LG TRRIP

Local Government Transport & Roads Research & Innovation Program

An initiative by: WALGA, The Government of Western Australia, Main Roads Western Australia

Technical Report: Sustainable road construction practices for Local Government roads in WA

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1.0

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About LG TRRIP

The Local Government Transport and Roads 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

The *Sustainable road construction practices for Local Government roads in WA* documents have been developed by the National Transport Research Organisation (NTRO) for the Western Australian Local Government Association (WALGA) with the support of Main Roads Western Australia (MRWA) under the Local Government Transport and Roads Research and Innovation Program (LG TRRIP).

The viability and range of recycled materials and sustainable practices (recycled materials and methods) suitable for adoption on local roads in WA is not well understood. Local governments require support and guidance to be able to make decisions for the selection of suitable materials and methods. The remoteness and capacity of many local governments presents significant challenges.

These documents have been prepared to enable and support local government implementation of sustainable road construction initiatives within Western Australia and in response to the commitment in the State Road Funds to Local Government Agreement to increase sustainable road construction practices through the greater use of recycled materials. To address the specific requirements and unique challenges of local government road construction activities within WA, this report is structured based on locality (metropolitan, regional, remote/very remote) and project type, including:

- granular resheeting/stabilisation (rural/regional)
- seal/reseal (regional/rural)
- rehabilitation base and seal (rural/regional)
- upgrade widening (all)
- asphalt overlay (metro)
- metro rehabilitation (mill and re-mill) – base rehabilitation
- improvement projects (all) – e.g. new carriageway, turning lanes, traffic circles etc.

This report identified numerous recycled materials and methods that can be used to improve sustainability within road construction, including:

- recycled materials:
  - reclaimed asphalt pavement
  - crushed recycled concrete and crushed brick
  - recycled crushed glass
  - crumb rubber
  - fly ash
  - bottom ash
  - blast furnace slag
  - food and garden organics
  - recycled plastics
  - recycled materials in road furniture
- sustainable practices:
  - foamed bitumen stabilisation
  - bitumen emulsion stabilisation
  - cementitious stabilisation
  - soil/subgrade stabilisation
  - warm mix asphalt
  - hot-in-place asphalt recycling

– in situ recycling of concrete pavements
– marginal and non-standard materials.

Sustainability innovation within the road construction space is constantly evolving to address the requirements of international goals, government policy and strategic plans and societal expectations. This report provides information on the current status (known at the time this document was prepared) of the use of recycled materials and methods for road construction. This report shows that there are many options to improve sustainability in road construction, and that there is ample opportunity to increase the uptake of these options within their most suited applications. Improved awareness and education in how these materials are used, supported by policy and procurement drivers, new and improved specifications and more modern recycling facilities with increased capacity, can all contribute to increases in the use of recycled materials, sustainability outcomes and a more circular economy. Future reviews and revisions of this report may be required to align with emerging technologies and emerging recycled materials.

The key outcomes of this project are demonstrated through a selection and implementation process for the integration of sustainable practices in road construction. The practitioners guideline includes a methodology for selecting potential sustainable options and identifying which option will best suit the project. A practitioner can use the guideline by entering the project type and locality into a chart that will provide a range of applicable recycled materials and methods for consideration. Each of the recycled materials and methods options are supported by a detailed fact sheet providing comprehensive advice including availability, engineering performance and technical specifications, from which a practitioner can decide whether to adopt the option. These parameters provide the information required to enable a feasibility check specific to individual project works. Example scenarios are provided to guide the user through the process to aid in achieving best practice outcomes.

The complete advice contained within this technical report has enabled the preparation of the practitioners guide. For additional information or guidance not included within these documents, please contact WALGA and/or NTRO.

Acknowledgements

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1 Introduction

1.1 Background

These documents on the *Sustainable road construction practices for Local Government roads in WA* have been developed by the National Transport Research Organisation (NTRO) for the Western Australian Local Government Association (WALGA) with the support of Main Roads Western Australia (MRWA) under the Local Government Transport and Roads Research and Innovation Program (LG TRRIP).

LG TRRIP was established in 2022 by MRWA and WALGA as a research and innovation program dedicated to the needs of the local government road network in WA. The objective of the program is to achieve better implementation of innovative practice by improving the specialist capability of local government through a collaborative program of projects which deliver advanced technology and cost-effective solutions to roads and transport issues for the people of Western Australia.

1.2 Purpose

The viability and range of recycled materials and sustainable activities suitable for adoption on local roads in WA is not well understood. Local Governments require support and guidance to be able to make decisions for the selection of suitable materials and practices. The remoteness and capacity of many local governments present significant challenges.

These documents have been prepared to enable and support local government implementation of sustainable road construction initiatives within Western Australia.

The documents are designed to assist local governments to make informed decisions for the use of recycled materials and sustainable practices in road construction and preservation works. The objective of the documents are to present a decision methodology that local governments can use to inform the availability and applicability of suitable recycled materials and sustainable construction practices based on the type of project and its locality.

1.3 Structure

The following documents have been prepared:

- Practitioners Guide
- **Technical Report** (this report)**.**

The content and relationship between these 2 documents are summarised in Table 1.1.

Table 1.1: Structure of the documents

Document	Content
Practitioners Guide	A practitioners guideline in a user-friendly format. The key content is included in tables and graphical formats to provide practical solutions interpretable by non-technical practitioners.
Technical Report	The technical report containing all the background research and supporting technical information.

1.4 Scope and Methodology

In order to deliver a practical guideline that could assist local governments in making informed decisions the following scope of works was required:

- a catalogue of established road building recycled materials options and methods

- provision of guidance including availability, applicability, durability, cost implications, whole-of-life impacts, environmental benefit and applicable design and construction specifications and other information to assist practitioners to make decisions on what options may be suitable for adoption
- the cases for adoption to be separated into Metro, Regional and Remote
- identification of any potential for local governments to manage waste that can then be processed and included in roadworks.

To ensure the required project scope of works was realised, the development of the documents was undertaken in 5 stages:

1. **Literature review:** the project undertook a review of WA, interstate, national and international literature to develop a catalogue of established and proven recycled materials and sustainable road construction practices used in road construction. Research was undertaken and in the following areas:
    - General applications and specifications
    - Engineering performance
    - Environment
    - Work health and safety
    - Case studies
    - Potential future applications.
2. **Desktop study:** a desktop study was undertaken to identify all sources and suppliers of recycled materials, their location and operational delivery distances of their products.
3. **Stakeholder engagement:** stakeholders were identified and engaged in 2 groups:
    - Local government and MRWA representatives as experts and practitioners

    a. The selected methodology for practitioners' engagement was to seek nominations to form an expert reference group, which would then attend an interactive workshop to assist with the development of the documents.

    - Suppliers to understand product availability and other relevant information.

    b. To further understand the availability of recycled materials and recycling services in WA, suppliers were contacted to provide details about the specifics of their services and products and the range they can deliver in WA. As the information being sought could be provided in a structured format, the selected method of engagement was to use an online survey.
4. **Draft Practitioners Guide:** Upon completion of the required research, studies and interactive engagement, the information obtained was used to prepare the Technical Report component of the documents.
5. **Draft Technical Report and final presentation:** The finalisation of the Technical Report enabled the development of the Practitioners Guide. The project delivered an awareness session to all interested stakeholders to raise awareness and understanding of the information contained within the documents. This presentation was in the form of an online webinar.

2 Sustainability Fundamentals in Road Construction

2.1 Sustainability Fundamentals Overview

2.1.1 Introduction to Sustainability

The concept and application of sustainability is a high-profile action item in all industries and sectors internationally, nationally and on a local level. Internationally, the concept of sustainability can be traced to the Brundtland Commission Report where it was defined as ‘meeting the needs of the present without compromising the ability of future generations to meet their own needs’ (Brundtland Commission 1987). Subsequent definitions of sustainability have been tailored to address each intended purpose.

Stemming from the origins of sustainability is the concept of sustainable development, a strategic approach which promotes positive environmental, social and economic outcomes. In support of sustainable development, the United Nations member states have adopted several sustainability-based agreements. Of significance is the 17 sustainable development goals (refer Figure 2.1).

Figure 2.1: 17 sustainable development goals

Source: UN SDG Advocates (2023).

This international momentum in the sustainable development space has both enabled and supported the development and implementation of policy and action within Australia. Infrastructure Australia promotes the concept that sustainability outcomes are reliant on balancing social, economic, environmental and governance outcomes (Infrastructure Australia 2021). These principles are further defined in Table 2.1.

Table 2.1: Infrastructure Australia sustainability principles

Component of sustainability	Principle
Social	Infrastructure and policies should improve quality-of-life, access and wellbeing, to create an inclusive and fair society.
Economic	Infrastructure and policies should grow productivity, the Australian economy and allow equitable access to economic and growth opportunities, while efficiently using financial resources.
Environmental	Infrastructure and policies should protect environmental outcomes by reducing pollution, balancing resource consumption, conserving natural ecosystems and resources, and supporting climate mitigation and adaption.
Governance	Infrastructure and policies should build trust in governance and institutions through transparent, accountable and inclusive decision making.

Source: Infrastructure Australia (2021).

2.1.2 Circular Economy

In support of the sustainable development goals and the principles of sustainability, Australia has developed the 2018 *National Waste Policy* (Department of Climate Change, Energy, the Environment and Water 2018) and the 2019 *National Waste Policy Action Plan* (Department of Climate Change, Energy, the Environment and Water 2019). Of relevance is the alignment with Sustainable Development Goal 12 Responsible Consumption and Production. The 2018 National Waste Policy drives the integration of recycled materials in infrastructure and introduces the concept of the circular economy:

> The circular economy aims to change the patterns of natural resource use in the economy in order to achieve sustainable growth by slowing, narrowing to closing material loops (Department of Climate Change, Energy, the Environment and Water 2018).

This means shifting social practice from 'take, make, use and dispose' to an approach where the useful value of resources is maintained for as long as feasibly possible. The outcome of this will be improved waste management, job creation, protection of the environment and improved management of valuable finite natural resources. This process is described in Figure 2.2.

Figure 2.2: The circular economy

Source: Department of Climate Change, Energy, the Environment and Water (2019).

The 2019 *National Waste Policy Action Plan* includes quantifiable targets to measure the success of implementation. Key targets applicable to road construction are detailed in Table 2.2.

Table 2.2: National Waste Policy Action Plan targets

Target	Action
Target 3: 80% average resource recovery rate from all waste streams following the waste hierarchy by 2030.	3.6 Prioritise the development of national standards and specifications, or adopt appropriate international standards and specifications, for the use of recycled content in a broad range of capital works projects, prioritising road and rail.
Target 4: Significantly increase the use of recycled content by governments and industry.	4.1 Determine use of recycled content in road construction to establish a baseline and allow reporting on actions to significantly increase recycled content use.

Source: Department of Climate Change, Energy, the Environment and Water (2019).

These targets are supported through the WA *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Strategy) (Waste Authority 2019b). The applicable objectives and targets set out in this strategy are detailed in Figure 2.3.

Figure 2.3: WA Waste Avoidance and Resource Recovery targets

Avoid	Recover	Protect
Western Australians generate less waste.	*Western Australians recover more value and resources from waste.*	***Western Australians protect the environment by managing waste responsibly.***
2025 – 10% reduction in waste generation per capita **2030** – 20% reduction in waste generation per capita	**2025** – Increase material recovery to 70% **2030** – Increase material recovery to 75% **From 2020** – Recover energy only from residual waste	**2030** – No more than 15% of waste generated in Perth and Peel regions is landfilled **2030** – All waste is managed and/or disposed to better practice facilities

Source: Waste Authority (2019b).

The Western Australian Waste Strategy (Waste Authority 2019b) supports a sustainable, low waste, circular economy in which human health and the environment are protected from the impacts of waste. To achieve this, it is recognised much of the waste that is generated must be valued as a resource that can be reused or recycled for the benefit of the economy.

The Waste Strategy (Waste Authority 2019b, p 26) states that 'Achieving the avoidance targets will require an emphasis on the waste materials that, by weight, currently make up more than 90 per cent of the waste Western Australians generate:

- Construction and demolition (C&D) materials: concrete, asphalt, rubble, bricks, sand and clean fill
- Organics: food organics and garden organics
- Glass: packaging and containers
- Plastics: packaging and containers' [relevant sections extracted]

2.1.3 Strategic Drivers for Sustainable Road Construction

The implementation of sustainable development policy has created a greater need for research and development into sustainable road construction practices. Via the *Recycled and Sustainable Materials at Main Roads, Reference Guide* (Main Roads Western Australia 2022), Main Roads Western Australia (MRWA) have noted several drivers guiding the use of sustainable construction materials and practices and promoting the circular economy in road construction, including but not limited to:

- beneficial reuse of existing recyclable materials waste streams (i.e. crumb rubber, recycled construction and demolition waste, reclaimed asphalt pavement (RAP), plastics, etc.).
- alignment with local, national, and international policy and commitments.

The benefits of utilising recycled materials are supported by the limitations associated with using virgin materials (refer Table 2.3).

Table 2.3: Limitations of natural resources

Material	Issue
Gravel	• Mining of gravel causes land degradation, biodiversity loss. • Limited good quality supply of raw gravel in WA.
Sand	• Global sand crisis due to high amount of construction and population growth. • Around 10 million tonnes of sand goes to landfill each year in WA.
Limestone	• Large amount of embodied energy. • 3.13 kg of CO_2-e produced from mining one tonne of limestone. • Natural limestone can degrade overtime from environmental conditions. • Limited good quality limestone ($CaCO_3$ content above 60%).
Rock/aggregate	• Rock extraction and processing has high embodied energy costs. • Significant amount of rock/aggregate required in road construction.

Source: MRWA (2022).

Further, Cocks et al. (2017) note the following additional benefits of using recycled materials in road construction:

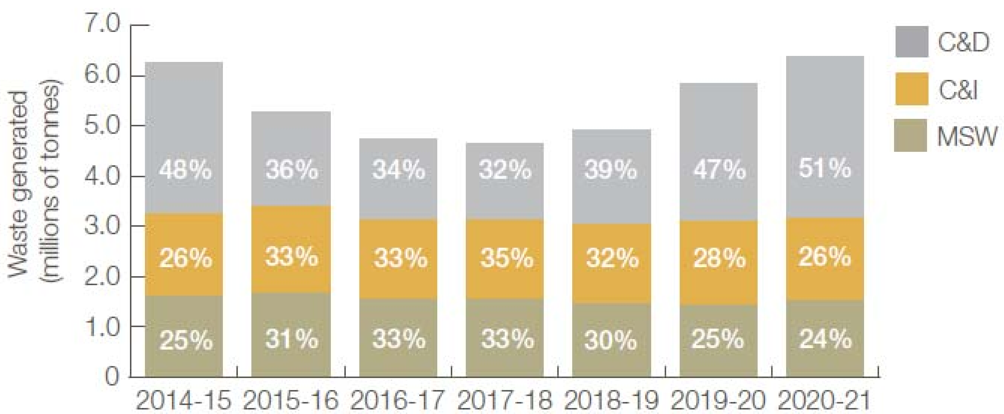
- cost savings, typically via the in situ reuse/recycling of existing roads
- reduced traffic disruption resulting from the import of virgin materials
- reduction in landfill of waste materials
- reduction in atmospheric emissions
- reduced environmental degradation from extractive industry activities
- reduced noise and dust from extractive industry activities.

The Waste Authority's report *Waste and Recycling Snapshot: Western Australia 2020–21* (2022a) provides data on the state's production of wastes. Of special interest to this report are the quantities of construction and demolition (C&D) waste, plastics and glass sourced in municipal solid waste (MSW).

C&D waste generated in Western Australia

C&D waste generation has been increasing in recent years, and in 2020–21 the total tonnage and proportion of C&D in the waste stream exceeded the quantities since 2014–15 (refer Figure 2.4).

Figure 2.4: Waste generation composition by waste stream

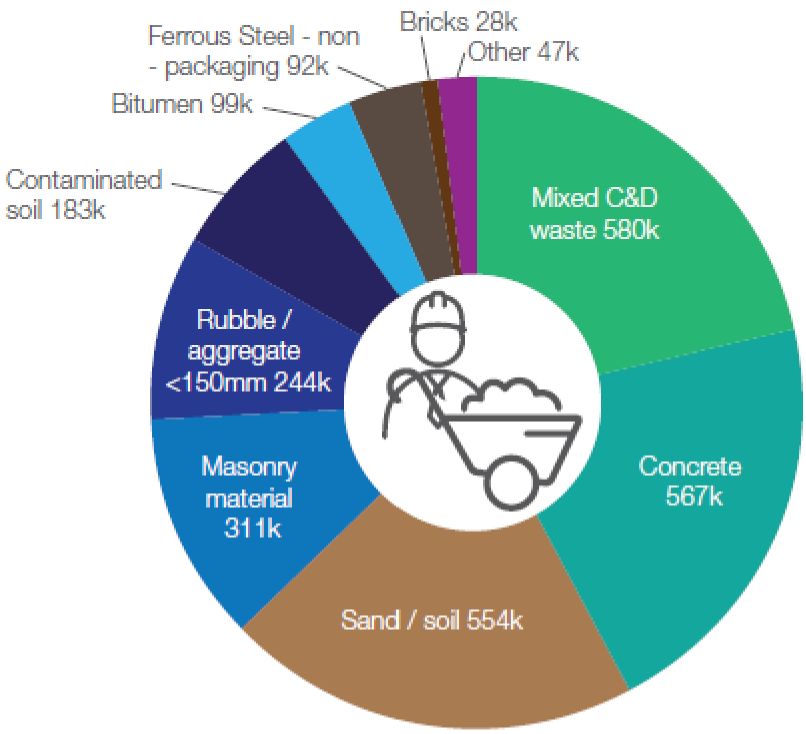


Source: Waste Authority (2021).

The Waste Strategy target is to reduce C&D by 15% (2025) and 30% (2030) from the 2014–15 baseline. The per capita C&D was 1,188 kg per person in 2014–15, and 1,184 kg/person in 2020–21 (Waste Authority 2021 p 10).

The mix of waste types in the C&D stream in 2020–21 is shown in Figure 2.5.

Figure 2.5: Materials recovered (t) from the C&D waste stream 2020–21



Source: Waste Authority (2021).

Not all C&D waste that can be recycled is used in WA, and vice versa, not all road construction materials that include C&D recycled waste has C&D waste from WA.

Other wastes generated in Western Australia

The Waste Authority report for 2020–21 (Waste Authority 2022a), reported the following quantities of wastes were recovered from all collection services in 2020–21:

- 69,804 tonnes of glass waste
- 10,285 tonnes of rubber waste
- 22,044 tonnes of plastic waste
- 357,612 tonnes of organics waste.

2.2 Legislative Framework

This report has been prepared in general accordance with the processes and requirements outlined in current legislation, industry standards and best practice guidelines as set out in:

- Commonwealth:
  - 2018 *National Waste Policy* (Department of Climate Change, Energy, the Environment and Water 2018)

- 2019 *National Waste Policy Action Plan* (Department of Climate Change, Energy, the Environment and Water 2019)

- WA:
  - *Environmental Protection Act 1986* (EP Act)
  - *Environmental Protection Regulations 1987* (EP Regulations)
  - *Environmental Protection (Landfill) Levy Act 1998*
  - *Health (Miscellaneous Provisions) Act 1911* (Health Act)
  - *Land Administration Act 1997*
  - *Local Government Act 1995*
  - *Local Government (Uniform Local Provisions) Regulations 1996*
  - *Main Roads Act 1930*
  - *Public Works Act 1902*
  - *Waste Avoidance and Resource Recovery Act 2007* (WARR Act)
  - *Waste Avoidance and Resource Recovery Levy Act 2007* (WARR Levy Act)
  - *Waste Avoidance and Resource Recovery Levy Regulations 2008* (WARR Levy Regulations)
  - *Work Health and Safety Act 2020* (WHS Act)
  - *Work Health and Safety (General) Regulations 2022* (WHS Regulations*).*

Please refer to the Western Australian Legislation web site for copies of the relevant legislation, available for free via https://www.legislation.wa.gov.au/.

2.2.1 Commonwealth Legislation and Guidelines

Key policies have been developed at the national level to facilitate the implementation of sustainable development practices and a circular economy within Western Australia. This includes the 2018 *National Waste Policy* (Department of Climate Change, Energy, the Environment and Water 2018) and the associated 2019 *National Waste Policy Action Plan* (Department of Climate Change, Energy, the Environment and Water 2019). The 2019 *National Waste Policy Action Plan* outlines the actions and targets required to achieve the objectives of the policy.

2.2.2 Waste Legislation

The *Waste Avoidance and Resource Recovery Act 2007* (WA) (WARR Act) is the principal legislation dealing with waste management in WA. The WARR Act consolidates waste management-related provisions from the Health Act, EP Act and the *Environmental Protection (Landfill) Levy Act 1998* (WA).

Part 1, section 5 lists the objectives of the WARR Act as follows:

6. The primary objects of this Act are to contribute to sustainability, and the protection of human health and the environment, in Western Australia and the move towards a waste-free society by –
   a. promoting the most efficient use of resources, including resource recovery and waste avoidance; and
   b. reducing environmental harm, including pollution through waste; and
   c. the consideration of resource management options against the following hierarchy –
      i. avoidance of unnecessary resource consumption;
      ii. resource recovery (including reuse, reprocessing, recycling and energy recovery);
      iii. disposal.
7. The principles set out in the EP Act section 4A apply in relation to the objects of this Act. The direct environmental impacts of the waste sector, from both local government and private operators, are managed predominantly through the EP Act and related subsidiary legislation.

Waste or resource?

The Western Australian Department of Water and Environmental Regulation (DWER) provides an insight into whether recycled materials utilised in road construction would be considered a waste or a resource. The *Factsheet: Assessing Whether Material is Waste* (DWER 2018) (the factsheet) provides definitions for waste in terms of the regulations and generally. It should be noted that the use of the term **waste** in this document is as provided by the factsheet. Waste is:

> (a) anything left over or superfluous, as excess material, by-products etc., not of use for work in hand (i.e. unwanted or excess material, viewed from the perspective of its source); and/or
>
> (b) any matter whether useful or useless which is gotten rid of into the environment.

It is not suggested or implied that the description of any material as waste in this document should be construed as a legal definition of a waste product.

The following example has been sourced from the factsheet:

> At Premises B, mixed construction and demolition materials are accepted from third parties onto the premises. The third parties bringing the materials to Premises B do not want them and either pay the owner/occupier of Premises B to take them or give them to the owner/occupier for free.
>
> - The materials are processed in a number of different ways including (but not necessarily limited to) the following:
> - An excavator breaks up large materials and removes reinforced steel. The materials are also passed through a jaw crusher;
> - The materials then pass through vibratory screens, air blowers and under belt magnets that remove plastics, metals and other undesirable materials;
> - After initial screening the materials pass through a hand-picking station where any residual contaminants are removed;
> - Finally, the materials are passed through an impact crusher and two screens which separate the materials into different size fractions;
> - The processed materials are tested for asbestos content and against relevant Main Roads material specifications;
> - Subject to meeting asbestos and Main Roads specifications, the materials are sold as recycled fill sand, road base and drainage aggregate to third parties.
>
> In this scenario, the incoming materials are regarded as waste by DWER at the time of their receipt at Premises B. However, the materials are substantially and materially transformed through processing into new products that are different to the materials accepted at the gate. There is also a market for these products. When purchased and used by consumers these products would not be classified as waste by DWER.
>
> Any contaminant materials screened out during the processing of the construction and demolition materials received at Premises B that are not wanted by the owner/occupier of Premises B to make recycled fill sand, road base and drainage aggregate would remain waste in DWER's view.

This example explores the potential reuse of waste construction and demolition materials for reuse in road construction. Although the material is considered waste upon receipt at the waste processing facility, processing of the material to meet the required road construction specifications re-assigns the materials as a beneficial resource. This example sets a positive precedent for achieving sustainable outcomes in road construction via the reuse of recycled materials within road infrastructure.

The factsheet further advises 'Material may cease to be waste, because, for example, it has been reprocessed into a new product or recycled. However, the new product or recycled material may become waste again if it becomes excess to the requirements of its owner.'

For the purposes of this report, once materials have been processed into usable road construction materials, they are no longer considered to be waste. Note however that unusable portions of the recycled materials, arising during processing or in construction, may subsequently become waste.

Who determines if material is waste?

The factsheet also covers this in detail. In summary, the person who generates the material and does not want it (for use or as a product), causes the material to be 'unwanted' and so it is considered to be waste. It does not matter if another person may have a use for it, or values it.

Any material voluntarily given to local government through a transfer station or managed waste collection service is considered to be giving it away as unwanted material. As such, the material can be considered waste by the local government on receiving it. See also the WARR Act Section 55.

When does unwanted material, that is, waste, become the property of the local government?

As provided by the WARR Act, Section 55:

> Subject to any prescribed exceptions, and to the EP Act, all waste received by a local government —
>
> (a) becomes the property of the local government; and
>
> (b) may be destroyed, sold or otherwise disposed of by the local government.

The local government can then determine if they wish to process the waste into a recycled product.

2.2.3 Environmental Protection Legislation and Licensing

Premises on which certain activities are carried out and from which emissions or discharges are made are known as 'prescribed premises' and listed in Schedule 1 of the EP Regulations because of their potential to cause emissions and discharges to air, land or water. These categories include premises on which waste is generated, stored or buried. such as premises where:

- solid waste produced on other premises is stored or discharged onto land (Category 61A)
- solid waste is stored pending its final disposal or re-use (Category 62)
- asphalt manufacturing (Category 35)
- bitumen manufacturing (Category 36).

Premises that process waste may need to be licensed as provided by the EP Regulations.

DWER (2018) advise that the *Waste Avoidance and Resource Recovery Levy Act 2007* (WARR Levy Act) and the *Waste Avoidance and Resource Recovery Levy Regulations 2008* provide for a levy to be payable in respect of 'waste disposed to landfill', at certain categories of prescribed premises.

When is a licence needed for waste-derived materials?

A key issue of the current Western Australian legislation is that it does not include a framework for waste-derived materials. It does not prescribe when waste-derived materials will cease to trigger the licensing and waste levy regimes under the EP Act, WARR Act, WARR Levy Act and the subordinate regulations enabled under these Acts. Industry has reported that the uncertainty around whether material is waste (and hence, whether its storage, burial, discharge onto land, irrigation or incineration will attract licensing and waste levy requirements) is inhibiting the uptake of and market development for waste-derived materials. This is potentially driving a preference for the use of virgin raw materials and resulting in valuable non-virgin resources being sent to landfill. Feedback from industry indicates support for the development of a legislative framework that provides for a risk-based assessment and approval process for bespoke use of waste-derived materials.

DWER have released 2 waste reform papers for comment. *Closing the Loop: Waste Reforms for a Circular Economy, Consultation Paper* (DWER 2020) was developed in direct alignment with the *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Authority 2019b) to protect human health and the environment from waste and support a shift to a circular economy in WA. DWER (2020) includes specific legislation proposals and the development of a legislative framework for waste-derived materials.

Local governments will need to seek advice from DWER as to whether the waste they are processing and the resulting recycled materials will be considered waste and require licensing of their premises and activities.

2.2.4 Work Health and Safety Legislation

The *Work Health and Safety Act 2020* (WHS Act) applies whenever work is undertaken and extends from the workers and contractors doing the work, to other persons who may be put at risk from the work underway. In the context of the life cycle of waste processing to recycling materials, supply of materials, and road construction the responsibilities may include waste facility site safety, processing plant operations, material deliveries, material testing laboratories, road surveying and site visits, site construction activities, maintenance activities and traffic management of the sites. The key factor to consider in all these cases is determining what additional risks are created, arising from the recycled material that would not otherwise be present in the works.

Once the construction work is completed, the asset is made available for use by the community. As long as no work is being undertaken on the asset, the WHS Act is no longer active. However, there will be an expectation from the community to ensure that the community and environment is protected from adverse impacts of recycled materials embedded in road assets.

The local government will need to ensure the assets are adequately managed as they wear and age, to ensure the embedded materials to not create adverse impacts on the community. The safety of the community in using the assets therefore needs to be assessed under other legislation and standards as provided in Section 2.2.5 below, and as part of the decision process provided in Section 8.

2.2.5 Legislation for the Management of Local Roads

Under the *Land Administration Act 1997*, clause 55 (2):

> Subject to the *Main Roads Act 1930* and the *Public Works Act 1902*, the local government within the district of which a road is situated has the care, control and management of the road.

For clarification the term ‘road’ is defined in the *Land Administration Act 1997*, and this does not include private roads. The Act does not further elaborate the meaning of ‘care, control and management’.

Note the *Local Government (Uniform Local Provisions) Regulations 1996* also define a ‘Government road’ as being a road declared by an order of Council under the *Public Works Act 1902*.

The *Main Roads Act 1930* clause 24 (5) defines a ‘secondary road’ as being the responsibility of local government:

> The local government of a district in which a secondary road or any part of a secondary road is situated shall be responsible for maintaining such secondary road or part; *(continues)*

As provided by the *Main Roads Act 1930*, in the event that the local government fails to maintain a road, the Commissioner of Main Roads may direct for work to be undertaken.

All roads that are declared ‘highways’ or ‘main roads’ are under the responsibility of MRWA as defined in the *Road Responsibility Policy* (MRWA 2021), which is issued as procedural advice to the *Main Roads Act 1930*.

Local governments are delegated responsibility for local roads as provided by section 2.1.2 of the *Road Responsibility Policy*, which states:

> All other public roads in WA (with the exception of the previously mentioned access roads to remote communities and roads in National Parks etc.) are the responsibility of local government and are managed by incorporated municipal councils across the State.

MRWA also retains responsibility for traffic signs and devices on local government roads and certain types of bridges.

