Technical report: Reclaimed Asphalt Pavement in Asphalt Applications on Local Government Roads in WA

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About LG TRRIP

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

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

Summary

This report presents the underpinning research for the development of a practitioners' guidelines for Western Australian Local Government: *Practitioners Guideline: Reclaiming Asphalt Pavement in Asphalt Applications on Local Government Roads in WA*. This research was undertaken by the Western Australian Local Government Association (WALGA) with the support of Main Roads Western Australia (MRWA), under the Local Government Transport and Road Research and Innovation Program (LG TRRIP).

Addressing the Australian Waste Policy Action Plan, Western Australia (WA) has developed the Waste Avoidance and Resource Recovery Strategy 2030, setting targets for the increased recovery of waste materials as valuable resources. This has contributed to a drive to increase the use of recycled materials in road construction, thus leading to the development of a series of such guidelines to support local government in this endeavour and give confidence to road managers.

This report presents details of a project that sought to define the current state of practice in the use of reclaimed asphalt pavements (RAP) in asphalt in WA. This work included a literature review, a series of stakeholder engagement activities and the identification of gaps in current practice. The work resulted in recommendations regarding material supply, mix design considerations, and asphalt manufacture, placement and quality assurance (QA) that will be subsequently refined into succinct and practical guidance for local government. This aimed to supplement guidance already available in local and national resources, standards and specifications.

RAP is processed in both batch and continuous plants, with batch processing plants most commonly available in Perth. The Institute of Public Works Engineering Australasia (WA) and Australian Flexible Pavement Association (WA Branch) (2023), *Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Surfacing*, permits RAP up to 15% by mass (wt.%) without any changes in the mix, and this is followed by local government practitioners. However, RAP use and practitioner expertise was considered to be low. The most predominant challenges identified were associated with the availability of RAP. RAP is typically transported to asphalt plants where it is crushed and stockpiled for later use, rather than being used in situ. Consultations suggested that defining ownership, i.e. ensuring RAP extracted for local government roads is used in the same jurisdiction, may encourage more local government use. A further challenge is obtaining quality RAP which is free of contaminants, due to WA's common use of a thin asphalt surfacing on granular basecourse pavement. Practitioners indicated a willingness to introduce RAP into their low-volume road network, and they expressed they would value guidance regarding the management and supply of RAP, and further technical guidance targeted to uses greater than 10 wt.%.

This work has established that there is drive across local government to use recycled materials in road construction and that targeted guidance, which addresses the specific construction practices, common asphalt types, and availability considerations for local governments, is desired by practitioners. The *Practitioners' Guideline: Reclaiming Asphalt Pavement in Asphalt Applications on Local Government Roads in WA* will aim to offer the supporting information and tools necessary to establish this confidence among local government in WA and increase the use of RAP in asphalt.

Acknowledgements

The authors would like to acknowledge the collaboration and input of the Western Australian Local Government Association and all those who contributed during the stakeholder engagement process.

Acronyms and Glossary

Acronyms

AAPA	Australian Asphalt Pavement Association
AfPA	Australian Flexible Pavement Association
CRMA	Crumb rubber–modified asphalt
CRMB	Crumb rubber–modified binder
DGA	Dense-graded asphalt
DSR	Dynamic Shear Rheometer
FGGA	Fine gap-graded asphalt
GGA	Gap-graded asphalt
GRS	Geotextile reinforced seal
HMA	Hot mix asphalt
IPWEA	Institute of Public Works Engineering Australasia
LG TRRIP	Local Government Transport and Road Research and Innovation Program
MRWA	Main Roads Western Australia
NTRO	National Transport Research Organisation
OGA	Open-graded asphalt
PAH	Polycyclic aromatic hydrocarbon
PMB	Polymer modified binder
PPE	Personal protective equipment
PSD	Particle size distribution
QA	Quality assurance
QC	Quality control
RAP	Reclaimed asphalt pavement
RDG	Residential dense-graded
SAMI	Strain alleviating membrane interlayer
SDS	Safety data sheet
SMA	Stone mastic asphalt
TBR	To be reported
WALGA	Western Australian Local Government Association

WARRIP	Western Australian Road Research and Innovation Program
WHS	Work health and safety

Glossary of Terms

DGA	Dense-graded asphalt: A mixture of coarse aggregate, fine aggregate, filler and bitumen, placed hot and compacted to a dense state as a pavement layer or resurfacing (Austroads 2015a).
FGGA	Fine gap-graded asphalt: A dense mix with intermediate sized fractions replaced by finer fractions. It may also contain more filler. Fine gap-graded mixes rely on the stiffness of the fine aggregate/filler/binder mixture for stability (Austroads 2015a).
OGA	Open-graded asphalt: A bituminous mix using aggregate containing only small amounts of fine material and providing a high percentage of air voids (Austroads 2015a).
QA	Quality assurance: The systematic action necessary to give confidence of satisfactory quality. An element of QA is quality control (Austroads 2015a).
QC	Quality control: Those tests necessary to determine and control the quality of the product being produced (Austroads 2015a).
RAP	Recycled asphalt pavement: The material reclaimed from an asphalt pavement by various means including cold-milling, grader, backhoe, jackpick or other methods (Austroads 2015a).
SMA	Stone mastic asphalt: A gap-graded wearing course mix with a high proportion of coarse aggregate, which interlocks to form a skeletal structure to resist permanent deformation. It has a high binder content (Austroads 2015a).

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1 Introduction

The Australian Waste Policy Action Plan, which was prepared by the Australian state and territory governments and the Australian Local Government Association in 2019, has set a target of 80% resource recovery by 2030. In response to this Action Plan, Western Australia's (WA's) *Waste Avoidance and Resource Recovery Strategy* 2030 has set targets of increased material recovery to 70% by 2025 and 75% by 2030 (Waste Authority 2023a). In addition, the *State Road Funds to Local Government Agreement (2023/24–2027/28)* includes a commitment by local government to increase its usage of recycled materials in road construction. During the term of the agreement, systems and processes to support, monitor and report the use of recycled materials are to be developed (Main Roads Western Australia & WALGA 2023). To achieve this, national standards and specifications that guide the uptake of recycled materials in road construction, need to be developed (Department of Climate Change, Energy, the Environment and Water 2019).

The Western Australian Local Government Association (WALGA), with the support of Main Roads Western Australia (MRWA) under the Local Government Transport and Road Research and Innovation Program (LG TRRIP), engaged the National Transport Research Organisation (NTRO) to develop a series of documents to guide local government practitioners regarding the increased adoption of recycled materials in road construction.

WA is divided into regions, namely metropolitan, regional, remote and very remote. Metropolitan WA includes the greater Perth region, regional WA includes the inner and outer regional areas surrounding Perth, remote WA is primarily the area surrounding regional WA, including some isolated remote zones along the coast, while the rest is considered very remote WA (Howland et al. 2023). Howland et al. (2023) provided an overview of the types of roads that fall within the jurisdiction of local government in WA including various possible construction scenarios. Approximately 39,500 km of sealed roads in WA are managed by local government (WALGA 2017). Of these, as of 2022, 12,960 km of pavements are comprised of asphalt wearing courses placed in built-up areas (WALGA 2022).

This project follows the *Sustainable Road Construction Practices for Local Government Roads in WA* (Howland et al. 2023), focusing on the use of reclaimed asphalt pavements (RAP) in asphalt. Although RAP has seen a recent uptake by several authorities across Australia, local government in WA may still benefit by more targeted guidance on the design, specifications and construction of RAP asphalt in order to further increase its uptake.

The project involved a comprehensive literature review to identify suitable technologies, applications, material sources, workplace health and safety (WHS) and environmental considerations, specifications, challenges, risks and mitigation measures applicable to the use of RAP in asphalt. The findings of the literature review were also used to identify where additional resources and/or technical guidance is required to facilitate and support the wider adoption of RAP on the local road network in WA.

These recommendations are aimed to supplement guidance already provided by local and national (e.g. Austroads, Australian Flexible Pavement Association (AfPA), Institute of Public Works Engineering Australasia (IPWEA)) standards and specifications. The main objective is to deliver a practical guideline that will assist local governments to make informed decisions regarding the design and implementation of RAP in asphalt.

1.1 Structure of the Report

Two key documents were delivered as part of this project:

1. Technical report (this report): the underpinning research that led to the development of the practitioners' guideline.
2. Practitioners' guideline: Reclaimed asphalt pavement in asphalt applications on local government roads in WA – succinct guidance to enable the wider adoption of RAP in asphalt.

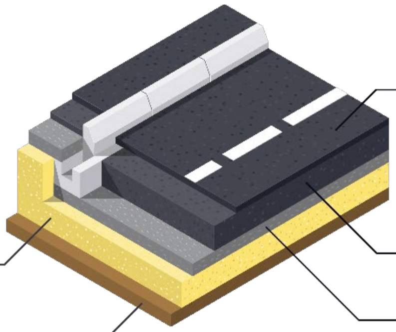
In this report:

- Section 2 provides an overview of the different relevant asphalt mixes and materials.
- Section 3 provides current practices and guidance for the use of RAP in asphalt, specifically:
  - technology
  - applications
  - benefits
  - challenges, risks and mitigation measures
  - national practice
  - WA practice.
- Section 4 describes the stakeholder consultation activities, their purpose and the process followed. The questionnaires used to engage with the stakeholders are provided in Appendix A.
- In Section 5, the outcomes of Sections 3, and 4 are critically assessed to identify the gaps in WA practice. Available relevant guidance on specifications, mix design, construction and asphalt laying are also summarised and additional considerations related to the use of RAP in asphalt pavements are identified.
- Section 6 includes conclusions and recommendations for future work.

2 Asphalt Mix Types and Materials

Asphalt can be used in different applications, and its desired properties will depend on the location and function within a pavement structure. Figure 2.1 illustrates the different layers generally adopted in a flexible pavement which includes asphalt in surface courses, intermediate layers or basecourse layers (Austroads 2014).

Figure 2.1: Typical asphalt layers incorporated in flexible pavements



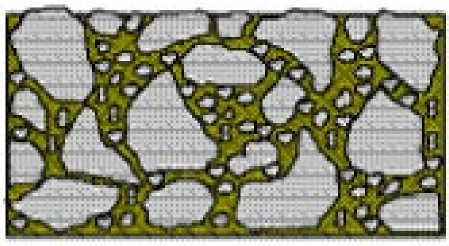
The type of bituminous binder used in the asphalt layer varies depending on the type of the mix selected (e.g. dense-graded asphalt (DGA), open-graded asphalt (OGA), gap-graded asphalt (GGA), fine gap-graded asphalt (FGGA) or stone mastic asphalt (SMA)). DGA has been the most common mix type since the 1970s. More recently, OGA and SMA have seen a rapid uptake as a wearing course on freeways or other applications where improved surface texture, reduced noise or increased safety are a requirement. Regardless, DGA remains the preferred mix type for base, intermediate and wearing courses (Austroads 2009a).

Sections 2.1 to 2.4 present brief details of the various asphalt mixes used in WA, and Section 2.5 provides a brief description of RAP.

2.1 Dense-graded Asphalt

DGA comprises a mixture of continuously graded aggregates, sand and fillers mixed with binder. DGA can be tailored to suit different applications based on the design target air voids, nominal aggregate size and particle size distribution (PSD), and type of binder (Austroads 2009a). A schematic of a typical DGA mix is presented in Figure 2.2.

Figure 2.2: Typical dense-graded asphalt mix

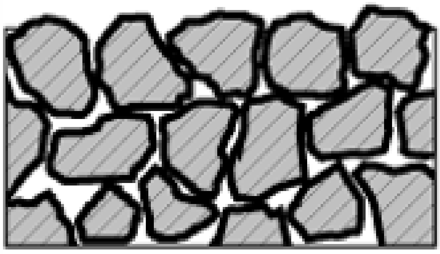


In lightly trafficked roads, mix designs with a nominal aggregate size below 14 mm are most commonly used. The main source of pavement deterioration in these applications is ravelling caused by the hardening of the binder. In heavily trafficked roads, mix designs with coarser nominal size aggregates and stiffer binders are typically used (Austroads 2009a).

2.2 Open-graded Asphalt

OGA primarily contains coarse aggregates and a small amount of fine aggregates, designed to target an air voids content between 18 and 25%. Unmodified bitumen or a modified binder can be used depending on the expected traffic volumes and axle loads. OGA pavements typically fail due to ravelling of the surface aggregate caused by the hardening of the binder (Austroads 2009a). OGA is characterised by good skid resistance, a smooth riding surface, reduced light reflectivity, reduced tyre noise and reduced water spray (Austroads 2014). A schematic of a typical OGA mix is presented in Figure 2.3.

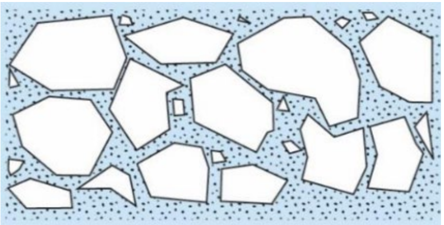
Figure 2.3: Typical open-graded asphalt mix



2.3 Stone Mastic Asphalt

SMA is a mix with good deformation resistance provided by the stone-on-stone mechanical interlocking and the binder mastic stiffened by the presence of filler (Austroads 2009a). Binders used in SMA pavement layers can include Class 320 (C320) bitumen, multigrade bitumen or polymer modified binders (PMBs) (Austroads 2014). SMAs may contain cellulose or mineral fibres that minimise drainage of the high binder content during transport and pavement construction (Austroads 2009a). SMA is characterised by low permeability, low levels of traffic noise and high durability (resistance to reflective cracking and deformation) (Austroads 2014). A schematic of a typical SMA mix is presented in Figure 2.4.

Figure 2.4: Typical stone mastic asphalt mix

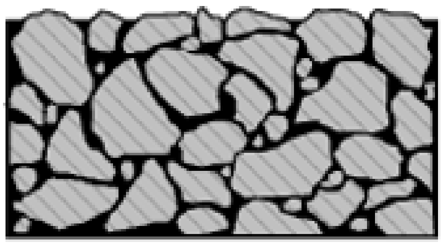


Source: Rice et al. (2020).

