoom Rd between Kalamunda Rd to Hulley RD; (SLK-0 to SLK60)		
Project length *(m or kms)*	110	Who filled in this template	Shaphal Subedi
Contact details *(Mobile, email)*	892579950; Shaphal.Subedi@kalamunda.wa.gov.au	Date filled in *(dd/mm/yyyy)*	2/02/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1/03/1965	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Laterite
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Asphalt	Rehab status (e.g. once, twice)	Once (1/01/1993)
When last rehabilitated?	28/11/2022	Details of rehabilitation	Asphalt install of 30mm 10 DG Crumbed Rubber 75 MB
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate,*	Asphalt, crushed aggregate	Recycled material used *(e.g. RCC, RCG, CR,*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Wear Course	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used	18.00%
Was any processing required/done at the site before use?		Total quantity or volume used in the project	
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	5 m3
Specification/Guide *(e.g. MRWA Spec. 501)*		Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	No	Cost issues	No
Recycled materials performance	Good	Environmental issues and risks identified and how those risks	No
Is the recycled materials used documented? (if yes, where?)	No	Is performance of the recycled materials being monitored? (if yes, how?)	No

Overall Comments

Project 3	Grace Road Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth Main*	City of Kalamunda		
Project *(e.g. White Road Rehab.)*	Grace Road Kalamunda, Road Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Grace Road between Robins RD and Betti RD		
Project length *(m or kms)*	130	Who filled in this template	Shaphal Subedi
Contact details *(Mobile, email)*	892579950; Shaphal.Subedi@kalamunda.wa.gov.au	Date filled in *(dd/mm/yyyy)*	2/02/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1/07/1974	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Laterite
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	28/11/2022	Details of rehabilitation	Asphalt install of 30mm 10 DG Crumbed Rubber 75 MB
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate,*	Asphalt, crushed aggregate	Recycled material used *(e.g. RCC, RCG, CR*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Wear Course	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in Binder
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used	18%
Was any processing required/done at the site before use?		Total quantity or volume used in the project	4 m3
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*		Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	No	Cost issues	No
Recycled materials performance	Good	Envronmental issues and risks identified and how those risks	No
Is the recycled materials used documented? (if yes, where?)	No	Is performance of the recycled materials being monitored? (if yes, how?)	No

Overall Comments

Project 4	Rich Street Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Kalamunda		
Project *(e.g. White Road Rehab.)*	Rich Street Gooseberry Hill Road Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Rich Street between Davies Cr to Parke RD		
Project length *(m or kms)*	89m	Who filled in this template	Shaphal Subedi
Contact details *(Mobile, email)*	892579950; Shaphal.Subedi@kalamunda.wa.gov.au	Date filled in *(dd/mm/yyyy)*	2/02/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1/07/1974	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Laterite
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Single Seal	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	24/11/2022	Details of rehabilitation	Asphalt install of 30mm 10 DG Crumbed Rubber 75 MB
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate,*	Asphalt, crushed aggregate	Recycled material used *(e.g. RCC, RCG, CR*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Wear Course	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*		Percentage of recycled material used	18%
Was any processing required/done at the site before use?		Total quantity or volume used in the project	9 m3
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*		Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*		Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	No	Cost issues	No
Recycled materials performance	Good	Environmental issues and risks identified and how those risks	No
Is the recycled materials used documented? (if yes, where?)	No	Is performance of the recycled materials being monitored? (if yes, how?)	No

Overall Comments

Organisation	City of Cambridge
Total Projects	4

Project 1	Oceanic Drive Westbound Rehabilitation

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Town of Cambridge		
Project *(e.g. White Road Rehab.)*	Oceanic Drive Westbound (Tullow to Hawtree) - Road Rehabilitation		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	2.57 to 3.62		
Project length *(m or kms)*	1050m	Who filled in this template	Mulenga Kabengele
Contact details *(Mobile, email)*	08 9285 3150, Mkabengele@cambridge.wa.gov.au	Date filled in *(dd/mm/yyyy)*	26-May-23