The conclusion from the legislation is that when a road is not a main road or highway, and where it has not been identified by MRWA as a road under their management and control, then the road is a local road, also referred to as a secondary road. Local governments are responsible for the care, control and management of local roads (not including private roads).

The legislation does not specify minimum care and management standards. Local governments should refer to the MRWA codes of practice and industry standards to determine the appropriate level of maintenance and management of roads in their jurisdiction.

Section 8.3 provides a risk assessment methodology that helps define the standards for maintenance and management of roads that have been constructed with recycled materials and methods.

2.3 Health Safety and Environmental Impacts

Upon sourcing a recycled material for use in road construction, a Safety Data Sheet (SDS) should be obtained from the supplier (refer Section 8.3). Where local government is processing waste materials for use in road construction, a SDS may need to be generated (refer Section 7.2.2 for further information). The SDS should provide specific information with respect to the health, safety and environmental hazards, properties and other relevant information.

Further information on the potential environmental and human health impacts associated with each recycled material is detailed in Section 4 and summarised in the Factsheets in the Practitioners Guide.

2.3.1 Environmental Contaminants

If not assessed and managed appropriately, the use of recycled materials in road infrastructure has the potential to introduce potential contaminants of concern which may lead to contamination of the nominated project site. As defined in the ASC NEPM (National Environmental Protection Council 2013):

> ***Contamination*** means the condition of land or water where any chemical substance or waste has been added as a direct or indirect result of human activity at above background level and represents, or potentially represents, an adverse health or environmental impact.

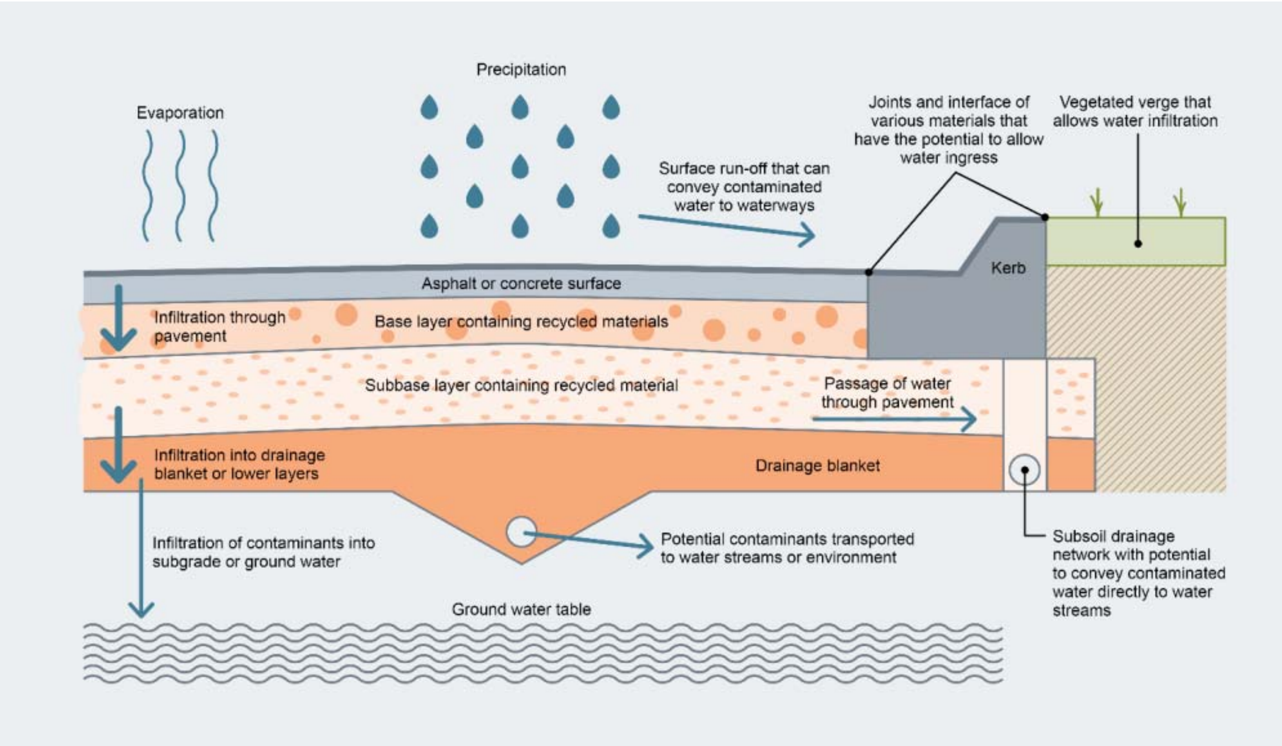
Potential contaminants (e.g. heavy metals, hydrocarbons, pesticides, etc.) may be introduced through a variety of mechanisms. With respect to road construction, the source of contaminants would most likely be introduced via the new recycled material utilised or the nominated road construction practice. Other potential sources of contamination may result from the standard operation of the road (e.g. tyre rubber particles, hydrocarbons, etc.). It is noted that historical contamination present at the project site or adjacent to the site may also result in adverse human health and environmental impacts. Identification of the hazard associated with the introduced material and/or practice is essential to mitigating and managing the risk.

An understanding of the potential human health and environmental impacts can best be gained via the development of a conceptual site model (CSM). A CSM is a tool used in the determination of the potential risk to human health and/or the environment as a result of specific environmental conditions (National Environmental Protection Council 2013). The CSM is formulated to identify the likely presence or absence of the:

- source
- exposure pathway
- exposed population/receptor.

An example CSM detailing the interaction between recycled materials within a road pavement and surface water/groundwater flows is shown in Figure 2.6.

Figure 2.6: Diagram of interactions between water mechanisms and road pavement cross-section



Source: Austroads (2022c).

The potential for impacts to human health and the environment will vary depending on the type of recycled material (e.g. crushed concrete and bricks, crumb rubber, etc.) and the proposed road construction practice. An example of potential contamination sources, pathways and receptors is included within Table 2.4.

Table 2.4: Example contamination sources, pathways and receptors

Source	Pathways	Receptors
• Asbestos contamination of recycled crushed concrete and bricks utilised within road construction	Transport of asbestos fibres through the air during crushing and/or construction works. • Environmental: – air (dust) – soil • Human health: – inhalation	• Construction workers • General public

As the introduction of recycled materials in road construction presents an additional risk of human health and environmental impacts, it is essential that these risks are clarified and where present, mitigated or managed. This will ensure that the greater benefits associated with utilising recycled materials in road construction can be realised.

Mitigation of the potential impacts to human health and the environment are supported through the implementation of sustainable development activities. The World Health Organization describes sustainable development as broad scale actions that 'provide benefits today without sacrificing environmental, social and personal health in the future' (World Health Organization 2023).

Where applicable and appropriate, mitigation of any potential impacts associated with contamination can be achieved via a proactive assessment by suitably qualified and experienced consultants in accordance with the following standards and guidelines:

- *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards* (enHealth 2012)
- *Guideline: Assessment and Management of Contaminated Sites*, November 2021, Government of Western Australia (DWER 2021b)
- *Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia* 2021 (Department of Health 2021)
- N*ational Environment Protection (Assessment of Site Contamination) Measure 1999* (ASC NEPM) *(as amended 2013)* (National Environmental Protection Council 2013)
- *Per- and Poly-Fluoroalkyl Substances (PFAS) National Environmental Management Plan*, Version 2.0 January 2020 (PFAS NEMP) (HEPA 2020)

2.3.2 Work Health and Safety

Road construction works generally are associated with a myriad of work health and safety hazards. Example hazards include, but are not limited to exposure to noise, working around plant and equipment, exposure to dust and hazardous substances. Further, Safe Work Australia Workplace Exposure Standards (WES) exist for key road construction related air emissions hazards including bitumen fumes (asphalt, petroleum) and respirable crystalline silica (RCS) (Safe Work Australia 2022). It is important that these hazards are managed or mitigated in accordance with nationally accepted legislation and guidelines.

Where introducing sustainable materials and work practices, it is essential that any new or changed hazards are assessed and managed/mitigated accordingly. The hazards identification process must be conducted for all phases of the lifecycle of the material, including construction, maintenance, operation, demolition or dismantling and disposal. The hazards relevant to the conventional materials which are being replaced should also be identified for comparison. Appendix C of the *Safe Design of Structures: Code of Practice* (Safe Work Australia 2018) includes a checklist of potential hazards which may be considered in the assessment.

Further information on constructability health and safety impacts is included in Section 8.3.5.

2.4 Sustainable Road Construction Principles

In support of the use of recycled materials in road construction, or the implementation of sustainable road construction practices, it is essential that the following pillars of sustainability are considered:

- recycled materials to enable equivalent performance, if not better, than traditional materials
- introduce no uncontrollable health and safety concerns for workers or the general public
- produce no long-term environmental impacts (e.g. leachates/microplastics generation)
- be fully recyclable at end of life.

To ensure successful implementation of these pillars of sustainability, key factors need to be assessed, including:

- availability of materials.
  - This is particularly important to local government within Western Australia due to the geographical extent of the state, and material availability in a rural, regional and metropolitan context.
- applicability of the recycled material or sustainable road construction practice to the required works
- engineering performance
- cost implications

- whole-of-life impacts
- health, safety and environmental impacts
- environmental benefits.

To enable an effective review of the proposed recycled materials within a road construction context, the following parameters were identified for each recycled material and where possible, each sustainable road construction practice:

- general applications and specifications, in the Western Australian context
- engineering performance, with consideration of:
  - Benefits of utilising the recycled material (e.g. increase in material strength) or performance parameters in design.
  - Minimum properties for use in road construction (where applicable)
- environmental benefits and potential impacts
- work health and safety hazards and risks
- examples of the recycled materials being applied in field trials or construction projects.
- potential future applications, including:
  - current research projects
  - industrial developments (e.g. new recycling facilities).
  - emerging markets.

These parameters have been assessed for each recycled material in the subsequent sections. For a summarised factsheet on each recycled material, refer to the Practitioners Guide.

3 Road Construction in Western Australia

3.1 Funding Context

3.1.1 State Road Funds to Local Government Agreement

Through the *State Road Funds to Local Government Agreement 2023/24 to 2027/28* (MRWA 2023), local government is allocated a portion of funding from motor vehicle licence fee collections for works on local government roads. This includes:

- direct grants for local roads (untied funding for routine maintenance)
- road project grants (specific preservation and improvement high priority projects)
- the State Black Spot Program (for improving road safety in high-risk crash zones).

The Agreement states:

> As part of this Agreement, Local and State Governments commit to:
>
> Increasing sustainable road construction practices through the greater use of recycled materials.

and

> Within the first two years of this Agreement Main Roads Western Australia, WALGA and RRGs will collaborate to establish a system(s) / process(s) for monitoring, reporting and advancing the use of recycled materials focusing, but not limited to, LGA works funded within this Agreement.

These documents respond to this commitment.

None of the local government managed programs listed above specifically require, nor exclude the use of recycled materials or sustainable construction methods, however the capital cost is a significant determining factor in all of them. WALGA is currently working with the Regional Road Groups to include sustainability in the multi-criteria assessment methodology that is used to prioritise projects funded from the road project grants category in the Agreement.

Whilst these documents are supported by and targeted to projects funded through the state roads agreement, it is envisaged that it will be suitable for use for all local government road construction works.

3.1.2 Commonwealth and Other State Funding Programs

Local governments may be able to access funding through the Regional Economic Development grants (DPIRD 2023), subject to meeting the regional priorities (for their region) and grant submission requirements provided by the Department of Primary Industries and Regional Development (DPIRD).

Local governments may also be able to access funding through the Growing Regions Program managed through the Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA). This Australian government agency program 'provides grants of between $500,000 and $15 million to local government entities for capital works projects that deliver community and economic infrastructure projects across regional and rural Australia' (DITRDCA 2023).

The guidelines can assist with identifying suitable recycled materials and methods to use in road construction. When the project scopes and benefits are aligned to the grants program objectives, the recycled materials and methods can form part of submissions for the above grant programs.

3.1.3 Local Government Revenue

Funds provided through the State Road Funds to Local Government Agreement can cover 100% of funding (via direct grants and Australian Black Spot Program grants), or up to two-thirds (66%) of funding via the other funding sources.

Each local government will need to fund the balance that is not covered by the agreement and will also need to fund any projects and works that do not meet the grant funding program requirements. Local government funded projects are not driven by the imperative to meet the commitment for sustainable road construction practices inherent in the funding programs. Local governments are therefore driven to adopt recycled materials and sustainable construction methods due to:

- cost savings, where recycled materials and methods can be sourced at lower cost than non-recycled
- reductions in landfill and cost savings that can arise
- social values in protecting the environment and reducing waste, driven through councils
- government and corporate obligations towards supporting the Western Australian *Waste Avoidance and Resource Recovery Strategy 2030*.

3.2 Road Construction Scenarios

The documents are designed to support road managers to make decisions at the project level. The decision process in the documents therefore needs to cover the range of project scenarios likely to be encountered across the state. The scenarios are defined in terms of the type of work and the locality, which are the most likely drivers defining the availability and applicability of recycled materials and sustainable practices.

The following road construction scenarios have been prepared to support the effective implementation of these documents. These scenarios have been based on:

- localities
- project types.

3.2.1 Localities

The state of Western Australia is the largest state by area in Australia. The majority of the population in Western Australia lives in and around the greater Perth Region, with 80% of the population residing in 0.25% of the total available land area (approximately 253 billion hectares) (Australian Bureau of Statistics 2021). Different areas within Western Australia require different types of road construction. To facilitate the implementation of these documents, despite the vast locality differences, the following localities have been established:

- Metropolitan
- Regional (includes outer Metropolitan)
- Remote
- Very remote.

Metropolitan WA

Metropolitan WA primarily includes the greater Perth region.

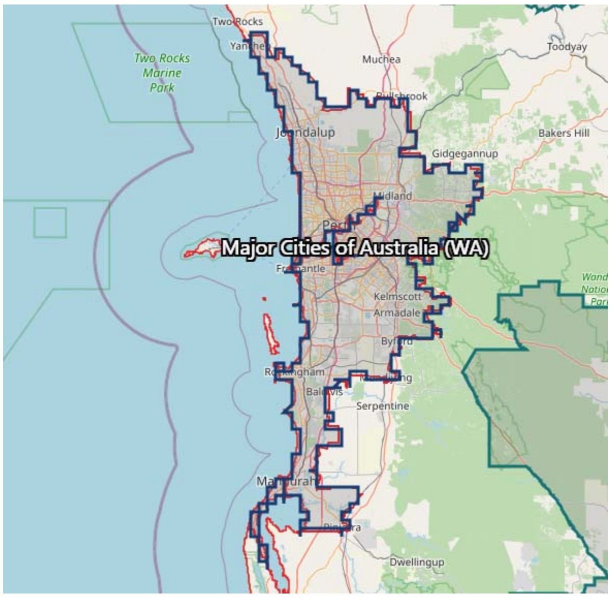
A map of this area is shown in Figure 3.1 and Figure 3.2. The challenges and benefits of conducting sustainable road construction works in this region are detailed in Table 3.1. In accordance with the MRWA *Operational Procedure 112 – Operational Boundaries and Asset Responsibilities* (MRWA 2020b), the following local government areas are listed as metropolitan local government: City of Armadale, Town of Bassendean, City of Bayswater, City of Belmont, Town of Cambridge, City of Canning, Town of Claremont, City of Cockburn, Town of Cottesloe, Town of East Fremantle, City of Fremantle, City of Gosnells, City of

Joondalup, Shire of Kalamunda, Town of Kwinana, City of Melville, Town of Mosman Park, Shire of Mundaring, City of Nedlands, Shire of Peppermint Grove, City of Perth, City of Rockingham, Shire of Serpentine-Jarrahdale, City of South Perth, City of Stirling, City of Subiaco, City of Swan, Town of Victoria Park and Town of Vincent or City of Wanneroo.

Figure 3.1: Metropolitan WA within the state

Source: Australian Bureau of Statistics (2022).

Figure 3.2: Metropolitan WA



Source: Australian Bureau of Statistics (2022).

Note that Figure 3.2, being produced from the Australian Bureau of Statistics site, does not exactly match the definition of regional local governments from the Department of Local Government, Sport and Cultural Industries. For example the City of Mandurah (appearing at the southern end of the figure) is identified as regional by the Department.

Table 3.1: Metropolitan WA locality challenges and opportunities

Locality	Challenges	Opportunities
Metropolitan	• High volume of road users to manage during construction • Higher engineering performance requirements • Low cost of transport waste to landfill, countered by high landfill charges	• High availability of suppliers within close proximity • Reduced cost of transport for recycled materials

Regional WA

Regional WA is positioned in an inner regional area and an outer regional area surrounding the greater Perth region.

A map of this area is shown in Figure 3.3 and Figure 3.4. The challenges and benefits of conducting sustainable road construction works in this region are detailed in Table 3.2.

Figure 3.3: Inner regional WA

Source: Australian Bureau of Statistics (2022).

Figure 3.4: Outer regional WA

Source: Australian Bureau of Statistics (2022).

Table 3.2: Regional WA locality challenges and opportunities

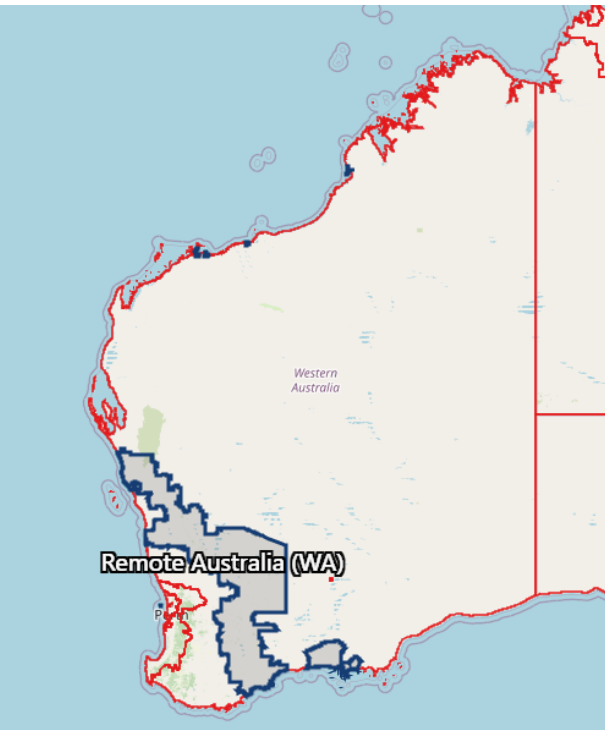
Locality	Challenges	Opportunities
Regional	• Longer distance for transport of supplies (primarily outer regional areas) • Higher cost of transport for recycled materials • Lower waste levy for landfill in regional areas • Environmentally sensitive ecosystems • Some local governments have limited resources and expertise	• Apart from the newer urban areas, lower volume of road users than in metropolitan areas • Greater opportunity for own waste sourcing and separation • Greater opportunity for partnerships with large private operators e.g. mines

Remote WA

A large portion of remote WA surrounds the regional areas, with small isolated remote zones along the northwest coastline.

A map of this area is shown in Figure 3.5. The challenges and benefits of conducting sustainable road construction works in this region are detailed in Table 3.3.

Figure 3.5: Remote WA



Source: Australian Bureau of Statistics (2022).

Table 3.3: Remote WA locality challenges and benefits

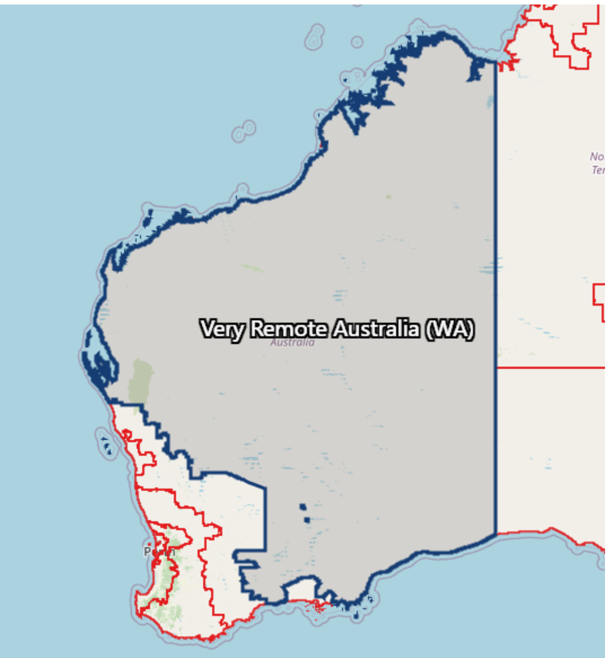
Locality	Challenges	Opportunities
Remote	• Limited suppliers within close proximity • Long distances for transport of supplies • Lower waste levy for landfill in remote areas • Environmentally sensitive ecosystems • Local governments have limited resources and expertise	• Low volume of road users • Potential for equipment and machinery to be available in (relatively) close proximity due to the prevalence of the mining industry in WA • Greater opportunity for own waste sourcing and separation • Greater opportunity for partnerships with large private operators e.g. mines

Very remote WA

The majority of Western Australia (by area) is considered very remote. It generally includes all areas outside of the state's southwest.

A map of this area is shown in Figure 3.6. The challenges and benefits of conducting sustainable road construction works in this region are detailed in Table 3.4.

Figure 3.6: Very remote WA



Source: Australian Bureau of Statistics (2022).

Table 3.4: Very remote WA locality challenges and benefits

Locality	Challenges	Opportunities
Very remote	• Limited suppliers within close proximity • Long distances for transport of supplies • Environmentally sensitive ecosystems • Difficult to justify road construction expenditure due to low volume of users • Local governments have limited resources and expertise	• Low volume of road users • Potential for equipment and machinery to be available in (relatively) close proximity due to the prevalence of the mining industry in WA • Greater opportunity for own waste sourcing and separation • Greater opportunity for partnerships with large private operators e.g. mines

3.2.2 Project Types, Materials and Methods

Whilst it is envisaged that these documents will support improvements to sustainability in all road construction projects, several key project types, materials and methods have been identified as ideal for implementation. These types of projects may be fully or partly funded through the state roads agreement.

Key project types, materials and methods to which these documents would apply, include:

- granular resheeting/stabilisation (rural/regional)
- seal/reseal (regional/rural)
- rehabilitation base and seal (rural/regional)
- upgrade widening (all)
- asphalt overlay (metro)
- metro rehabilitation (mill and re-mill) – base rehabilitation
- improvement projects (all) e.g. new carriageway, turning lanes, traffic circles etc.

These types are described further in Table 3.5. A schematic of typical road infrastructure components has been included in Figure 3.7.

A methodology for assessing which project types, materials and methods can be applied is detailed in Section 8.

Table 3.5: Project types and road infrastructure components

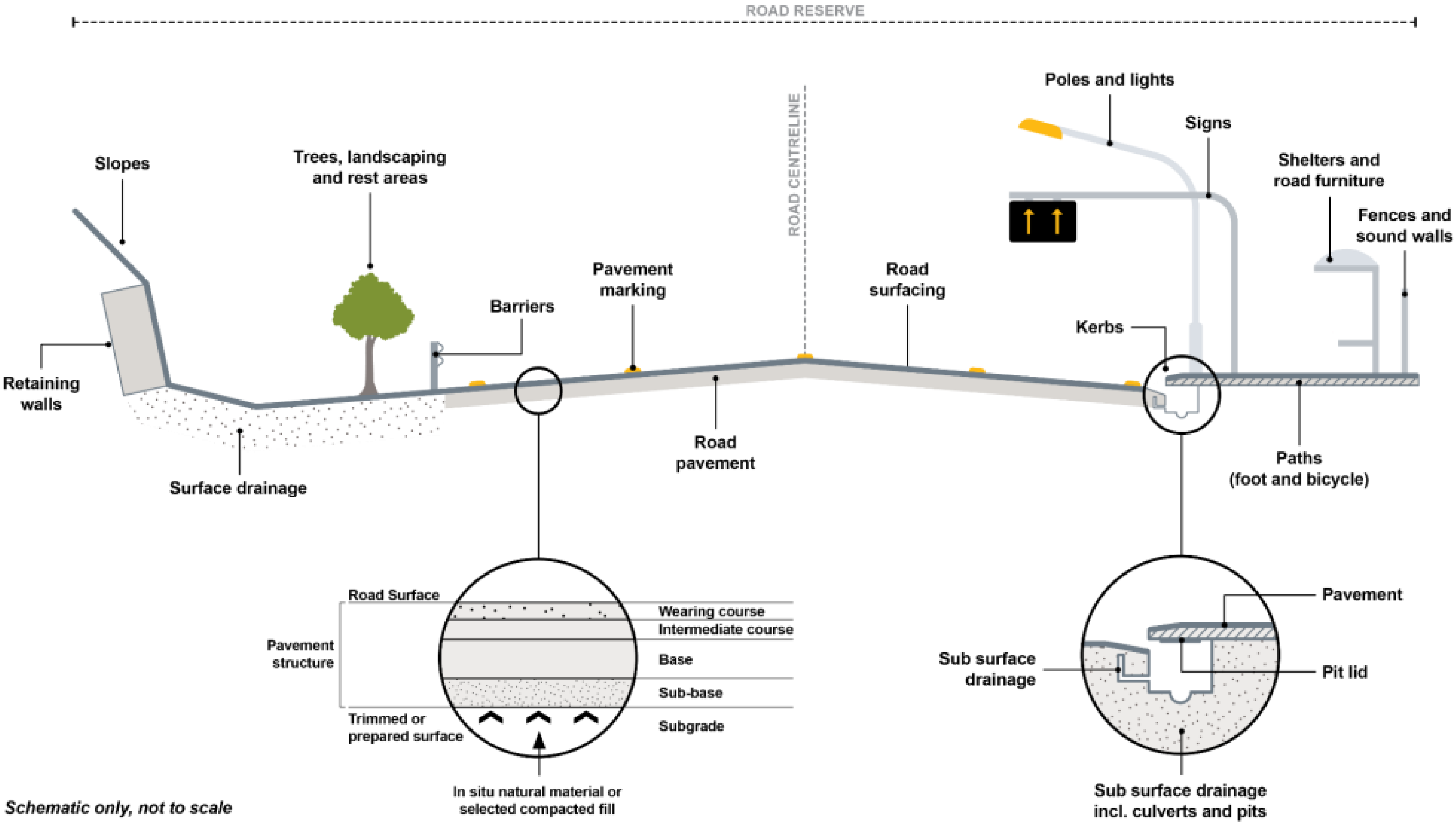
Project type	Locality	Description	Road infrastructure components					
			Seals	Asphalt	Unbound pavements	Concrete[1]	Earthworks/ Embankment	Ancillaries
Granular resheeting/ stabilisation	Regional Remote Very remote	Road pavement stabilisation: The modification of any natural or prepared material to improve or maintain its load carrying capacity. Several different materials and techniques are available to enable stabilisation (e.g. fly ash can be used in lime stabilisation, stabilisation can be carried out in situ). Resheet: To recondition a pavement, by adding a new layer of material			✓	✓	✓	
Seal/reseal	Regional Remote Very remote	Seal: A seal is a thin surface layer of bituminous material into which aggregate is incorporated. It is applied to provide a durable wearing course Reseal: A sprayed seal applied to a surface which has an existing seal For pavements, bitumen resealing, asphalt re-sheeting and gravel re-sheeting are the most common forms of periodic maintenance.	✓	✓				
Rehabilitation base and seal	Regional Remote Very remote	Rehabilitation (pavement): Major surfacing action for the purpose of returning the structural condition of the pavement to its as-constructed or design condition (i.e. recurring or maintenance), or to exceed the as-constructed condition (i.e. capital or construction). Base/Basecourse: One or more layers of material usually constituting the uppermost structural element of a pavement and on which the surfacing may be placed. It may be composed of fine crushed rock, natural gravel, broken stone, stabilised material, asphalt or Portland cement concrete Seal: A seal is a thin surface layer of bituminous material into which aggregate is incorporated. It is applied to provide a durable wearing course	✓	✓	✓	✓		
Upgrade widening	All	The widening of an existing pavement or carriageway generally without alteration of level	✓	✓	✓	✓	✓	✓
Asphalt overlay	Metropolitan	Asphalt pavement: A pavement, the predominant structural strength of which is provided by asphalt layers		✓				
Metro rehabilitation (mill and re-mill) – base rehabilitation	Metropolitan	Milling: Removing the surface of a pavement (typically 25 to 7 mm in depth) with a machine equipped with a transverse rotating cutter drum	✓	✓	✓	✓		

Project type	Locality	Description	Road infrastructure components					
			Seals	Asphalt	Unbound pavements	Concrete[1]	Earthworks/ Embankment	Ancillaries
Improvement projects	All	**Improvement projects:** For example, new carriageway, turning lanes, traffic circles, etc.	✓	✓	✓	✓	✓	✓

1. Concrete for pavements not prevalent in WA.

Source: MG Lay Library (2015).

Figure 3.7: Typical road infrastructure components



Source: MRWA (2022).