2.4 Gap-graded Asphalt

A GGA typically has a binder content between 7 and 10 wt.% and is compacted to between 3 and 6% air voids. The maximum aggregate size and PSD tend to vary depending on the jurisdiction while both Marshall and Gyratory have been specified as the preferred method of compaction (Grobler 2020). A schematic of a GGA mix is presented in Figure 2.5.

Figure 2.5 Typical gap-graded asphalt mix



2.5 Reclaimed Asphalt Pavement

RAP is derived from the milling of existing asphalt wearing or intermediate courses during re-surfacing activities (Figure 2.6) or from surplus plant mix asphalt. RAP is typically re-processed for reuse in new roads (MRWA 2022). The use of RAP in asphalt is widely established throughout Australia. However, RAP management and usage varies among the different jurisdictions. RAP is typically added as partial aggregate and binder replacement, and its incorporation of up to approximately 30 wt.% in asphalt mixes does not require the modification of existing plants; however, specialised high RAP-content plants are also available. RAP can be added in both batch and continuous mixing plants using conductive or convective heating, respectively (van Aswegen & Latter 2019).

In 2021–22, 119,208 t of asphalt materials were recovered in WA. While the waste generation or recovery rate for these materials in not available, generally the recovery rate for construction and demolition waste in WA is 85% (Waste Authority 2023b).

Figure 2.6: Reclaimed asphalt pavement

3 Reclaimed Asphalt Pavement

3.1 Technology

RAP is derived from the milling or excavation of existing asphalt pavement layers or from plant surplus. RAP can be incorporated back into asphalt either in situ or transferred to an asphalt plant where it can partially replace a component of new asphalt mixes (Austroads 2009a). An example RAP stockpile is shown in Figure 3.1. In Australia, approximately half of the RAP generated is reused in hot mix asphalt (HMA), while most of the remainder is incorporated in base and/or subbase layers and a small amount in cold recycling and/or as a fill (Austroads 2009b). This report only focuses on the use of RAP in new asphalt mixes.

Figure 3.1: RAP stockpiles

When RAP interacts with the virgin binder, it tends to result in an increase in the overall viscosity of the binder in the new asphalt mix. This is because the binder in the RAP has, through its previous life, been hardened as a result of oxidation. This increase in viscosity has also been found to be proportional to the concentration of RAP. It is noted that the extent of oxidation in the RAP binder is affected by both the environmental and loading conditions during its previous service life and the type of binder in the RAP mix. PMB mixes have been found to generally be comparatively less affected by oxidation (Noferini et al. 2017).

RAP mixed in a batch plant, such as that illustrated in Figure 3.2, relies on heat transfer from the superheated virgin aggregates. The temperature to which the virgin aggregates need to be heated depends on the percentage of RAP added, the temperature of the RAP, the moisture content of the RAP and the desired temperature for the manufactured mix. This method of adding RAP to new asphalt limits the effective concentration of RAP to 30 wt.% of the total mix. However, if the RAP is pre-heated, this concentration can be increased (Austroads 2014).

Figure 3.2: Asphalt batch plant

In batch plants, RAP can either be transferred via a cold feed bin and weigh hopper into the pugmill at ambient temperature or added to the aggregates at discharge from the dryer. The latter method allows for more efficient heat transfer during retention in hot bins; however, the clogging of screens is possible and needs to be monitored. Extended mixing times may be required for the sufficient softening of the binder in the RAP (Austroads 2014).

RAP can also be added in continuous (either parallel flow or counter flow) asphalt mixing plants. The most common way of adding RAP in a parallel flow mixing drum is by using a split feed with separate inlets for the virgin materials and RAP. It is also required that the drum flight systems are modified such that the virgin aggregates form a shield between the RAP and the flame to prevent overheating. A counter-flow continuous mixing plant typically uses extended burners that shield the RAP and bitumen from direct contact with flames, resulting in exhaust gases travelling through the dryer in the opposite direction of that of the aggregates (van Aswegen & Latter 2019).

van Aswegen and Latter (2019) reported that the practical limit for conventional asphalt plants is around 30% RAP. Plants that can accommodate greater than 50% RAP, however, have been developed overseas and are available in some locations throughout Australia. These plants use microwave heat transfer technology or the indirect heat transfer approach. The indirect heat transfer approach uses conductive heating through tubes or flutes which carry the exhaust gasses of a burner through the dryer. The microwave heat transfer technology employs parallel or counter-flow dryers to heat and dry the RAP. The RAP is then passed through a microwave heater to further increase its temperature to that appropriate for paving. Both technologies can theoretically achieve 100% RAP recycling. Practically, however, the typically high content of fines in RAP can make it impossible to achieve mix-compliant gradations (van Aswegen & Latter 2019).

The different plant configurations and typical maximum capabilities for RAP recycling are summarised in Table 3.1.

Table 3.1: Typical maximum RAP content capabilities based on plant configuration

Type of mixing plant	Method of RAP introduction to the mix	Heating method for RAP	Maximum RAP content (%)
Batch mixing plants			
Weight bucket	Cold feed via weight hopper	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP	15
Pugmill and bucket elevator	Cold feed via bucket elevator	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP	30
Bucket elevator	Bucket elevator via RAP collar	Convective: heated in heat transfer chamber (collar) on dryer	40
RAP dryer recycling technique (twin drums)	Pugmill via separate hot storage bin and weight hopper	Convective: heated in a typical parallel flow dryer	100
Continuous mixing plants			
Parallel flow with aggregate	Drier drum via cold feed bin	Convective: heated in typical parallel flow drier along with virgin aggregates	10
Parallel flow with RAP collar	Mid-entry drier drum via RAP collar	Convective: heating in parallel flow dryer in the middle of the drum	25
Parallel flow with after-mixer/coater	Continuous rotating mixing drum via cold feed bins	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP	30
Parallel flow with RAP collar and after-mixer/coater	Mid-entry drier drum via RAP collar	Convective: heating in parallel flow dryer in the middle of the drum	40
Counter flow with RAP collar	Mid-entry dryer drum via RAP collar	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP	50
Counter flow with after-mixer	Continuous rotating mixing drum via cold feed bins	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP	30
Counter flow with RAP collar and after-mixer	Dryer drum via RAP collar	Conductive: heated with virgin aggregate in the combustion area of the drier	40
Double-drum mixer	Outer mixing shell via cold feed bins	Conductive: direct heating, mixing superheated aggregates with cold and undried RAP as well as heated drying shell	70
Specialised high RAP facilities			
Indirect heat transfer	Batch or continuous mixing facility via rotating dryer	Conductive: heated in a rotating dryer via flues or tubes carrying burner exhaust gases through the dryer	100
Microwave heat transfer	Continuous rotating mixing drum via microwave heater	Convective: heated using parallel flow or counter flow dryer to elevated temperatures then microwave heated to paving temperatures	100

Source: Adapted from van Aswegen and Latter (2019).

3.2 Applications in Asphalt

RAP is primarily used in the manufacture of asphalt wearing, base and intermediate courses (Hall, Grenfell, Pandelidi, Yaghoubi, Chaudhry et al. 2022). Since RAP is derived from pre-existing pavements, it is reused with a relatively high degree of confidence when considering expected performance, materials that are likely present in the recycled content and overall performance outcomes. However, where wearing course mixes for heavy-duty pavements are considered, care needs to be taken as there is an uncertainty surrounding the effect of polishing of aggregates from prior use.

Austroads (2014) lists common design steps for incorporating RAP including:

1. characterisation of the RAP
    a. binder content
    b. recovered binder properties (penetration, softening point, and ductility or viscosity)

    c. aggregate grading and quality
2. determination of additional mix requirements
3. rejuvenator quantity and type determination
4. mix preparation and testing according to standard mix design criteria (Austroads 2014; Austroads 2017).

Typically, RAP is tested for its binder content and grading prior to its use in new pavements, with the aim being to advise the mix design (Austroads 2014). In addition, it has previously been noted that the morphology of the aggregates should be carefully considered. If the aggregates are rounded or polished, they may only be suitable for base and/or intermediate course applications (van Aswegen & Latter 2019).

Asphalt incorporating RAP needs to meet the same performance requirements as those met by asphalt comprising virgin materials only. Asphalt mixes with up to 15 wt.% RAP are rather common across Australia, while the incorporation of up to 40 wt.% has been allowed in specific applications where appropriate mix design has been considered, an appropriate manufacturing plant is available, and where appropriate process controls are implemented (Austroads 2009a).

Overall, the content of RAP added in asphalt does not only depend on the sources and properties of the RAP itself, but also on:

- plant type
- production temperature
- mixing time
- discharge temperature
- paving technology
- permitted emissions (Noferini et al. 2017).

RAP is primarily used as partial aggregate and binder replacement. Following milling, it has to be crushed and screened to size to meet the requirements of the selected application (Austroads 2014). According to Austroads (2002), when the RAP content does not exceed 15 wt.%, there is no need to apply special requirements to the RAP in HMA. This is provided that separate mix designs are prepared, and the Quality Plan includes a RAP Management Plan. In addition, generally, when between 15 and 30 wt.% of RAP is to be added, the use of a softer binder grade than what is otherwise specified is expected to sufficiently compensate for the hardening of the oxidised RAP binder. Alternatively, the use of a softer binder and/or rejuvenator can be tailored following penetration or viscosity test results from the recovered RAP binder. This approach is deemed more critical for heavily trafficked base applications or very heavily trafficked base and wearing course applications. If the material is accepted for use without any adjustments to the binder grade, the produced asphalt may exhibit increased flexural stiffness which could decrease fatigue cracking resistance in thin asphalt surfacing applications, especially as the RAP content approaches 25 or 30 wt.% (Austroads 2002).

When the mix specifies the use of PMBs, Austroads (2002) recommends that more than 15 wt.% RAP is not added, while it proposes that similar restrictions are not necessary when multigrade or standard bitumen grades are to be used. The addition of more than 30 wt.% RAP should also be permitted, but only in cases where the contractor can demonstrate the suitability of their manufacturing plant and that appropriate quality control (QC) procedures are followed. Such asphalt plants need to have the capacity to process increased RAP contents without risking the overheating of either the RAP or the new binder (Austroads 2002).

3.3 Benefits

3.3.1 Performance

It was discussed in Section 3.1 that the addition of RAP to a new mix is generally expected to result in the hardening of the binder. It is often assumed that, during the heating process in the asphalt plant, the aged binder of the RAP is combined with the virgin binder and the rejuvenator (if added), to create a blend with properties of the combined binder. However, this expectation has been challenged as the extension of binder blending during the process has not conclusively been determined. In this context, the concept of 'black rock' has been introduced, which suggests that it is possible that a double coat of old and new binder is formed on the RAP aggregates. In addition, aside from the extend of binder blending achieved during the asphalt mixing process, it has been found that a certain amount of time is required for the blend to stabilise. Consequently, the properties of the mix may change with time, whereby the binder blend becomes softer (Austroads 2015b).

While it is generally accepted that asphalt containing RAP could exhibit increased stiffness, mixes containing 15 wt.% or even up to 20 wt.% RAP are typically found to have comparable tensile strength, weathering performance, rutting resistance, ravelling resistance and fatigue cracking resistance when compared to asphalt without any RAP (Hall, Grenfell, Pandelidi, Yaghoubi, Chaudhry et al. 2022). DGA mixes containing up to 15 wt.% RAP have been found to have overall comparable performance with conventional mixes. However, when the incorporation of more than 15 wt.% RAP is considered, the binder grade may need to be adjusted, or rejuvenators may need to be introduced to compensate for the stiffness of the aged RAP binder (van Aswegen & Latter 2019).

Despite these general expectations, Austroads (2015b) concluded that there is a need to characterise the RAP binder for all mixes where more than 10 wt.% RAP is to be added. They warn that failure to do so may introduce a risk of reduced performance. Austroads (2015b) found that measuring the viscosity of the virgin binder, RAP binder and the rejuvenating agent and assessing them according to the developed methodology was a good indicator of the performance of the resulting DGA mix. It was also stated that this becomes increasingly important for mixes where the concentration of RAP exceeds 15 wt.%. It was, however, noted that these findings were based on a limited number of DGA mixes and a single source of RAP, but highlighted that they were still in line with other available literature (Austroads 2015b).

3.3.2 Environmental

Recycling asphalt back into asphalt not only decreases the amount of used resources sent to landfill, but also the amount of new material required for the rehabilitation or construction of new pavements (Austroads 2014). This in turn decreases quarrying and haulage activities and, hence, the deprivation of natural resources and emissions (Howland et al. 2023). Section 3.4 provides more detail on the environmental impacts of RAP.

3.3.3 Economical

In alignment with Section 3.3.2, the recycling of materials and subsequent reduction in virgin materials offers economic benefits to the user. These may include landfilling cost savings and, with the ability to reuse locally extracted materials in the nearby area, savings relating to the haulage and material costs for virgin-extracted resources. Indirect economic savings may also be attributed to the reduced environmental impact of landfilling and quarrying activities (Cocks et al. 2016; Infrastructure Australia 2023). Predominantly, however, these realised savings are the result of the reduced requirement for virgin binder content, particularly in intermediate and surface layers (Noferini et al. 2017).

An economic analysis of key recycled materials in the road and rail industry reported RAP as presenting the highest economic benefit of the commonly used materials, at 83% cost savings compared to virgin material costs (Hall, Grenfell, Pandelidi, Yaghoubi, Lyons et al. 2022).