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	Feb-23	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Crumb Rubber Gap Graded Asphalt, 350mm
Surfacing type *(e.g. reseal, thin asphalt,*	Asphalt	Rehab status *(e.g. once, twice)*	35 Years
When last rehabilitated?	Feb-23	Details of rehabilitation *(e.g. type, material used)*	Crumb Rubber Gap Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Excellent	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Minor

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt*	Asphalt	Recycled material used *(e.g. RCG, RCS, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Basecourse	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in Binder
Source of Recycled Material *(where the material derived from?)*	Recycled Tyres	Percentage of recycled material used *(e.g. 20%; 2.5%; 15%)*	Percentage ratio
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	1,882,800m cubed
Maxium allowable usage limit *(e.g. 2.5%; 10%; 20%)*	Percentage ratio	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	PSTS112	Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	Nil	Cost issues	Market Price Variations
Recycled materials performance	Excellent	Envronmental issues and risks identified and how those risks were	No
Is the recycled materials used documented? (if yes, where?)	Yes - AssetFinda	Is performance of the recycled materials being monitored? (if yes, how?)	Conditional Monitoring and Surveys

Overall Comments

Project 2	Southport Street Rehabilitation

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Town of Cambridge		
Project *(e.g. White Road Rehab.)*	Southport Street (Lake Monger - Bus Exit) Road Rehabilitation		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	SLK 0.5 to 0.85		
Project length *(m or kms)*	350m	Who filled in this template	Mulenga Kabengele
Contact details *(Mobile, email)*	08 9285 3150	Date filled in *(dd/mm/yyyy)*	30-May-23

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*		Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Asphalt
Surfacing type *(e.g. sprayed seal, thin asphalt,*	Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	Apr-23	Details of rehabilitation	Crumb Rubber
Overall current pavement condition *(e.g. poor, fair, good)*	Excellent	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	Severe

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt*	Asphalt	Recycled material used	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Basecource	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in Binder
Source of Recycled Material *(where the material derived from?)*	Recycled Tyres	Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	Percentage Ratio
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	478,500M cubed
Maxium allowable usage limit *(e.g. 5.5%; 10%; 20%)*	Percentage ratio	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	PSTS112	Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	None	Cost issues	Market Price Variations
Recycled materials performance	Excellent	Environmental issues and risks identified and how those risks were	No
Is the recycled materials used documented? (if yes, where?)	Yes - AssetFinda, Project Register	Is performance of the recycled materials being monitored? (if yes, how?)	Yes - Conditional Monitoring and Surveys

Overall Comments

Project 3	Ulster Road Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Town of Cambridge		
Project *(e.g. White Road Rehab.)*	Ulster Road Resurfacing		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Floreat		
Project length *(m or kms)*	620m	Who filled in this template	Mulenga Kabengele
Contact details *(Mobile, email)*	08 9285 3150	Date filled in *(dd/mm/yyyy)*	30/05/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	1/01/1965	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Asphalt
Surfacing type *(e.g. sprayed seal, thin asphalt,*	Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	May-23	Details of rehabilitation	Recycled Tyres
Overall current pavement condition *(e.g. poor, fair, good)*	Excellent	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	Moderate

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt*	Asphalt	Recycled material used	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Basecource	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in Binder
Source of Recycled Material *(where the material derived from?)*	Recycled Tyres	Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	Percentage ratio
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	999,000M cubed
Maxium allowable usage limit *(e.g. 3.5%; 10%; 20%)*	Percentage ratio	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	PSTS112	Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were	No	Cost issues	Market Price Variations
Recycled materials performance	Excellent	Envronmental issues and risks identified and how those risks were	No
Is the recycled materials used documented? (if yes, where?)	Yes - AssetFinda, Project Register	Is performance of the recycled materials being monitored? (if yes, how?)	Yes - Conditional Monitoring and surveys