4 Review of Recycled Materials and Applications

4.1 Recycled Materials and Products

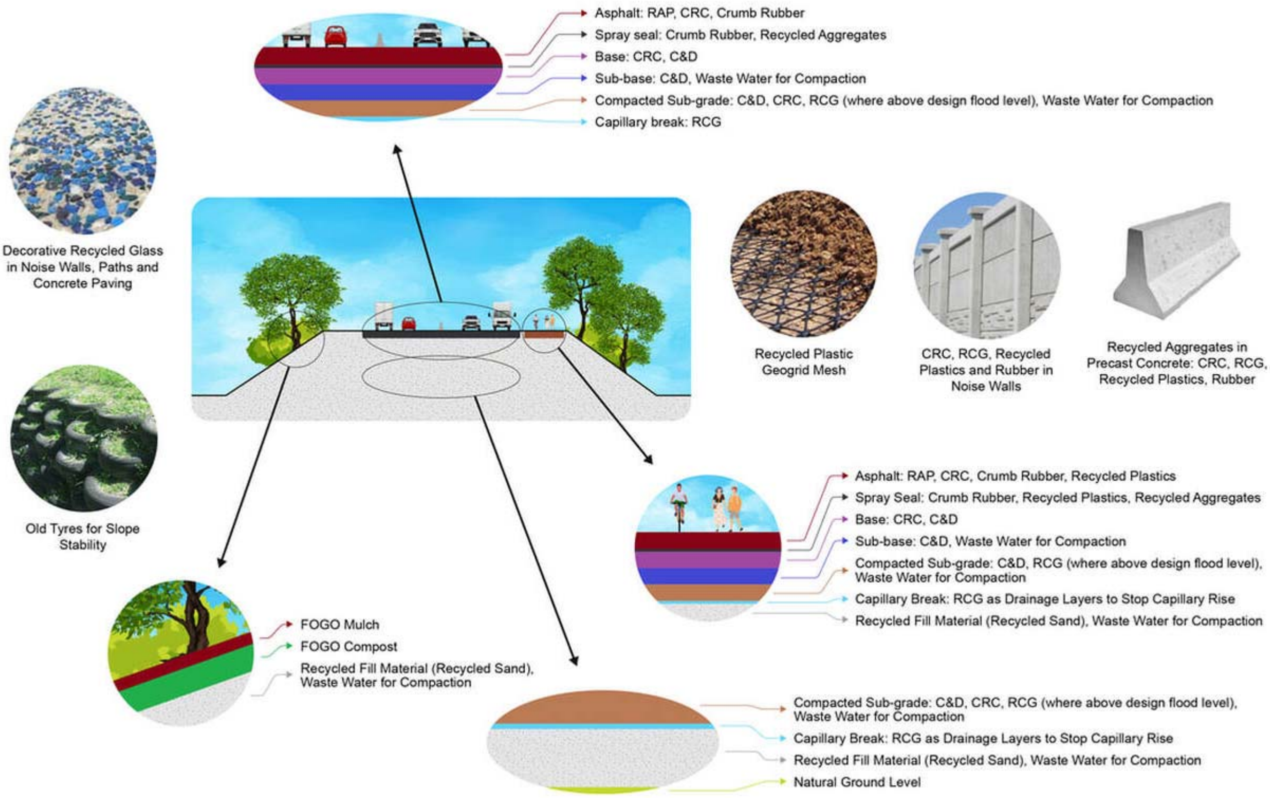
A literature review was undertaken to produce a comprehensive guideline containing current established road building recycled materials options and products, suitable for use on local roads within WA. The review incorporated information from specifications and guidelines within WA and other jurisdictions.

The following recycled materials were identified as established or in progress during the review and are further detailed in the subsequent sections:

- reclaimed asphalt pavement (RAP)
- crushed recycled concrete and crushed brick
- crushed glass
- crumb rubber
- fly ash
- bottom ash
- blast furnace slag
- food and garden organics (FOGO)
- recycled plastics
- recycled materials in road furniture
- emerging materials.

An example of best practice integration of some of these materials in road construction is shown in Figure 4.1.

Figure 4.1: Example integration of recycled materials in road construction



Source: SWA Innovation Hub (2022).

Several states within Australia, including WA and national organisations have produced best practice guides for the use of recycled materials in road construction. The following best practice guides have been utilised in the development of this literature review and to provide insight for the development of the Technical Report: Sustainable road construction practices for Local Government roads in WA:

- State based:
  - Department of Transport and Main Roads Queensland (TMR), Technical Note TN193 – *Use of Recycled Materials in Road Construction*, September 2020 (TMR 2020).
  - Ecologiq Victoria, *Recycled Materials in Road Infrastructure, Reference Guide* – September 2022 (Ecologiq 2022).
  - Main Roads Western Australia (MRWA), *Recycled and Sustainable Materials at Main Roads, Reference Guide*, November 2022 (MRWA 2022)
- National organisations:
  - Austroads, *Guide to Pavement Technology Part 4E Recycled Materials*, 2022 (Austroads 2022c).
  - Australian Road Research Board (ARRB), *Best Practice Expert Advice on the Use of Recycled Material in Road and Rail Infrastructure*, June 2022 (Hall et al. 2022).

4.1.1 Reclaimed Asphalt Pavement (RAP)

Reclaimed asphalt pavement (RAP) is former pavement material from an asphalt wearing or intermediate course which has been milled and re-processed for reuse in new roads (MRWA 2022). Dependent on state and local requirements, RAP has the potential to be used in the hotmix asphalt wearing course, basecourse and intermediate course (Hall et al. 2022).

The main use of RAP is as a component in the manufacture of new hot mix asphalt, however other processes that incorporate RAP include:

- in situ hot asphalt (hot-in-place asphalt recycling (HIPAR))
- in situ cold asphalt recycling
- cold plant (pug mill) mixing of RAP material (Rice et al. 2020).

Sustainable road construction practices are further discussed in Section 4.2.

General applications and specifications

RAP is approved for use through the MRWA specification, however these specifications limit the use of up to 10% RAP to be incorporated into the structural layers (i.e. not surface layers) of full-depth asphalt without additional mix design requirements (MRWA 2022).

MRWA (2022) notes that several local suppliers in Perth have approved mix designs containing 20–25% RAP. Due to the heat capacity, gaseous hydrocarbon emissions and processing costs, an upper limit of RAP content in hotmix asphalt is typically considered to be 40–50% (Rice et al. 2020).

The WALGA specification for the supply of recycled road base (Institute of Public Works Engineering Australasia (IPWEA & WALGA 2016) includes provisions for the use of RAP in base and subbase materials in proportions of up to 10% or 15% by mass. RAP that is highly variable in nature and physical properties may be more suited for use in granular pavement or fill applications (Nguyen et al. 2021).

Specifications relating to the use of RAP in WA are included within Table 4.1. Outside of WA, other state-based road agencies permit incorporating RAP within asphalt, with some states permitting higher proportions (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of RAP for use in applications not currently covered by Western Australian specifications.

Table 4.1: RAP specifications

Specification	Agency	Application
WA		
Specification for the Supply of Recycled Road Base (IPWEA & WALGA 2016)	Institute of Public Works Engineering Australasia/ Western Australia Incorporated and Western Australia Local Government Association	• Base < 50 mm asphalt or spray seal • Base ≥ 50 mm asphalt • Subbase • Class 1: Maximum 10% by weight • Class 2: Maximum 15% by weight
Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Road Surfacing (IPWEA/AAPA 2016a)	WALGA	• Requirements for materials. • Requirements for a RAP management plan.
Recycled Road Base and Recycled Drainage Rock (Waste Authority 2021)	Waste Authority	• Base and drainage
Specification 501 Pavements	MRWA	• Up to 15% (by mass of the material larger than 4.75 mm) of pavement materials can be RAP
Specification 504 Asphalt Wearing Course	MRWA	• The use of RAP for surface layers is not allowed
Specification 510 Asphalt Intermediate Course	MRWA	• The use of up to 10% RAP in asphalt intermediate course layers is allowed
Specification 515 In situ Stabilisation of Pavement Materials	MRWA	• The use of up to 10% (by volume) RAP in stabilised base and subbase layers is allowed
National		
EME2 Model Specification (Australian Asphalt Pavement Association (AAPA) 2018a)	Australian Asphalt Pavement Association (AfPA)	• High modulus asphalt • EME2 mix designs may include up to 15% RAP
Guide to Pavement Technology: Part 4E (Austroads 2022c)	Austroads	• Holistic guide to the use of recycled materials in roads • Framework for assessment of recycled materials.

Engineering performance

The quantity of RAP used within the asphalt mix can have an impact on overall engineering performance. Quantities of up to 20% (above currently accepted limits in WA) are reported to be comparable to a virgin asphalt mix, with little impact noted on properties such as ravelling, fatigue cracking, rutting and weathering (Hall et al. 2022). Asphalt mixes containing RAP have been found to be comparable in tensile strength, however, they may show an increase in stiffness compared to virgin asphalt (Hall et al. 2022).

Environment

Utilising RAP presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. It also has the potential to minimise or reduce the demand for virgin materials, in turn reducing the potential environmental impacts associated with extractive industry.

The potential impacts to the environment from the use of RAP will be associated with the types of materials originally utilised within the pavement (i.e. asphalt, asphalt with crumb rubber, etc.), but also the site conditions the former road was subject to. For example, RAP may include contaminants from vehicles, adjacent industrial activities, etc. If a road is situated next to an Australia Defence Force Base or an airport, the RAP may also be subject to contamination from per- and poly-fluoroalkyl substances (PFAS). If there is uncertainty around the contamination status of the asphalt material proposed to be utilised as RAP, advice should be sought from a suitably qualified environmental professional.

Waste asphalt is generally considered Inert Waste type 1 (detailed below) in accordance with the Landfill waste classification and waste definitions (DWER 2019b). The material will be considered a waste until it is reprocessed into a reusable product (RAP).

> Inert: Wastes that are largely non-biodegradable, non-flammable and not chemically reactive.
>
> Inert waste type 1: contains contaminants in concentrations less than the specified criteria.

The asphalt recycling process itself introduces several potential environmental benefits and risks. These are discussed further in Section 4.2.

Work health and safety

Similar to the potential environmental impacts, an increased health and safety risk may be associated with using RAP where the RAP contains unusual materials (e.g. plastics, crumb rubber, or historic pollutants) (Austroads 2022c). For typical unaltered RAP, it is likely that the health and safety risks associated with reprocessing will not exceed that of virgin asphalt construction. Prior to the use of RAP, a risk assessment should be completed to determine any atypical features and the likely resultant risk addition.

Waste recovery process

As asphalt pavements are fully recyclable, the potential to 'extract' and stockpile RAP for use in asphalt mixes is relatively high when compared with other waste materials, as the end-of-life location of the feedstock is not limited to being nearby to asphalt plants. The recovery process for RAP begins with milling of existing asphalt pavement at its end-of-life and breaking it down so it can be used as an aggregate in future asphalt mixes. RAP can also be obtained from waste of asphalt plant or from pavement chunks or cut offs removed from pavements during maintenance. Asphalt millings are then stockpiled before being processed and crushed for their use as an aggregate in future pavement mixes. Finally, the RAP is transported to the asphalt plant that combines the RAP according to specifications and their approved mixes. Examples of RAP stockpiles are shown in Figure 4.2.

Figure 4.2: Stockpile of RAP

Source: [Alex Fraser site visit] n.d., NTRO

However, in WA, RAP availability is limited due to the proportion of pavement that has only a thin layer of asphalt on deep granular pavement, which limits the amount of feedstock available for recovery. Although RAP can be imported from other states, low supply and large transportation distances of waste asphalt or RAP stockpiles could be a limitation on the usage of RAP in WA. Furthermore, due to this limit and the financial cost of importing or transportation, asphalt companies will typically use RAP milled in metropolitan or local areas. For rural areas, it is likely more economical to treat pavement in situ using foam bitumen stabilisation. Rural areas might also look into to use mobile asphalt plants for the incorporation of locally acquired RAP into their asphalt.

Case study

To demonstrate the successful reuse of this beneficial resource on a local level, the following case study from works undertaken by the City of Canning WA has been included below. This case study has been sourced from *The Use of Recycled Materials for Pavements in Western Australia*(Cocks et al. 2017) and demonstrates a local council's ingenuity with the sustainable reuse of construction materials.

Case Study: City of Canning RAP

The City of Canning has had a policy of storing all road profiling from any road construction or maintenance operations for future use, and this includes reclaimed asphalt from profiling jobs where only thin layers of asphalt are removed prior to resurfacing. For many years, the City offered free tipping at its landfill site for this material, and recycled the material in various layers depending on the type of road.

The material has been used widely as a subbase in heavy duty pavements, and as a base in residential pavements. Reclaimed asphalt has been used in hard stands, where over time with the heat of the sun in summer, the material becomes lightly bound and resists traffic quite well. Over the years however, other organisations have realised the value of recycled pavement materials and the supply of free material from other road agencies has now become scarce.

The City has undertaken no performance tests on the recycled asphalt material, but has been able to monitor the performance of roads using recycled materials for many years. In the case of heavy-duty pavements carrying significant truck traffic, it has only been used as a subbase. There have been no performance issues observed in the 25 year history of using this material in a subbase application that could be attributed to the subbase. In the case of lower volume roads, such as Carden Drive in Cannington, the entire road was constructed using reclaimed pavement material with a large proportion of asphalt. This road carries 1,700 vpd with 4% heavy vehicles and is now 22 years old and shows no signs of distress. The pavement consists of 300 mm of RAP on a sandy clay subgrade with 30 mm asphalt surfacing. Many other existing pavements in Canning in residential areas have been constructed with RAP and are performing as well as any conventional pavement after more than 20 years, showing no signs of distress.

Reclaimed pavement from old road pavements can successfully be used as a base in low volume roads and as a subbase in high volume roads. Where a high proportion of asphalt exists in the reclaimed material, it makes an excellent hardstand surfacing for informal truck and machinery parking areas and will over time under the influence of heat from the sun, become sufficiently bound to remain stable under turning vehicles.

Source: Cocks et al. (2017).

Potential future applications

Research indicates that up to 100% of RAP could be used in the production of new asphalt pavements (Hall et al. 2022). There is a potential that increased percentages of RAP could be explored within WA on an as needed basis (depending on the project, locality, etc.). A recent WARRIP research project investigated current materials and practice, in addition to plant capability in the Perth metropolitan area, resulting in the development of draft *Engineering Road Note 13B: Asphalt Mix Design with RAP* (ERN 13B) (Aswegen & Latter 2019).

With the integration of recycled materials within road infrastructure, additional research may be required into the suitability of reusing atypical RAP (e.g. RAP containing crumb rubber, plastics, crushed recycled concrete and bricks, etc.). Recent research conducted through WARRIP indicated that crumb rubber modified asphalt can be reused as RAP (Hall et al. 2022). This is supplemented by recent research completed on the future recyclability of RAP containing plastics by Austroads. It was concluded that the preliminary outcomes indicate the methodology for making RAP containing plastics is effective (Austroads 2022e).

4.1.2 Crushed Recycled Concrete and Crushed Brick

Crushed recycled concrete and crushed brick for use in road construction are typically generated from construction and demolition waste. The materials primarily comprise aggregates and cementitious adhesion medium, however foreign materials such as timber, steel and plastics generally require removal prior to reuse (Hall et al. 2022).

General applications and specifications

Crushed recycled concrete is approved for use through the MRWA specification as subbase material only. Extensive long-term trials have demonstrated that this recycled material is suitable for use as subbase under full-depth asphalt pavements (MRWA 2022).

To enable the additional use of sustainable materials, WALGA in conjunction with the IPWEA have prepared the *Specification for the Supply of Recycled Road Base* (IPWEA & WALGA 2016). This specification enables crushed recycled concrete to also be reused in road base applications.

Crushed brick is permitted for use to a maximum limit of 15% by mass retained on a 4.75 mm sieve in both MRWA and WALGA specifications as recycled road base. The *Roads to Reuse Recycled Base and Recycled Drainage Rock* specification (Waste Authority 2021) also allows crushed bricks to be used in recycled drainage rock.

Specifications relating to the use of crushed recycled concrete and crushed brick in WA are included within Table 4.2. Outside of WA, other state-based road agencies permit incorporating crushed recycled concrete and brick within pavements, footpaths and kerbs and within channels and culverts (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of crushed recycled concrete and crushed bricks for use in applications not covered by Western Australian specifications.

Table 4.2: Crushed concrete and bricks specifications

Specification	Agency	Application
WA		
Specification for the Supply of Recycled Road Base (IPWEA & WALGA 2016)	Institute of Public Works Engineering Australasia/ Western Australia Incorporated and Western Australia Local Government Association	• Crushed recycled concrete – Base < 50 mm asphalt or spray seal – Base ≥ 50 mm asphalt – Subbase – Class 1: Maximum 95% by weight – Class 2: Maximum 95% by weight as base, 100% by weight as subbase • Crushed bricks – Class 1: Maximum 10% by weight – Class 2: Maximum 15% by weight
Recycled Road Base and Recycled Drainage Rock (Waste Authority 2021)	Waste Authority	• Base (predominantly concrete) and drainage (mixture of coarse grained aggregate, including bricks) (waste processing specification)
Specification 501 Pavements	MRWA	• Crushed recycled concrete – Crushed recycled concrete may be used as subbase material under full depth asphalt pavements, subject to limitations. – Supply of crushed recycled concrete. • Crushed bricks – Up to a maximum limit of 15% by mass retained on a 4.75 mm sieve.
National		
AS 2758.1-2014 Aggregates and Rock for Engineering Purposes	Australian Standards	• Provides a basis for specifying requirements for aggregates intended for use in the production of concrete, including precast products.
Guide to Pavement Technology: Part 4E (Austroads 2022c)	Austroads	• Holistic guide to the use of recycled materials in roads. • Framework for assessment of recycled materials.

Engineering performance

Crushed recycled concrete is known to increase in strength and stiffness over time (IPWEA & WALGA 2016). It can be used in both bound and unbound applications (Austroads 2022c). The engineering performance of the material and its suitability for use in road construction projects will be subject to the nature of the parent concrete, the extent of contaminants present and the process utilised to recycle the materials (Hall et al. 2022). Some of the technical risks and mitigation measure associated with using crushed recycled concrete have been detailed by MRWA (2022) (refer Table 4.3).

Table 4.3: Risks associated with using crushed recycled concrete

Risk	Cause	MRWA mitigation measures
Cracking	Reactivation of cement	• Use as subbase under full depth asphalt. • Do not use as basecourse under heavy traffic. • Apply geofabric seal if used as basecourse.
Popping	Expansive contaminants (e.g. aluminium, gypsum)	• None identified (steel is removed). • Remove and replace if occurs.
Hazardous contaminants	Asbestos and other hazardous materials not removed in demolition	• Refer to Roads to Reuse product specification for recycled road base and recycled drainage rock (Waste Authority 2021). • Robust management systems. • Supplier end product testing. • DWER independent audit testing.
pH	Reactivation of cement	• Do not use near wetlands or groundwater sources.

Source: MRWA (2022).

Research indicates that crushed recycled concrete performs satisfactorily when compared to virgin aggregates, and it typically has higher moisture absorption, lower impact resistance, lower density and lower abrasion resistance (Hall et al. 2022).

Crushed brick is reported to have a high shear strength and good compactability and hence, suitable to be used as embankment fill (Sharma and Shrivastava 2022). The susceptibility of crushed brick to crushing though, restricts its use in road base applications. Arulrajah et al. (2011) suggested that crushed brick can be used in subbase layer. It is also reported that crushed brick could be blended with other recycled materials, such as crushed recycled concrete, to improve its durability and performance. Arulrajah et al. (2012) recommended that up to 25% crushed brick could be blended with crushed recycled concrete for road applications.

Environment

Utilising recycled crushed concrete and brick presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. As an aggregate replacement for use in road construction, it also has the potential to minimise or reduce the demand for virgin materials, in turn reducing the potential environmental impacts associated with extractive industry.

Similar to RAP (refer Section 4.1.1), the contaminants present in crushed recycled concrete and brick will depend significantly on the previous use of the product prior to demolition. Potential contaminants of concern may be extensive. For example, structures scheduled for demolition are often likely to originate from a time where the use of asbestos containing materials (ACM) was commonplace. Also, materials originating from high-risk activities such as a fuel station are likely to be impacted by hydrocarbons and not be suitable for reuse. The level of risk associated with the potential presence of these contaminants will determine the extent of processing and testing required to achieve a product suitable for reuse, if possible.

Another element for consideration is the pH of the material. Crushed recycled concrete is typically alkaline in nature and an elevated pH has the potential to leach from the materials. Crushed bricks can also have an elevated pH (Bauer et al. 2022). Whilst this leachate is likely to be buffered by the surrounding soil and reduce the likelihood of potential impacts to the surrounding environment, the following requirements are stipulated in the Roads to Reuse specification (Waste Authority 2021):

- pH > 9 only to be used under bituminous seal or asphalt.
- Recycled products should not be used within 0.5 m of the maximum groundwater level.
- Recycled products should not be used within public drinking water source locations.

Work health and safety

Two notable WHS risks that may be potentially introduced via the use of recycled crushed concrete and brick include:

- exposure to asbestos
- exposure to respirable crystalline silica (RCS).

Inhalation of asbestos fibres can cause asbestosis, lung cancer and mesothelioma (DWER 2021a). Symptoms of these diseases do not usually appear for approximately 20 to 30 years after the initial exposure to asbestos. Asbestos typically comes in 2 forms, bonded and fibrous. If asbestos fibres are in a stable material such as bonded asbestos-cement sheeting and are in good condition, they pose little health risk. If the bonded material is damaged, the fibres can become loose and airborne and pose a risk to health.

Similar to asbestos, exposure to RCS can result in a silicosis, an irreversible and progressive respiratory condition. It is a naturally occurring mineral that is a found in sand, concrete, bricks and rocks (e.g. granite, slate, sandstone) (Department of Mines, Industry Regulation and Safety 2021). Tasks that produce dust from these materials (e.g. dry sanding, dry cutting, earthworks, etc.) may increase the risk of exposure to workers.

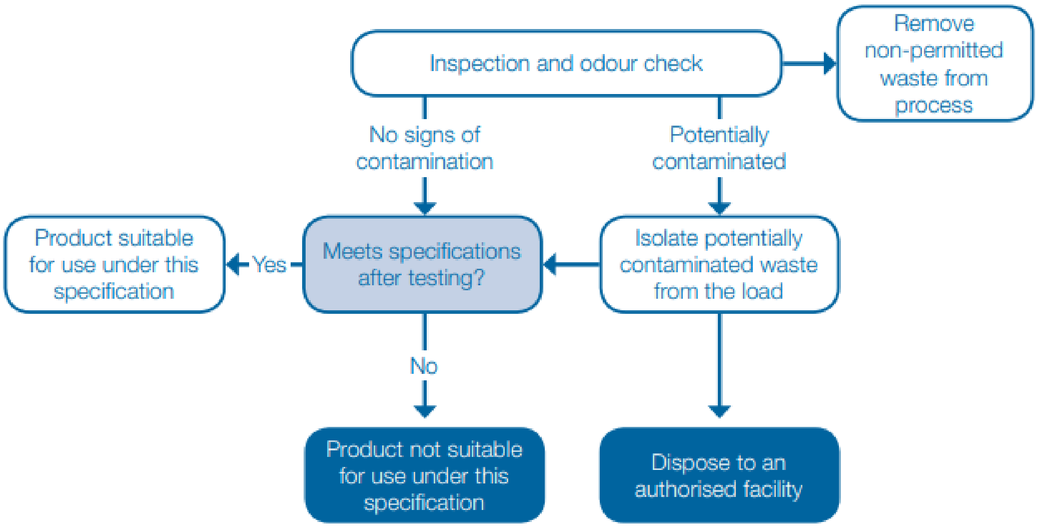
It is essential that risks associated with potential exposure to asbestos and RCS are managed where recycled crushed concrete and brick are to be utilised. Additional WHS risks associated with potential unknown contaminants are likely to be either reduced during processing or managed via appropriate personal protective equipment (PPE) and effective work hygiene controls.

Waste recovery process

In addition to materials such as brick and sand, the potential to recycle crushed recycled concrete and crushed brick into road infrastructure can greatly improve the sustainability of the construction and demolition sector. The waste from this sector will normally be collected at a drop off location or plant, as opposed to any on-site processes. This first step to recycling crushed concrete and brick is to remove any contaminants from the waste, such as steel, timber and plastics that are commonly added to concrete in the initial construction process. The processes used for this will vary depending on the contaminant and may include equipment such as compactors, separators, magnets, pulverisers and crushers. Once the concrete has been separated from the contaminants it can then be crushed and graded according to its application. Ensuring the concrete is free from contamination is highly important to its usefulness as a recycled product, therefore, recycling facilities must ensure their production of crushed recycled concrete is to the acceptable standard.

Roads to Reuse WA includes a product specification for recycled road base and recycled drainage rock (Waste Authority 2021). This specification details the pre-acceptance, acceptance, processing sampling and analysis and record keeping requirements to achieve the desired product (refer Figure 4.3). Ensuring the facility processing this waste for reuse has implemented this (or similar) process is essential to minimising any potential environmental impacts.

Figure 4.3: Waste acceptance process



Source: Waste Authority (2021)

Case study

To demonstrate the successful reuse of this beneficial resource on a local level, the following case study from the upgrade of Welshpool Road, City of Canning WA has been included below. This case study has been sourced from the City of Canning (2017) Information Sheet: *Use of Recycled Construction and Demolition Material in Civil Construction Projects*.

Case Study: Construction and Demolition Material in the Upgrade of Welshpool Road, City of Canning

Construction and demolition material was used as road base and subbase for an 860 m section of Welshpool Road, from a point west of Sevenoaks St to Leach Hwy in Welshpool. The road was a 4 lane undivided road, being widened by 4.5 m on each side of the existing road pavement. Welshpool Road carries a significant number of heavy vehicles including road trains serving 2 stock food manufacturers, and extra wide low loaders serving several heavy engineering construction companies. After construction, testing indicated that the road pavement produced using recycled material was at least as strong, and possible stronger, than conventional road base. Further testing over time has shown that the recycled product gains considerable strength with curing and is now very much stronger than conventional base materials.

Additional benefits of the use of recycled construction and demolition materials included:

- significant cost savings compared with traditional quarried materials
- savings in the disposal costs for demolished road materials, including concrete paths and kerbs. These materials were carted to the recycling yard for processing, rather than disposed of in landfill at a cost
- savings in transportation costs and associated greenhouse gas emissions
- approximately 2,000 m^3 of materials diverted from landfill
- approximately 2,000 m^3 of new materials saved from extraction from the environment.

Source: City of Canning (2017).

Potential future applications

The potential future application of crushed recycled concrete and brick primarily relates to improved capture and recycling of construction and demolition waste and also increased uptake in road infrastructure projects. Some of the key barriers to this uptake relate to a perceived high contamination rate, a lack of awareness of the benefits of recycling over landfilling and haulage distances (virgin materials are often available locally through quarries and borrow pits) (Hall et al. 2022).

The Roads to Reuse product specification for recycled road base and recycled drainage rock (Waste Authority 2021) enables greater clarity in the process for collection, processing and reuse of this material and should be leveraged as the guidance document for increased crushed recycled concrete and brick in road infrastructure projects.

4.1.3 Recycled Crushed Glass

Recycled crushed glass (RCG) originates as waste materials from both domestic and commercial/industrial sources. It is converted to materials suitable for use in road infrastructure via crushing, cleaning, screening and an even blending process (Austroads 2022a).

Within Western Australia there is an abundance of natural sand available for use within road construction projects. Therefore the economic viability of producing RCG for use in road construction may not be competitive when compared to the use of natural sand for the same applications.

General applications and specifications

RCG (recycled glass cullet) is approved for use in WA as embankment fill material only in accordance with MRWA specifications to a maximum 20% of mass limit (refer Table 4.4). Sources of permitted waste glass materials include food and beverage containers and building or window glass (MRWA Specification 302 Earthworks).

To enable the additional use of sustainable materials, WALGA in conjunction with GHD have prepared the *Earthworks and Pavement Construction – Road Building Model Specification* (GHD 2022c). This specification enables the use of RCG as general fill in non-structural applications (e.g. kerb and channel and low risk pavement applications).

Specifications relating to the use of RCG in WA are included within Table 4.4. Outside of WA, other road agencies permit incorporating RCG within asphalt, as a crushed rock supplement/sand replacement, in footpaths and kerbs and in drainage and fences (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of RCG for use in applications not covered by Western Australian specifications.

Table 4.4: Recycled crushed glass specifications

Specification	Agency	Application
WA		
Earthworks and Pavement Construction – Road Building Model Specification (section 4.6.3) (GHD 2022a)	WALGA	• General fill in non-structural applications
Specification 302 Earthworks	MRWA	• Imported fill for embankment construction. • Maximum allowable limit: 20% of mass
National		
ATS 3050 Supply of Recycled Crushed Glass Sand (Austroads 2022a)	Austroads	• Granular material and sand replacement in concrete
Crushing, Processing and Cleaning of Recycled Crushed Glass for Transport Infrastructure (Austroads 2022d)	Austroads	• Crushing, processing and cleaning of RCG
Development of a Specification for Recycled Crushed Glass as a Sand Aggregate Replacement (Austroads 2022b)	Austroads	• RCG as a sand aggregate replacement

The *Earthworks and Pavement Construction – Road Building Model Specification* (GHD 2022c) prepared for WALGA states that all glass for use in road construction shall be sourced from premises licensed under Part V of the Environmental Protection Act. Further requirements for the supply of RCG are detailed in Table 4.5.

Table 4.5: RCG acceptance limits

Particle size		Other requirements	
AS 1152 sieve size (mm)	% Passing by mass	Test	Limits
9.5	100	Organic Matter (AS 1289.4.1.1)	≤ 1%
4.75	70–100	Foreign Materials (WA 144.1)(1)	
2.36	35–88	High Density Material (brick, tile, etc.)	≤ 1%
1.18	15–45	Low Density Material (plastic, plaster, etc.)	≤ 1%
0.30	4–12	Wood and plant material	≤ 1%
0.075	0–5	4-day soaked California Bearing Ratio @ specified density & 100% OMC (WA 141.1)	Report(2)

2. The limits for foreign materials in the WALGA specification (GHD 2022c) = ≤ 1%.
3. To be included with conformance certification.

Source: GHD (2022c); MRWA (2020a).