3.4 Work Health and Safety and Environmental Impacts

Before its incorporation into new pavements, RAP is considered as Inert Waste type 1. Within this category are listed waste materials that are non-flammable, non-biodegradable and chemically not reactive that contain contaminants below specified criteria. Impacts to the environment are primarily associated with the materials that have been used in the manufacture of the original asphalt pavement, e.g. a recycled material. Additionally, former site conditions and the use of the road may impact the contamination level of the RAP, i.e. when the pavement has been exposed to industrial activities, is in the proximity of an airport, etc. In case there is doubt surrounding potential contamination of the milled asphalt, a suitably qualified environmental professional should be advised (Howland et al. 2023).

RAP deriving from asphalt that did not contain recycled materials originally is not considered to pose any additional risks to WHS when compared to the use of virgin materials (Howland et al. 2023). Additional consideration, however, may need to be given to RAP that includes materials such as crumb rubber or polymers (Austroads 2022b). This may be further dependent on RAP stockpiling practices, for example, if full awareness of the material contained in the stockpile is not available.

Rice and Harrison (2021) considered this factor and reported on US practice where the recycling of crumb rubber-modified asphalt (CRMA) as RAP has been practiced since the 1990s. Various accounts of emissions testing and dust sampling testing undertaken at plants and during paving reported no increase in any health concerns emerging from recycling the CRMA as RAP.

Mo et al. (2021) investigated additional WHS impacts of RAP, including risk of respirable particles and polycyclic aromatic hydrocarbons (PAHs). They found that RAP released more total benzene-soluble organic matter and PAHs than new asphalt as a result of oxidation. However, they highlighted that these findings are dependent on the material source, environmental exposure and road use. It was concluded that the risk of exposure to respirable particles and PAH near milling machines and during RAP handling is not negligible. The key outcomes from the research were recommendations for personal protective equipment (PPE), specifically appropriately rated respiratory protective equipment, when producing and handling RAP materials (Mo et al. 2021), which aligns with WA industry practice.

When considering the impacts to the environment, the potential of rejuvenators to facilitate leaching of PAHs and critical metals bound on RAP needs to be evaluated. Munoz et al. (2022) investigated the potential of rejuvenators to mobilise critical compounds from RAP when exposed to water. They found that less than 1% of the available PAHs were released; however, they noted the potential for continuing release with exposure to rain.

Therefore, it is reasonable to note that the use of rejuvenators together with RAP may have some WHS and environmental impacts and, as such, these should pose a consideration for industry when specifying their use. The individual risk of rejuvenators would need to be considered on a case-by-case basis, as rejuvenator products are highly variable. The particular rejuvenator being considered needs to be accompanied with a safety data sheet (SDS), which would guide practitioners in its use and relevant WHS measures required, if any (Austroads 2022a).

3.5 National Practice

Overall, the implementation of RAP in HMA mixes is well established in Australia, particularly in metropolitan areas, where it is more commonly available. While RAP is broadly allowed for use in new asphalt mixes, usage and management vary across the different jurisdictions. In general, RAP should be crushed, screened and fractionated into the appropriate size according to the mix requirements. For GGA mixes and for mixes containing more than 20% RAP, further fractionating RAP into fine and coarse can be helpful (van Aswegen & Latter 2019).

There are several RAP stockpile management systems available to ensure that the different material sources, quality and particle sizes are traceable. In addition, these systems ensure that RAP is stockpiled in accordance with accepted practice (van Aswegen & Latter 2019). Austroads (2016) proposed a detailed plan for sourcing, transport, processing and storage of RAP which requires:

- RAP sources to be traceable
- no base material, coal tar, concrete, plastics, timber, brick and scrap rubber to be present
- RAP to be free from clay, dirt, dust and other deleterious materials
- processing and storage of RAP to be undertaken at the processing site
- determination of the maximum aggregate size and further management of oversize material

- handling and transport from the processing site to the asphalt plan and handling and storage at the asphalt plan.

Austroads (2016) also demonstrated the significance of binder viscosity and binder content from RAP when designing a mix, and where these are carefully considered, no adverse effects should be expected. It was proposed that binder characterisation should be required when more than 15 wt.% RAP is to be added. Such assessments become more critical when mixes with lower binder content (such as in structural base layers) and high RAP percentages (above 30 wt.%) are considered. Furthermore, an evaluation protocol to determine the use of rejuvenators is currently under development with a draft protocol proposed by Austroads (2022a).

Austroads (2015b) provided a series of guidelines to be followed when more than 15 wt.% RAP is to be added in the new asphalt, as follows:

1. A representative RAP sample should be collected in accordance with AS 1141.3.1 *Sampling – Aggregates*.
2. Determine the binder content in the RAP in accordance with AS/NZS 2891.3.1 *Binder Content and Aggregate Grading (Reflux Method)*, AS/NZS 2891.3.3 *Binder Content and Aggregate Grading (Pressure Filter Method)* or another agreed method.
3. Extract the RAP binder following AGPT/T191 *Extraction of Bituminous Binder from Asphalt* or another agreed method.
4. Determine the complex viscosity at 60 °C of the virgin binder, RAP-extracted binder and selected rejuvenator (where used) using a dynamic shear rheometer (DSR) in accordance with AGPT/T192 *Characterisation of the Viscosity of Reclaimed Asphalt Pavement (RAP) Binder Using the Dynamic Shear Rheometer (DSR)*.
5. Determine the theoretical viscosity of the new binder blend comprising the virgin binder, RAP binder and rejuvenator (where used) in accordance with AGPT/T193 *Design of Bituminous Binder Blends to a Specified Viscosity Value*.
6. The binder proportions can be adjusted iteratively until the predicted viscosity is within the desired range.
7. Optionally, the actual viscosity of the blend can be determined using the DSR.

Following the determination of the binder blend viscosity targeted for the asphalt mix design, the strategy for incorporating RAP with different binder viscosities and/or binder may include:

- varying the RAP content in the mix
- altering the class of the virgin binder in the mix (referred to as grade bump)
- incorporating rejuvenators as needed
  - this may require a separate mix design to be developed by the road agencies (Austroads 2016).

3.5.1 Available Specifications

The specifications applicable to RAP in Australia are listed in Table 3.2.

Table 3.2: List of Australian specifications on the use of reclaimed asphalt pavements

Specification	Agency	Application	Reference
AS 2150 Asphalt – a guide to good practice	Standards Australia	• Above 15 wt.% RAP, suitable asphalt mix design, manufacturing plant, and documented QC can be demonstrated	AS 2150:2020

AS 2150:2020 requires that RAP is free from foreign material, and if tar is present, the milled asphalt must not be considered for use. The RAP is to be crushed and sieved to ensure the maximum particle size does not exceed the maximum nominal size of the asphalt to be produced or 20 mm (whichever is lower). The crushed product should be well graded and free flowing. The RAP is to be sampled as an aggregate following AS 1141.3.1 and tested for binder content, PSD, moisture content and other properties as specified. In addition, RAP is to be stockpiled separately under dry conditions. To prevent compaction, RAP should not be driven on during stockpiling (AS 2150:2020).

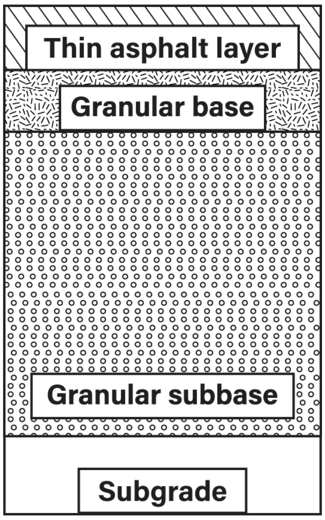
AS 2150:2020 also stipulates that RAP can be incorporated either heated or cold in a plant. Where RAP is heated, it should be sent directly to a hot bin or directly into the mixer, while cold RAP can be sent directly to the mixer. It is recognised, however, that sending cold material directly into the mixer might not be practical in batch plants. Where the RAP content is low, cold RAP can share an elevator with the hot aggregates and thereby bypass the screening process. In cases where the RAP content is relatively high, cold RAP should not be in contact with the hot aggregates prior to the mixing stage. It is further required that the feeding of RAP should be measured using a separate calibrated belt scale capable of detecting any interruptions in flow. During mixing, the binder should be added after the dispersion of RAP among the hot aggregates (AS 2150:2020).

In addition, AS 2150:2020 provides advice regarding the mix design process when RAP is added to asphalt. Overall, it is recommended that the same mix design process as for mixes that do not contain RAP is followed (including mix type and materials selection, aggregate proportions, binder content, laboratory trial mixes and plant trial mixes) with some alterations/additions. It is noted that before the commencement of the mix design process, the RAP should be analysed for the grading of the mineral aggregates, residual binder content and properties, and moisture content. Furthermore, once the proportion of RAP to the mix is verified, the results from the RAP grading are to be used to determine the grading of the combined aggregates. The results of the residual binder are to advise the type and content of binder and, where applicable, the rejuvenator. Lastly, mixes designed with more than 15 wt.% RAP are to be accepted only when a suitable asphalt mix design, manufacturing plant and documented QC procedures have been sufficiently documented (AS 2150:2020).

3.6 Western Australian Practice

In WA, the metropolitan road network is primarily comprised by thin asphalt layers. An example is presented in Figure 3.3.

Figure 3.3: Schematic representation of thin asphalt layer over a deep granular pavement



Consequently, the quantities of RAP available are comparatively low against some other states that have a larger network of thicker asphalt pavements (Cocks et al. 2016). Regardless, an opportunity exists to increase the uptake of RAP in asphalt mixes which will lead to improved sustainability outcomes (van Aswegen & Latter 2019).

The aim of WARRIP Project 2017-002 was to translate the outcomes of Austroads (2016) into the WA context. In this project, van Aswegen and Latter (2019) evaluated the variability of RAP stockpiles in metropolitan Perth and identified:

- potential impacts on the mix design process when incorporating locally sourced RAP

- a RAP management system that is suitable for the WA context
- any specific plant requirements to achieve the successful incorporation of different RAP percentages.

The project also investigated the applicability of Austroads Test Method AGPT/T193 when a PMB is selected as the base binder and developed specifications and supporting technical documents relating to the incorporation of greater than 10 wt.% RAP in WA asphalt mixes. Although variability in PSD, RAP binder content and complex viscosity of the RAP binder was observed in the processed RAP on both a daily and month-to-month basis, it was thought that these results could notably be improved should an improved RAP management plan and practices be adopted (van Aswegen & Latter 2019).

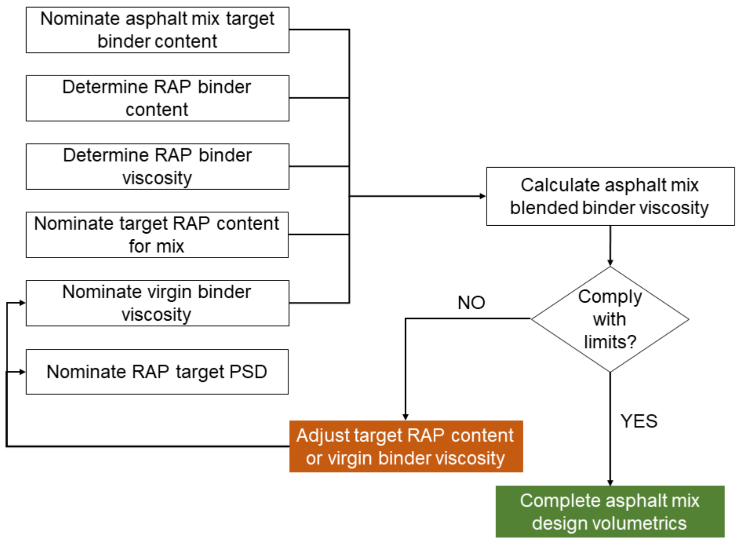
The output of the work conducted by van Aswegen and Latter (2019) was a draft Engineering Road Note 13B which included advice regarding the design of intermediate course asphalt mixes incorporating different levels of RAP, as follows:

- Level 1 – up to 10 wt.% RAP in accordance with Specification 510
- Level 2 – 11–25 wt.% RAP
- Level 3 – 26–40 wt.% RAP.

Draft Engineering Road Note 13B also outlined that the binder to be used in the mix containing RAP may be blended at the asphalt plant to a target viscosity or be a standard Austroads grade in accordance with ATS 3110.

For Level 2 RAP mixes, the asphalt manufacturer must nominate a target PSD for the processed RAP, while for Level 3 mixes, the RAP must be fractionated to coarse (100% retained on a 4.75 mm sieve) and fine (100% passing a 4.75 mm sieve) fractions. No natural sand is allowed in Level 2 and Level 3 asphalt mixes containing RAP. Rejuvenators or extender oils may not be present in asphalt mixes containing RAP either. Other general requirements and design criteria were kept in line with current MRWA specifications, with the exception of the method used for the determination of bulk density of the prepared specimens. The bulk density of asphalt mixes containing RAP should be determined in accordance with AS/NZS 2891.9.2 *Determination of Bulk Density of Compacted Asphalt (Presaturation Method)*, for harmonisation (van Aswegen & Latter 2019). The proposed MRWA mix design process is outlined in Figure 3.4, where the RAP properties are to be determined following AGPT/T191 and AGPT/T192.

Figure 3.4: Proposed asphalt mix design process



Source: Adapted from van Aswegen and Latter (2019).

3.6.1 Available Specifications

A list of WA specifications applicable when the use of RAP is considered is presented in Table 3.3.