Overall Comments

Project 4	Road Infrastructure - Various Locations

Basic Info

LG/Organisation *(e.g. City of Perth, Main Roads)*	Town of Cambridge		
Project *(e.g. White Road Rehab.)*	Road Infrastructure		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	Various locations - Refer to the details below		
Project length *(m or kms)*	3.784km	Who filled in this template	Mulenga Kabengele
Contact details *(Mobile, email)*	08 9285 3150	Date filled in *(dd/mm/yyyy)*	29-May-23

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	31/10/2013	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Recycled Concrete 200mm-300mm
Surfacing type *(e.g. sprayed seal, thin asphalt,*	Recycled Concrete	Rehab status (e.g. once, twice)	1-80 years
When last rehabilitated?	31/10/2023	Details of rehabilitation	Recycled Concrete
Overall current pavement condition *(e.g. poor, fair, good)*	Excellent	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	Minor

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate, asphalt*	Reclaimed Asphalt Pavement and Recycled Aggregates	Recycled material used	RAP
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	Base	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	New Construction
Source of Recycled Material *(where the material derived from?)*	Crushed Demolition	Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	100%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	100,863,000m cubed
Maxium allowable usage limit *(e.g. 5.5%; 10%; 20%)*	50% to 100%	Recycled material mixing process *(e.g. dry, wet etc.)*	
Specification/Guide *(e.g. MRWA Spec. 501)*	MRTS102	Any lab testing performed on the recycled material and	
Challenges faced and how those challenges were tackled?	Use of some recycled materials reduces road life as material degrade with the sun due to changes in asphalt properties. TOC expected road life is	Cost issues	Project funding constraints
Recycled materials performance	Excellent	Envronmental issues and risks identified and how those risks were	
Is the recycled materials used documented? (if yes, where?)	Yes, AssetFinda	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, through annual surveys and conditional monitoring

Overall Comments

Project 1	CLUBB AVE Resurfacing

Basic Info

LG/Organization *(e.g. City of Perth, Main Roads)*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	CLUBB AVE Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From: LUTH AVE To: SELBY ST		
Project length *(m or km)*	108m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of layers)*	Unbound granular Pavement with thin 30 mm asphalt wearing course.
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	2/03/2021	Details of rehabilitation *(e.g. type, material*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes &	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. base course, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.0%; 2.5%; 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project *(e.g. tonnes, m3)*	0.87 tonne
Maxium allowable usage limit *(e.g. 2.5%; 10%; 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and what was the result?	Yes
Challenges faced and how these challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how these risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CM9	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 2	WOOLNOUGH ST Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	WOOLNOUGH ST Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From: NORTHMORE ST To:ROBERTA ST		
Project length *(m or kms)*	380m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular pavement with thin 30 mm asphalt wearing course
Surfacing type *(e.g. sprayed seal, thin asphalt, open)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	5/03/2021	Details of rehabilitation *(e.g. type, material used)*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. base course, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.0%, 2.5%, 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	1.88 tonne
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 3	DAKIN ST Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	DAKIN ST Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From: NORTHMORE ST To:STEVENS ST		
Project length *(m or kms)*	120m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular pavement material with thin 30 mm asphalt wearing surface
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	17/02/2021	Details of rehabilitation *(e.g. type, material used)*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. base course, sub-base, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.5%, 2.5%, 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	0.65 tonne
Maxium allowable usage limit *(e.g. 5.5%, 10%, 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 4	OLD HAY ST Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	OLD HAY ST Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Side streets etc.)*	From: Hay St To: Dakin St		
Project length *(m or kms)*	300m	Who filled in this template	Daniel Ghasemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular pavement material with thin 30 mm asphalt wearing surface
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	17/02/2021	Details of rehabilitation *(e.g. type, material used)*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCG, RCS, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. base course, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.0%, 2.5%, 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	0.37 tonne
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 5	ROWLAND ST Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	ROWLAND ST Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Sidestreets etc.)*	From: HAY ST To:BARKER RD		
Project length *(m or kms)*	180m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	21/03/2021	Details of rehabilitation *(e.g. type, material used)*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCG, RCS, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.6%; 2.5%; 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	0.76 tonne
Maxium allowable usage limit *(e.g. 3.5%; 10%; 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 6	SUBIACO RD Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	SUBIACO RD Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Sidestreets etc.)*	From: HAMILTON ST To:THOMAS ST		
Project length *(m or kms?*	500m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement Details