Engineering performance

In road construction applications, RCG is typically used as a replacement for granular material. It is generally processed to pass the 4.75 mm sieve and for a comparative particle size, it is noted to have similar properties to natural sand (Hall et al. 2022). The engineering properties of RCG comparative to natural sand is included in Table 4.6. As shown, the RCG for the assessed particle size range is comparable to natural sand. The differences between RCG and natural sand primarily relate to grain size, particle shape, chemical properties, foreign materials, compaction (density) and material fabric and particle assemblage (Hall et al. 2022).

Table 4.6: Engineering properties of recycled crushed glass and natural sand

Property		Typical RCG	Typical similar-sized sand
Compaction	MDD	1.69–1.79 t/m^3 (1)	1.63–2.14 t/m^3 (2)
	OMC	12.5–13.6% (1)	21–9% (3)
Permeability		1.0 x 10^{-4} to 6.5 x 10^{-6} m/s	10^{-4} to 10^{-6} m/s

Property	Typical RCG	Typical similar-sized sand
Specific gravity	2.48–2.49	2.64–2.66
CBR	18–21% (4)	10–40% (5)
Thermal conductivity(6)	Limited data	2.3–3.8 W/mK
Electrical resistivity(6)	> 2,000 Ω cm	50–2,000 Ω m
pH	7.1–8.7	Varying with geology

1. Standard compaction.
2. 1.63–1.94 t/m^3 for poorly graded sand (SP), and 1.78–2.14 t/m^3 for well-graded sand (SW).
3. 21–12% for poorly graded sand, and 16–9% for well-graded sand.
4. Standard compaction. Data extracted from one single study on crushed glass classified as SW-SM.
5. 10–20% for poorly graded sand, 15–40% for well-graded sand.
6. Parameters varying largely with chemical composition, density, particle packing and moisture content.

Source: Austroads (2022b).

The particle size of RCG is a critical factor in achieving positive results in road construction, as indicated by the particle size distribution limits displayed in Table 4.5. Within unbound applications, incorporation of RCG up to 15% has been successfully demonstrated when a < 10 mm particle size is used (Austroads 2022c). Within embankment and non-structural fill applications, incorporating RCG has been shown to improve the engineering properties of subgrade such as permeability and resilient modulus (Hall et al. 2022).

Environment

One of the key notable challenges associated with utilising RCG is the potential for contamination from foreign materials (Austroads 2022b). As glass does not degrade over time, waste glass materials are ideally reused where possible or recycled into higher value items than embankment fill material (MRWA 2022). Utilising RCG does however present the opportunity to reduce the volume of material being sent to landfill, particularly in rural areas where no facilities are locally available to recycle glass into higher value items and haulage distances are significant.

The potential presence of foreign materials in RCG presents an environmental risk from an increase in chemical and physical contaminants, including metals, total organic carbon and an elevated electrical conductivity. Examples of potential foreign materials include:

- other items present in commingled recycling bins (plastics, ceramics, organic matter, etc.)
- non-glass items present on food and beverage containers (e.g. plastic and metal lids, paper labels, etc.)
- construction and demolition materials (window frames, bricks, etc.).

To further limit the potential for contamination, the recycled glass must not originate from the following sources (Austroads 2022a):

- cathode ray tubes
- fluorescent and incandescent lights
- glass recovered from electrical equipment
- glass recovered from a laboratory source
- porcelain product or cook tops
- glass from hazardous waste containers.

Contaminant limits have been prescribed in ATS 3050 Supply of Recycled Crushed Glass Sand (Austroads 2022a). These contaminant limits are noted to align with prescribed reuse criteria outlined in the Queensland Government *End of Waste Code: Glass Fines* (EOWC010001051) (Department of Environment and Science 2022) and the *Recovered Glass Sand Order 2014* (NSW EPA 2014). Sampling and analysis for total concentration and leachable concentrations of those (and additional) contaminants was conducted to form the basis of the NSW EPA *Recovered Glass Sand Order*. The results of the assessment were found to be below the laboratory's limit of reporting or nominated criteria (Department of Environment and Climate Change, NSW 2007).

As demonstrated in Section 2.3, where appropriately processed and utilised as a resource in road construction projects RCG would not be considered a waste material. Further, research indicates that the use of RCG in road construction presents a low risk of impact to the environment where appropriate quality control processes are in place to ensure the contaminants present are within accepted guideline values.

Work health and safety

The Department of Environment and Climate Change (2007) indicated that potential additional work health and safety hazards introduced via the use of RCG in road construction include glass dust and glass particle handling. This report indicated that the risk of exposure from both hazards is considered low or negligible. Additional studies summarised in Austroads (2022b) identified a minimal skin penetration hazard RCG with a maximum particle size of 6 mm and a minimal risk via exposure to glass fines as dust.

Although the reported risk to human health is considered low, the implementation of suitable controls including, but not limited to personal protective equipment (PPE) and dust suppression/extraction are recommended.

Waste recovery process

RCG is another highly in demand recycled product for transport infrastructure and has a relatively simple recycling process. In some asphalt plants, recycled glass is merely crushed to a sand-like particle size before being incorporated into the mix, which can be done on site if the facility has the equipment for crushing the glass or alternatively procured from a source of crushed glass. Additionally, recycled glass is often easily sourced locally with some areas having separate disposal of glass to other waste in the MSW stream. Due to contamination from labels and other matter that may remain on the inside of the bottle, the glass might require washing prior to the final crushing. These contaminants have the potential to cause a fire in the plant or create an odour, but these risks can be managed without the washing process. However, there exists a current supply problem with recycled crushed glass, where high quality recycled glass if often diverted back to its original use as containers for food and beverages. This action does utilise the recycled glass for a higher end use, and requires less energy to reuse, but does limit the amount of crushed glass that is available for incorporation into road infrastructure. Examples of crushed glass stockpiles are shown in Figure 4.4.

Figure 4.4: Crushed glass stockpiles

Source: [Alex Fraser site visit] n.d., NTRO

Case study

To demonstrate the successful reuse of this beneficial resource on a local level, the following case study from the Northlink 3 project has been included below. This case study has been sourced from the MRWA *Recycled Materials Reference Guide* (MRWA 2022).

Case Study: Recycled Crushed Glass in Embankment Fill in the Northlink 3 Project

The Northlink 3 (northern section) (Ellenbrook to Muchea) Project was able to use approximately 70,000 tonnes of crushed recycled glass as embankment fill. The material was used in earthworks to stabilise clay-based soils and materials, and also used for dust suppression in the embankment layer as the amount of water thismaterial holds is greater than limestone. The contractor on the project adhered to Specification 302, which allows up to 20% of the fill content to be crushed recycled glass.

There were a number of considerations and challenges to overcome in using the material. These issues included overcoming the absence of any glass recycling facility in WA, the amount of embodied energy required to process the glass cullet (in terms of the project's environmental footprint), and the cost of using this material compared to using virgin materials. Another key issue was whether the glass properties would be able to behave in a similar way to limestone in this context.

However these challenges were overcome and the benefits of using the matieral included:

- a reduction in virgin materials used
- reduced amounts of land cleared to store virgin material stockpiles
- leadership shown and a standard set for future Main Roads projects
- assisted in transforming the WA market ofrecycled glass products.

Source: MRWA (2022).

Potential future applications

Similar to recycled crushed concrete and bricks, the potential future applications of RCG primarily relate to improved capture and recycling of glass waste and also increased uptake in road infrastructure projects. Some of the key barriers to this uptake relate to a perceived high contamination rate, a lack of awareness over the level of health and safety risk (i.e. lower than perceived) and haulage distances (virgin materials within WA are often available locally through quarries and borrow pits) (Hall et al. 2022). Recent national publications on the supply and processing of recycled crushed glass should provide an avenue for further developments in this space (Austroads 2022b; Austroads 2022d). In support of improved reuse of RCG, research is underway within WA to economically optimise the production of recycled crushed glass material (MRWA 2022).

4.1.4 Crumb Rubber

Crumb rubber is sourced from end-of-life tyres that are processed via shredding and crumbing (Rice et al. 2020; Queensland Department of Transport and Main Roads 2020). In Australia in 2020–21, approximately 459,000 tonnes of tyres reached their end-of life (Mitchell 2022). In WA in 2021–22, in excess of 1,900 tonnes of crumb rubber, equivalent to 380,000 car tyres, was used on the state road network (MRWA 2020a).

Crumb rubber is used as a bitumen modifier in spray-seal applications and is the most utilised recycled material in Australian road construction (Austroads 2022c). Crumb rubber contains valuable polymers and carbon black that can increase skid resistance and improve drainage (MRWA 2022).

General applications and specifications

Crumb rubber is approved for use through the MRWA specification in WA as a crumb rubber modified (CMB) binder in asphalt and sprayed seal applications. Although crumb rubber has been used for a long period of time in WA in bituminous seals applications, recent research has enabled the use of crumb rubber modified asphalt (MRWA 2022). The CMB binder is to be manufactured using Class 170 bitumen and recycled rubber from suitable sources (e.g. Tyre Stewardship Australia (TSA) approved or MRWA accredited) (GHD 2022b).

Specifications relating to the use of crumb rubber in road infrastructure in WA are included within Table 4.7. Outside of WA, other road agencies permit incorporating crumb rubber within road infrastructure as a binder modifier, in asphalt, lightweight embankments, retaining walls and drainage (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of crumb rubber for use in applications not currently covered by Western Australian specifications.

Table 4.7: Crumb rubber specifications

Specification	Agency	Application
WA		
Sprayed Bituminous Surfacing: Road Building Model Specification (GHD 2022c)	WALGA	• Crumb rubber modified binder (CMB) shall be manufactured using Class 170 bitumen and recycled rubber from end-of-life vehicle tyres or other suitable sources
Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Road Surfacing (IPWEA & AAPA 2016)	WALGA	• Requirements for materials
Specification 503 Bituminous Surfacing	MRWA	• 5% by mass rubber can be utilised in geotextile reinforced seals in Class 170 bitumen • Rubber binder to be supplied from a bulk mixing facility. The facility shall be capable of mixing the rubber blend to ensure the rubber is thoroughly mixed prior to transport
Specification 511 Materials for Bituminous Treatments	MRWA	• A minimum quantity of 18% crumb rubber by mass of total binder shall be used in the crumb rubber modified asphalt binder • Crumb rubber in crumb rubber modified binders shall consist of rubber processed from end-of-life tyres or other suitable rubber products • Crumb rubber shall be sourced from a Tyre Stewardship Australia accredited tyre recycler or a Main Roads approved supplier
Specification 516 Crumb Rubber Open Graded Asphalt	MRWA	• A minimum quantity of 18% crumb rubber by mass of total binder shall be used in the crumb rubber modified asphalt binder • The crumb rubber shall be designed to meet the requirements of Table 516.1, without the inclusion of a warm mix additive
National		
Technical Specification ATS 3110 Supply of Polymer Modified Binders (Austroads 2020a)	Austroads	• Crumb rubber supply
Crumb Rubber Modified Open Graded and Gap Graded Asphalt (Australian Asphalt Pavement Association 2018b)	AfPA	• Requirements for crumb rubber modified (CRM) open graded asphalt (OGA) surface layers with a nominal maximum aggregate size of 10 mm and 14 mm.

Engineering performance

In addition to reusing a product originally destined for landfill, the integration of crumb rubber offers performance benefits in both sprayed seal and asphalt applications. Some of these benefits and associated challenges are shown in Table 4.8.

Table 4.8: Crumb rubber benefits and challenges

Performance benefits		
Asphalt applications	Sprayed seal applications	Challenges
• Resistance to cracking (indirect) • Aging and oxidation resistance (indirect) • Rutting resistance • Durability • Lower maintenance costs (frequency)	• Crack resistance • Productivity • Oxidation resistance • Aggregate retention on heavily trafficked roads	• Crumb rubber/binder segregation and degradation • Road construction costs • Emissions

Source: Hall et al. (2022).

In asphalt, crumbed rubber can improve rutting resistance and fatigue due to its high viscosity and elasticity (Austroads 2022c). In line with t WA specifications for the integration of crumb rubber, higher percentages of crumb rubber (> 18% by mass of total binder) has been demonstrated to effectively mitigate reflective cracking of failed pavements (Austroads 2022c).

Environment

Utilising waste tyres presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. It also has the potential to minimise or reduce the demand for virgin materials, in turn reducing the potential environmental impacts associated with the production of polymers and petroleum derived bitumen products. Hall et al. (2022) reports that crumb rubber modified roads can also aid in reducing traffic noise.

The primary potential environmental impacts associated with waste tyres are associated with the potential discharges and emissions from tyre fires (Waste Authority 2019a). Waste tyres are considered Inert Waste type 2 (detailed below) in accordance with the *Landfill Waste Classification and Waste Definitions* (DWER 2019c). The material will be considered a waste until it is reprocessed into a reusable product.

> Inert waste type 2 means waste consisting of stable non-biodegradable organic material such as tyres and plastics which require special management to reduce the potential for fires.

Tyre Stewardship Australia (TSA) has released a *Tyre Particle Health, Environment and Safety* report (Mitchell 2022). This report included a literature review of studies on tyre derived products. Heavy metals, hydrocarbons, volatile organic compounds (VOCs) are reported as key potential contaminants of concern. This is supported by DWER (2021b) for potential contaminants of concern associated with the rubber manufacturing and processing industry.

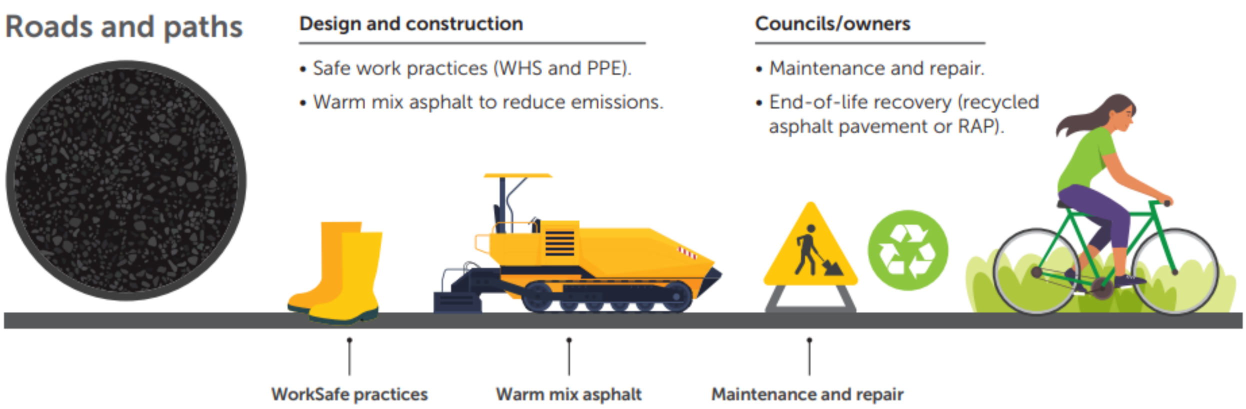
It is acknowledged that there is limited information available on the potential environmental impacts of reusing tyres in road construction across the lifecycle. The generation of air emissions during processing and construction, leaching of potential contaminants of concern, and release of microplastics to the environment through road degradation are all areas which should be considered for assessment during design processes.

Work health and safety

The widely accepted method for integrating crumb rubber into bitumen for use in asphalt and sprayed seals involves heating the mixture. This heating process has the potential to emit fumes and airborne particles as a result of potential contaminants of concern within the crumb rubber. Emissions of volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH) are known to increase as temperature increases (Mitchell 2022). The TSA *Tyre Particle Health, Environment and Safety* report (Mitchell 2022) indicates there is a minor to moderate risk to workers during construction, however the levels are reportedly well below Safe Work Australia Standards.

Air emissions and fumes may be reduced by lowering the mixing temperature during the binder modification process (Austroads 2022c). Areas where additional actions may be required include the integration of safe work practices and utilising warm mix asphalt to reduce emissions (refer Figure 4.5).

Figure 4.5: Actions to reduce tyre particle impacts during the lifecycle of materials



Source: Mitchell (2022).

Waste recovery process

Crumb rubber in asphalt and sprayed seals is another recycling alternative that utilises waste materials that are easily sourced locally. Crumb rubber once acquired can easily be incorporated by the binder supplier or used in the sprayer when sealing the pavement. As with most other materials, the supply source needs specific processing for its use in road infrastructure. End-of-life tyres comprise several materials, such as steel and fibres, that need to be separated from the rubber before it can be ground into crumb rubber. Tyre Stewardship Australia (TSA) gives accreditation to recyclers and collectors of end-of-life tyres and the production of crumb rubber. Ensuring the crumb rubber meets the specifications for its use in road and transport infrastructure is fundamental to its adoption and allows contractors and local governments to utilise TSA approved products confident that they comply with the quality and standards. Although other tyre recyclers exist, the use of the other products do not comply with the MRWA specifications.

Despite the abundance of end-of-life tyres, the haulage distances from the required facilities to some areas make its use unfeasible. Although stockpiling crumb rubber in local areas would make it available for use in more local government areas, restrictions on stockpiling remain limiting to the incorporation of crumb rubber in rural locations.

Case study

To demonstrate the successful reuse of this beneficial resource, the following case study from the East Boundary Road, East Bentleigh VIC project has been included below.

Case Study: Crumb Rubber Asphalt

In March 2020, a trial of crumb rubber asphalt (CRA) wearing course was successfully placed on East Boundary Road, East Bentleigh, in the eastern metropolitan suburbs of Melbourne. The site is an arterial road with moderate traffic (19,000 annual daily traffic and 6% commercial vehicles), comprising 2 trafficked lanes and one bicycle/parking lane. The first-of-its-kind trial consisted of 2 controls and 4 CRA mixes, including dense graded, stone mastic and gap graded asphalt. The 1.4-km trial site used an equivalent of 1,600 car tyres. Performance results from the two-year field monitoring are expected by mid-2022.

Department of Transport Victoria (DoT Vic) and Tyre Stewardship Australia (TSA) jointly funded the trial. ARRB coordinated the trial and delivered performance monitoring, laboratory analysis and reporting on outcomes. Boral, Downer and Fulton Hogan provided trial mixes based upon the Australian flexible Pavement Association's (AfPA) pilot specification for crumb rubber asphalt (CRA) designs. Additionally, Bitu-mill was engaged for the construction and placement of the materials.

Emissions testing during construction demonstrated no concern about exposure for crew members. All airborne particulates, compounds and fumes, were below or well below the limits set by SafeWork Australia.

With pavement performance monitoring still ongoing, the key benefits of the trial so far have been the successful implementation of a widely collaborative project and the promotion of CRA as a sustainable pavement option. This full-scale demonstration trial is a clear indicator that industry is ready and keen to explore and implement new and innovative materials, with the backing of industry bodies including AfPA, TSA and the asset owner, in this instance DoT Vic.

Source: Hall et al. (2022).

Potential future applications

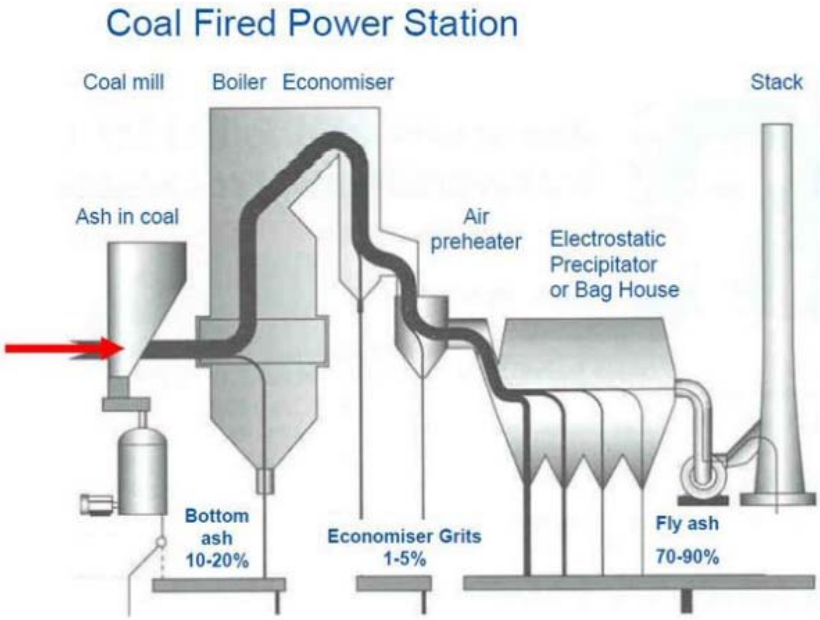
Recent research undertaken in WA has enabled the integration of crumb rubber into asphalt, in addition to the well-established sprayed seals application. Research is currently underway to investigate further increasing the percentage of crumb rubber in road construction (Ecologiq 2022).

In addition to the use of crumb rubber in roads, there is a potential market for the creation of road structures and furniture waste tyres. These options are discussed further in Section 4.1.10.

4.1.5 Fly Ash

Fly ash is a by-product of the coal combustion process (Hall et al. 2022) (refer Figure 4.6). It can be blended with and used as a partial replacement for general purpose cement in concrete and pavements (TMR 2020). It is a commonly used product and is generally considered inert and compatible with most construction materials (Austroads 2022c).

Figure 4.6: Fly ash/bottom ash from coal combustion



Source: Hall et al. (2022).

The US EPA (2023) notes the following benefits are associated with the reuse of fly ash and coal ash products generally:

- environmental benefits: reduced greenhouse gas emissions associated with extractive industry, reduced landfill disposal
- economic benefits: reduced disposal costs, increased revenue from the sale of coal ash, savings from the reduced use of other natural materials
- product benefits: improved strength, durability and workability of materials.

General applications and specifications

Fly ash is approved through the MRWA specification as a supplementary cementitious material (SCM) in blended cement for use in stabilisation works, concrete for structures, as a low strength infill and the in situ stabilisation of pavement layers. It is also approved through the MRWA specification for use as a mineral filler in asphalt microsurfacing works. When used as an SCM, the use of fly ash is required to conform to the requirements of AS/NZS 3582.1-2016, *Supplementary Cementitious Materials: Part 1: Fly Ash*.

Specifications relating to the use of fly ash in road infrastructure in WA are included within Table 4.9. Outside of WA, other road agencies permit incorporating fly ash within road infrastructure for in situ stabilisation and within concrete in varying limits (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of fly ash for use in applications not covered by Western Australian specifications.

Table 4.9: Fly ash specifications

Specification	Agency	Application	Material	Max limit (% by mass)
WA				
Specification 302 Earthworks	MRWA	• Cement stabilisation of subgrade	SCM in blended cement	Not specified
Specification 404 Culverts	MRWA	• Concrete for culverts	SCM in blended cement	25
Specification 410 Low Strength Infill	MRWA	• Low strength infill for the backfilling of redundant or abandoned pipes, culverts and other buried structures	SCM in blended cement	Not specified
Specification 515 In situ Stabilisation of Pavement Materials	MRWA	• In situ stabilisation of granular pavement layers	SCM in blended cement	Not specified
Specification 820 Concrete for Structures	MRWA	• High performance concrete for structures	SCM in blended cement	25
Specification 507 Microsurfacing	MRWA	• Microsurfacing	Mineral filler	Not specified
National				
AGPT04C-17 (Austroads 2017b)	Austroads	• Lean-mix concrete subbase	SCM in binder(1)	60
		• Base concrete	SCM in binder(2)	20
ATS 5330 (Austroads 2020b)	Austroads	• Geopolymer concrete	Binder	Not specified
ATS 3450 (Austroads 2021)	Austroads	• Microsurfacing	Mineral filler	Not specified
AGPT04B-14 (Austroads 2014)	Austroads	• Asphalt	Mineral filler	Not specified
AGPT04D-19 (Austroads 2019a)	Austroads	• Stabilisation (pavement and earthworks)	Binder	Not specified
			SCM	Not specified
AGPT4L-09 (Austroads 2009b)	Austroads		Binder (in cement-FA blends)	50
			Binder (in lime-FA blends)	75
			Binder (in lime slag-FA blends)	50
			Binder (in cement slag-FA blends)	40
AS 3972-2010 General Purpose and Blended Cements	Australian Standard	• Details what level of SCMs can be used for different cement types.	Refer standard.	Refer standard.

1. The total binder content is 10%, consisting of 6% fly ash and 4% cement.
2. The total binder content is 15%, consisting of 3% fly ash and 12% cement.

Engineering performance

To meet the AS/NZS 3852.1 requirements, fly ash must have 75% of particles passing the 45 μm sieve (Hall et al. 2022). Fly ash produced from brown and black coal are classified as Class C and Class F respectively with brown coal having the higher lime content (approximately 15–30% as opposed to < 7% for black coal) (Austroads 2022c). However, fly ash produced from both black and brown coal are considered useful as an SCM due to their pozzolanic properties.

As outlined above, the engineering performance benefits associated with the use of fly ash in concrete includes increased durability, increased strength and improved workability (Hall et al. 2022; US EPA 2023). The requirements associated with the use of fly ash as an SCM, and subsequently supporting these performance benefits, is guided by AS/NZS 3582.1. As detailed in Austroads (2022b), these requirements include:

- fineness (% passing a 45-micron sieve)
- loss on ignition
- moisture content

- SO_3 content
- aggregate applications.

As a mineral filler in asphalt, fly ash offers improved rutting resistance, improved stability, improved moisture resistance (Hall et al. 2022). It also has the potential to reduce stripping and workability (Austroads 2022c).

Environment

Based on the nature of this coal combustion by-product, there are potential environmental risks associated with the reuse of fly ash (Austroads 2022c). In a coal combustion process, fly ash is a powdery residue material captured within the stack. It has the potential to contain potential contaminants of concern such a heavy metals (e.g. mercury, arsenic, copper and chromium) (Agency for Toxic Substances and Disease Registry 2019). DWER (2021b) also reports fly ash can contain sulfates, metals, total dissolved solids, selenium and actinide elements (U, Th). The potential environmental risks associated with these contaminants are primarily associated with leaching and are compounded by the likely variability in the fly ash. It is noted that when bound, the potential for leaching of any contaminants is greatly reduced (Environmental Protection Authority, Western Australia 2013).

The potential environmental risks associated with the reuse of fly ash are extensively reported. However, as it is a widely available by-product currently destined for landfill, the environmental, economic and product based beneficial reuse opportunities must be explored. The environmental benefits of reusing fly ash includes the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. It also has the potential to minimise or reduce the demand for virgin materials. Examples of support for the reuse of fly ash and coal ash generally are noted through the Queensland DES *End of Waste Code for Coal Combustion Products* (Department of Environment and Science 2021) and the NSW EPA *Coal Ash Order and Exemption* (NSW EPA 2022).

Work health and safety

Fly ash may create a respiratory hazard when dry which can lead to flu-like symptoms (Agency for Toxic Substances and Disease Registry 2019). This is primarily due to dust generation caused by the low density and particle size of the material, however dust suppression, compaction and suitable storage techniques may aid in reducing that risk (Austroads 2022c).

Similar to the potential environmental impacts, the potential WHS risks are likely to vary due to the feedstock or process. Cement Australia (2019) reports the following health and safety risks associated with fly ash through their supplied product Safety Data Sheet (SDS):

- causes skin irritation
- causes serious eye irritation
- may cause respiratory irritation
- may cause damage to organs through prolonged or repeated exposure (lungs).

In addition to the above noted respiratory hazards, the product is noted as having the potential to contain sufficient quantities of respirable crystalline silica (RCS) to require management (Cement Australia 2019). Additional information on RCS is included in Section 4.1.2. Each of these potential risks will require assessment and management prior to and during use of the material.

Additional WHS risks associated with the listed potential contaminants of concern are likely to be either reduced during processing or managed via appropriate personal protective equipment (PPE) and effective work hygiene controls.

Waste recovery process

Unlike the previous materials, fly ash is produced exclusively by the commercial and industrial (C&I) waste steam as a by-product of coal fired power plants, of which there are 4 in WA, see Section 5.3.3 below.

During the operation of the plants, fly ash is collected by separators in the chimney of the power plant, and therefore, is locally available only in areas adjacent to these stations. However, as the fly ash is often used as a supplementary cementitious material in many areas, it is commonly transported across states and potentially available at local building and construction suppliers. Once procured contractors can use this recycled product instead of hydrated lime or cement without requiring additional equipment. However, as research into further uses of fly ash develop and specifications include this technology, additional requirements might be needed to incorporate the material. Due to the variability of the quality from different plants and types of coal used, the use of fly ash may be subject to testing and product that meets the required quality might not be available locally.

Case study

Fly ash has been successfully utilised as an SCM within concrete since 1975 (Hall et al. 2022) and has been used successfully within road construction projects internationally, nationally and locally within WA. To enable use of stockpiled fly ash material in Collie WA, the WA Government is supporting research into the production of geopolymer concrete. The geopolymer concrete production incorporates a mixture of fly ash, slag, sodium silicate, sodium hydroxide and water containing aggregates to produce a low-calcium product that is resistant to sulphate attack (MRWA 2022).

To demonstrate the reuse of this beneficial resource, the following case study detailing the research project at Collie, WA has been included below.

Case Study: Fly Ash in Geopolymer Concrete

The establishment of a new geopolymer concrete manufacturing industry in regional Western Australia is on the horizon, following a successful feasibility study conducted by Murdoch University. Laboratory and field trials demonstrated Collie, 200 km south of Perth, has the necessary resources to make products such as retaining wall blocks, sea walls, sound barrier walls, culverts, kerbing, and storm water pipes.

Up to 500,000 tonnes of fly ash are being produced in the town, with vast stockpiles remaining from 60 years of coal-fired power generation that could be reclaimed long after the power stations in Collie and Muja close in 2030. Collie's fly ash is 'very good quality' for making geopolymer concrete. A comparison of fly ash sourced from power stations in Collie, Eraring in NSW, and Tarong in Queensland, found the WA fly ash was the most reactive during geopolymerisation due to its finer particle size, leading to the highest compressive strength concrete.