Table 3.3: List of Western Australian specifications on the use of reclaimed asphalt pavements

Specification	Agency	Applications	Reference
Technical specification, tender form and schedule for supply and laying of asphalt surfacing	IPWEA/AfPA	• Up to 15 wt.% with no change to the mix • Mix approval is required for use of more than 15 wt.% • RAP shall not be used in SMA	IPWEA (WA) & AfPA (WA Branch) (2023)
Specification 501, Pavements	MRWA	• Up to 15 wt.% of material larger than 4.75 mm	Specification 501:2023
Specification 502, Stone mastic asphalt	MRWA	• RAP shall not be included in the production of SMA	Specification 502:2022
Specification 504, Asphalt wearing course	MRWA	• RAP is not allowed in surface layers	Specification 504:2024
Specification 510, Asphalt intermediate course	MRWA	• Up to 10 wt.% in 14 or 20 mm asphalt intermediate course • Greater than 10 wt.% in Level 2 or 3 asphalt mix designs in 14 or 20 mm asphalt	Specification 510:2022
Specification 511, Materials for bituminous treatments	MRWA	• RAP incorporating fines to be crushed to produce a nominal 7 or 10 mm sized material • Level 3 RAP shall be crushed into a coarse fraction (100% passing 4.75 mm) and a fine fraction (100% passing 4.75 mm)	Specification 511:2025
Specification 515, In situ stabilisation of pavement materials	MRWA	• Up to 10 vol.% in stabilised base and subbase layers	Specification 515:2021

IPWEA (WA) and AfPA (WA Branch) (2023) permit the incorporation of up to 15 wt.% of RAP without making any changes to the mix, while it mandates the development of a specific mix which is approved by the local government when greater percentages of RAP are considered. The use of RAP in SMA mixes is explicitly prohibited. It is worth noting that the specification includes requirements for corrective actions to be taken should the bitumen content, PSD and filler content deviate from the mix design as a result of the RAP (IPWEA (WA) & AfPA (WA Branch) 2023).

MRWA Specification 501:2023 allows for 15 wt.% RAP retained on the 4.75 mm sieve in crushed recycled concrete subbase, where it is listed as a foreign material.

Although MRWA Specification 504:2024 recognises the opportunity for using RAP, it excludes it from use in wearing course asphalt (including DGA), which is also the case for other recycled materials.

MRWA Specification 511:2025 allows for the use of different percentages of RAP in asphalt intermediate courses. The specification requires that the selection of the base binder takes into account the viscosity of the RAP binder when selecting a target viscosity for the binder blend. It is also expressed that these formulations should be calculated separately for each lot of RAP. The specification provides accepted properties for the various bitumen classes, separate to those of AS 2008. It does, however, allow for other classes of bitumen to be used that are not listed in the specification, but conform to AS 2008, for the production of Level 2 and Level 3 RAP mixes. Surplus RAP from an asphalt plant or material retrieved from an asphalt layer in situ are classified as RAP. These materials must not contain granular pavement materials, organic matter, soil, clay, glass, concrete bricks, other building materials, coal tar-based products, laterite asphalt, raised pavement markers, geotextiles, or road surface treatments (Specification 511:2025).

Specification 511:2025 also provides requirements for the processing and storage of RAP. The RAP material must be stockpiled separately prior to processing for use. The RAP that incorporates fines must also be crushed and screened to produce a nominal 7 or 10 mm material. RAP without any fines may be crushed and screened to produce a nominal 14 mm sized material (100% passing a 13.2 mm sieve and 98% retained on a 6.7 mm sieve). For Level 3 mixes, the RAP must be crushed to coarse (100% retained on 4.75 mm sieve) and fine (100% passing 4.75 mm sieve) fractions. Before use, the RAP must be free flowing and, if not, it must be crushed and screened again, as required. After the RAP has been processed, the material must be stored in a facility that is covered at the top and at least 3 sides to avoid being exposed to rainfall or other sources of moisture. To further prevent the absorption of any excess moisture potentially present, RAP must also be stored on a concrete floor which has an inclination towards a drain. To ensure traceability, the RAP must be stored in lots following processing. The asphalt manufacturer must also prepare a management plan documenting the origin of RAP, stockpiling prior to processing, processing, storage and testing. They further need to detail the plant's capacity to incorporate the specific RAP Level (Level 1, Level 2 or Level 3) and the process of manufacture of the asphalt containing RAP. All RAP samples are to be tested for PSD and bitumen content according to WA 730.1 and for moisture content according to WA 212.1 or WA 212.2 (Specification 511:2025).

Specification 510:2022 requires that RAP meet the requirements in Specification 511, including those for preparation and storage and the preparation of a management plan. Specification 510:2022 also references Level 2 and Level 3 RAP mixes as described in Engineering Road Note 13. It is also expressed that the target binder properties in the mix should be equivalent to a C320 bitumen. In addition, Specification 510:2022 outlines that the asphalt plant must have the capability to produce Level 2 and 3 asphalt mixes with consistent properties and appearance. The plant must have the capacity to incorporate the processed RAP to the virgin aggregates immediately prior to the mixing stage. When RAP is incorporated, the binder content of the RAP must be considered when calculating the quantity of bitumen required during manufacture. The specification allows for the incorporation of up to 10 wt.% (of the total aggregate) to be used to produce 14 or 20 mm asphalt mixes. The quantity of hydrated lime added to the asphalt mix must also take into consideration both the mass of RAP and the virgin aggregates. For Level 2 and Level 3 asphalt mixes, the viscosity of the virgin and RAP binder blend must not exceed the limits for a C600 bitumen according to Specification 511. For Level 3 mixes, specifically, all fractions must be heated above 100 °C prior to the mixing stage. It is also required that mixing and drying of the aggregates and RAP be sufficient to achieve a moisture content within the specified limits (Specification 510:2022).

Specification 515:2021 allows for the incorporation of RAP up to 10 vol.% of the stabilised layer as a supplementary material. The particle size of the crushed RAP, obtained from the profiling of the asphalt pavement, must not exceed 26.5 mm (Specification 515:2021).

3.6.2 Sources of Reclaimed Asphalt Pavements in Western Australia

As mentioned, RAP is primarily derived from the process of milling an existing asphalt pavement. Waste from asphalt plants can also be reused as RAP. Although the in situ recycling of RAP is feasible, RAP is most often stockpiled and crushed (Howland et al. 2023) in WA according to Specification 511 (Clause 511.09.03).

In WA, the availability of RAP is limited because asphalt pavements mainly comprise a thin asphalt layer on a deep granular pavement. Asphalt is mostly available in metropolitan localities and so the use of RAP is most likely in these areas also. In addition, there is an understanding that transportation costs to remote localities could potentially be prohibitive, while long haulage distances would not be beneficial to the environment either (Howland et al. 2023).

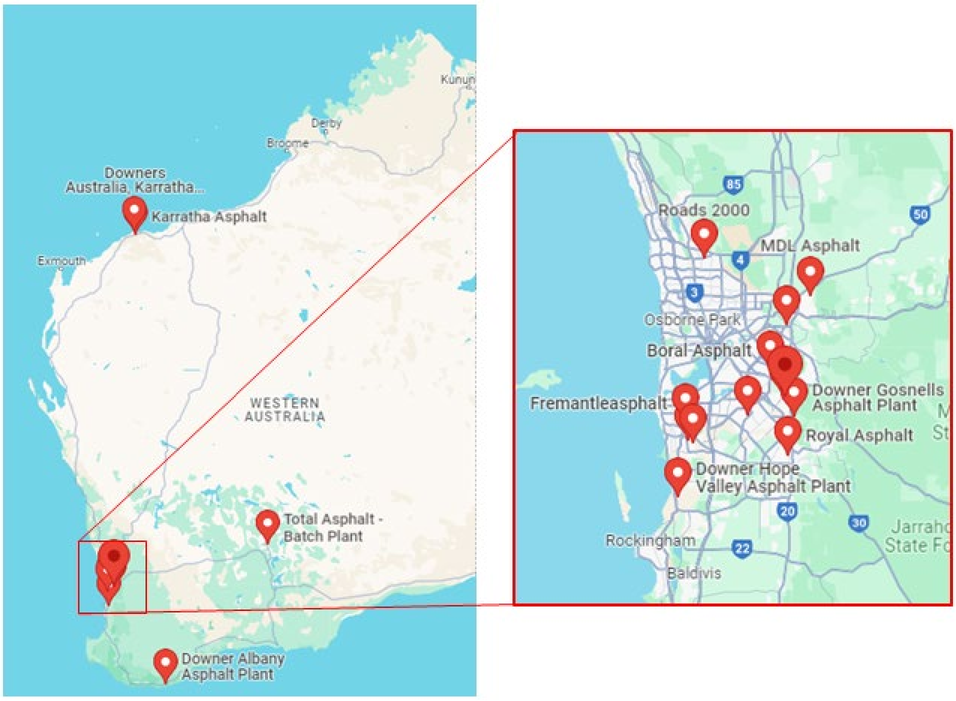
Asphalt contractors are the primary recyclers of RAP, and those in WA with demonstrated experience and capacity include:

- Fulton Hogan
- Downer
- Colas
- WA Recycled Asphalt
- Boral
- Karratha Asphalt

- Asphalt Recyclers Australia
- Malatesta Group.

Although some asphalt plants are available across the WA coast, they are mainly concentrated in Perth (Howland et al. 2023). Their geographical location is represented in Figure 3.5.

Figure 3.5: Location of asphalt producers in Western Australia



Source: Google Maps (2024), 'Asphalt plants in Western Australia, map data, Google, California, USA.

3.7 Challenges, Risks and Mitigation Measures

While there are several benefits from the use of RAP, certain challenges and risks may arise. These, along with potential mitigation measures, are summarised in this section.

Howland et al. (2023) conducted a workshop during which the participants were asked to list the reasons that would hinder the use of RAP. From the 24 responses received, only 5 participants already use RAP while 8 would be very likely to use it. For those that do not use the product:

- 5 were unsure about its life, durability and overall effects on asphalt quality
- 5 found that RAP is not certified or tested by an appropriate authority
- 4 explained that RAP is not available in their area
- 3 were not familiar with its construction (Howland et al. 2023).

Knowledge sharing to industry about the potential benefits, applications, available specifications and management requirements for RAP may support an increased usage. It is also important to ensure that while policy supports the use of RAP, more direct approaches such as mandating the use or overly specific targets should be carefully considered due to the potential for perverse outcomes, such as stifling innovation or requiring the transport of materials for long distances (Infrastructure Australia 2023). Optimising the use of RAP, among other recycled materials, without mandates is reflected in the strategies of some jurisdictions (TMR 2022.; State Government of Victoria 2023). It is worth recognising, however, that when carefully crafted, mandates can offer beneficial outcomes, such as MRWA's use of crumb rubber-modified binders (CRMBs) in OGA (West 2015).

Although it is recognised that several RAP management systems are available and sites are guided to develop RAP Management Plans (Specification 510:2022, Specification 511:2025, AAPA 2018), there is no single framework for the recovery, characterisation, documentation and storage of RAP which may result in inconsistencies.

Notably, AfPA has developed RAP Management Plan best practice guidance, in collaboration with its members involved in the use of RAP (AfPA 2022). The document identified the 3 main sources of RAP (milling, pavement demolition and plant returns) and established the critical material selection parameters. This includes inspection for foreign materials and contaminants, such as concrete, tar, asbestos and others; level of PMB content; or strain alleviating membrane interlayer (SAMI). RAP sources with the latter 2 are advised to be stored and managed separately. Additionally, the best practice guidance encompasses processing and crushing of RAP, stockpiling, screening during processing and stockpiling after processing.

Further, insights from RAP suppliers suggest that growth in the targeted RAP use in WA would require additional capital investment in plant and laboratory capacity to ensure suppliers could adequately produce and test increased quantities (van Aswegen & Latter 2019). Austroads (2016) outlines a comprehensive framework for a RAP Management Plan, as detailed in Section 3.5, that may guide WA's approach. Additionally, international resources are available such as the USA's National Asphalt Pavement Association's (NAPA) best practice guidance (West 2015).

Challenges with stockpiling and use of RAP may be exacerbated due to higher levels of variation in asphalt mixes being used as a result of the introduction of a wider range of recycled materials. As new and emerging materials are utilised in asphalt mixes, an assessment of their suitability as RAP sources may, therefore, be required. Rice and Harrison (2021) considered this concern from a CRMA perspective and, ultimately, determined that standard reclamation, processing, production and subsequent paving processes were able to be followed for RAP containing CRMA.

3.8 Case Studies

The use of RAP is allowed in WA in asphalt, unbound pavements, earthworks and embankments, and ancillary applications, with a key challenge for its use being the feedstock availability (Howland et al. 2023). Some case studies are summarised in Table 3.4 and further detailed in Sections 3.8.1 to 3.8.4.

Table 3.4: Case studies of reclaimed asphalt pavement

Location	Application	Contractor	Outcomes
Carden Drive, Cannington	300 mm of RAP on sandy clay subgrade with 30 mm asphalt surfacing 1,700 veh/day with 4% heavy vehicles	Unknown	No performance testing undertaken, however no reported signs of distress (at 22 years). City of Canning has a history of constructing local pavements in residential areas with local sources of RAP and reported pavements performing well after 20 years.
Cecilia and Skerne Lanes, Port Coogee	750 sqm of Reconophalt™; plastic bags, toner cartridges, crumb rubber and RAP	Downer, Densford Civil	No performance monitoring reported to date. Downer claims improved fatigue life compared to standard asphalt.
Third Avenue, Kelmscott	Reconophalt™ 25% RAP, with user printer cartridges and crumb rubber	Downer	No performance monitoring reported to date.
Great Eastern Highway, Rivervale and Ascot	20 mm C320, 10% RAP, warm mix asphalt technology	Boral	RAP mix performed equivalent to standard warm mix asphalt mix in terms of tensile strength ratio, fatigue and performance deformation. Site performing well after 3 years.

Source: City of Cockburn (2019), Cocks et al. (2016), METRONET (2021).

3.8.1 City of Canning

The City of Canning has a history of constructing local pavements in residential areas with local sources of RAP, and while no formal performance data is available, anecdotal evidence suggests that the asphalt pavements are performing well after 20 years in service (Cocks et al. 2016). Between 2008 and 2016, the city recycled 95% of its road base and has been mandating the use of 5 wt.% glass and 10 wt.% RAP for over a decade (Beyer & Cooper 2020).

Along Carden Drive, Cannington, a pavement was constructed using 300 mm of RAP on sandy clay subgrade with 30 mm asphalt surfacing. The road carries approximately 1,700 vehicles per day of which 4% are heavy vehicles. As noted above, no formal performance testing has been undertaken; however, the city has reported no signs of distress after 22 years in service (Beyer & Cooper 2020; Cocks et al. 2016).