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular with thin 30 mm asphalt wearing surface
Surfacing type *(e.g. sprayed seal, thin asphalt, open)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	13/04/2021	Details of rehabilitation *(e.g. type, material used?*	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate*	Asphalt	Recycled material used *(e.g. RCG, RCS, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. basecourse, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.6%, 2.5%, 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	2.55 tonne
Maxium allowable usage limit *(e.g. 3.5%, 10%, 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks were	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Project 7	CUNNINGHUM TCE Resurfacing

Basic Info

LG/Organisation *(e.g. City of Perth, Main*	City of Subiaco		
Project *(e.g. White Road Rehab.)*	CUNNINGHUM TCE Resurfacing Project		
Project location *(e.g. Coordinates, SLK, Sidestreets etc.)*	From: STUBBS TCE To:MILLINGTON AVE		
Project length *(m or kms)*	300m	Who filled in this template	Daniel Gharemi, Senior Project Engineer
Contact details *(Mobile, email)*	0451940004, danielg@subiaco.wa.gov.au	Date filled in *(dd/mm/yyyy)*	4/09/2023

Pavement

Date of pavement construction or opened to traffic *(dd/mm/yyyy)*	NA	Pavement type and configuration *(e.g. unbound granular, asphalt & thickness of*	Unbound granular with thin asphalt wearing surface of 30 mm
Surfacing type *(e.g. sprayed seal, thin asphalt, none)*	Crumb Rubber Dense Graded Asphalt	Rehab status (e.g. once, twice)	Once
When last rehabilitated?	15/04/2021	Details of rehabilitation	Crumb Rubber Dense Graded Asphalt
Overall current pavement condition *(e.g. poor, fair, good)*	Good	Distress type and severity (e.g. cracking, ravelling, potholes & minor,	Cracking

Recycled Materials Details

Conventional material used *(e.g. crushed aggregate,*	Asphalt	Recycled material used *(e.g. RCC, RCG, CR, RAP)*	CR
Pavement layers where recycled material was used *(e.g. base course, subbase, fill)*	NA	Application of recycled material *(e.g. replacement of fine aggregate, consumed in binder)*	Consumed in binder
Source of Recycled Material *(where the material derived from?)*	Sourced from WA by Fulton Hogan	Percentage of recycled material used *(e.g. 2.5%; 2.5%; 15%)*	15%
Was any processing required/done at the site before use?	No	Total quantity or volume used in the project	1.63 tonne of CR
Maxium allowable usage limit *(e.g. 2.5%; 10%; 20%)*	15%	Recycled material mixing process *(e.g. dry, wet etc.)*	Wet
Specification/Guide *(e.g. MRWA Spec. 501)*	Spec. 516	Any lab testing performed on the recycled material and	Yes
Challenges faced and how those challenges were tackled?	NA	Cost issues	NA
Recycled materials performance	Good	Environmental issues and risks identified and how those risks	NA
Is the recycled materials used documented? (if yes, where?)	Yes, City of Sbiaco CMS	Is performance of the recycled materials being monitored? (if yes, how?)	Yes, regular visual inspection

Overall Comments

Abbreviations
RCC: Recycled Crushed Concrete
RCG: Crushed Recycled Glass
CR: Crumb Rubber
RAP: Reclaimed or Recycled Asphalt Pavement
EOL Tyre: End of Life Tyre

Appendix D Pilot Database

The pilot database spreadsheet captures basic information including organisation, project location and dimensions. The section related to details of the pavement includes pavement construction completion date, pavement type, configuration, surfacing and rehabilitation status. The section on recycled materials provides details of the conventional and recycled materials used, quantity, source, processing, testing, specification limits, challenges faced, performance monitoring and cost-related issues.

WARRIP

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www.warrip.com.au | info@warrip.com.au | Perth, Western Australia