The manufacturing process, known as Colliecrete, uses fly ash and other industrial by-products and waste materials as an ingredient in the low carbon concrete product. The WA Government revealed the feasibility study 'highlights the potential to establish a geopolymer concrete manufacturing industry and create jobs and has identified options for industry partners to commercialise the technology'.

It announced that Murdoch University will now put together a consortium to commercialise the project that will be eligible for capital investment. The university developed the product by partnering with Synergy, Bluewaters Power Station and South 32, with funding from the WA Government.

Source: Corbett (2022).

Potential future applications

As outlined in the case study above, research by Murdoch University and the Government of Western Australia is currently being conducted to explore the potential production and use of geopolymer concrete. This research aims to utilise the extensive supply of fly ash. MRWA (2022) is supporting this research into the long-term strength and durability of box culverts for use in road works and drainage, with the objectives of:

- investigating its long-term strength
- assessing precast construction requirements
- assessing comparative durability
- developing a specification for box culverts.

It is noted that some jurisdictions are working on shifting from coal-fired power generation in response to addressing sources of climate change pollutants. This shift may lead to a future reduction in fly ash supplies. For example, the Queensland Government has committed to increasing renewable energy generation by 2035 and converting all publicly owned coal-fired power stations into clean energy hubs (Queensland Government 2022). Although unlikely to impact Western Australia in the immediate future, the transition to clean sources of energy is occurring at the global scale.

4.1.6 Bottom Ash

Bottom ash is a by-product of black coal combustion and waste-to-energy processes (Hall et al. 2022) (refer Figure 4.6). This variability in source materials and processing methods can result in a product that has variable physical properties and chemical composition. Further, there are potential environmental risks associated with the use of bottom ash in road construction projects. As a result of these factors, bottom ash is not widely used in road construction applications, however it is potentially suitable for use as an aggregate replacement in embankment/structural fill applications and as drainage layer materials (Austroads 2022c).

General applications and specifications

There are limited specifications in Australia for the use of bottom ash in road infrastructure, with further research required to optimise its use and to determine and manage any associated health, safety and environmental impacts (Austroads 2022c). The only road agency to have a specification for the use of bottom ash is Transport for NSW (TfNSW) which allows 10% by mass to be used in base and subbase as granular material (TfNSW specification D&C 3051 2020). This specification may be utilised to inform field trials for the use of bottom ash for use in applications not currently covered by Western Australian specifications.

Engineering performance

Bottom ash is a well graded material with a particle size generally ranging from 75 µm to 40 mm (Hall et al. 2022). It has a lower density and higher porosity than virgin aggregates, making it potentially suitable for drainage applications (Austroads 2022c).

An et al. (2014) investigated the use of waste-to-energy derived bottom ash for use in concrete and asphalt. This study identified an overall reduction in performance when bottom ash is used as a fine aggregate replacement in concrete applications (An et al. 2014). These findings are supported by Hall et al. (2022), which indicated that in comparison to fly ash, bottom ash is not ideal for use as a supplementary cementitious material due to the additional processing required (i.e. crushing and screening) and the lower quantities of amorphous silica and alumina.

A study of bottom ash in hot mix asphalt (HMA) applications conducted by An et al. (2014) concluded that 20% replacement of fine aggregate by bottom ash resulted in increased strength, stiffness and moisture resistance properties. During this study, the optimum binder content ratio was increased by 1.1% (An et al. 2014). It is noted that this increase in binder content may have significant cost implications. Austroads (2022c) also reported improved fatigue cracking resistance and reduced wearing resistance in bottom ash in HMA applications.

Based on these studies, additional research is required for the practical application of bottom ash in road infrastructure, particularly in asphalt. Prior to the use of bottom ash in any road construction, it is essential that the physical and chemical properties be analysed and assessed as suitable for the proposed application.

Environment

Based on the nature of this coal combustion and waste-to-energy by-product, there are potential environmental risks associated with the reuse of bottom ash (Austroads 2022c). In a coal combustion process, bottom ash is a coarse material captured at the bottom of a coal furnace. It has the potential to contain contaminants of concern such a cresol, semi-volatile organic compounds and polycyclic aromatic hydrocarbons (Agency for Toxic Substances and Disease Registry 2019). DWER (2021b) also reports bottom ash and fly ash can contain sulphates, metals, total dissolved solids, selenium and actinide elements (U, Th). In addition, Queensland's Department of Environment and Science (DES) notes bottom ash associated with end-of waste facilities has the potential to contain PFAS due to the processing of biosolids (DES 2021). These potential environmental risks are compounded by the likely variability in the bottom ash by-products. It is noted that when bound, the potential for leaching of any contaminants is greatly reduced (Environmental Protection Authority, Western Australia 2013).

Advice provided to the Western Australian Environmental Protection Agency (EPA) on the environmental and health performance of waste to energy technologies (Environmental Protection Authority, Western Australia 2013) outlined the following recommendations with respect to the use of bottom ash:

- Bottom ash must be disposed of at an appropriate landfill facility unless approval to reuse is obtained.
- Any proposed reuse of bottom ash must demonstrate the health and environmental safety and integrity of the proposed use, through characterisation and leachate testing.

The potential environmental risks associated with the reuse of bottom ash are extensively reported. However, as it is a widely available by-product currently destined for landfill, the environmental, economic and product based beneficial reuse opportunities must be explored. The environmental benefits of reusing bottom ash include the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. It also has the potential to minimise or reduce the demand for virgin materials. Examples of support for the reuse of bottom ash and coal ash generally are noted through the Queensland DES *End of Waste Code for Coal Combustion Products* (DES 2021) and the NSW EPA *Coal Ash Order and Exemption* (NSW EPA 2022).

Work health and safety

Similar to the potential environmental impacts, the potential WHS risks are likely to vary due to the feedstock or process. Cement Australia (2020a) reports the following health and safety risks associated with bottom ash through their supplied product Safety Data Sheet (SDS):

- causes skin irritation
- causes serious eye irritation
- may cause respiratory irritation
- may cause damage to organs through prolonged or repeated exposure (lungs).

In addition to the above noted respiratory hazards, the product is noted as having the potential to contain sufficient quantities of respirable crystalline silica (RCS) to require management (Cement Australia 2020a). Additional information on RCS is included in Section 4.1.2. Each of these potential risks will require assessment and management prior to and during use of the material.

Additional WHS risks associated with the listed potential contaminants of concern are likely to be either reduced during processing or managed via appropriate personal protective equipment (PPE) and effective work hygiene controls.

Waste recovery process

Like fly ash, bottom ash is another by-product of coal combustion plants, and hence can be sourced locally in areas adjacent to these plants. However, as it has a more limited use as a granular material, bottom ash is not commonly stocked by building and construction suppliers. In those areas further away from a coal power plant, the bottom ash must be hauled from coal power plants in other states or areas. Additionally, bottom ash can also be sourced from waste-to-energy incineration plants which generates more bottom ash than through coal fired power plants, but currently there are none of these plants operating in WA. However this still might increase supply of imported bottom ash.

Case study

To demonstrate the successful reuse of this beneficial resource, the following case study from the New Intercity Fleet Maintenance Facility project at Kangy Angy, NSW has been included below.

Case Study: Bottom Ash Fill

In June 2018, construction of a fleet maintenance facility commenced in the regional area of Kangy Angy, on the NSW Central Coast. The facility was required for the adequate maintenance of the New Intercity Fleet (NIF). The NIF is a fleet of new trains transporting passengers between Newcastle, the South Coast (including Sydney) and the Blue Mountains. As part of the project's sustainability plan, recycled materials, including bottom ash, were used in the construction of various sections of the facility. In total, 85,000 tonnes of bottom ash, sourced from Eraring Power Station in NSW, were used as an alternative fill material. This replaced quarried material in abutment fill for both vehicle access bridges and rail bridges. It was also used for backfill of utility trenches, in embankments under the facility and the lay-down area for construction materials. Bottom ash was selected due to specific ground conditions, groundwater and restricted access to site.

At a density of 1.25 t/m^3, it is lighter than general fill, at a density of 2.0 t/m^3. This meant less materials usage (85,000 tonnes of bottom ash as opposed to 149,000 tonnes of virgin material). It also meant less consumption of natural resources, lighter fill and embankments (less applied load to the ground) and fewer truck movements for transporting materials. Using bottom ash resulted in a free-draining working layer that reduced the drainage time following a wet weather event. With performance similar to that of virgin material, using bottom ash resulted in a 15% cost saving.

Source: Hall et al. (2022).

Potential future applications

The allowed use of bottom ash within road construction in Australia is currently limited, with NSW being the only state to enable the use of bottom ash in base and subbase layers within road construction (*Design & Construct Specification* D&C 3051 2020). Support for the use of bottom ash is however growing nationally. Research is underway in Queensland to enable the use of bottom ash in earthworks, drainage and concrete applications (Hall et al. 2022). Further, new bottom ash recycling facilities are being constructed in Maryvale, Victoria (Sustainability Matters 2022) and Kwinana, Western Australia (Kerman 2023) to manage by-products from waste-to-energy facilities and convert the materials into a reusable product.

4.1.7 Blast Furnace Slag

Blast furnace slag is a by-product of the steel and iron manufacturing process (Hall et al. 2022). It can be blended with and used as a partial replacement for general purpose cement in concrete and pavements (TMR 2020). The 5 commonly referenced types of blast furnace slag according to Austroads (2022c) include:

- granulated blast furnace slag
- ground granulated blast furnace slag
- blast furnace slag (rock slag)
- basic oxygen steel slag
- electric arc furnace slag.

General applications and specifications

Similar to fly ash, blast furnace slag is approved through the MRWA specification as a supplementary cementitious material (SCM) in blended cement for use in stabilisation works, concrete for structures, as a low strength infill and the in situ stabilisation of pavement layers. When used as an SCM, the use of fly ash has to conform to the requirements of AS 3582.2 *Supplementary Cementitious Materials: Part 2: Slag: Ground Granulated Blast Furnace*.

Specifications relating to the use of blast furnace slag in road infrastructure in WA are included within Table 4.10. Outside of WA, other road agencies permit incorporating blast furnace slag within road infrastructure for in situ stabilisation of pavement, within concrete and as an aggregate additive (refer Appendix A). These specifications and guidelines may be utilised to inform field trials for the use of blast furnace slag for use in applications not covered by Western Australian specifications.

Table 4.10: Blast furnace slag specifications

Specification	Agency	Application	Material	Max limit (% by mass)
WA				
Specification 302 Earthworks	MRWA	• Stabilisation of subgrade	SCM in blended cement	Not specified
Specification 410 Low Strength Infill	MRWA	• Low strength infill for the backfilling of redundant or abandoned pipes, culverts and other buried structures	SCM in blended cement	Not specified
Specification 515 In situ Stabilisation of Pavement Materials	MRWA	• In situ stabilisation of granular pavement layers	SCM in blended cement	Not specified

Specification	Agency	Application	Material	Max limit (% by mass)
Specification 820 Concrete for Structures	MRWA	• High performance concrete for structures	SCM in blended cement	65
Specification 901 Concrete: General Works	MRWA	• Concrete for general non-structural works	SCM in blended cement	Not specified
National				
AGPT04C-17 (Austroads 2017b)	Austroads	Concrete pavements	SCM in blended cement	Not specified
ATS 5330 (Austroads 2020b)	Austroads	Geopolymer concrete	Binder	Not specified
AGPT4L-09 (Austroads 2009b)	Austroads	Stabilisation (pavement and earthworks)	Binder (in cement-GGBFS blends)	60
			Binder (in lime-GGBFS blends)	70
			Binder (in lime-fly ash-GGBFS blends)	50
			Binder (in cement-fly ash-GGBFS blends)	40
AS 3972-2010 General Purpose and Blended Cements	Australian Standard	Details what level of SCMs can be used for different cement types	Refer standard.	Refer standard.

Engineering performance

Blast furnace slag has been used extensively historically in road construction applications, with ground granulated being the most predominantly used (Austroads 2022c). The nominated concrete utilised by MRWA (S50M) utilises 60% ground granulated blast furnace slag and 8% silica fume to aid in the reduction of thermal expansion and resultant cracking (MRWA 2022). It is also resistant to chloride and sulfate attack, proving useful in a marine or other aggressive environments (e.g. certain types of soils and/or groundwater). When used in subgrade/soil stabilisation works as a cementitious or geopolymer binder, a higher strength and durability is reported over standard Portland Cement, with additional benefits noted when combined with fly ash (Hall et al. 2022).

Environment

Utilising blast furnace slag presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. It also has the potential to minimise or reduce the demand for virgin materials (i.e. Portland cement), in turn reducing the potential environmental impacts associated with extractive industry.

Due to the nature and origins (i.e. steel production) of the product, blast furnace slag is likely to contain high levels of heavy metals and a high pH. The potential environmental risks associated with these contaminants of concern are primarily associated with leaching. It is noted that when bound, the potential for leaching of any contaminants is greatly reduced (Environmental Protection Authority, Western Australia 2013).

Work health and safety

Cement Australia (2020b) reports the following health and safety risks associated with ground granulated blast furnace slag through their supplied product Safety Data Sheet (SDS):

- causes skin irritation
- causes serious eye irritation
- may cause respiratory irritation.

Each of these potential risks will require assessment and management prior to and during use of the material. Additional WHS risks associated with the listed potential contaminants of concern are likely to be either reduced during processing or managed via appropriate personal protective equipment (PPE) and effective work hygiene controls.

Waste recovery process

As previously detailed, blast furnace slag (BFS) is a by-product of steel manufacturing plants, and much like fly ash, it can be sourced locally if there is a plant in the area, which is limited to the Perth metropolitan area. It, however, is also a widely used supplementary cementitious material, that can be transported to and stocked in local building and construction suppliers. However, there is an identified shortage of BFS due to lack of distribution and storage that is in part due to its 'competition' with fly ash that is more widely adopted in practice.

Case study

To demonstrate the successful reuse of this beneficial resource, the following case study from the New Intercity Fleet Maintenance Facility project at Kangy Angy, NSW has been included below.

Case Study: Blast Furnace Slag

On 7 May 2017, the State and Commonwealth Governments announced a $2.3 billion package of road and rail infrastructure works, which will reduce congestion and lead to smarter, safer, and more efficient journeys around Perth's southern suburbs. The Armadale Road North Lake Road Bridge was part of the package. The Armadale Road to North Lake Road Bridge project was allocated $237 million as part of the $2.3 billion road and rail infrastructure works package, jointly funded by Federal ($189.6 million) and State ($47.4 million) governments.

The Armadale Access Alliance, a consortium comprising Laing O'Rourke and BG&E in partnership with Main Roads Western Australia, was commissioned to design and construct the project following a competitive tendering process in early 2019.

The project included:

- construction of a new bridge
- additional lanes and turning capacity
- new entry/exit ramps
- upgraded roads (including 2 new roundabouts).

As a part of the project's sustainability goals, recycled materials were to be utilised in place of virgin materials. One project target included:

- >30% SCM (replacement of Portland Cement with fly ash or slag in structural concrete).

The following initiative was implemented to achieve this target:

- Low heat cement mix S40LHwas included in the structural design for cast in situ elements with thickness greater than 500 mm (circa 2,300 m^3). Type LH cement is the mixture of Type GP cement and ground blast furnace slag with approximate ratio 35%: 65%. This contributes to use of SCMs on the project.

The project was noted to have achieved the >30% target by the July 2021 review.

Source: Adapted from Armadale Road to North Lake Road Bridge (2021) and Armadale Access Alliance (2021).

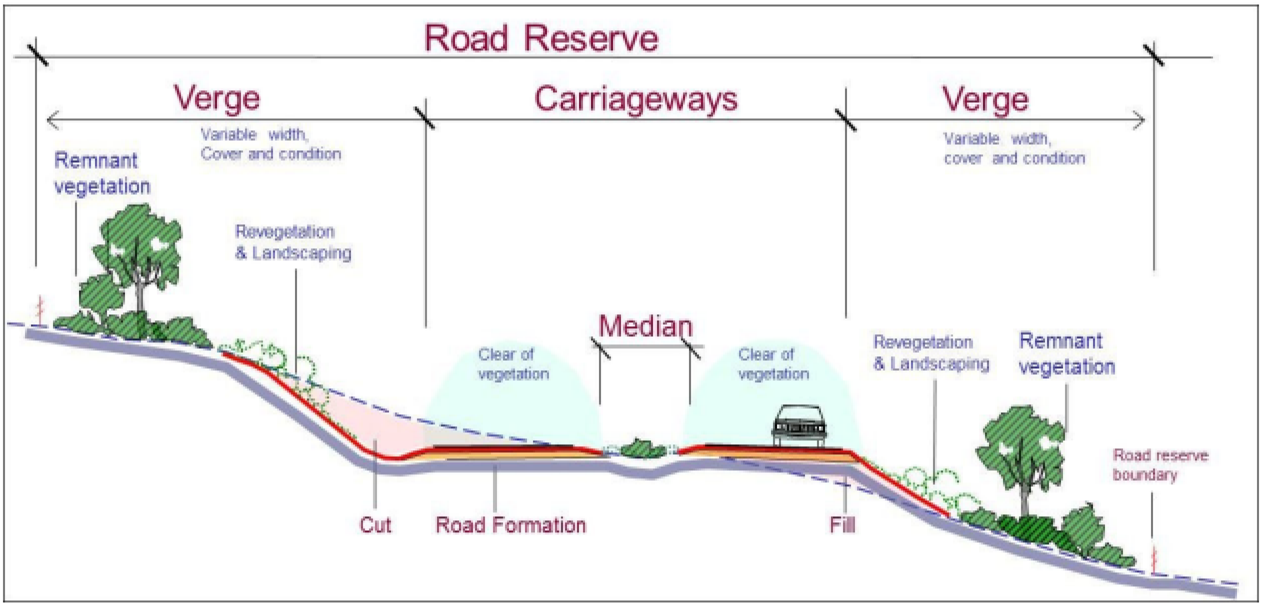
Potential future applications

Blast furnace slag is well established and the most widely used SCM in Australia (Hall et al. 2022). No research areas are currently noted regarding this product.

4.1.8 Food Organics and Garden Organics

Food Organics and Garden Organics (FOGO) are biodegradable organic waste from either a plant or animal (Hall et al. 2022). These materials have been identified by the Western Australian Sustainability Waste Alliance (SWA) for use in topsoil, soil conditioner and mulch (MRWA 2022). An example of potential uses of these recycled materials within the context of road construction is shown in Figure 4.7

Figure 4.7: Recycled organics for reuse in a road reserve



Source: SWA Innovation Hub (2022).

General applications and specifications

Within transport infrastructure applications, specifications for landscaping are widely available, however the integration of FOGO derived products is a relatively recent concept. The use of FOGO within soil conditioner, mulch and topsoil should be completed in a manner that addresses the site conditions (tailored to the physical, chemical and biological conditions of the receiving site) and meets the requirements stipulated in AS 4454-2012 and AS 4419-2018 (SWA Innovation Hub 2022).

Specifications relating to the use of FOGO in road infrastructure WA are included within Table 4.11.

Table 4.11: Recycled organics specifications

Specification	Agency	Application	Material	Max limit (% by mass)
WA				
Food and Garden Organics (FOGO) derived soil conditioner, mulch and topsoil	SWA	• Landscaping and rehabilitation elements of transport infrastructure projects	Soil conditioner, mulch and topsoil	Unrestricted, meeting the requirements of AS 4454-2012 and AS 4419-2018.
National				
AS 4454-2012 Composts, Soils Conditioners and Mulches	AS	• Composts, soil conditioners and mulches	Composts, soil conditioners and mulches	N/A
AS 4419:2018 Soils for Landscaping and Garden Use	AS	• Landscaping and garden use	Composts, soil conditioners and mulches	N/A

Engineering performance

FOGO are considered soil amendment products. The objective of these products is to increase microbial activity within the soil, increase organic matter content, improve erosion and sedimentation resistance, promote water permeability and increase the nutrient content in the soils (SWA Innovation Hub 2022).

The engineering performance associated with the use of FOGO relate to the physical, chemical and biological properties of the material scheduled for reuse and how that material aligns with the requirements of the receiving site. The required parameters are included within AS 4454-2012 and AS 4419-2018. For example, AS 4454-2012 provides guideline values for products including raw mulch, pasteurised products, composted products and mature compost. Guideline values include physical properties (e.g. pH, electrical conductivity, moisture content), agronomy properties, cation and anions, etc. Due to the environmental risk associated with the reuse of recycled organics, AS 4454-2012 also outlines the maximum contamination parameters (detailed further below).

AS 4419-2018 provides similar guideline values, however these are specific to the underlying soil strata. For example, parameters such as bulk density, permeability and particle size are considered. The application of either AS 4454-2012 or AS 4419-2018 will be based on the requirements of the project and receiving site.

Environment

Utilising FOGO presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. Further, composting FOGO via aerobic processes reduces the amount of greenhouse gases and leachates created under anerobic landfill conditions (SWA Innovation Hub 2022).

Similar to RAP, recycled concrete and bricks and recycled glass, there is a risk of introducing contaminants from the FOGO waste stream into the end product receiving site. It is noted that one of the primary exposure pathways is via the leachability of the contaminants. At a minimum, it is recommended that all FOGO products adhere to the contamination criteria outlined in Table 3.1I of AS 4454-2012. Potential contaminants may include, but not be limited to:

- foreign materials (e.g. microplastics, asbestos, glass, metal, etc.)
- pathogens (e.g. faecal coliforms, salmonella)
- nutrients
- heavy metals
- pesticides
- PFAS.

It is noted that PFAS is not listed as a potential contaminant in AS 4454-2012 but may be present due to applications associated with the agricultural industry or waste processing industry in general (Wilkinson et al. 2021). Any assessment of suspected PFAS impact should be conducted in accordance with the PFAS National Environmental Management Plan (HEPA 2020). PFAS, in additional to nutrients and heavy metals are also noted by DWER (2021b) as being potential contaminants associated with compost manufacturing.

To limit the potential for environmental impact from potential contaminants in FOGO, the Western Australian DWER has prepared the *Guideline: Better Practice Organics Recycling* (DWER 2022) to enable processors to produce quality outputs.

Work health and safety

Potential WHS risks, in addition to those that would be encountered during standard landscaping works, primarily relate to the potential contaminants introduced via the waste stream. Notable WHS risks that may be potentially introduced via the use of recycled organics include:

- exposure to asbestos
- exposure to PFAS
- exposure to pathogens.

WHS risks associated with PFAS and asbestos are discussed in Sections 4.1.1 and 4.1.2 respectively.

Additional WHS risks associated with potential unknown contaminants are likely to be either reduced during processing or managed via appropriate personal protective equipment (PPE) and effective work hygiene controls.

Waste recovery process

FOGO waste makes up over half the waste generated in the MSW steam (Waste Authority 2021) and with policies and processes for its collection already in place across the state, recycled organics are possibly the most easily locally sourced material. The Municipal Waste Advisory Council, which has a delegated authority on municipal waste issues, coordinates actions across local government waste organisations and shares knowledge on programs, grants and research in waste management. These programs and policies streamline collection and recycling across WA and include guidelines on waste behaviour changes such as bin tagging, verge side collection guides, funding schemes and waste legislation. *The Standards for Recycled Organics Applied to Land* (Municipal Waste Advisory Council 2007) called for the development of standards for the use of recycled organics to guide local governments in developing procedures for using this waste that follows best practice.

The collected waste may then undergo processing before it is fit for use in infrastructure. The waste can be converted into its recycled product form via several processes such as washing, composting, vermicomposting, dehydration and grading. Locations for this are in both metropolitan and rural areas. The processes employed will depend on the type of FOGO waste (such as green waste, waste timber, animal waste and others) and its respective properties (such as moisture content of the waste).

Local governments can consider the facilities and equipment locally available to help inform their waste gathering procedures, as their waste collection policies should aim to feed the local recycling facilities and the processes used by these facilities. Waste gathering methods will affect the suitability of the waste to various processing methods and its eventual recycled-life use. The end use should also be considered, and the output from collecting and processing should also aim to meet the demand for recycled organics in the surrounding area.

Case study

To demonstrate the successful reuse of this beneficial resource on a local level, the following case study from the Anstey Wetlands (situated along the Forrest Highway that links Perth to Bunbury) has been included below. This case study has been sourced from the Anstey Wetland – a compost case study (Department of Environment and Conservation 2013).

Case Study: Compost in Anstey Wetlands

The Anstey Wetland, situated along the Forrest Highway that links Perth to Bunbury, is an outstanding example of using compost to recycle valuable resources and help create thriving ecosystems. The wetland development, which spans over 20 hectares, is very successful. It was constructed in 2008 through a collaborative partnership between the Western Australia Waste Authority, the Department of Environment and Conservation, Main Roads Western Australia and the compost industry. Composted products have been critical to establishing vegetation on the particularly challenging site.

Approximately 50% of the waste generated by the municipal, commercial and industrial sectors is organic. It includes cleared vegetation and degraded topsoil from major road infrastructure projects, which is commonly sent to landfill or used as 'spoil' under road surfaces. When constructing the Forrest Highway, these valuable organic resources were recycled, through composting, for use in landscaping. With advice and support from the compost industry, the Anstey Wetlands project partners decided to trial composting on site and use compost to create the wetland. The compost helped to overcome challenging conditions including poor soils, limited native seed bank and topography.

The Western Australian composting industry and waste management i.e. waste management specialists, provided advice and support regarding on-site composting, selection of composted products, application rates, trial plot size and also carried out regular monitoring by scientific experts. Vegetation cleared during highway construction was chipped to produce mulch that was turned several times during site construction allowing for pasteurisation temperatures to be generated. Composted soil conditioner was brought in from off-site and this met Australian Standard AS 4454 for composted soil conditioner and was also subject to a complete laboratory analysis by a National Association of Testing Authorities (NATA) accredited laboratory.

Composted soil conditioner and mulch helped to create a favourable soil environment for seed germination and plant establishment. Compost added organic matter to the sandy soils, which improved the soil's structure, stability and created a habitat for beneficial soil microbes. Water infiltration rates decreased and soil water holding capacity increased – seedlings were able to make better use of the limited water resources on site. Composted products were also a source of slow-release nutrients – soils were more fertile which improved seedling germination and plant establishment. Improvements in soil structure and plant establishment made the site more resilient to wind and rain erosion.

Despite the many challenges of the site, composted products have helped establish a healthy and vibrant wetland system. Almost 30 species of birds now inhabit the wetland which also provides habitat for a range of fauna including the bobtail lizard, bandicoots and snakes as well as a diverse array of invertebrates.

Source: Adapted from Department of Environment and Conservation (2013).

Potential future applications

The recovery and reuse of FOGO is a key priority in the WA *Waste Avoidance and Recovery Strategy 2030* (Waste Authority 2019b). This strategy includes a 2025 target for all local governments in the Perth and Peel region to provide consistent 3 bin kerbside waste collection systems.

The potential future application with respect to recycled organics (FOGO) primarily relate to increased uptake in FOGO derived soil conditioners, mulches and topsoil products. Some of the key barriers to this uptake relate to a perceived high contamination rate and an unwillingness of councils to take responsibility for feedstock contamination (GHD 2021). The *Food and Garden Organics (FOGO) Derived Soil Conditioner, Mulch and Topsoil Specification* (SWA Innovation Hub 2022) and the *Guideline: Better Practice Organics Recycling* (DWER 2022) enable greater clarity in the process for collection, processing and reuse of this material and should be leveraged as the guidance documents for increased recycled organics in road infrastructure projects.

4.1.9 Recycled Plastics

The use of recycled plastics in road infrastructure is an emerging area of research with numerous field trials underway. Although virgin plastics are used to create modified bitumen and asphalt, the use of recycled plastics for this purpose comes with its own challenges. Recycled plastics for use in asphalt and concrete can be sourced as a waste product from commercial, industrial and municipal sources. The suitability for the integration of plastics in asphalt and concrete applications depends on numerous factors, including but not limited to:

- type of plastic
- contamination of the recycled waste plastic material
- proposed end use/design of the pavement
- proposed integration method of the recycled plastic material
- potential environmental risks (e.g. generation of microplastics, generation of harmful leachates).

General applications and specifications

There are no specifications in Australia for the use of recycled plastics in asphalt and concrete. The majority of specifications that enable the use of recycled materials are performance based, in that a recycled material may be included on the condition that the performance requirements can be met (Hall et al. 2022). with further research required to optimise its use and to determine and manage any associated health, safety and environmental impacts (Austroads 2022c).

Engineering performance

Recycled plastics can be integrated into asphalt and applications via 3 methods: dry, wet and hybrid (Austroads 2022c). These methods are described in Table 4.12.

Table 4.12: Recycled plastics integration methods

Method	Description	Quantity (% wt)	Application
Dry	Higher melting temperature plastics are added to the aggregates as a partial fine aggregate replacement.	2–3%	Asphalt and concrete
Wet	Lower melting temperature plastics are blended with bitumen to make a recycled plastic modified bituminous binder.	6% bitumen (0.3% total asphalt)	Asphalt and sprayed seals
Hybrid	Lower melting temperature plastics are added with the aggregates in the asphalt plant, where they are expected to melt and be combined with the bitumen during mixing.	0.6%	Asphalt

Source: Hall et al. (2022).

As recycled plastics are not as strong as natural aggregates, only a small quantity can be substituted into asphalt via the dry method without affecting the performance of the pavement (Austroads 2022c). The resultant pavement will not be as stiff or durable as conventional asphalt (Hall et al. 2022). When combined via the wet or hybrid methods, preliminary research suggests the resultant pavement may end up being overly stiff and brittle (Hall et al. 2022). As a result, this may be at the detriment of fatigue properties. Consideration would also need to be given to the end-of-life prospects for the plastic modified pavement and its ability to be reused or recycled. Recycled plastics can be used in non-structural and low risk concrete applications as a partial aggregate replacement or a fibre reinforcement.