3.8.2 City of Cockburn

The City of Cockburn surfaced 750 m^2 at Cecilia and Skerne Lanes in Port Coogee, with Downer's Reconophalt™. The Reconophalt™ product contains 7 tonnes of RAP as well as 40,000 plastic bags, 900 toner cartridges and 210 kg of crumb rubber. The contractor reported improved fatigue life compared to conventional asphalt; however, it is noted that no independent performance data is available for this site. The city is intending to continue to use recycled products (City of Cockburn 2019).

3.8.3 METRONET

METRONET used Downer's Reconophalt™ at the Denny Avenue Level Crossing Removal project. The cul-de-sac section of Third Avenue, Kelmscott is the first site of a WA State Government project to utilise Reconophalt™. The 900 m^2 section contains 15 tonnes of RAP as well as 47,368 plastic bags, 1,078 toner cartridges and crumb rubber equivalent to 71 car tyres. Performance data is not yet available for this site (METRONET 2021).

3.8.4 City East Alliance

The City East Alliance incorporated recycled materials along sections of the Great Eastern Highway project. These included recycled sand for fill and crushed recycled demolition waste for subbase. They also conducted a study comparing warm mix asphalt with and without RAP. Initial testing demonstrated that 10 wt.% RAP mix performed equivalently to standard warm mix asphalt mix in terms of tensile strength ratio, fatigue and deformation resistance. The site had been in place for 3 years at the time of reporting, and annual visual inspections presented no issues (Cocks et al. 2016).

4 Stakeholder Engagement

4.1 Purpose and Methodology

A key objective of this project was to build local government knowledge in the use of RAP in asphalt applications in WA. A 3-stage stakeholder engagement process was, therefore, carried out to obtain information relating to:

- local material sources and constraints in obtaining RAP materials
- mix design guidance, detailing suitability of applications regarding traffic and location
- guidance to assist practitioners to select and motivate adoption of applications including economic and engineering aspects
- specifications
- risks and mitigation measures
- construction guidance
- QC and supervision
- WHS and environmental considerations.

The targeted stakeholders included local government representatives (through WALGA), material suppliers, AfPA members, MRWA personnel, contractors and consultants. The stakeholder engagement methodology is discussed in Sections 4.1.1 to 4.1.3.

4.1.1 Initial Survey

An online survey was distributed to local councils, industry representatives, asphalt manufacturers and binder suppliers. The survey was intended to source an appropriate contact list and develop an initial understanding of the local usage and awareness of RAP in asphalt. As it was delivered in conjunction with LG TRRIP 07 *WA Local Government Practitioners' Guideline for the Use of CRMB in Sprayed Seal Applications*, the survey was also used to distinguish between the local government that primarily use asphalt and those that primarily use sprayed seals, or both.

The survey, provided in Appendix A, asked participants:

- their current awareness of, or experience with, RAP in asphalt
- the types of asphalt mixes and the projects in which these technologies are employed
- any perceived limitations for adopting these technologies.

Following the survey, a 2-hour workshop with local government practitioners and a series of industry interviews were undertaken.

4.1.2 Local Government Workshop

A 2-hour workshop was hosted online on 24 May 2024, focusing on the use of RAP in asphalt. The workshop sought to gather specific feedback regarding the use of, or barriers to, RAP and to understand the needs of local government in order to scope the guideline developed as part of this project. It was also useful to obtain a better appreciation of the local government road network.

The workshop comprised a presentation introducing the project objectives and desired outcomes, followed by the use of Mentimeter, an interactive presentation software, and an open-forum discussion to obtain feedback from the participants. The Mentimeter questions are presented in Appendix A. They sought to understand:

- what tools and resources would facilitate the adoption of RAP in asphalt

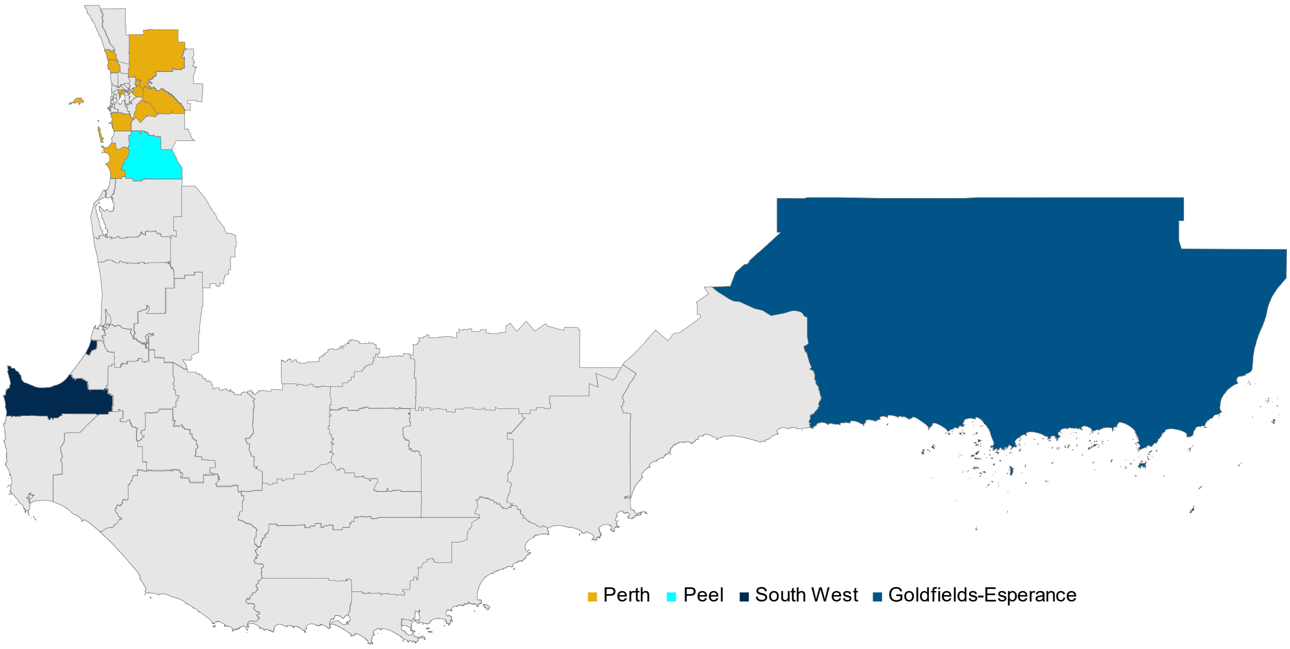
- the main barriers to adoption (e.g. budget constraints, know-how, material supply, etc.)
- when RAP is used, which guidelines, specifications, or advice are currently followed.

To supplement the learnings from the workshop, a follow-up online survey was sent to the invitees, encompassing the Mentimeter questions (Appendix A). Representatives from the following local governments were in attendance or responded to the survey, along with representatives from MRWA and WALGA:

- City of Belmont
- City of Bunbury
- City of Busselton
- City of Cockburn
- City of Gosnells
- City of Joondalup
- City of Kalamunda
- City of Perth
- City of Rockingham
- City of Subiaco
- City of Swan
- Shire of Esperance
- Shire of Serpentine-Jarrahdale
- Town of Bassendean.

As shown in Figure 4.1, the majority of the participants represented local governments in the Perth region, with one in Peel, 2 in South West, and one in Goldfields-Esperance. No responses were received from the Kimberley, Pilbara, Gascoyne, Mid West, Wheatbelt or Great Southern regions.

Figure 4.1: Local government participation



4.1.3 Interviews with Private Industry

Between 20 and 28 May 2024, 3 interviews were conducted with industry. The main discussion topics are provided in Appendix A. One MRWA representative, as well as one consultant and one road base/aggregate recycler were consulted. These interviews were seeking insight regarding:

- current usage, including types of projects where these materials are employed
- available specifications and technologies
- barriers to adopting these materials
- experience with local governments
- barriers to engaging local government as clients.

4.2 Outcomes of the Stakeholder Engagement

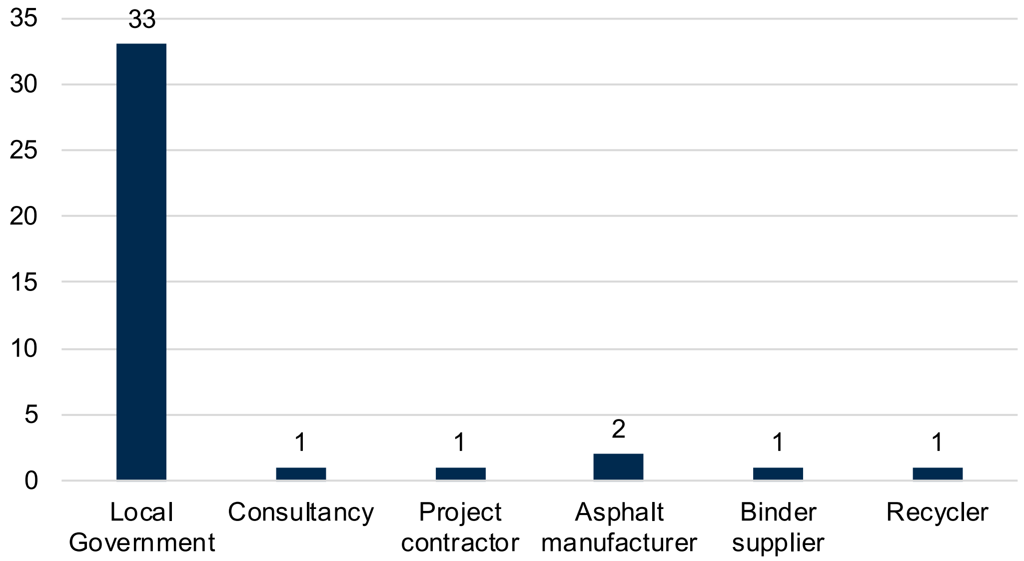
Section 4.2 outlines the general details of the stakeholders that participated in the various engagement activities and the learnings from these activities as they apply to the use of RAP in asphalt.

4.2.1 The Participants

Initial survey

The initial online survey enquired about the use of RAP in asphalt and crumb rubber-modified binders in asphalt and sprayed seals and was completed by 39 participants, of which the majority were local government representatives. Six industry representatives also completed the survey, as shown in Figure 4.2. Twelve of those responses included insights on the use of RAP. Fifteen respondents reported no experience with the technologies or materials discussed.

Figure 4.2: Initial survey participants, by organisation type



Local government workshop

The 2-hour workshop was attended by 10 local government representatives, 3 WALGA representatives and 2 MRWA personnel. The workshop was followed up by a survey to provide the opportunity to those who could not attend to provide their responses. Seven additional responses were received from the survey.

Through participation in a Mentimeter questionnaire and open-forum discussion during the session, it was found that, generally, experience with RAP was low and local governments are seeking further guidance to use this material. Just 50% had previously used RAP.

Participants were keen to benefit from the use of recycled materials, with most jurisdictions having some form of sustainability plan or targets in place, such as adopting circular economy principles or achieving carbon neutrality. The consensus, however, was that current targets and available direction were high-level, and, so, personal drive was key. Generally, opportunities for the use of recycled materials were taken as they arose, with consideration to performance needs, availability, and budget. Further outcomes from the workshop and follow-up survey are discussed in Section 4.2.3.

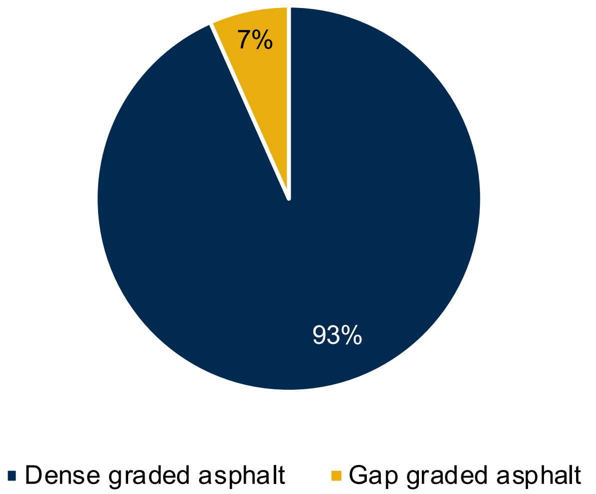
Industry interviews

Three individual interviews were conducted with key industry stakeholders between 20 and 28 May. The interviews were held via Microsoft Teams or phone call, excepting the recycler where feedback was provided by email correspondence on 15 May 2024. These interviews were conducted in partnership with LG TRIPP 07, due to experience with both asphalt and sprayed seal technologies.

4.2.2 The Western Australian Practice Landscape

Almost unanimously, the workshop and follow-up survey respondents communicated that the most common asphalt mix type is DGA, as shown in Figure 4.3. DGA constitutes between 50 to 95% of each jurisdiction's works, with a mean of 79%. The use of DGA is followed by SMA, some sporadic use of GGA and OGA, and other types including sprayed seals and gravel pave.

Figure 4.3: Most common pavement types across the local government network



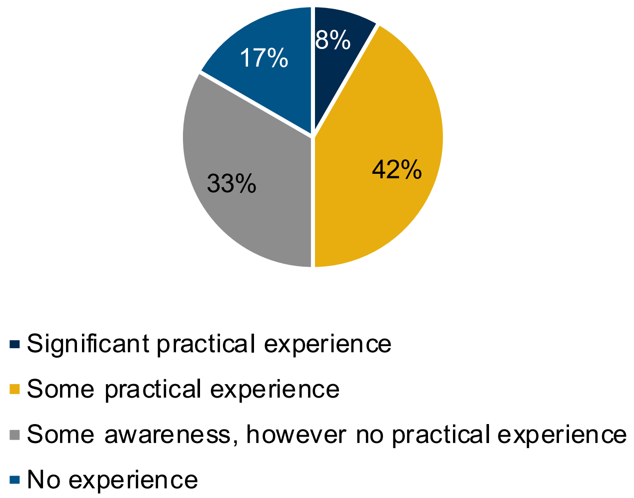
This finding demonstrates that the guidelines should focus on resources related to DGA, considering this is overwhelmingly the most common mix type used.

4.2.3 Reclaimed Asphalt Pavement Practice in Western Australia

The learnings from the stakeholder engagement process regarding industry and local government experience in the use of RAP in asphalt across WA is discussed in Section 4.2.3. The initial survey revealed that just over 59% of the local government respondents do not have experience with using RAP. Of these, 22% only use sprayed seals in their municipalities, so the use of RAP would not be expected. In terms of the rest, there is the potential for RAP to be used; however, local government practitioners are not necessarily being made aware of its use by the asphalt manufacturers.

A summary of the responses from local government practitioners regarding their experience with RAP in asphalt is shown in Figure 4.4. The results suggest that there is some awareness or limited experience, and few respondents have significant practical experience.

Figure 4.4: Experience of local government practitioners with the use of reclaimed asphalt pavements in asphalt



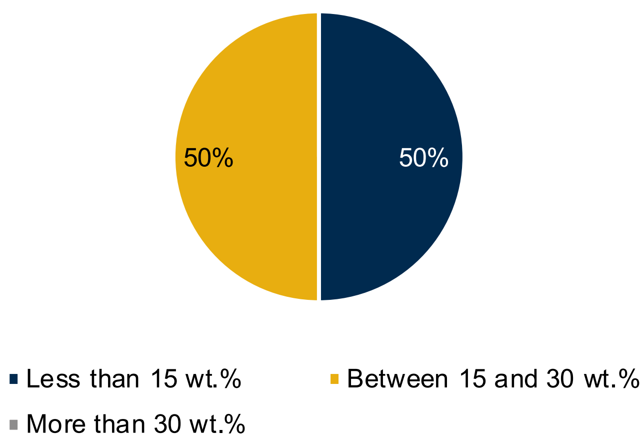
Technology

RAP can be processed in batch or continuous plants. Stakeholder consultations revealed that there is one continuous plant in Perth, while the rest are batch plants. Conventional plants can process mixes with up to 50% RAP, while, in theory, some plants which have additional heating capacity can process mixes with up to 100% RAP.

One respondent reported that all Perth-based plants are capable of processing RAP. Further consultations confirmed that all plants in WA have the capacity to process mixes with up to 10 wt.% RAP, the major plants can process asphalt with up to 25 wt.% RAP, while 2 plants have the capacity to process Level 3 RAP or higher.

The use of RAP by local government is summarised in Figure 4.5. The results indicate that there is a split between less than 15 wt.% and 15 to 30 wt.%. The workshop participants generally considered less than 10 wt.% as 'business-as-usual', in line with Austroads and IPWEA recommendations. Some consideration is being given to QC and mix design at 10 to 30 wt.%. No respondents were using over 30 wt.%.

Figure 4.5: Concentration of reclaimed asphalt pavement used by local government practitioners, per mix



Generally, there is not a desire or expected need to use high levels of RAP, i.e. over 20 wt.%. This is due to the relatively low amount of asphalt used in WA and, therefore, a low availability of RAP. There is an expectation that a low use of RAP would be sufficient to recycle all RAP material generated in WA.

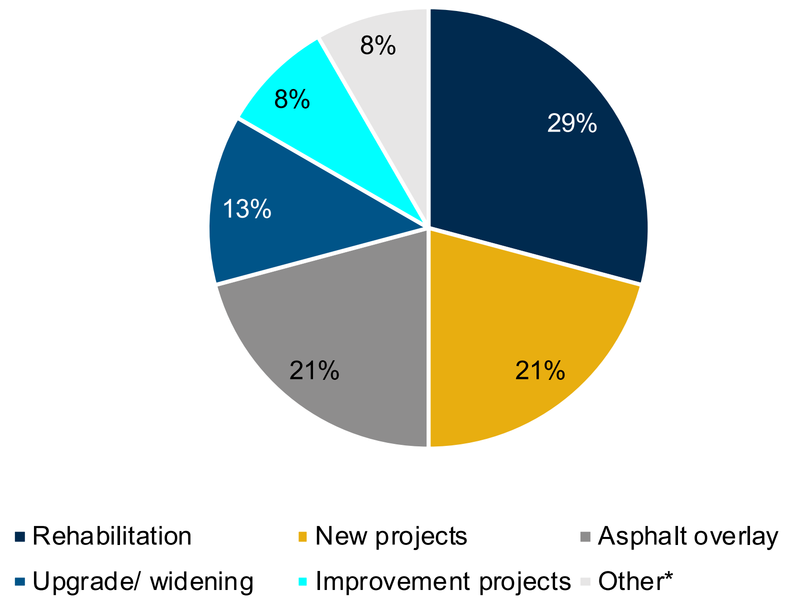
Addititionally, high percentages of RAP may require rejuvenators and further research to develop specifications to formulate a position on their use.

Applications in asphalt

As discussed in Section 3, RAP is primarily recycled in new asphalt mixes in the wearing, base and intermediate courses. However, its application in wearing courses needs to be carefully thought through. MRWA Specifications 502:2022 and 504:2024 prohibit the use of RAP in DGA wearing course and SMA. This is mainly due to fatigue performance concerns or linked to the use of PMBs in these mixes where the use of RAP is excluded so that it does not dilute the PMB, thus reducing the benefits associated with their use. Respondents suggested that choices need to be made depending on intended use. For example, the use of RAP in lightly trafficked (35 to 50 blow compaction) applications such as car parks could be considered (with limits still applying), but potentially not for heavy duty (75 blow) compaction mixes.

In the initial survey, respondents were asked to advise the applications where they had used RAP. The responses are outlined in Figure 4.6.

Figure 4.6: Use of reclaimed asphalt pavement in asphalt according to project type



* Hardstand and driveway for the yard, [foot]path network.

In terms of the pavement layers where RAP was used, the most common was the wearing course with 8 responses, followed by basecourse with 7, intermediate course with 3, while one respondent reported the use of RAP in hardstand and driveway applications.

All workshop and survey responses indicated previous use of RAP had been in DGA, but one respondent had also used it in OGA. The primary use was in HMA in wearing course or intermediate course, with one application in in situ recycling.

Supply

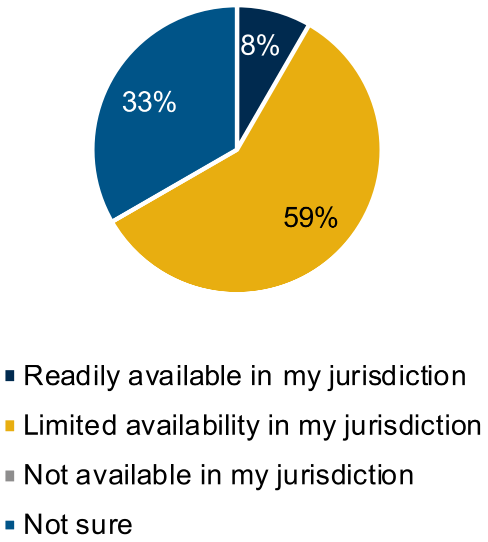
As discussed in Section 3, there are plants in WA that can process RAP which is typically stockpiled rather than recycled in situ. However, the availability of RAP may be limited as asphalt pavements in local government roads in WA mainly comprise a thin asphalt layer on a granular base.

It was unclear from the stakeholder engagement sessions how much RAP is available in WA. It was recognised, however, that with projected rehabilitation works involving the use of full-depth asphalt pavements in the next 15 to 20 years, availability is expected to increase, while demand is expected to remain stable.

It was also noted during the stakeholder consultations that the use of RAP may not be financially and environmentally beneficial for use outside metropolitan Perth. This is because costs associated with the use of RAP can be mostly attributed to the need for reprocessing and haulage. If the site is too far away from the asphalt plant, then it might be decided that the profiling company could take ownership of the RAP. As a result, some RAP is used for non-road applications, such as trucking depots and driveways, resulting in lower volumes being available to asphalt contractors. One respondent suggested that this is likely because specifications do not clarify ownership of RAP once it is removed from the road and the road managers do not have custodianship or ownership of the RAP extracted from their networks. As a result, and in order to use the RAP from their network, they may need to purchase it and compete with non-asphalt buyers. Defining ownership of the RAP may enable local government to make greater use of RAP.

The perceived availability of RAP by local government practitioners is presented in Figure 4.7. The data suggests that the perceived availability of RAP is limited, despite the fact that most of the survey participants are located in the Perth metropolitan region, where it may be expected that materials would be more readily available than in the outer regions.

Figure 4.7: Perceived availability of reclaimed asphalt pavements by local government practitioners



Most of the perceived challenges regarding RAP use were related to supply and the quality of supply, including variability, QC, contamination, stockpile management and local availability. It was suggested that the quality of supply was linked to the conventional use of thin asphalt surfacings (25–30 mm) on granular pavement. This would make the extraction of RAP from the underlying pavement without contamination challenging.

Specifications and guidance

This section discusses the specifications and RAP management guidance that is presently in use across WA and identifies the guidance that would support respondents in increasing implementation of RAP in asphalt. It was evident from the discussion in Section 3 that guidance regarding the management of RAP stockpiles is available. This was also reflected by one response in the initial survey which noted that the IPWEA/AfPA specifications regarding the use of RAP are reasonably mature.

Stakeholders suggested that the use of a RAP management plan is paramount and beneficial to the asphalt contractors. MRWA Specification 511:2025 requires asphalt manufacturers to develop a RAP management plan. However, a single consistent RAP management plan is not used, thus introducing variability in management. It was also recognised that QA is highly dependent on a contractor's QC.

Local government workshop participants considered RAP management to be the role of the asphalt manufacturers, though they recognised the importance of RAP management plans for mix design, QC, moisture control, PSD, characterisation, contamination and stockpiling and handling.

Overall, the workshop participants indicated that they would support the use of RAP in their jurisdiction if more guidance was available, including instruction regarding the re-recyclability of RAP.

Benefits

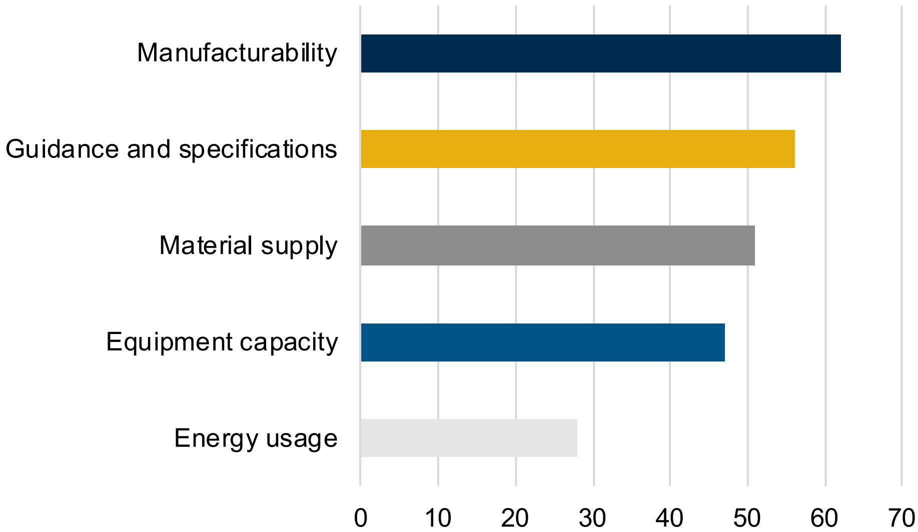
Although certain benefits, primarily environmental and economic, relating to the use of RAP in asphalt were identified, no clear benefits were identified in the initial survey. One survey respondent noted that the incorporation of RAP may provide increased stiffness in thin asphalt pavements. Workshop participants considered the main benefits to be cost reduction and sustainability, i.e. circularity and waste reduction.

Challenges, risks and mitigation measures

The literature review noted that during a previous stakeholder engagement, participants identified certain challenges associated with the use of RAP, including uncertainty relating to long-term performance, a lack of QA protocols, availability and know-how.

In the initial survey undertaken as part of this project, respondents were asked to rank the major limitations for the adoption of RAP in asphalt. The limitation ranked first received 5 points, and so on. The results are shown in Figure 4.8, from greatest to least impact.

Figure 4.8: Limitations on the adoption of reclaimed asphalt pavement



Some of the anecdotal challenges or reasons for not using RAP in asphalt reported in the surveys and workshop include:

- not practical for remote areas
- irregular availability or insufficient supply
- changing mindsets
- concerns associated with variability and QC, including PSD
- lack of understanding or technical knowledge
- use of RAP not relevant to local government practices, e.g. foam bitumen stabilisation for rehabilitation, or low use of asphalt
- limited data on RAP availability in WA.

It was also suggested that knowledge of RAP management and its use during construction was important, as compaction issues may arise. It was further noted that the amount added to the mix needed to be carefully considered.

Summary

The stakeholder workshops and surveys indicated that the use of RAP by local government in WA is generally low. Many respondents did not use RAP at all, and those that did had limited practical experience. The most common use was in DGA mixes for rehabilitation (e.g. asphalt overlay) and new works at no more than 30 wt.%. It was generally understood that less than 10 wt.% may be considered ‘business as usual’, though they would seek guidance regarding the use of higher proportions of RAP.

Asphalt plants in Perth have the capacity to process RAP, though availability is generally low. It was suggested that this was a result of RAP frequently being used in other industries, aside from road construction, and the fact that asphalt layers in the local government network are relatively thin. Consultations suggested that defining ownership, i.e. ensuring RAP extracted for local government roads is used in the same jurisdiction, may encourage an increase in use by local government. Most of the perceived challenges associated with the use of RAP were related to supply and the quality of supply, i.e. contamination, stockpile management, etc. Some respondents expressed uncertainty relating to long-term performance.