Environment

Utilising recycled plastics presents the opportunity to recover valuable resources and reduce the volume of material being sent to landfill. The key areas for potential environmental impact from the integration of recycled plastics includes:

- leaching of potential contaminants of concern
  - This will depend on the type of plastic utilised, but may include volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), etc.
- generation and release of microplastics
  - The impacts of microplastics on the environment are an emerging issue with extensive research being conducted.

Further, depending on the waste stream utilised (e.g. commercial and industrial or municipal), there is the potential for the presence of additional unknown contaminants. When bound, the potential for leaching of any contaminants and the release of microplastics is greatly reduced however further investigation is required into the potential long-term impacts of recycled plastics in road infrastructure (Environmental Protection Authority, Western Australia 2013).

Work health and safety

Similar to the integration of crumb rubber in asphalt and sprayed seals (refer Section 4.1.4), the hybrid and wet methods include a heating process which has the potential to emit fumes and airborne particles from potential contaminants. Emissions of VOCs and PAHs are known to increase as temperature increases (Mitchell 2022). Further research may be required to verify the extent of potential impacts to human health.

Areas where additional actions may be required include the integration of safe work practices, utilising warm mix asphalt to reduce emissions, and the use of personal protective equipment (PPE).

Waste recovery process

Recycled plastic is again a highly available material with recycling capacity in WA. However, the recycling and use of waste plastic will depend on the type of plastic waste. The process for recycling plastic begins with the collection of waste plastic from sources across all 3 waste streams, which may already be separated from other waste materials or will require separation. The waste is then transported to recycling facilities where it is sorted based on its type of plastic (PET, DFPE, PVC, etc.) and cleaned to remove any contaminants that remain on the plastic (such as paper, additives and liquids). The plastic must also be dried, after contaminants have been removed and no moisture remains that may impact its performance. As recycled plastic has a range of other uses, it might also be melted into pallets or similar and stockpiled ready for transportation to other facilities that will reuse it. Depending on the plastic type and the intended use, the material might be melted to be mixed with additives such as stabilisers, processing aids, and compatibilisers that improve the performance of the recycled product.

If the recycled plastic pellets are to be used for drainage covers, bollards, cones, pipes and other ancillary components and road furniture, then it will be transported to the producers of these products. The equipment and process for creating the recycled products will vary across products as well as the type of waste plastic that can be used.

If the recycled plastic is to be used in bitumen, the plastic is then shredded and added to the bitumen with a high shear mixer before it is then transported to the site to be laid. Additional testing of the bitumen may also be carried out to ensure that it meets the performance criteria.

Case study: Concrete application

Polyrok is a manufactured material, made from soft plastic bags and packaging (Rawson 2020). It takes the form of a rock-like shape, which has commercial and environmental benefits across a range of industries, including construction. When used as a substitute to mineral aggregate in concrete, Polyrok makes the product lighter, easier to work with, more thermally efficient and durable. Natural mineral aggregate is a finite resource, and increasingly has a costly impact through its extraction process. Table 4.13 shows the physical properties of Polyrok.

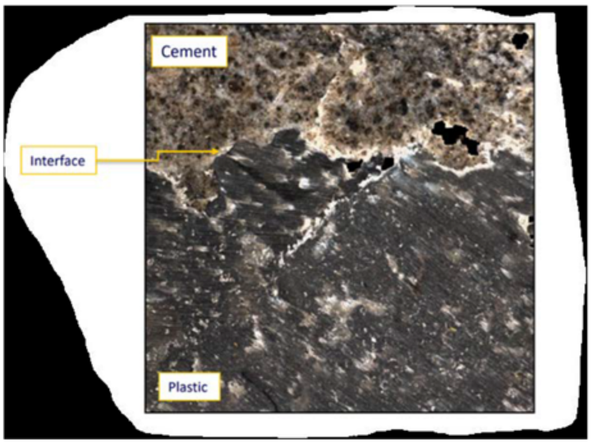
Table 4.13: Physical properties of Polyrok

Properties	Description
Polymer	Plastic sourced from post-consumer soft plastic waste
Reactivity	Inert and does not interact with cement or admixes
Main polymer constituents	HDPE, LDPE
Thermal conductivity	0.35 to 0.5 Wm-1K-1
Specific heat range	1,700 to 1,900 JK-1Kg-1
Specific gravity	0.82
Bulk density	0.4–0.5 kg/L

Source: Rawson (2020).

The manufacturing process creates a surface finish that enables bonding to the cement paste (refer Figure 4.8).

Figure 4.8: Polyrok bonding to cement



Source: Rawson (2020).

The addition of 5% of Polyrok aggregates provides 11% reduction in abrasion (Rawson 2020).

To demonstrate the successful reuse of this resource in concrete applications, the following case study from Mackay Regional Council, Queensland is outlined below.

Case Study: Mackay Regional Council Plastic in Concrete

More than 800,000 soft plastic bread bags from thousands of Queensland households have been recycled into a new aggregate replacement in concrete, with Mackay Regional Council pouring the state's first batch of Polyrok concrete in March 2022.

Source: Arreza (2022).

Case study: Asphalt application

To demonstrate the successful reuse of this recycled plastic in asphalt applications, the following case study from Stanley and Margaret St, Richmond has been included below.

Case Study: Stanley and Margaret Streets, Richmond Plastic in Asphalt

High density polyethylene (HDPE) plastics are introduced to asphalt via incorporation in binder product. This minimises the risk of micro-plastics generation and aids in the achievement of multiple performance benefits (Alex Fraser 2018).

Stanley and Margaret Streets in Richmond were repaved in 2018 with PolyPave, a product containing recycled glass, asphalt, and HDPE plastic (hard plastic/bottles) amounting to almost 100 tonnes of recycled waste. The project resulted in a reduction of 97.3 tonnes of waste going to landfill and a decrease of 633 kilograms of carbon emissions. Moreover, around 7,300 plastic bottles and 55,000 glass bottles were repurposed. This is equivalent to 1,500 wheelie bins full of waste plastic and glass, or the yearly curb side recycling collection for all homes in Stanley Street. The green mix design also included several tonnes of recycled asphalt (Parkinson Group 2020).

Alex Fraser (2018) suggested the incorporation of recycled plastics in asphalt may result in the following benefits:

- increased fatigue life
- improved asphalt rut resistance
- increased asphalt modulus/stiffness
- increased wet tensile strength
- reduction in asphalt mix flow and creep
- reduced effect of ultraviolet radiation damage
- less sensitivity to increased pavement temperature
- reduction in plastic to landfill and ocean eco systems.

Source: Alex Fraser (2018),.Parkinson Group (2020).

Potential future applications

Research is underway nationally to better understand the engineering performance and potential environmental, health and safety impacts of incorporating recycled plastics in road infrastructure. These studies include research and trials into utilising both hard and soft plastics in asphalt applications (Ecologiq 2022). The research project *Investigating the Use of Recycled Plastic in Future Sustainable Road Infrastructure* is also underway in Western Australia through the WARRIP program.

In addition to the use of recycled plastics in asphalt and concrete, the potential reuse options for recycled plastics in road furniture are discussed further in Section 4.1.10.

4.1.10 Recycled Materials in Road Furniture

The construction and integration of sustainable road furniture is an essential part of sustainable road construction. Road furniture includes those components outside of the standard road pavement and may include, but not be limited to:

- footpaths
- noise and retaining walls
- drainage infrastructure
- electrical and communications infrastructure
- signage and markers
- guideposts and bollards
- geosynthetics (geogrids and geotextiles).

There may be opportunities for the recycled materials discussed throughout Section 4.1 to be utilised in road structures and furniture. Some of these opportunities are shown in Table 4.14.

Table 4.14: Recycled materials in road structures and furniture

Material	Footpaths	Noise walls	Retaining walls	Underground infrastructure	Guideposts and bollards	Signage and markers	Geosynthetics	Landscaping
Reclaimed asphalt pavement (RAP)	✓							
Crushed concrete and bricks	✓	✓	✓					
Crushed glass/glass fibres	✓	✓	✓			✓	✓	✓
Crumb rubber/tyres	✓		✓		✓			✓
Fly ash	✓	✓	✓	✓				
Bottom ash	✓	✓	✓					
Blast furnace slag	✓	✓	✓	✓				
Food and garden organics (FOGO)								✓
Recycled plastics	✓	✓	✓	✓	✓	✓	✓	

Source: Hall et al. (2022),.MRWA (2022).

General applications and specifications

There are limited specifications dictating the use of recycled materials in road infrastructure and furniture (refer Table 4.15). The technical requirements dictated in these specifications may be leveraged to lead the development of road structures and furniture incorporating recycled materials and subsequent field trials.

Table 4.15: Recycled materials in road structures and furniture specifications

Specification	Agency	Application
WA		
Specification 404 Culverts	MRWA	• Use of fly ash in seawater or saline groundwater environments
Specification 602 Guide Posts	MRWA	• Use of rubber and plastic in flexible guide posts
Specification 820 Concrete for Structures	MRWA	• Use of fly ash in seawater or saline groundwater environments
Specification 904 Noise Walls	MRWA	• Use of recycled materials not included • Primarily dictates use of bricks and concrete

Environment, health and safety

The environment, health and safety benefits and impacts noted in previous sections apply when using those recycled materials in road structures and furniture. As each item will differ, there is however a potential for the risks to vary throughout the product's lifecycle. For example, tyre rubber in footpaths or guideposts may have a higher risk of releasing microplastics to the environment. It is recommended that the potential environment, health and safety impacts be considered and assessed prior to the procurement and/or manufacture of road structures and furniture containing recycled materials.

Case study

The extent of processing and equipment required to successfully utilise crumb rubber in road construction may result in the process currently being unachievable for some rural and regional local councils. As such, the following case study demonstrates the successful reuse of whole recycled tyres in wall systems, as opposed to crumb rubber. It has been sourced from the Tyre Stewardship Australia website (Tyre Stewardship Australia 2018).

Case Study: Recycled Tyres in Wall Systems

TSA accredited recycler, Lomwest Enterprises of Western Australia, has created a multi-application, high-performance wall system using baled end-of-life tyres sandwiched between highly stable concrete skins.

The walling system (called C4M) is built in modules and can be used for retaining walls, sound barriers, sea and blast walls, cyclone shelters and even race track impact barriers. They are manufactured off-site which allows for quick, easy and safe onsite construction. They can also have their outer surfaces architecturally modified to fit in with or enhance their environment.

Each C4M module contains 100 tightly baled used car tyres, sandwiched between precast panels and can be up to 2.4 metres in height. They also meet Australian and New Zealand stability, durability and relevant load standards, including for cyclone shelter construction and as fire rated partition walls.

The C4M walls are particularly effective in applications requiring energy absorption and stability such as with noise or in seaside and shifting soil applications. In addition, their fire-retardant properties provide added value in fire risk areas.

A recent example of the successful use of C4M walls is at BP's Kwinana refinery. There the modules have been used for a blast wall to protect infrastructure and personnel. Over 60 lineal metres of 3-m-high wall were manufactured and installed..

As befits a product that has a high recycled content, the C4M module is also highly recyclable due to the relatively flexible nature of the tyre bale. At the end of an application's life the concrete faces can be crushed-off by an excavator leaving the tyre bale intact for re-use with new face panels.

The TSA market development program is helping to fund further independent assessment of the benefits available from incorporating used tyres in such applications. The work, undertaken by Curtin University in Perth, will also assist in developing design parameters and quantifying performance properties for additional uses.

Innovative products, such as the C4M walls, can show the way forward in creating new green job opportunities and broader economic benefits from a previously intractable environmental challenge.

Source: Adapted from Tyre Stewardship Australia (2018).

4.2 Sustainable Road Construction Methods

A literature review was undertaken to produce a comprehensive guide of established sustainable road construction practices, suitable for use on local roads within WA. The review incorporated information from specifications and guidelines within WA and other jurisdictions.

Sustainable road construction practices use a modified process to achieve the target performance requirements in a sustainable manner. This may include repairing pavements via stabilisation techniques, recycling the existing materials within the road to conduct repairs or constructing new pavements, using locally available marginal and non-standard materials. Implementing a sustainable road construction practice will depend significantly on the availability of the equipment in the required locality.

The following sustainable road construction practices were identified as established or in development during the review and are further detailed in the subsequent sections:

- foamed bitumen stabilisation
- bitumen emulsion stabilisation
- cement stabilisation
- soil/subgrade stabilisation
- warm mix asphalt
- hot-in-place asphalt recycling
- in situ recycling of concrete pavements
- marginal and non-standard materials
- emerging practices.

4.2.1 Foamed Bitumen Stabilisation

Foamed bitumen stabilisation is generally undertaken within local government areas in Western Australia to remediate roads susceptible to cracking (MRWA 2022). It is a bitumen stabilisation technique utilised to provide cohesion in granular soils and improve waterproofing properties in clayey soils (Hall et al. 2022). Foamed bitumen is created via the mixture of foaming agent (application specific), air, water and hot C170 bitumen (Austroads 2019a). This mixture of materials produces an instantaneous expansion of the bitumen of up to 15 times its original volume (Austroads 2019a). Upon contact with the pavement, very fine droplets of bitumen are dispersed onto the underlying soils and/or pavement (Hall et al. 2022). Hydrated lime is also typically used as a secondary binder to stabilise road surfaces and form a cemented finish. This process improves strength during curing.

As highlighted by the Transport for NSW technical direction PTD 2015/00, a suitability assessment for the use of foamed bitumen stabilisation may include the following factors:

- cost
- pavement design requirements
- utility depth
- vibration during compaction
- moisture
- plasticity and particle size distribution (PSD) of the granular material

- existing bound pavement.

Stabilised pavements generally have numerous benefits over repairs completed with virgin materials. Some of these benefits include reduced construction costs compared with full depth asphalt pavements and improved moisture and flood resistance in comparison to granular materials susceptible to moisture. As the process stabilises the materials in situ, reduced cartage of additional materials is also required. White and Middleton (2010) note that some additional sustainability benefits include:

- reduced energy and emissions usage through reduced maintenance gradings
- reduced energy and emissions through reduced cartage of raw materials
- reduced road traffic costs due to improved rideability
- reduced dust emissions.

General applications and specifications

Foamed bitumen stabilisation is enabled through the MRWA Specification 515 for the *In-situ Stabilisation of Pavement Materials*. It is supported in local government via the WALGA *Pavement Rehabilitation Road Building Model Specification* (GHD 2022b).

Specifications relating to foamed bitumen stabilisation in WA are included within Table 4.16. Although foamed bitumen stabilisation practices have been used in different regions throughout Australia, the pavement materials in WA are different and therefore the process cannot be simply transferred from other states without the appropriate trials and testing process (MRWA 2022).

Table 4.16: Foamed bitumen stabilisation specifications

Specification	Agency	Application
WA		
Pavement Rehabilitation Road Building Model Specification (GHD 2022b)	WALGA	• Foamed bitumen products and materials, plant and equipment, environmental considerations, quality control
Specification 515 In-situ Stabilisation of Pavement Materials	MRWA	• Foamed bitumen products and materials, plant and equipment, construction and acceptance
National		
AGPT04D-19 Guide to Pavement Technology Part 4D Stabilised Materials (Austroads 2019a)	Austroads	• Materials and design
AGPT/T301 Determining the Foaming Characteristics of Bitumen (Austroads 2017e)	Austroads	• Test methods
AGPT/T302 Mixing of Foamed Bitumen Stabilised Materials (Austroads 2017d)	Austroads	• Test methods
AGPT/T303 Compaction of Test Cylinders of Foamed Bitumen Stabilised Mixtures Part 1 Dynamic Compaction using Marshall Drop Hammer (Austroads 2017a)	Austroads	• Test methods
AGPT/T305 Resilient Modulus of Foamed Bitumen Stabilised Materials (Austroads 2017f)	Austroads	• Test methods

Equipment and materials

The materials for stabilisation works can be plant-mixed or mixed in situ (Austroads 2019a). These processes are further described in Table 4.17.

Table 4.17: Stabilised materials mixing process

Process	Details
Plant-mixed	The plant-mixed process requires a stationary pugmill for the mixing of the stabilisation binder with the granular material. The stabilised material is then transported to site in trucks where it is spread, compacted, shaped, and cured as required.
In situ stabilised	The in situ stabilised process is conducted via mobile machinery and equipment, whereby a stabilisation binder is added to existing on-site materials and mixed with a purpose-designed road recycler. The material is then shaped, compacted and cured.

Source: Austroads (2019a).

Foamed bitumen stabilisation requires a variety of plant and equipment to ensure the successful application of the product. This includes plant for the supply of the stabilising agent, plant for the spreading of the chemical stabilising agent and plant for stabilisation (MRWA Specification 515). An example of a foamed bitumen stabilisation construction train is shown in Figure 4.9.

Figure 4.9: Foamed bitumen stabilisation construction train

Source: Rice et al. (2020).

Case study

To demonstrate the successful use of this resource on a local level, the following case study from the Wheatbelt region in WA has been included below.

Case Study: Foamed Bitumen Stabilisation Wheatbelt

In the Wheatbelt, Main Roads have used foam bitumen stabilisation, which (in regional environments) is economically sustainable and a time efficient process to stabilise the road surface. Over 6,200 m^2 has already been treated using this method. The application used 1.5% bitumen and 0.8% hydrated lime. Hydrated lime is commonly used as a secondary binder to stabilise road surfaces and form a cemented finish. This process improves strength during curing.

Source: MRWA (2022).

4.2.2 Bitumen Emulsion Stabilisation

Bitumen emulsion stabilisation is the process of incorporating a bitumen emulsion mixture into the upper pavement layer to improve the pavement strength (Aus-spec 2020). A bitumen emulsion mixture is comprised of approximately 60% bitumen and 40% water with a small quantity of emulsifier (Austroads 2019a). The emulsifier is either positively (cationic) or negatively (anionic) charged to ensure the mixture is kept in suspension and adheres to the aggregate (Hall et al. 2022). This process is best used for stabilisation of materials that have a low cohesion and plasticity and decreases the permeability and moisture sensitivity of the road surface (MRWA 2022). Similar to the foamed bitumen stabilisation process, hydrated lime is also typically used as a secondary binder to stabilise road surfaces and form a cemented finish. This process improves strength during curing.

General applications and specifications

There is currently limited use of bitumen emulsion stabilised materials in Australia (Austroads 2019a). Bitumen emulsion stabilisation is enabled through the MRWA Specification 511 for the Materials for bituminous emulsions. It is supported in local government via the WALGA *Pavement Rehabilitation Road Building Model Specification* (GHD 2022b).

Specifications relating to bitumen emulsion stabilisation in WA are included within Table 4.18.

Table 4.18: Bitumen emulsion stabilisation specifications

Specification	Agency	Application
WA		
Pavement Rehabilitation Road Building Model Specification (GHD 2022b)	WALGA	• Bitumen emulsion products and materials, plant and equipment, environmental considerations, quality control
Sprayed Bituminous Surfacing Road Building Model Specification (GHD 2022c)	WALGA	• Bitumen emulsion products and materials, plant and equipment, environmental considerations, quality control
Specification 511 Materials for Bituminous Treatments	MRWA	• Bitumen emulsion and materials, plant and equipment, construction and acceptance
Specification 515 In-situ Stabilisation of Pavement Materials	MRWA	• Bitumen emulsion construction and acceptance
National		
AGPT04D-19 Guide to Pavement Technology Part 4D: Stabilised Materials (Austroads 2019a)	Austroads	• Materials and design

Equipment and materials

Similar to foamed bitumen stabilisation, bitumen emulsion stabilisation materials can be either plant-mixed or mixed in situ (Austroads 2019a). Where in situ stabilisation works are being conducted, Aus-spec (2020) indicates the following equipment would be required:

- centrally mounted mixer with suitable power for adequate mixing of materials
- two separate pumping/injection systems regulated by the ground speed of the reclaimer/stabiliser for metering the bitumen and water
- a control device that calibrates the application rate in litre/m^2 of residual bitumen.

Case study

To demonstrate the application of this technique on a local level, the following case study from the Wheatbelt region in WA has been included below.

> Case Study: Wheatbelt Bitumen Emulsion Stabilisation
>
> The Main Roads Wheatbelt Region have been undertaking extensive pavement repairs using different emulsion stabilisation methods for over 3 years. In the 2020–21 financial year, 2,300 m^3 of pavement was to be treated by stabilising the basecourse.
>
> Source: MRWA (2022).

4.2.3 Cementitious Stabilisation

Cementitious stabilisation is utilised to stabilise granular materials with properties considered inadequate for use in pavements (e.g. cohesionless sands, silts, low-plasticity clays, etc.). Cement stabilisation can be tailored to meet the requirements of the specific granular materials. For example, Austroads (2019a) details the following binder applications by 28-day unconfined compressive strength (UCS):

- heavily bound or heavily cemented: > 3 MPa
- lightly bound or lightly cemented: 1–2 MPa
- modified: 0.7–1 MPa.

The combination of either cement or SCMs such as fly ash, blast furnace slag and lime with water into the granular mix will produce a bound material (Austroads 2019a). This process will generally improve the moisture susceptibility of a material and increase stiffness through increased tensile strength (Austroads 2019a; Hall et al. 2022).

The incorporation of fly ash and blast furnace slag as recycled materials, including engineering performance and environmental, health and safety risks, are discussed in Sections 4.1.5 and 4.1.7 respectively.

General applications and specifications

Any cement used for stabilisation works must comply with the requirements of AS 3972 and SP43 and, unless otherwise specified by local government, must be type LH (GHD 2022b). In accordance with MRWA Specification 515, high-early strength cement, type HE, must not be used as a stabilising agent. Cementitious stabilisation is also supported in local government via the WALGA *Pavement Rehabilitation Road Building Model Specification* (GHD 2022b).

Fly ash and blast furnace slag is approved through the MRWA specification as a supplementary cementitious material (SCM) in blended cement for use in stabilisation works, concrete for structures, as a low strength infill and the in situ stabilisation of pavement layers. When used as SCMs, the use of fly ash and blast furnace slag is required to conform to the requirements of AS/NZS 3582.1-2016, *Supplementary Cementitious Materials: Part 1: Fly Ash* and AS 3582.2 *Supplementary Cementitious Materials: Part 2: Slag: Ground Granulated Blast Furnace*. Smith and Hansen (2003) explored the following blends for stabilisation, reporting efficiency benefits with those containing the higher slag content:

- 70/30 cement/fly ash
- 70/30 cement/slag
- 75/25 cement/Fly ash
- 40/60 cement/slag.

Specifications relating to cementitious stabilisation in road infrastructure WA are included within Table 4.19.

Table 4.19: Cementitious stabilisation specifications

Specification	Agency	Application	Material	Max limit (% by mass)
WA				
Pavement Rehabilitation Road Building Model Specification (GHD 2022b)	WALGA	• Cement stabilisation works	N/A	N/A
Earthworks and Pavement Construction (GHD 2022a)	WALGA	• Earthworks and pavement construction	N/A	N/A
Granular Pavements Materials Road Building Model Specification (GHD and WALGA 2022)	GHD and WALGA	• Supply of unbound and centrally stabilised (plant-mix) granular pavement materials, including basecourse and subbase	N/A	N/A
Specification 302 Earthworks	MRWA	• Cement stabilisation of subgrade	SCM in blended cement	Not specified

Specification	Agency	Application	Material	Max limit (% by mass)
Specification 404 Culverts	MRWA	• Concrete for culverts	SCM in blended cement	25
Specification 410 Low Strength Infill	MRWA	• Low strength infill for the backfilling of redundant or abandoned pipes, culverts and other buried structures	SCM in blended cement	Not specified
Specification 515 In-situ Stabilisation of Pavement Materials	MRWA	• In situ stabilisation of granular pavement layers	SCM in blended cement	Not specified
Specification 820 Concrete for Structures	MRWA	• High performance concrete for structures	SCM in blended cement	25
Specification 507 Microsurfacing	MRWA	• Microsurfacing	Mineral filler	Not specified
Specification 901 Concrete: General Works	MRWA	• Concrete for general non-structural works	SCM in blended cement	Not specified
National				
AGPT04C-17 (Austroads 2017b)	Austroads	• Lean-mix concrete subbase	SCM in binder(1)	60
		• Base concrete	SCM in binder(2)	20
ATS 5330 (Austroads 2020b)	Austroads	• Geopolymer concrete	Binder	Not specified
ATS 3450 (Austroads 2021)	Austroads	• Microsurfacing	Mineral filler	Not specified
AGPT04B-14 (Austroads 2014)	Austroads	• Asphalt	Mineral filler	Not specified
AGPT04D-19 (Austroads 2019a)	Austroads	• Stabilisation (pavement and earthworks)	Binder	Not specified
			SCM	Not specified
AGPT4L-09 (Austroads 2009b)	Austroads		Binder (in cement-FA blends)	50
			Binder (in lime-FA blends)	75
			Binder (in lime slag-FA blends)	50
			Binder (in cement slag-FA blends)	40

1. The total binder content is 10% consisting of 6% fly ash and 4% cement.
2. The total binder content is 15% consisting of 3% fly ash and 12% cement.

Equipment and materials

Similar to the aforementioned stabilisation techniques, cementitious stabilisation can be undertaken either in situ or through a fixed-plant mix pugmill operation (Hall et al. 2022). Cementitious stabilisation in the field (in situ) is shown in Figure 4.10.

Figure 4.10: Cementitious stabilisation construction

Source: Rice et al. (2020).

Case study

To demonstrate the application of this technique on a national level, the following case study from the Bruce Highway in Northern Queensland has been included below.

Case Study: Bruce Highway Cement Stabilised Base

The Bruce Highway is a 1,700 km major state highway running adjacent to the Queensland coastline, connecting Brisbane to Cairns. The road section is located outside of Ingham, approximately 110 km north of the Townsville CBD. The interregional route caters to both commuter and commercial traffic including an AADT of 6,991 and 15% heavy vehicles in 2013. This road section was constructed in 2008 and consists of a spray seal surfacing, 300 mm plant-mixed cement modified base (PM-CMB) layer (2% stabilising agent), 150 mm unbound granular subbase, and 150 mm select fill subgrade. The pavement was designed to service 1.19 x 107 ESA, 66% of which had been consumed by January 2013. The overall condition of the road section was categorised as good during the desktop review, with the majority of the sections excellent, 8 sections categorised as good and 5 categorised as mediocre, all as a result of the rutting criteria.

The overall good condition of the road section was confirmed during a site inspection. Isolated areas of low-severity rutting and light wheel path flushing were observed as shown in the above figure. Signs of recent inundation were detected but without any associated structural pavement distress. The road section is an example of an intermediate life (6 years) pavement exhibiting good performance in a high-risk environment.

Source: Griffin et al. (2015).

4.2.4 Soil/Subgrade Stabilisation

Soil/subgrade stabilisation is undertaken to stabilise granular materials with properties considered inadequate for use in pavements (e.g. cohesionless sands, silts, low-plasticity clays, etc.). Stabilisation is typically undertaken to improve properties including strength, permeability, volume stability and durability (Rice et al. 2020). Some common soil/subgrade stabilisation methods include:

- granular stabilisation (blending multiple different types of granular materials to improve properties (Rice et al. 2020))
- cementitious stabilisation (refer Section 4.2.3)
- lime stabilisation (ideal for use in clayey soils as lime binds to clay particles to make it less susceptible to moisture changes (MRWA 2022))
- chemical additives (primarily used as a binder for fine soil particles (Rice et al. 2020))
- geotextiles and geogrids.

General applications and specifications

Soil and subgrade stabilisation is an important element of sustainable road construction. Lime stabilisation is permitted for use in WA in accordance with MRWA Specification 302 *Earthworks*. Additional in situ stabilisation requirements for granular pavement layers are detailed in MRWA Specification 515 *In Situ Stabilisation*. Soil/subgrade stabilisation is also supported in local government via the WALGA specifications; *Pavement Rehabilitation Road Building Model Specification* (GHD 2022b), *Earthworks and Pavement Construction* – Road Building Model Specification (GHD 2022a).

Specifications relating to the use of stabilisation in road infrastructure in WA are included within Table 4.20.

Table 4.20: Soil/subgrade stabilisation specifications

Specification	Agency	Application	Material	Max limit (% by mass)
WA				
Pavement Rehabilitation Road Building Model Specification (GHD 2022b)	WALGA	• In situ stabilised pavement materials.	N/A	N/A
Earthworks and Pavement Construction – Road Building Model Specification (GHD 2022a)	WALGA	• Earthworks and pavement construction	N/A	N/A
Specification 302 Earthworks	MRWA	• Lime stabilisation of subgrade	SCM in blended cement	Not specified
National				
AGPT04D-19 (Austroads 2019a)	Austroads	• Stabilisation (pavement and earthworks)	Binder	Not specified
			SCM	Not specified

Equipment and materials

Soil/subgrade stabilisation can be undertaken either in situ or through a fixed-plant mix pugmill operation (Hall et al. 2022). The requirements for the equipment required for in situ stabilised pavement materials is detailed in the WALGA specification *Pavement Rehabilitation Road Building Model Specification* (GHD 2022b).

4.2.5 Warm Mix Asphalt

Warm mix asphalt refers to the preparation of asphalt at a lower temperature than hot mix asphalt.

Cocks et al. (2017) list the benefits of using warm mix asphalt as:

- improved and extended workability
- consistent compaction
- energy savings
- reduced emissions

- extended paving season
- increased haul distance (i.e. the distance to the asphalt plant can be increased)
- reduced issues with crack sealant
- less oxidised binder at time of construction
- reduce brittleness of binder
- improved rideability.