Most perceived benefits were related to cost savings and sustainability, with only one respondent expressing a possible strength benefit from the use of RAP in thin asphalt pavements. Generally, respondents were aware of the available IPWEA/AfPA and MRWA specifications, and it was acknowledged these were relatively mature in terms of RAP use, especially for lower volumes. These findings suggest that local government practitioners will value guidance around the management of RAP to give confidence regarding supply and technical information targeted to the use of greater than 10 wt.% RAP.

5 Outcomes and Recommendations

5.1 Western Australian Local Government Landscape

The consultations with local government practitioners and industry experts, presented in Section 4, found that asphalt managed by local government is mainly placed in metropolitan Perth. In more remote regions, where the network is sealed, sprayed seals are mainly used. The most predominant asphalt mix type constructed and maintained by local government is DGA followed by SMA. These mixes are specified for WA practice in:

- Specification 504:2024 *Asphalt Wearing Course*
- Specification 502:2022 *Stone Mastic Asphalt*
- IPWEA/AfPA 2023 *Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Surfacing.*

The specifications address asphalt plant requirements, weather conditions during construction, compaction (temperature, voids and equipment) and management systems (quality, safety, environmental). Although IPWEA (WA) and AfPA (WA Branch) (2023) includes notes regarding the relevant management systems, Specifications 504:2024 and 502:2022 reference Specification 201 *Quality Management*. It is evident that local practitioners look to these specifications for guidance.

Overall, there is a clear appetite among local government practitioners to adopt more recycled content in asphalt, including RAP. However, practitioners in general agreed that there is a lack of guidance to support their incorporation within the local government network. Relevant guidance already available, gaps and avenues to address these gaps are discussed in Sections 5.2 to 5.4, the material supply is discussed in Section 5.5, and recommendations for future work are presented in Section 6.3.

5.2 Specifications

RAP is specified as a material in its characteristics, properties and manufacture in Specification 511:2025. It is noted that although Specifications 504:2024 and Specification 502:2022 explicitly exclude the use of RAP in DGA wearing course and SMA, respectively, they consider the needs of a state-managed network. As such, these specifications do not offer advice on how 'business as usual' practices need to vary, if at all, when RAP is to be included.

IPWEA (WA) and AfPA (WA Branch) (2023) allow for up to 15 wt.% RAP without any change to the mix, except for SMA, where the use of RAP is not permitted.

5.2.1 Additional Considerations for Reclaimed Asphalt Pavements

The use of RAP in wearing courses is not permitted by MRWA, mainly due to the expected impact on fatigue performance as a result of binder ageing. During the consultation sessions, however, it was noted that the MRWA guidance needs to be considered based on application and mix type. For example, RAP may be used in light duty (35 to 50 blow) mixes, but not in heavy duty (75 blow) mixes. In addition, RAP should generally not be considered for use in SMA and GGA mixes because of issues related to fatigue life. Another consideration surrounding the use of RAP that is not addressed in the specifications, is whether the new mix includes a PMB. In these cases, the use of RAP may result in a decrease of the overall content of PMB, hence potentially compromising expected performance.

5.3 Design Guidance

Overall, the selection of an appropriate mix design was not found to be a challenge for local government practitioners. The appropriate asphalt mix treatment depends on factors including, but not limited to:

- overall pavement design
- performance requirements
- condition of existing pavement
- operating environment
- construction requirements
- whole-of-life costs.

These factors guide decisions regarding:

- asphalt mix type
- nominal size of the aggregates in the mix
- layer thickness
- type of binder
- type of aggregate (Austroads 2014).

As discussed in Section 5.1, the local government road network in WA primarily comprises DGA followed by SMA. DGA is a versatile mix type with the capacity to accommodate traffic ranging from pedestrian to heavily trafficked urban arterial roads. Asphalt surfacings are typically thin (25 to 30 mm) on a granular base; their main application is, therefore, the wearing course.

SMA is comparatively more expensive and more complex to construct but introduces increased surface texture (reducing water spray and noise) and deformation resistance (Austroads 2014). As such, IPWEA (WA) and AfPA (WA Branch) (2023) recommend the use of SMA mixes when increased rut resistance and fatigue life are required.

Austroads (2014) recommends the selection of nominal aggregate sizes for DGA and SMA wearing courses (Table 5.1) and the selection of layer thickness (Table 5.2), with the minimum layer thickness being at least 3 times – and the maximum compacted layer thickness limited to below 4–5 times – the nominal aggregate size of the selected mix.

Table 5.1: Typical mix sizes depending on application

Application	Typical nominal mix size (mm)
DGA lightly trafficked pavements	7 or 10
DGA medium to heavily trafficked pavements	10 or 14
DGA highway pavements	Typically 14 but also 10
DGA heavy duty industrial pavements	14 or 20
SMA	7, 10, or 14

Source: Adapted from Austroads (2014).

Table 5.2: Typical asphalt layer thickness based on nominal mix size

Nominal mix size (mm)	Recommended compacted layer thickness range (mm)
5	15–20
7	20–30
10	25–40
14	35–55
20	50–80

Note: Range for 28 mm nominal mix size is also provided; however, it is not applicable for local government roads as it is recommended for OGA and DGA basecourse applications.

Source: Adapted from Austroads (2014).

IPWEA (WA) and AfPA (WA Branch) (2023) includes DGA mixes with nominal aggregate size of 10, 14, and 20 mm for highways, arterial roads, industrial roads and distributor roads, and 5, 7, 10 (residential dense graded (RDG)), and 14 (RDG) mm mixes for residential streets, culs-de-sac, and recreational areas. It also includes SMA mixes with 5, 7, 10, and 14 mm nominal aggregate size. In line with Austroads (2014), IPWEA (WA) and AfPA (WA Branch) (2023) also recommends a layer thickness between 3 and 5 times the maximum nominal aggregate size in the mix.

MRWA 6706-04-154:2004 provides guidance on the mix type selection (including DGA and SMA mixes) based on speed limits and traffic type and volume. Requirements for surface texture characteristics consider:

- speed limits
- rainfall
- pavement drainage
- geometry.

Lyons et al. (2020) provided a quick tool for the selection of the appropriate surfacing treatment, shown in Table 5.3.

Table 5.3: Guide for the selection of appropriate surfacing treatment

Property requiring improvement	Asphalt				Sprayed seals				Microsurfacing	Correction seal plus GRS	Correction seal plus GRS & asphalt overlay
	DGA	FGGA	SMA	OGA	Surface enrichment	Single/single	Double/double	Geotextile reinforced			
Roughness	✓	✓	✓	✓	✗	✗	✗	✗	1	✓	✓
Waterproofing	✓	✓	✓	✗	2	✓	✓	✓	1	✓	✓
Skid resistance	3	3	✓	✓	✗	✓	✓	✓	3	✓	4
Structural strength	6	1	✓	1	✗	✗	✗	✗	✗	4	4
Shear resistance	✓	1	✓	✗	✗	✗	2	1	✓	1	4
Water spray reduction	✗	✗	✓	✓	✗	5	5	5	✓	✓	4
Flexibility (strain tolerance)	2	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓
Reflection cracking	1	1	2	1	✗	✗	✓	✓	✓	✓	✓
Shape correction ability	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓

Notes: Geotextile reinforced seal (GRS)

✓ recommended

✗ not recommended

1 little to no improvement

2 moderate improvement

3 reasonable

4 depends on asphalt type

5 depends on nominal aggregate size

6 depends on substrate.

Source: Adapted from Lyons et al. (2020).

Specifications 504:2024 and 502:2022 require that all mixes are assessed in accordance with:

- WA 731.1 *Stability & Flow of Asphalt: Marshall Method*
- WA 732.2 *Maximum Density of Asphalt: Rice Method*
- WA 733.1 *Bulk Density & Void Content of Asphalt*.

It is also specified that asphalt mixes within the Perth metropolitan area must use granite rock and 1 wt.% hydrated lime. A different adhesion agent must be used if hydrated lime is not practicably available.

5.3.1 Additional Considerations for Reclaimed Asphalt Pavements

Local government practitioners reported that RAP up to 15 wt.% (commonly around 10 wt.%) is being used in DGA, where available, without any modification to the mix, in line with IPWEA (WA) and AfPA (WA Branch) (2023).

van Aswegen and Latter (2019) developed an asphalt mix design process that considers the target binder content, virgin binder viscosity and PSD when RAP is to be included (shown in Figure 3.4). They proposed that these are considered when more than 15 wt.% RAP is incorporated in the asphalt mix. Concerns regarding the incorporation of greater than 15 wt.% are typically addressed by the selection of a softer-grade bitumen or rejuvenating agents. However, such increased contents of RAP are rarely considered due to RAP availability, not only in WA but Australia-wide.

5.4 Construction Guidance

5.4.1 Management Systems

As discussed in Section 5.1, specifications in WA provide guidance on the construction of both DGA and SMA. The first aspect to be considered is management systems. These include quality, occupational safety and environmental safety requirements. According to IPWEA (WA) and AfPA (WA Branch) (2023) and Specification 201:2024, all works should only be undertaken if the Contractor can provide a quality management plan conforming with the requirements of AS/NZS ISO 9001:2016 *Quality Management Systems*. In addition, IPWEA (WA) and AfPA (WA Branch) (2023) requires that a safety management certification for ISO 45001:2018 *Occupational Health and Safety Management Systems – Requirements with Guidance for Use* (supersedes AS/NZS 4801) and AS/NZS ISO 14001:2016 *Environmental Management Systems – Requirements with Guidance for Use* must also be supplied.

5.4.2 Manufacture and Transport of Asphalt

Manufacture and transport of asphalt includes asphalt mixing plant requirements, mix temperature, storage temperature, the use of workability additives, testing requirements and frequency, vehicle type and temperature for transport.

Specification 504:2024 and Specification 502:2022 allow for the manufacture of asphalt in a central mixing plant of any configuration (batch, continuous or drum) so long as they comply with AS 2150:2020.

One aspect to consider is the temperature of the mix at the discharge point. Specification 502:2022 and Specification 504:2024 list the required temperature for the SMA and DGA mixes, respectively, at the point of discharge. The temperature at the discharge point is dependent on the binder grade selected for the mix. These specifications cover C170, C320 and PMBs for DGA and PMBs for SMA mixes. As such, for mixes containing RAP, these might need to be considered separately. Storage and handling of the asphalt mix should also be considered separately to what is advised by Specification 504:2024 and Specification 502:2022 as they are also dependent on the binder selected for the mix.

Specification 201:2024 provides a testing schedule for materials (according to Specification 511) and asphalt (according to Specifications 502, 504, 516, and 517). Table B.1 provides a summary of the minimum requirement for testing frequency and testing methods. These requirements may be considered to be sufficiently covered.

Specification 502:2022 and Specification 504:2024 sufficiently cover the requirements for vehicle type suitable for the transport of the mix, temperature record, heat loss and delivery rate. The temperature in the truck, however, is dependent on the requirement for temperature at discharge and so varies depending on the binder. As these specifications do not cover the use of RAP, the temperature in the truck should be considered separately.

5.4.3 Asphalt Laying

Asphalt laying includes surface preparation, equipment, weather conditions, compaction and density requirements. IPWEA (WA) and AfPA (WA Branch) (2023) provides requirements for the preparation of the works (Section 8) and details for laying of the mix (Section 9) covering:

- undue delays
- delivery
- protection of drains and removal of debris
- traffic management and control
- joints
- survey control
- delivery dockets.

These may be followed irrespective of the materials used. Weather conditions and delivery temperature, however, should be considered separately.

Equipment, compaction and density requirements are covered in Specification 502:2022, Specification 504:2024 and IPWEA (WA) and AfPA (WA Branch) (2023) for SMA and DGA, respectively, and should remain in accordance with these specifications depending on the selected mix.

5.4.4 Additional Considerations for Reclaimed Asphalt Pavements

As discussed in Section 5.2.1, although RAP is excluded from use in a wearing course, it may be considered for use in 35 to 50 blow mixes. Regarding construction guidance, aside from the existing requirements outlined by IPWEA (WA) and AfPA (WA Branch) (2023), Specification 504:2024 and Specification 502:2022, where RAP is to be added, a RAP management plan should be in place.

In addition, the potentially increased stiffness of the RAP binder needs to be considered when surface temperature requirements, temperature of the mix at discharge point and temperature of the mix during transport are specified. Alternatively, the adjustment of the base bitumen grade and/or the addition of rejuvenating agents may be considered based on the performance characteristics of the aged binder.

Further, it is expected that the moisture content of the RAP will impose practical limitations on the content of RAP to be added to the asphalt mix. One way this can be mitigated is by increasing the temperature of the virgin aggregates, which will dry out the RAP upon mixing. A proposed temperature increase for the virgin aggregates, dependent on the moisture content of the RAP, is provided in Table 5.4.

Table 5.4: Required temperature increase of virgin aggregates to remove moisture (grey areas to be avoided)

RAP content (wt.%)	Moisture content of RAP (%)					
	1	2	3	4	5	6
	Required increase in virgin aggregate temperature (°C)					
10	4	8	12	16	20	24
15	6	12	18	24	30	36
20	8	16	24	32	30	48
25	10	20	30	40	50	60
30	12	24	–	–	–	–

Source: Adapted from van Aswegen and Latter (2019).

5.5 Material Supply

As noted in Section 4.2.3, the supply of RAP may be scarce, mainly due to the relatively limited amount of asphalt available in WA, but also due to challenges associated with the quality of RAP retrieved from the local government network, which is often contaminated with basecourse materials. This is a result of the thickness of these asphalt pavements, and it is recognised that it can be difficult to avoid contaminants during profiling.

It is advisable that the RAP is used at the site from where it was retrieved. Practice in WA, though, is that RAP be stockpiled and reprocessed in the asphalt plants. Most plants in WA have the capacity to process RAP and incorporate it back into asphalt, with a couple of plants having the ability to process high-RAP content asphalt.