Benefits such as the increased haulage distance would be advantageous in regional, remote and very remote areas. An example of reduced emissions from warm mix asphalt is shown in Figure 4.11.

Figure 4.11: HMA fuming (left)/WMA no fuming (right)

Source: Cocks et al. (2017).

Austroads (2019b) notes that most warm mix asphalt technologies require some form of licensing, modified asphalt mixing plant or the use of proprietary products as additives. Common processes for achieving a warm mix asphalt includes:

- foamed bitumen
  - direct injection
  - two-component binder system
  - addition of synthetic zeolite
- addition of workability additives (e.g. Rediset)
- additional of waxy type additives (e.g. Sasobit)
- bitumen emulsions.

General applications and specifications

The use of warm mix asphalt is enabled through several MRWA specifications, depending on the required application (e.g. wearing or intermediate course). The warm mix additives approved for use on MRWA projects include:

- Sasobit
- Evotherm.

The MRWA specifications are supported in local government via the WALGA Tender Specification, Tender Form and Schedule for Supply and Laying of Asphalt Road Surfacing (IPWEA & AAPA 2016). The WALGA specification states that warm mix asphalt must meet the same requirements as hot mix asphalt, with the exception of the temperature.

Specifications relating to foamed bitumen stabilisation in WA are included within Table 4.21.

Table 4.21: Warm mix asphalt specifications

Specification	Agency	Application
WA		
Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Road Surfacing (IPWEA & AAPA 2016)	WALGA	• Foamed bitumen products and materials, plant and equipment, environmental considerations, quality control.
Specification 502 Stone Mastic Asphalt	MRWA	• Products and materials, mix design, manufacture and transport, placing of asphalt
Specification 504 Asphalt Wearing Course	MRWA	• Products and materials, mix design, manufacture and transport, placing of asphalt
Specification 510 Asphalt Intermediate Course	MRWA	• Products and materials, mix design, manufacture and transport, placing of asphalt
Specification 511 Materials for Bituminous Treatments	MRWA	• Workability additives
Specification 516 Crumb Rubber Open Graded Asphalt	MRWA	• Products and materials, mix design, manufacture and transport, placing of asphalt
National		
Guide to Pavement Technology Part 3: Pavement Surfacings (Austroads 2009a)	Austroads	• General application
Guide to Pavement Technology Part 4B: Asphalt (Austroads 2014)	Austroads	• Applications, mix designs, manufacturing
Guide to Pavement Technology Part 4F: Bituminous Binders (Austroads 2017c)	Austroads	• Additives

Equipment and materials

Standard hot mix asphalt plant and equipment can generally be modified to suit warm mix asphalt requirements, depending on the chosen technology (Cocks et al. 2017). For example, standard hot mix asphalt equipment can be used for additive based warm mix asphalt technologies, with the simple edition of facilities for handling, dosing and blending of additives (Austroads 2014). Further, binder foaming technologies require asphalt mixing modifications (Austroads 2014).

Case study

To demonstrate application of this technique on a local level, the following case study from the Great Eastern Highway Road project in WA has been included below.

Case Study: Warm Mix Asphalt on the Great Eastern Highway

The Great Eastern Highway project, constructed by the City East Alliance, included the implementation, demonstration and construction of warm mix asphalt with and without RAP on the route. Free water foamed bitumen technology for the production of WMA was selected, as after the initial capital outlay, apart from routine maintenance of the foaming manifold, only water was required for the production of the foam. The Alliance committed to an Astec free water foaming manifold which was retrofitted to the existing asphalt plant.

Asphalt mixes used in the trials were the MRWA approved Boral job mix 33 (JM33) which is a continuously graded 20 mm mix using C320 binder that made up the bulk of the intermediate layers of the structural pavement. The layers were placed in lifts of around 60 to 85 mm with a diluted cationic emulsion tack coat (CRS Cat 30) applied at each interface at a rate of around 0.6 L/m^2. The upper layer of the intermediate mix and the wearing course asphalt was the Boral (JM34), a 14 mm continuously graded mix using an A15E polymer modified binder. The mixes were all compacted to 96% Marshal density with a minimum allowable air voids content of 3%. A water proofing spray seal was applied on top of the first layer of 14 mm mix and comprised a 10 mm +5 mm double-double seal using 2.0 L/m^2 of CRS60/170 applied as 1.1 and 0.9 L/m^2 to each layer respectively.

There are 9 individual trial sections which are 110 m to 150 m in length which extended from chainage 3340 to chainage 4300. The aim of the trials was to construct individual sections that had only WMA with and without RAP at different locations within the pavement and compare the performance of each section over time against the control which is essentially the balance of the project.

During the implementation of the WMA, the newly installed foaming manifold was used to produce HMA (170 °C) and the paving crew immediately acknowledged that the product was easier to place and compact. There was a marked increase in the density achieved and the overall finish was improved. As a consequence, the foaming apparatus was used continuously during the production of the HMA for the entire project. Continuously graded mixes (20 mm and 14 mm) were laid using C320 binder and the placing temperatures were lowered to 140 °C. The workability was found to be quite acceptable with no detrimental effects on the asphalt test results. The aim was to construct the WMA trials at 130 °C but during normal production as the temperature of the mix was reduced it was found that drying of the aggregate was not always satisfactory and binder coating was not acceptable. A temperature of 140 °C was found to be acceptable for the mixes produced with C320 binder.

The various trial sections comprised RAP/hot mix and RAP/warm mix. By 2020 the trials have been in place for 3 years and an annual visual inspection had not revealed any difference in the performance of the pavement. MRWA view this section as a long-term trial and have on their business plan in the following years to extract samples to check lead indicator performance such as modulus, indirect tensile strength and possibly fatigue testing in the foreseeable future, to assess the performance.

Source: Adapted from Cocks et al. (2017).

4.2.6 Hot-in-Place Asphalt Recycling

The hot-in-place asphalt recycling (HIPAR) process is an in situ pavement rehabilitation technique that mills an existing road and re-lays the recycled mix in one passing. As detailed in Austroads (2019b), it is undertaken using a train of equipment which:

- heats and mills the existing asphalt surface material (to a depth of approximately 50 mm)
- mixes the millings with aggregate, binder and a rejuvenating agent as required
- places and compacts the new mix onto the pavement in a single pass.

Austroads (2019b) indicates that appropriate uses for HIPAR include:

- rehabilitation of major structurally sound roads
- restoration of surface shape, texture and skid resistance
- rejuvenation of oxidised binders
- rehabilitation of problem asphalt layers
- addition of a thin layer of asphalt to a pavement.

Some of the key benefits of the HIPAR process are related to the fact that the pavement rehabilitation process can be undertaken in one pass, using existing road materials. These benefits include:

- cost savings
- reduced use of virgin materials
- reduced traffic delays.

Key factors requiring consideration prior to the adoption of this technology include the significant quantity of gas required for heating and the details of the existing pavement (e.g. properties and thickness of the existing asphalt and the presence of moisture in the pavement) (Austroads 2019b).

General applications and specifications

There are currently limited specifications in Australia covering the HIPAR process in road infrastructure, with further research required to improve uptake. Austroads has included details of the HIPAR process in the *Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design* (Austroads 2019b) (refer Table 4.22). Details of the HIPAR process have not been identified within WA specifications.

Table 4.22: HIPAR specifications

Specification	Agency	Application
National		
AGPT05-19 Guide to Pavement Technology Part 5 Pavement Evaluation and Treatment Design (Austroads 2019b)	Austroads	• Process outline

Equipment and materials

The HIPAR process is conducted in situ via a recycling train (refer Figure 4.12) typically including (Geopave 2001):

- pre-heater(s)
- delivery truck (add mix)
- main unit
  - receiving hopper for add mix
  - hoppers for storing materials
  - scarifier
  - pugmill mixer
  - augers and conventional asphalt tamping screed
  - binder/rejuvenator tank
  - distribution auger and screed
- rollers.

Figure 4.12: HIPAR recycling train

Source: Geopave (2001).

4.2.7 In situ Recycling of Concrete Pavements

In situ recycling can be conducted to rehabilitate and recycle existing concrete pavements. The 2 main techniques for undertaking these works include 'crack and seat' and rubblisation. These techniques fracture the existing concrete pavement into smaller pieces, prior to constructing a new road on the surface (TMR 2022). The 2 techniques are summarised in Table 4.23.

Table 4.23: In situ recycling processes

Technique	Process details
Crack and seat	Existing concrete pavements are cracked into 300 mm to 600 mm square sections. The sections are then rolled and pushed down onto the underlying pavement.
Rubblisation	The existing concrete pavement is pulverised until it resembles a coarse granular material. An asphalt overlay is then applied over the fractured and seated slabs to strengthen the pavement.

Source: Austroads (2019a).

As in situ concrete recycling is a relatively costly process, the severity of deterioration and the requirement for extensive repair should be taken into account prior to selecting this option (Austroads 2019a).

General applications and specifications

There are currently limited specifications in Australia outlining the process for the in situ recycling of concrete materials, with further research and field trials required to improve uptake. Austroads has included details of the crack and seat and rubblisation process in the *Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design* (Austroads 2019b) (refer Table 4.24). Details of this process have not been identified within WA specifications.

Table 4.24: In situ concrete recycling specifications

Specification	Agency	Application
National		
AGPT05-19 Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design (Austroads 2019b)	Austroads	• Process outline

Equipment and materials

In situ recycling of concrete pavements is conducted using specialised equipment. For example, RPQ Group use a machine with 2 lines of multiple falling weights called hammers that break and pulverise the pavement at predetermined intervals to complete rubblisation works (RPQ Group 2023) (refer Figure 4.13). For the 'crack and seat' technique, the weights are modified to hit the surface to create 1 m^2 slabs, prior to being further processed by a roller (RPQ Group 2023).

Figure 4.13: Rubblisation works

Source: RPQ Group (2023).

4.2.8 Marginal and Non-standard Materials

Marginal and non-standard materials are naturally sourced materials that do not necessarily meet the specifications for use in road construction. Typically comprising naturally occurring gravels, weathered rocks and occasionally clayey sands, they are known to successfully perform as granular base and subbase materials (Austroads 2018). These materials are often required for use in regional environments as they are prevalent and readily available (Cocks et al. 2017). The use of recycled materials (e.g. crushed recycled concrete and bricks, RAP, etc.) and sustainable practices such as in situ recycling should still be encouraged to reduce the dependency on natural resources.

General applications and specifications

The use of marginal and non-standard materials is enabled through the MRWA Specification 501 *Pavements*. This specification includes guidance notes for natural laterites and ferricretes for use in selected regions. It is supported by the Austroads publication *Appropriate Use of Marginal and Non-standard Materials in Road Construction and Maintenance* (Austroads 2018). Use of natural fragmented ferricrete and lateritic gravel is also supported in local government via the WALGA specification Granular Pavements Materials Road Building Model Specification (GHD and WALGA 2022).

Specifications relating to the use of marginal and non-standard materials in WA are included within Table 4.25.

Table 4.25: Marginal and non-standard materials specifications

Specification	Agency	Application
WA		
Granular Pavements Materials Road Building Model Specification (GHD and WALGA 2022)	GHD and WALGA	• Supply of unbound and centrally stabilised (plant-mix) granular pavement materials, including basecourse and subbase
Specification 501 Pavements	MRWA	• Guidance notes available for natural laterites and ferricretes for use in selected regions
National		
AP-T335-18 Appropriate Use of Marginal and Non-standard Materials in Road Construction and Maintenance (Austroads 2018)	Austroads	• Materials and use

Equipment and materials

Marginal and non-standard materials can be used in road construction using conventional equipment and machinery (Austroads 2018).

Case study

To demonstrate the successful use of these materials on a local level, the following case study incorporating crushed recycled concrete with ferricrete (natural gravel) in WA has been included below.

Case Study: Crushed Recycled Concrete with Ferricrete

The idea of blending and crushing recycled concrete with ferricrete (laterite cap rock) was first proposed in 1996 by Warren Slater (of Quarry Park Pty Ltd) as a means of utilising demolition rubble from the Broome meatworks. Samples from concrete and ferricrete crushed separately were assessed for particle size distribution. Theoretical particle size distributions were calculated for various combined proportions of the 2 materials. The Broome study led to a recommended blend of 2 parts ferricrete to one part concrete. In 1997 the Eastern Metropolitan Regional Council (EMRC) commissioned a trial of a blend of ferricrete (2 parts) and concrete (1 part). The ferricrete came from the Red Hill waste disposal site where it had been excavated as part of construction of waste cells. The concrete came from recovered concrete road kerbing and similar sources. There were 2 reasons for the trial:

- Adding moist ferricrete to the dry concrete before crushing was intended to reduce the dust created in the concrete crushing process.
- Based on theoretical particle size distributions, the blended material should have superior properties to the crushed concrete on its own.

A blend of crushed recycled concrete and crushed ferricrete was used to construct a 500 m long section of Victoria Road in West Swan between West Swan Road and Tomlin Road. A visual assessment of the pavement in 2016 (about 17 years after construction) indicated very good performance with defects limited to meandering cracks adjacent to Moreton Bay fig trees at 2 locations.

Source: Cocks et al. (2017).

4.3 Emerging Materials and Methods

The aforementioned recycled materials and sustainable road construction practices continue to undergo research and development works to further define and enable successful use projects. Examples of research projects recently completed or currently underway in this space within WA through the WARRIP program include:

- Evaluating the digestion potential of crumb rubber in road grade bitumen – *in progress*
- Investigating the use of recycled plastic in future sustainable road infrastructure – *in progress*
- Investigating the use of reclaimed asphalt pavement from asphalt containing crumb rubber modified binder
- Investigating the use of recycled materials in granular support layers in Western Australia

- Implementing the increased use of reclaimed asphalt pavement (RAP)
- Transfer of crumb rubber modified bitumen technology to Western Australia
- Development of specifications and technical guidelines for warm mix asphalt.

4.3.1 Recycled Materials

All waste streams can be considered for use in road construction. A key consideration with any emerging material however is ensuring long-term performance benefits whilst ensuring the safety and sustainability of the environment, community and workers (TMR 2020). All appropriate investigations, including sampling and analysis of materials by suitably qualified professionals, need to be completed and accepted prior to the use of any emerging material.

Mining waste

Recycled materials for potential use in road construction projects are often the by-product of a new or existing process. The prevalence of the mining industry within WA introduces numerous by-product materials as potential resources for use in road construction practices. MRWA (2022) includes the following list of some of the mining waste (overburden) opportunities:

- Kimberley Region:
  - Savannah Nickel waste rock
  - Pacific Niugini Nicholson’s gold deposit
  - Rio Tinto Argyle Diamond Mine
- Pilbara Region
  - Marandoo Rio Tinto iron ore deposit
  - FMG CID deposit
  - Novo Resources – Beaton’s Creek
- Goldfields Region
  - Austral Pacific ex Paris and HHH mines
- Wheatbelt Region
  - Dalwallinu gold mine
- Great Southern Region
  - Mt. Cattlin Mine Site – Galaxy Resources, Ravensthorpe
- Mid-West Gascoyne Region
  - Plutonic Mine
  - Crusher dust.

Advances in mining and industry also present opportunities in the recycled materials space. The abundance of lithium mining in Western Australia has demonstrated that Australia has become a key supplier of lithium globally (Kurmelovs 2022). Applicable producing, or soon to be producing, lithium mines in Western Australia include Pilgangoora, Mount Cattlin, Early Grey, Mount Marion and Bald Hill deposits, plus other deposits with significant lithium resources (Geoscience Australia 2019). The mining waste (overburden) associated with these new ventures may also present opportunities for increasing the quantity of recycled materials in road construction.

Waste-to-energy by-products

In addition, and as detailed in Section 4.1.6, a new bottom ash recycling facility is being constructed in Kwinana (Kerman 2023) to manage by-products from waste-to-energy facilities and convert the materials into a reusable product. This facility may also present opportunities for increasing the quantity of incinerator bottom ash and incinerator bottom ash aggregate in road construction.

Another material increasingly under consideration for reuse is biochar, a thermally treated biosolids material. Biochar is another by-product of the waste-to-energy process. It can also be generated during the treatment of soils containing PFAS. Reuse of this material in road construction is a preferential outcome to minimise volumes currently sent to landfill. Similar to bottom ash however, consideration of the environmental risks associated with reusing this product are essential.

Recycled sand

Recycled sand can be generated via the processing of construction and demolition waste. It can be used in embankments and subgrade layers in accordance with MRWA *Specification 302 Earthworks*, however it is recommended that the Main Roads Materials Engineering Branch be contacted for further information (MRWA 2022).

It is essential that any recycled sand used in road construction projects is free of contaminated soils and other deleterious materials (MRWA 2022). To support this, a recycled sand specification is under development by the Department of Water and Environmental Regulation.

4.3.2 Emerging Sustainable Road Construction Practices

Ongoing research and development efforts are also working to ensure the continual improvement of sustainable road construction practices. Some of these emerging techniques include, but are not limited to:

- bio-binders: binders derived from renewable resources
- recycled crushed glass as a powder to be used as a pozzolan (i.e. reacting with lime to form stabilised materials (Austroads 2022c)
- intelligent compaction.

Intelligent compaction refers to the use of a roller equipped with an integrated measurement system and sensors that provides an operator with real-time feedback on the status of the compaction efforts, without the need for timely external testing (NACOE 2022). It has the potential to provide a reduction in greenhouse gas emissions due to the optimised construction practices.

5 Desktop Study on Recycled Material Availability

The practical usage of recycled materials and sustainable practices will depend on the availability of material processing facility and equipment, which will vary from local government area to area. The following section investigates this availability, beginning from the waste generation and recovery process to the recycled product that is ready to be incorporated into transport infrastructure.

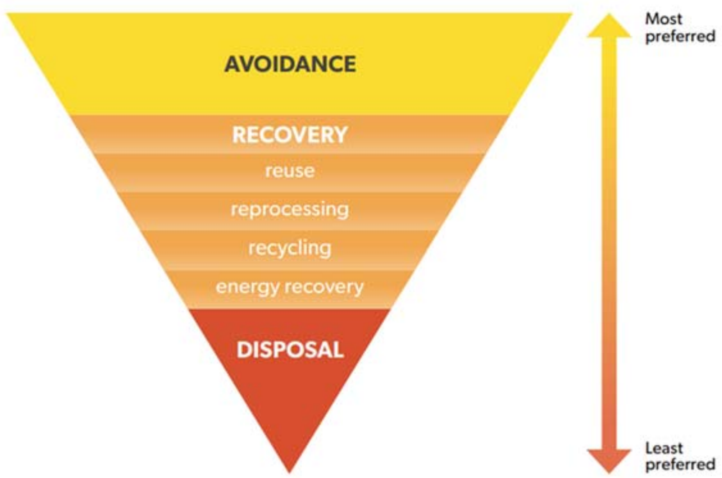
5.1 Waste Management

The guiding principle of a circular economy is to take products from waste at the product's end-of-life and incorporate them into the life of another product. With Western Australia's increasing amount of waste generation and relatively low waste reuse rate, when compared with other Australian states and nationally (Pickin et al. 2018), waste not only becomes a significant sustainability issue, but also a significant challenge to recycled material availability. Both local and state governments have created policies and incentives to improve the outcomes to waste management across the state. The Waste Authority's *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Strategy) set targets for each step of their 'avoid, recover, protect' strategy for managing waste, aiming to increase material recovery to 75% by 2030.

Complementing the circular economy outlook is the waste management hierarchy, which ranks the various products' end of life alternatives in order of the most sustainably beneficial options. The waste hierarchy adopted by the Waste Strategy, shown in Figure 5.1, begins with avoiding waste by reducing waste generation. Next, where waste is inevitable the second stage of the hierarchy is to recover as much benefit from the product, this benefit goes towards other products and processes. Finally, if no more material or energy can be recovered from the waste, then it is to be disposed of in the most sustainable way possible. It is in this middle grouping, that products contribute to a circular economy by contributing to another product.

The hierarchy within this grouping is in order of the most benefit with the least input of resources, being reuse, reprocessing, recycling and energy recovery. For example, a glass bottle being reused as a glass bottle for another drink has full recovery of the product with minimal costs (the only cost being the transportation from its 'waste location' to the plant where it is reused), but where the glass requires repurposing such as crushing, this would be a less desirable end use, as the energy required to recover this benefit is higher. Although the recovery process of various recycled materials in road infrastructure may not fit as definitively into one of these subcategories, this hierarchy supports the use of the maximum amount of recycled material with the least energy to utilise the material.

Figure 5.1: Waste hierarchy according to WA waste strategy

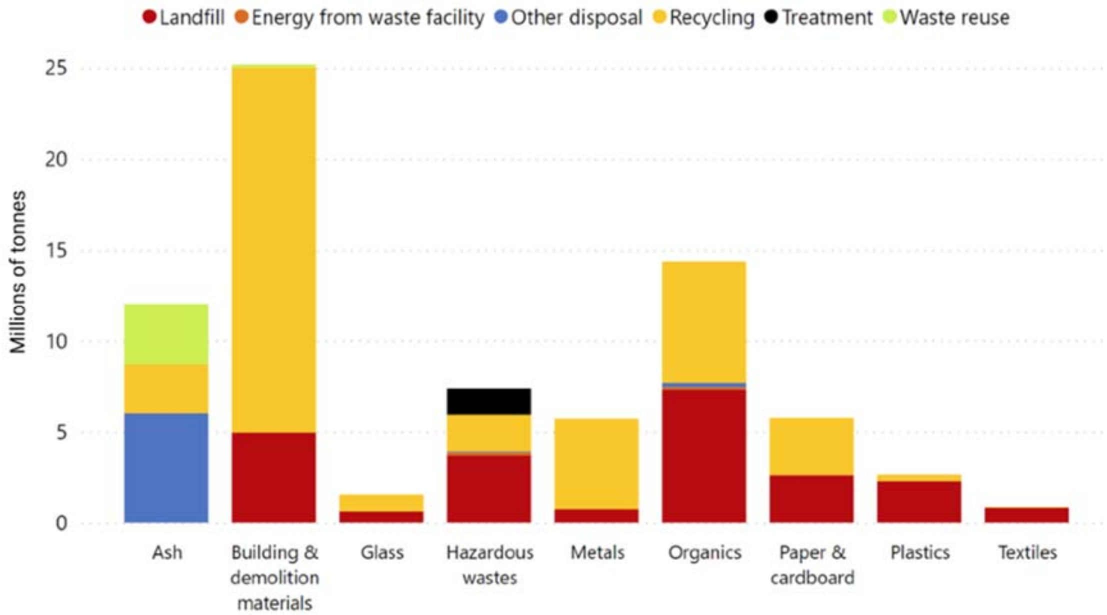


Source: Waste Authority (2019b).

However, maximising recovered benefit and minimising energy are not the only factors that determine which recovery processes are/should be used. The recovery process for materials will depend on the waste material, the intended recycled product to be produced, the demand for the recycled product and the combination of availability of the material and equipment needed to process it. Therefore, not all waste materials will be recovered via the highest possible recovery method, but it remains an important tool for planning waste management strategies.

Figure 5.2 shows the amount of waste and the end-of-life destination for various materials nationally. This data demonstrates the current successes of material recycling and the opportunities that are present to divert further waste from landfill. Building and demolition waste is the area with the highest amount of recycling, largely due to the number of facilities and companies that work to recycle this waste. The recycling of waste from building and demolition is also encouraged across the industry. Furthermore, recycling organic waste presents the greatest opportunity to divert waste from landfill, with plastics, and paper and cardboard also presenting a significant opportunity. This underscores the need to further adopt uses for recycled organics and recycled plastic in road infrastructure.

Figure 5.2: Waste management of materials in Australia 2020–21



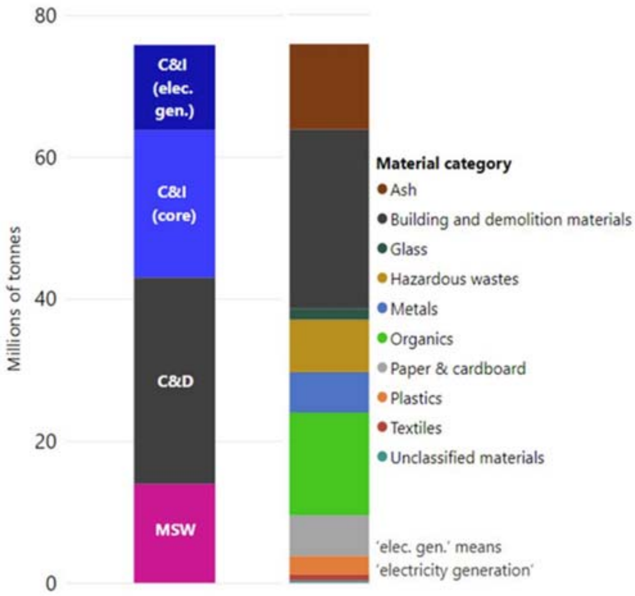
Source: National Waste and Recyclling Industry Council 2022.

Western Australia, consistent with other jurisdictions, categorises waste into 3 streams:

1. municipal solid waste, (MSW) (waste generated from households and local governments),
2. commercial and industrial (C&I) waste
3. construction and demolition (C&D) waste.

The amount of waste generated according to the National Waste Report 2022, by the streams nationally in 2020–21 is shown in Figure 5.3 There has been a 3.3% decline of waste per-capita over the last 15 years (DCCEEW 2023a). However, this is comprised of a 13% decrease in the MSW per capita and a 21% decrease in C&I waste, but a 39% increase in C&D waste due in large part to major development projects. Over this same time, the waste disposal has decreased to 37% of total waste generated, more than doubling the amount of waste recovered in the C&D steam. Table 5.1 shows the amount of waste generated, in millions of tonnes, by these streams in WA and the percentages that are recovered or disposed to landfill.

Figure 5.3: Waste generation in Australia by stream and material 2020–21



Source: DCCEEW (2023a).

Table 5.1: Waste generation in WA by stream and recovery v disposal 2020–21

	MSW	C&I	C&D	Total
Waste generated	1.5 mt	1.6 mt	3.2 mt	6.4 mt
Recovery	29%	40%	84%	60%
Disposal	71%	60%	16%	40%
Main materials	Organics (52%)	Metals (27%), paper (18%)	Concrete (80%)	

Source: Waste Authority WA (2021).

5.1.1 State Waste Management Actions

The Waste Authority is an agency of the Government of Western Australia. They produced and implement the Waste Strategy, and publish annual action plans, describing actions and strategies that are to be put in place to realise the goals and target of the Waste Strategy. The current action plan calls for the following:

- statewide communications on waste avoidance, resource recovery and waste disposal
- financial support for a three-bin kerbside collection system for all local governments in Perth and Peel regions by 2025
- sustainable government procurement to encourage use of recycled products.
- implement local government waste plans
- review the waste levy
- review of waste infrastructure and future infrastructure
- update data collection
- fund the recovery from waste.

These headline strategies are amongst 50 strategies outlined in the Waste Strategy and are each accompanied by targets, indicators, and timeframes, as well as a brief discussion of the challenges and risks. These strategies provide a range of measures to be implemented, comprising of grants, investigations, training, framework developments, testing and more.

5.1.2 Local Government Waste Management Actions

Local governments are required to prepare waste plans that support the Waste Strategy as set out by the Department of Water and Environmental Regulation (DWER) in their *Guidance Document Local Government Waste Plans* (DWER 2019b).

Waste management actions differ amongst local government areas, and there is not a set of waste management and collection strategies that are, or should be, adopted across all local governments. Waste management actions must align with the local waste capabilities and opportunities. Examples of local government waste strategies and actions taken at different stages of the waste and recycling cycle, either in WA or by local governments include:

- Waste reduction strategies:
  - waste reduction campaigns targeted at residents and industries
  - waste data collection and reporting
  - behaviour change
  - incentives or regulations for waste reduction.
- Waste collection actions to separate materials and assist the amount of waste that can be recovered by recycling facilities:
  - kerbside waste collection policies
  - better bins or bin tagging
  - separate collection locations for specific waste materials such as plastic (and types of plastic), green waste, paper and cardboard, and glass.
- Recycling facilities and processes
  - Council run drop-off locations and material recovery facilities with greater capacity and incentives for waste material that can be recycled
  - Expanding waste centres and refuse locations to provide processing of materials such as crushing or collecting materials for reuse
  - Locations for stockpiling recycled products such as crushed glass, crusher concrete and crumb rubber.
- Use of recycled products
  - Roads to Reuse Program
  - Requiring suppliers to use or report on the potential use of recycled materials in their works and services
  - Promotion of local markets for recycled products
  - Adopting best practice and guidance for the incorporation of recycled materials into infrastructure and works.

Furthermore, WALGA strives to support local governments in facilitating better waste management strategies and improving their sustainability and the circular economy. In collaboration with Waste Net, Waste Authority, Municipal Waste Advisory Council and others, WALGA attempts to facilitate the communication and sharing of resources across local governments to further improve waste management across WA.

Refer to Section 7.2 for information and opportunities for local governments to increase the use of recycled materials in road construction.

5.1.3 Industry Peak Bodies

In addition to the Waste Authority, the following agencies and associations have common aims to improve industry and public practices in the collection, processing, recycling and disposal of waste. They follow a common principle in supporting a circular economy:

- Western Australian Local Government Association (WALGA)
- National Waste and Recycling Industry Council (NWRIC) and the Waste and Recycling Industry Association of Western Australia (WRIWA)
- Australian Packaging Covenant Organisation (APCO)
- Australian Council of Recycling (ACOR)
- Australian Organics Recycling Association (AORA).