Additionally, and as discussed in Sections 3 and 4.2.3, it was recognised that if RAP was to be used in all new pavements, then there would only be enough RAP for approximately 20 wt.% to be added. However, the content of RAP should be considered carefully for each application. For example, RAP should not be introduced into wearing courses designed for heavy traffic or where the virgin binder is a PMB. At the same time, however, for a lightly trafficked road or parking lot, the incorporation of greater than 20 wt.% RAP in the asphalt mix may be considered, where RAP is available.

6 Conclusions

In this report, a literature review was undertaken to (1) provide a better understanding of the potential applications of RAP in asphalt, and (2) identify pathways for their adoption by WA local government. The literature review:

- introduced the technologies of RAP in asphalt
- identified appropriate applications
- highlighted some of the benefits and considerations
- summarised the available specifications
- identified material sources
- recognised certain challenges and potential mitigation measures.

The literature review was followed by a series of engagement sessions with industry experts and local government practitioners. The aim of these consultations was to provide a better insight into current WA practice and the barriers local government in WA is facing when considering the incorporation of RAP in asphalt.

6.1 Western Australian Landscape

The stakeholder consultations revealed that the majority of the asphalt pavements laid across the WA local government network comprise DGA followed by SMA, with some sporadic uses of GGA and OGA.

6.2 Reclaimed Asphalt Pavement in Asphalt

RAP can be processed in both batch and continuous plants. Stakeholder consultations revealed that there is one continuous plant in Perth, while the rest are batch processing plants. They were all thought to have the capacity to process mixes with up to 10 wt.% RAP, while 2 plants have the capacity to process mixes with more than 30 wt.% RAP.

Although MRWA specifications explicitly prohibit the use of RAP in wearing courses, the IPWEA/AfPA specification permits its use up to 15 wt.% without any changes in the mix. It was recognised that such decisions need to be made on a case-by-case basis depending on performance requirements.

In WA, RAP is typically transported to asphalt plants where it is crushed and stockpiled for later use, rather than being used in situ. As such, RAP from resurfacing activities is typically stockpiled for use in new asphalt mixes when it logistically makes sense. This means that it may alternatively be sold for use in other applications. Further, it was recognised that the extraction of quality RAP that is free of basecourse materials is challenging, due to the thin asphalt layers typically found in the local government network. These factors were recognised to restrict the overall availability of RAP. Largely, local government practitioners were willing to introduce RAP into their network, particularly in concentrations below 15 wt.%, which is considered ‘business as usual’.

6.3 Future Work

The work undertaken as part of this project revealed that there is guidance available regarding the use of RAP; however, the guidance does not specifically address the types of pavements that local governments in WA mostly use in practice. MRWA specifications focus on RAP in intermediate and basecourse applications. Local government practitioners explained that their road network is primarily comprised of a thin asphalt surfacing over a granular base. As such, there is little opportunity for them to readily adopt these specifications. On the other hand, the IPWEA/AfPA specification allows for the use of RAP in DGA; however, practitioners feel that relevant guidance is limited.

Although RAP is explicitly excluded from use in wearing courses and SMA mixes, these restrictions should be followed on a case-based scenario. The main concern surrounding the incorporation of RAP relates to the expected increased stiffness of the RAP binder. As such, it is not deemed appropriate for layers expected to have good fatigue resistance. However, there are tools that can be adopted and measures that can be taken to mitigate any such risks. Research could be undertaken to quantify these requirements and provide confidence regarding their performance during service life.

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Appendix A Questionnaire for Stakeholder Consultations

A.1 Initial Survey

Name:

Organisation:

3. What type of organisation do you represent?
    a. Road agency
    b. Asphalt manufacturer
    c. Binder supplier
    d. Local Government practitioner
    e. Consultant/Contractor
    f. Other (please specify)
4. Do you have experience working with RAP?
    a. No
    b. Yes
5. If 'Yes' to Q8, in what applications do you use RAP?
    a. Subgrade
    b. Base course
    c. Intermediate course
    d. Wearing course
6. If 'Yes' to Q8, in what project types do you mostly use RAP?
    a. Upgrade widening
    b. Asphalt overlay
    c. Rehabilitation
    d. Improvement projects
    e. New projects
    f. Other (please specify)
7. If 'No' to Q8, what do you perceive is the greatest limitation for adopting RAP in your practice?
    a. Manufacturability
    b. Equipment capacity
    c. Guidance and specifications
    d. Energy usage
    e. Material supply
    f. Other (please specify)
8. Is there anything else you would like to add?

A.2 Local Government Workshop

General questions:

1. What asphalt mix type is most common in your practice?
2. If you had to provide a % estimate for this type, what would you say that is?
3. Do you sometimes use other mix types? What would they be?

4. If you had to provide a % estimate for this type, what would you say that is?
5. Would you say there is a strong focus on using recycled content in your projects?
6. Are there any specific sustainability targets you are aiming to meet when considering new infrastructure projects?

RAP in asphalt questions:

1. Do you have experience with RAP in asphalt?
2. In what asphalt mix types have you used RAP before?
3. What technology do you often use for RAP-containing asphalt? For example, would it be HMA, cold recycling, something else?
4. Where would you primarily source your RAP from? From a material supplier, the asphalt manufacturer, in-situ recycling?
5. In a couple of words, how do you decide when to use RAP?
6. Would you typically add less than 15 wt.%, between 15 and 30 wt.%, more than 30 wt.%?
7. Is there a specification that you follow when designing RAP asphalt or mostly relying on know-how?
8. If you use a specification, which one do you choose?
9. Do you follow/ implement/ require a RAP management plan?
10. If “yes” to Q9 which one?
11. In a couple of words, what part of the RAP management plan you feel is the most critical?
12. When using less than 15 wt.% RAP in the new asphalt mix, is this business as usual, or do you still apply some pre-cautionary measures? If yes, in a couple of words, what are they?
13. When using between 15 and 30 wt.% RAP in the new asphalt mix, do you take any pre-cautionary measures or use as business as usual? If yes, in a couple of words, what are they?
14. When using more than 30 wt.% RAP in the new asphalt mix, do you take any pre-cautionary measures or use as business as usual? If yes, in a couple of words, what are they?
15. In a couple of words, what do you perceive to be the main benefit of RAP in asphalt?
16. In a couple of words, what do you perceive to be the greatest challenge regarding the use of RAP in asphalt?
17. In a couple of words, what adjustments, if any, do you make to the mix design when incorporating RAP?
18. Do you generally find it easy to access RAP?
19. If RAP is not part of your common practice, in a couple of words, why do you find that is?
20. If sufficient guidance was available, do you think that you would be supportive of the use of RAP in the local road network within your jurisdiction?

A.3 Industry Interviews

The key themes raised with industry personnel throughout the individual interviews include:

- Ideal/practical use of RAP for local government networks
- Awareness/examples of current use by local governments
- Economic and material supply considerations
- Contractor and local government knowledge, in producing, stockpiling, using RAP in asphalt
- Available technologies/products, i.e., asphalt plants, current product offerings
- Specifications and their transfer to local governments
- Benefits
- Challenges and risks

Appendix B Quality Management

B.1 Testing Frequency for Materials and Asphalt

Table B.1 summarises the minimum testing frequency requirements for asphalt and RAP according to Specification 201:2024.

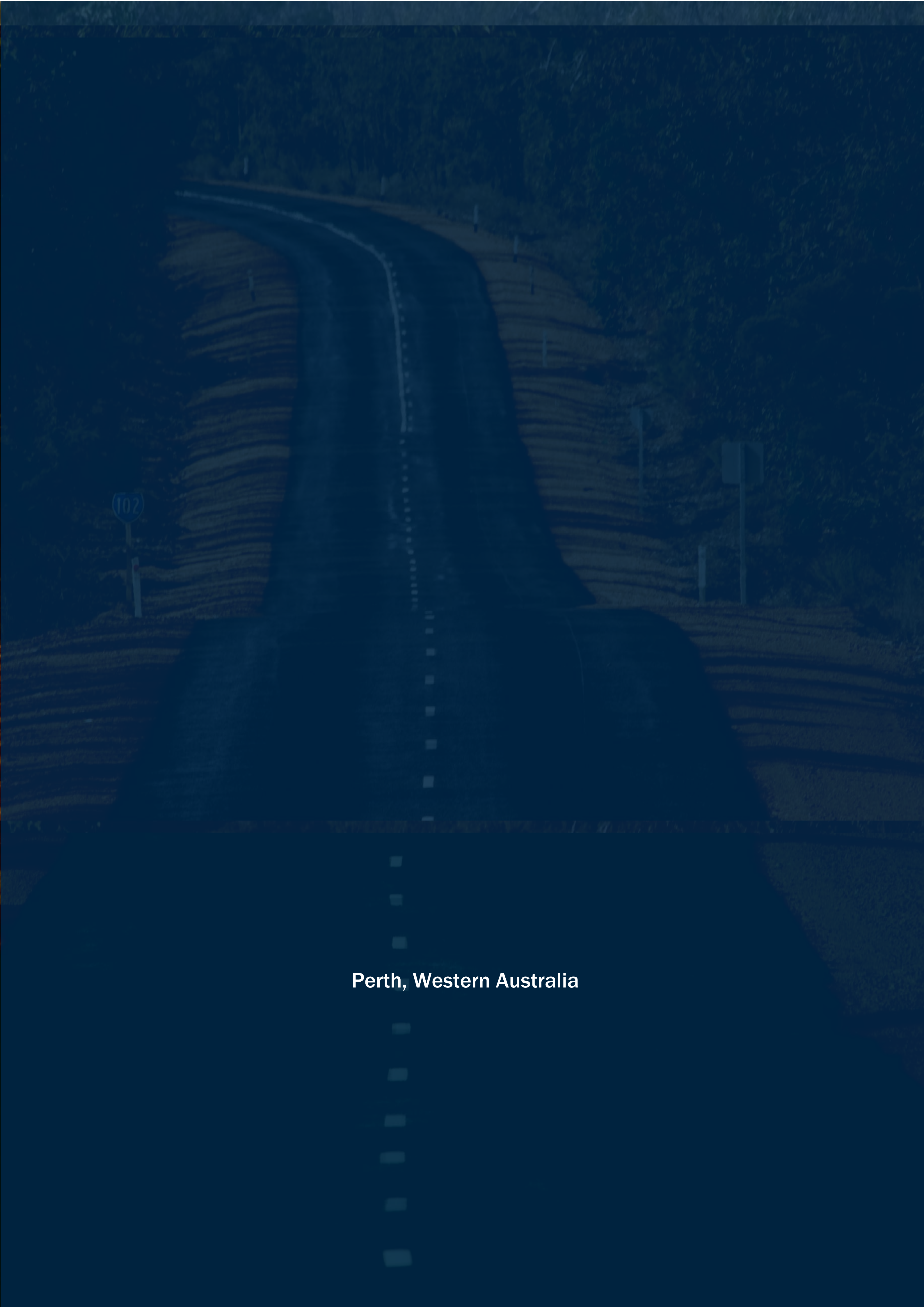
Table B.1: Testing frequency requirements for materials and asphalt according to Specification 201:2024

Construction element	Conformance assessment	Test method		Minimum frequency	
Asphalt[1]	Routine testing – full test	PSD and bitumen content	WA 730.1	3[3]	Per Lot
		Maximum density	WA 732.2	3[3]	Per Lot
		Bulk density and void content	WA 733.1 or 733.2	3[3]	Per Lot
		Stability and flow	WA 731.1	3[3]	Per Lot
		Gyratory VMA and air voids	AS/NZS 2891.2.2 & 2891.8 & 2891.9.2	4[4]	Per Lot
	Routine testing – partial test	PSD and bitumen content	WA 730.1	5[5]	Per Lot
		Maximum density	WA 732.2	5[5]	Per Lot
	Periodic testing	Temperature on discharge	-	1	Per Lot
		Moisture content	AS/NZS 2891.10 or using a T660	1	Per week
		Degree of particle coating	AS/NZS 2891.11	1	Per week
		Asphalt binder drain off	AGPT/T235	1	Per Lot
		Stripping potential of asphalt	ATM 232	1	Per 5,000 tonne
		Resilient modulus	AS/NZS 2891.13.1	1	Per 5,000 tonne
	Tack coat supplied by the contractor	Residue from evaporation	AS/NZS 2341.23	1	Per batch
	Compaction	Temperature on delivery	-	1	Per truck[6]
		Layer thickness	WA 705.1	10	Per Lot[7]
		Per cent Marshall density	WA 733.1 or 733.2	Table 201A-1[8]	Per Lot
		In situ air void content	WA 733.1 or AS/NZS 2891.8	Table 201A-1[8]	Per Lot
	Geometrics	Surface width		1	Per 10 m[9]
		Surface shape[10]	WA 313.2 or 313.4		
		Surface levels	MRS 67-08-43	1	Per 10 m[9]
RAP[2]	Properties	PSD and bitumen content	WA 730.1	3	Per 1,000 tonne
		Foreign materials	WA 144.1	3	Per 1,000 tonne
		Moisture content	WA 212.1 or 212.2	3	Per 1,000 tonne
		Viscosity at 60 °C	AGPT/T192	1	Per Lot

1. Specification 502:2022, Specification 504:2024, Specification 510:2022, Specification 516:2020 and Specification 517:2023.
2. Specification 511:2025.
3. Frequency reduced to 2 for Lots < 150 tonne or 1 for Lots < 50 tonne.
4. Frequency reduced to 3 for Lots < 350 tonne, 2 for Lots < 150 tonne or 1 for Lots < 50 tonne.

5. Frequency reduced to 4 for Lots < 2,000 tonne, 3 for Lots < 1,600 tonne, 2 for Lots < 1,200 tonne, 1 for Lots < 800 tonne or 0 for Lots < 450 tonne.
6. Measured in paver on random basis.
7. The mean shall be taken to represent the Lot.
8. WA 733.1, Section 5.1.2 – Paraffin wax.
9. Survey pickup.
10. As necessary to meet the specified tolerances.

Source: Adapted from Specification 201:2024.



Perth, Western Australia