WALGA has a standing committee called the Municipal Waste Advisory Council, which in turn promotes information through the WasteNet web site (WALGA 2023). WALGA provides the following information through WasteNet relevant to this report:

- Better Practice Verge Collection Guidelines – to maximise the amount of material recovered.
- Pro Forma Waste Local Law – which may provide the facility for local governments to control waste streams and quality. Local governments should contact WALGA for advice on this matter.
- Planning for Waste Management – development applications from the perspective of land use planning..

The NWRIC produced an important reference in 2022 *National Recovered Material Specifications for Sorting and Processing Facilities* (NWRIC 2022). The report presents a large number of recommendations towards improving the specifications and methods of recovering materials from MSW. The report includes some recommendations relevant to local government on how they could acquire better specifications for separated waste streams.

As reported in their Annual Report 2022*,* WRIWA (2022) sought independent engineering advice recommending improved MRWA specifications and the use of Roads to Reuse compliant material as subbase for all MRWA sealed pavements.

The focus of APCO is the packaging supply chain, and in respect of this report that includes various types of plastic packaging materials and glass. Through their web site (APCO 2023), they promote the Australian Packaging Covenant (the Covenant), a national regulatory framework under the National Environment Protection (Used Packaging Materials) Measure 2011. Their Collective Impact Framework includes as Strategy 3.2 'Increase use of recycled packaging materials in other products and civil construction'.

ACOR (2023) provide recycled materials specifications, including:

- beneficiated cullet specifications (glass)
- post-consumer PVC bottles bale specifications
- PET container specifications
- HDPE bottle recyclate feedstock specifications.

AORA (2023) aims for surplus organic material to be 'sustainably and cost-effectively recycled; and to promote the beneficial use of compost, soil conditioners and mulches in primary industries'. In 2019 they produced the report *International Comparison of the Australian Standards for Composts, Soil Conditioners and Mulches* (AS 4454-2012) (AS 4454-2012 is the standard for Composts, Soils Conditioners and Mulches).

A key finding relevant to this report, is that compliance to AS 4454-2012 is voluntary and it is not intended to be a regulatory mechanism to control product quality. The report covers significant detail on a range of heavy metal, organic, and microplastics contaminants.

5.2 Recycling and Recovery

To incorporate recycled materials into road infrastructure, waste materials need to be reprocessed to be converted from their end-of-life state to become usable as a recycled raw material. Details for each material have been included in Section 5.1 above.

5.3 Materials Recovery and Recycled Product Facilities

Fundamental to the incorporation of recycling materials in local government projects is the availability of recycled products. In addition to various performance and product criteria that determine the suitability of a product for use in road and transport infrastructure, the location of the facilities that produce recycled products can further restrict the potential applications of recycled materials and practices for use. These facilities may work at different stages of the recycling cycle, ranging from collection of waste material to processing and finally, preparation of the recycled product. Although one facility can potentially do one or more of these functions, often with the described materials a combination of facilities will be required to incorporate recycled materials into roads.

Recycling facilities can loosely be divided into 2 primary categories, distinguished based on the degree of processing required for the materials they handle: primary and secondary recyclers.

Primary recyclers focus on collecting and separating materials for direct reuse or sending for further processing, secondary recyclers refine and process materials that require additional treatment or refinement before they can be reused. For example, for crushed recycled concrete, the waste concrete will be collected from the C&D worksite and transported to a C&D recycling facility that will separate out the concrete from other wastes (such as plastic, glass, sand and more) by a primary recycler such as a materials recovery facility. The waste concrete will then go a secondary recycler which will create the recycled product by crushing this concrete, removing contaminants and grading the material into the required size of an aggregate road base. However, some facilities might act as both a primary and secondary recycler collecting the waste and outputting the recycled product at the one location.

Understanding the local availability of both primary and secondary recyclers will allow local governments and suppliers to better understand the availability of recycled products and the applications that are available to local councils. This might also allow councils to identify the gaps in local infrastructure to use particular recycled materials and engage with stakeholders to expand the number of applications that a local government can implement.

Methodology

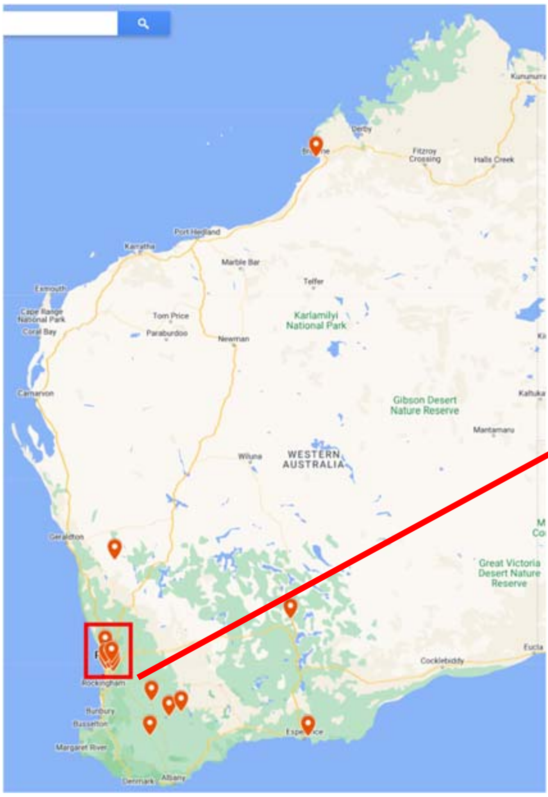
A database of recyclers was compiled from the Department of Climate Change, Energy, the Environment and Water (DCCEEW) Waste and Resource Recovery Data Hub (DCCEEW 2023b) and the WALGA Roads Infrastructure and Depot Services supplier list (WALGA n.d.a.) along with further web searching and input from stakeholders. These lists along with company information from websites and business information platforms, allowed the compilation of a list of suppliers that contains the type of recycler and infrastructure, their locations and the recycled materials they use. The list includes over 200 suppliers that are involved in the recycling process of the identified materials and forms the base for scoping the availability of recycled materials in local government areas. This list will be further refined based on the findings gathered during the stakeholder engagement to include specifics about each facility's capacity and capabilities.

5.3.1 Primary Facilities in Western Australia

Material recovery facilities

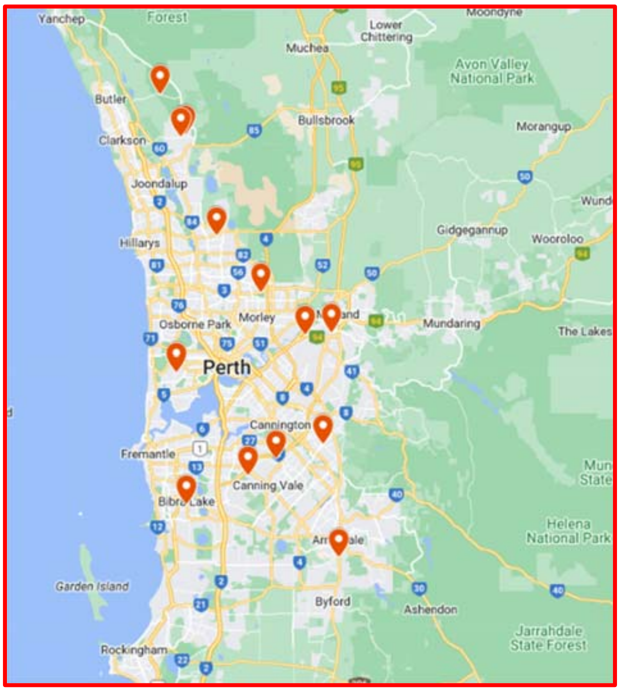
As mentioned above, materials recovery facilities (MRFs) mainly separate waste into its component materials. This is often the first step in the recycling process and therefore, these facilities are commonly drop-off locations for large amounts of waste. Although these materials are present across WA, they are mainly concentrated around Perth, with some facilities locally in the south-west of WA, Esperance, Broome and Kalgoorlie as shown in Figure 5.4 and Figure 5.5.

Figure 5.4: Location of MRFs in WA



Note: Section in red box is enhanced in Figure 5.5.

Figure 5.5: MRFs in Perth area



Source: DCCEEW and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

Included in these MRFs are 3 Cleanaway facilities located in Albany, Kalgoorlie and Guildford. In addition to these 3 MRFs, Cleanaway has facilities in over 30 other locations in WA that extend their waste collection capacity across WA (Cleanaway n.d.). The Guildford Cleanaway, in Perth, is capable of processing 50 tonnes of waste an hour, which facilitates the recycling of over 7,000 tonnes of plastic annually. To separate the waste, MRFs employ some of the following equipment:

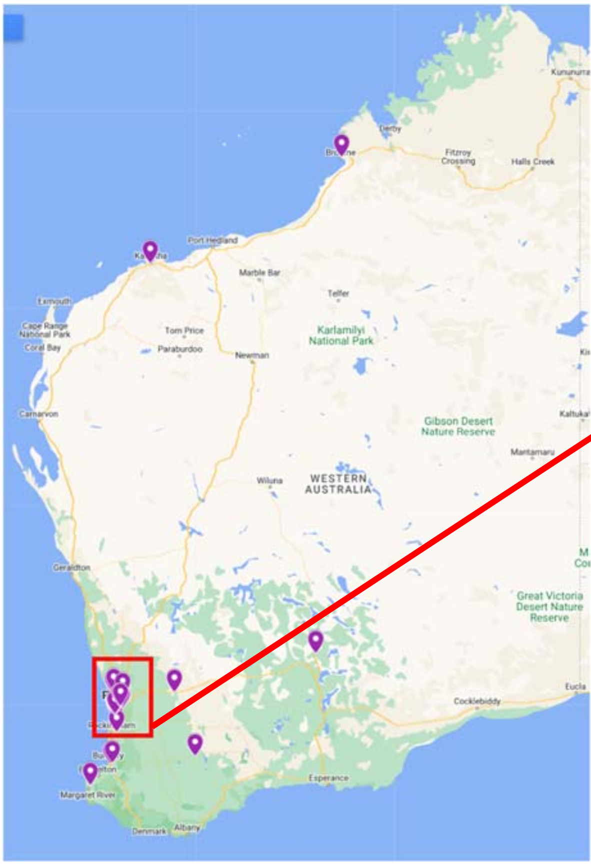
- Debris Roll Screens, which separate smaller materials from the waste and crushes large volumes of glass
- Newsort Screens, which identify bottles, cans, and other containers
- Air jets that separate paper and lawn clippings
- Electromagnets that extract metallic waste out of the waste stream
- Plastic optical sorters, a combination of lasers and air jets that identify specific plastic types such as PET, HDPE and mixed plastic.

The separated waste is then stored, ready for transportation to other recycling facilities or users of recycled products.

C&D recycling facilities

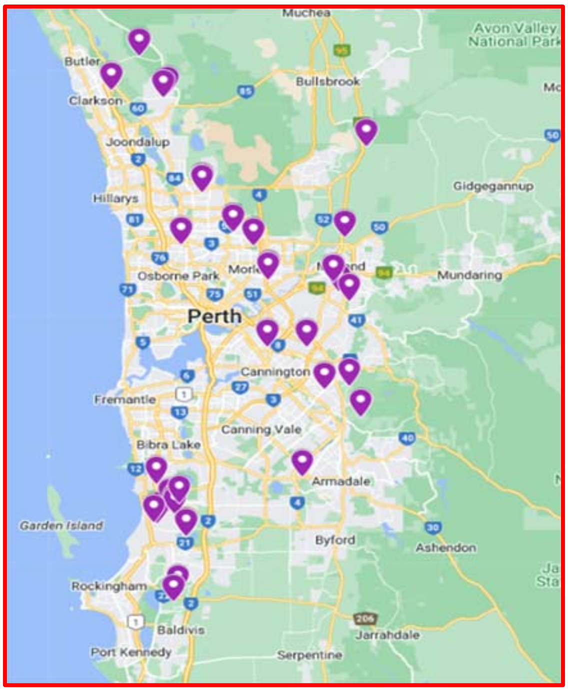
As highlighted in Section 5.1, the C&D waste stream not only has the highest amount of generated waste but also has the highest amount of recycled material as shown in Figure 5.2, for which the number and capability of C&D recycling facilities are integral. The C&D recycling facilities encompass a range of facilities across WA and are based mainly to service construction and demolition works. Again, the facilities are concentrated in and around the Perth area, with locations also in the south-west of WA, Karratha, Broome and Kalgoorlie. Figure 5.6 and Figure 5.7 show the locations of the facilities registered under the DAWE data hub on recycling and waste.

Figure 5.6: Location of C&D recycling facilities WA



Note: Section in red box is enhanced in Figure 5.7.

Figure 5.7: C&D recycling facilities in Perth area



Source: DCCEEW and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

These facilities vary in their services, range of waste and processing capabilities. Although such facilities are designed to meet the large volume of waste collection required by the C&D waste stream, lower waste volumes from other industries and municipal waste might also be accepted and this consumes part of their waste collection capacity. Another service some facilities provide is pick-up and skip services for collecting waste rather than acting merely as a drop-off facility. Facilities also vary on the types of waste they accept, however, common C&D waste such as concrete, metals and plastic are accepted at all facilities. The C&D recycling facilities are typically more restrictive on the types of waste they collect and recycle then MRFs. These facilities in addition to waste collection often sort waste into its components much like other materials recovery facilities. These facilities commonly do some additional processing and may output simple recycled products such as sand, concrete and glass containers.

5.3.2 Secondary Facilities in Western Australia

To incorporate recycled products into roads, further processing is often required, and although some processing can be done at the primary recyclers' facilities, often more specialised equipment and facilities are required to complete the waste's transformation into a recycled product.

Asphalt plants

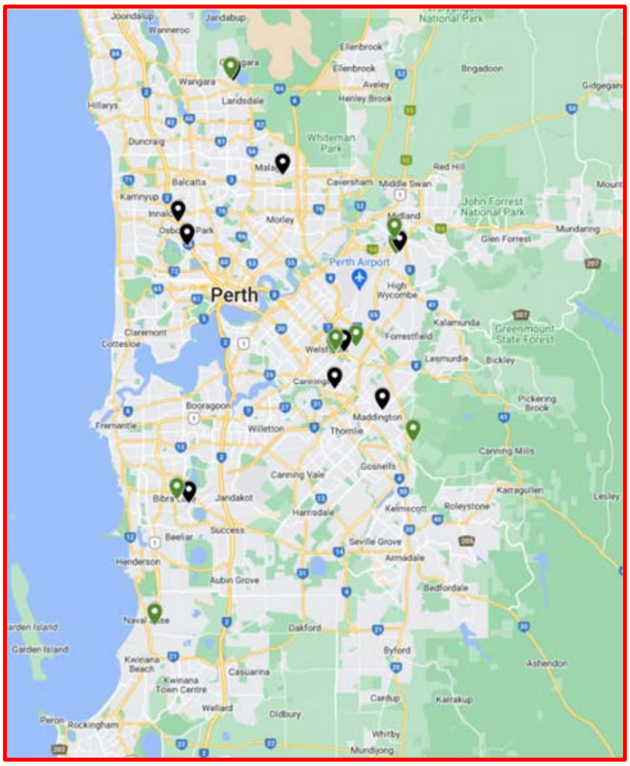
As many of the identified waste materials can only be incorporated into infrastructure by adding them into the asphalt mix, a large factor in including recycled products, are the asphalt plants. This includes the capability of asphalt producers to incorporate recycled products in their asphalt mixes, and the availability of these plants to transport this material to the site or areas needed. Asphalt plants that already have experience and capacity to include recycled materials include Fulton Hogan, Downer, Colas, WA Recycled Asphalt, Boral, Karratha Asphalt, Asphalt Recyclers Australia and Malatesta Group. Figure 5.8 and Figure 5.9, show the asphalt plants in WA including those that do not have the capability to use recycled materials, as it possible that their ability to use recycled materials can change.

Figure 5.8: Location of asphalt producers in WA

Notes:

- Section in red box is enhanced in Figure 5.9.
- Location pins in black have no capability to recycle materials, green pins do.

Figure 5.9: Asphalt producers in Perth area



Source: DCCCEEW and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

Rubber recycling

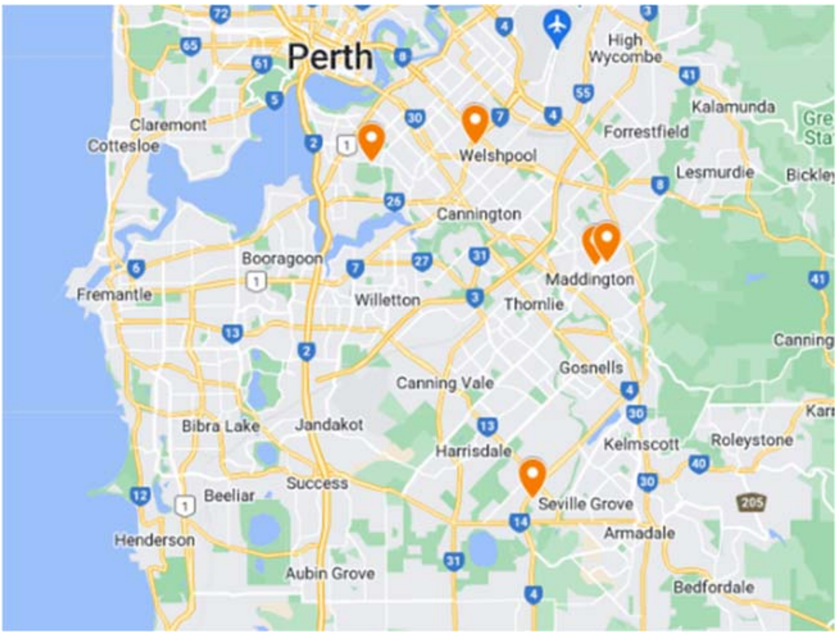
Recovery waste tyres is a highly important challenge for sustainable waste programs as it contributes to a large amount of waste generated each year. A number of waste collection sites and material recovery facilities include the capability of collecting and storing waste tyres, however the facilities for shredding and processing are not as common. TSA accredited facilities in WA include Tyrecycle in O'Connor, part of the City of Fremantle LGA, and WA Tyre Recovery in Albany (Tyre Stewardship Australia, n.d.). Crumb rubber might need to be imported from other facilities due to the low number of facilities and as the recycled products from Tyrecycle are not all suited to asphalt mixes.

Although TSA facilities are recommended for local governments to use, not all rubber recyclers are TSA accredited, such as Elan Energy Matrix in Welshpool that has had their approval suspended or other facilities that have not attained their accreditation. TSA aims to reduce the negative impact on the environment of the disposal of end-of-life tyres via landfill, illegal dumping or undesirable export while increasing the recycling rate of the tyres in a safe and sustainable process. If engaging with a non-accredited TSA recycler, local governments should investigate the reason for their lack of accreditation and ensure their recycling and waste processes align with TSA standards. However, using these facilities can enhance the local availability of crumb rubber for local governments and fruitful engagement between these facilities and local government might allow for companies to grow and attain TSA accreditation through their collaboration. Local governments should at least monitor non-accredited facilities to be aware of these facilities as they might become suitable in the future.

Plastics recycling

The recovery and processing of waste plastic can be complicated for its use in road infrastructure due to many different types of plastic and their applications as a recycled product. Plastic reprocessing plants are located in the Perth city area (see Figure 5.10 below), Broome and Picton East.

Figure 5.10: Location of plastics reprocessing facilities in Perth area



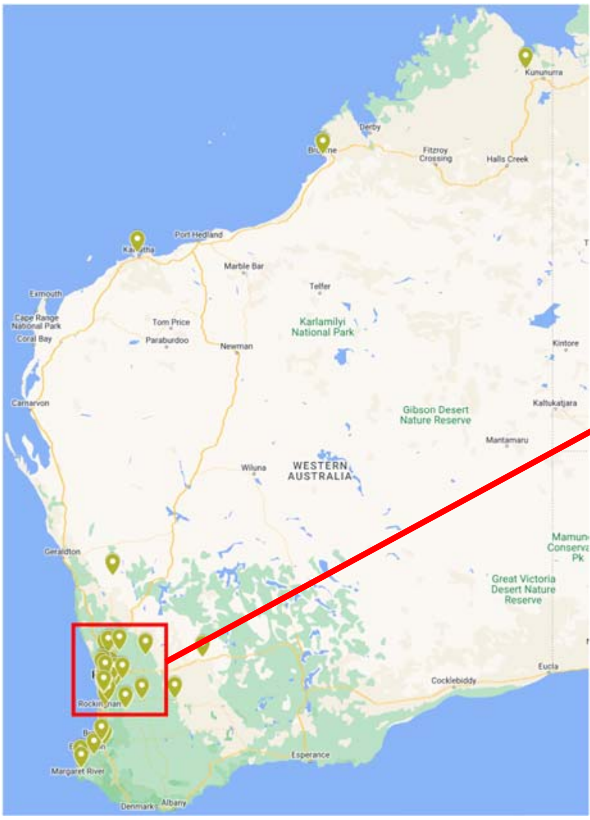
Source: WALGA and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

In addition to plastic reprocessing plants, recycled plastic products (such as pipes, road furniture, cones, safety barriers, etc.) might be manufactured by companies that trade solely in these products. Such manufacturers will likely have their own source of waste plastic, either through plastic recovery facilities or local collections. Local governments might be aware of local suppliers of these products through their local buy engagements and policies and should make note where these products can be incorporated into road infrastructure works.

Organics recycling locations

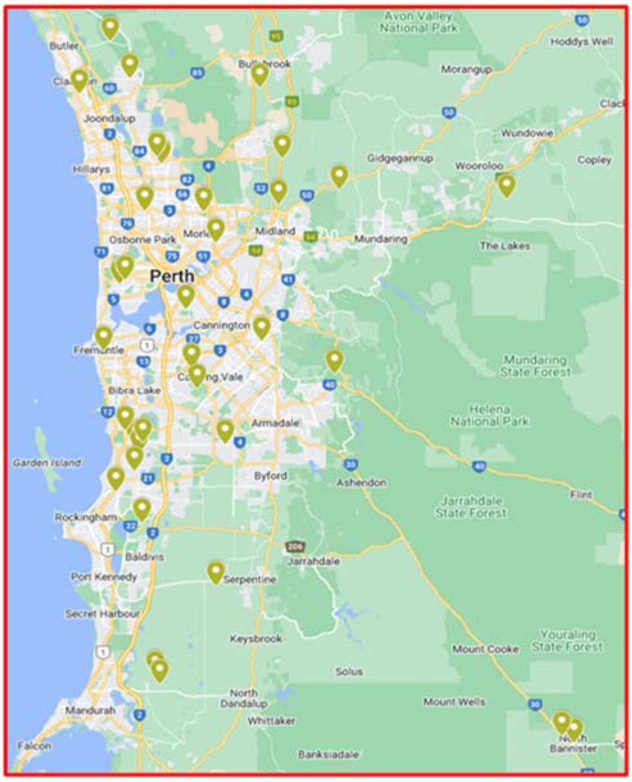
Organics recycling locations are located more diversely than many of the other recyclers and organics might also commonly be processed alongside other waste collection and primary recycling sites. As the process for recycling organics is not equipment intensive, using the same location for collecting and recycling of organic waste is possible and potentially cost saving. Figure 5.11 and Figure 5.12 show the locations from which recycled organics can be sourced, which includes several local government waste facilities, such as Broome, Wellington and Morawa. These locations are more common in south-western WA, with some locations also in larger areas in the north such as Karratha, Broome and Wyndham. Additionally, more small businesses are likely to also provide recycled organics locally. However due to the many uses of recycled organics, much of the recycled product these facilities produce might not be directed into road infrastructure. As with recycled plastic products, local governments should aim to create partnerships with local processors of organics waste and maximise the use of this product. Local governments can also review waste collection practices and waste locations and facilities to increase their production of recycled organics.

Figure 5.11: Location of recycled organics facilities in WA



Note: Section in red box is enhanced in Figure 5.12.

Figure 5.12: Recycled organics facilities in Perth area

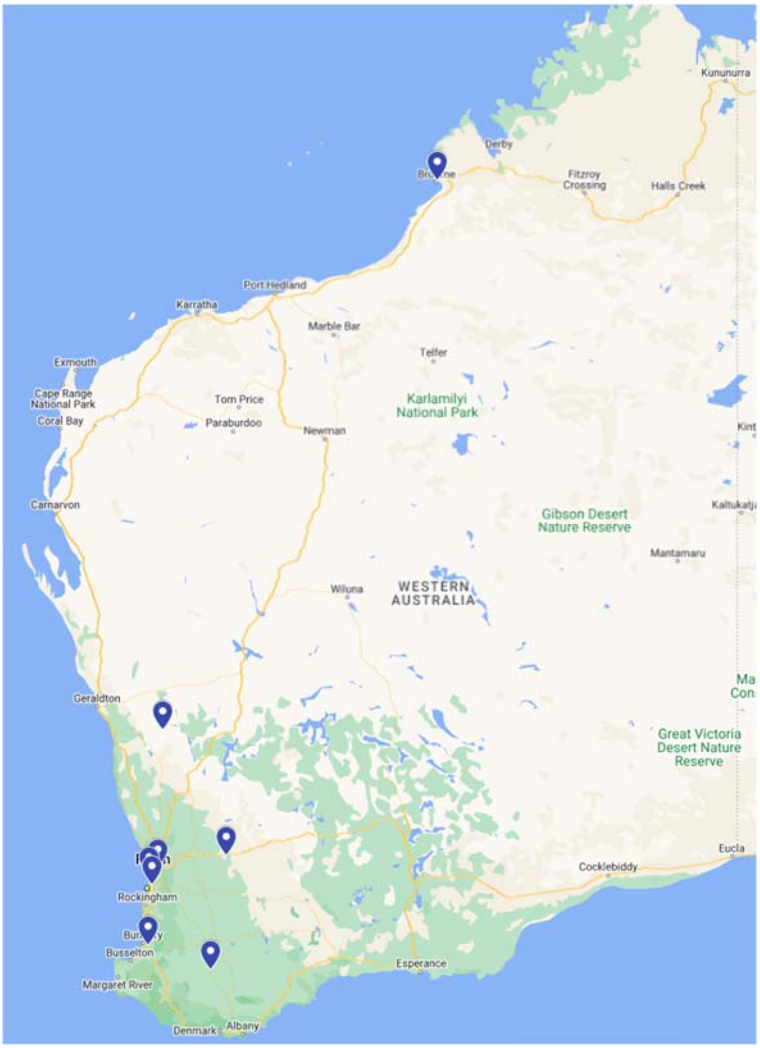


Source: DCCEEW and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

Glass recycling facilities

Much of the recycling of glass occurs at material recovery facilities . Typically, good quality glass will be reused or repurposed as a recycled glass container or similar, and therefore only a smaller portion of the glass will be crushed. Often available on site of primary recyclers, is crushing equipment, which eliminates the need for further processing before the recycled glass is fit for use in asphalt mixes and other aggregate applications or stockpiling. Mobile crushing equipment can also be utilised to reduce the need for transporting glass to a secondary facility. Figure 5.13 shows the registered glass recycling facilities which are in the Perth area, Broome, Morawa, Tammin, Kojonup and Bunbury areas.

Figure 5.13: Location of glass recycling facilities in WA



Source: DCCEEW and Google Maps (2023), 'WA Recycling Locations', map data, Google, California, USA.

5.3.3 Other Facilities in WA

Mobile equipment

In addition to primary and secondary facilities, mobile equipment and plants can be used to further expand the use of recycled materials in roads. Equipment can vary even in the sorting and processing stages of recycling. should be available from. Equipment such as a mobile crushers or shredders can be hired from civil construction and equipment leasing companies. Local governments should enquire with local companies to see what is available and match this with the information above about the equipment used in recycling processes.

Mobile asphalt plants can also be utilised to combine recycled products with asphalt, although location of these plants can still be limiting for rural areas. Companies including Colas, Boral, Roads 2000 and AAA Asphalt have mobile plants capable of producing over 100 tonnes per hour. Although not all these companies produce asphalt mixes that incorporate recycled material, it might be possible to use these mobile plants for a recycled material containing mix if the supplier can assure its quality and performance. The ability for asphalt to be produced in mobile plants expands the potential to use locally sourced recycled products.

Coal-fired power plants

As discussed above, fly ash and bottom ash are locally sourced only in areas around a coal-fired power plant. In WA, there are 4 coal power plants, all located in the Shire of Collie (Global Energy Monitor Wiki

2021). Although these plants may contribute to the feedstock of fly ash and bottom ash, much of the supply of these products is imported from Queensland and NSW. Therefore, local availability of these materials will depend on the imports by local suppliers which is additionally influenced by the demand for fly ash and bottom ash in these areas. However shortages of supply will continue to limit use of fly and bottom ash.

Steel manufacturers

BFS is produced as a by-product of steel manufacturing, such plants are located in and nearby to the Perth metropolitan area. However, as with fly ash and bottom ash, local availability of blast furnace slag will depend more on the imported supply of blast furnace slag than proximity to a steel manufacturing plant,. Local governments can collaborate with local steel manufacturing plants to supply blast furnace slag.

6 Stakeholder Engagement

6.1 Purpose and Process

6.1.1 Stakeholders

WALGA, as the primary stakeholder, managed the projects engagement process being delivered by ARRB. The research and engagements in the project led to the production of the technical report and guide. All content met the performance measures required by WALGA. They also provided the input and expertise in facilitating content for the local government audience.

Stakeholders were identified and engaged in 2 groups:

1. local government and MRWA representatives as experts and practitioners
2. suppliers to understand product availability and potential.

6.1.2 Purpose

The literature review reported in Section 4 was completed prior to initiating engagement with the practitioners and suppliers. The purpose of engaging with these stakeholders was to understand the level of knowledge and ability of local government stakeholders to use the products, the market availability of products, and constraints in their use. For example, fly ash as a potential recycled material product was understood in the literature but had limited availability from suppliers and potentially was not understood by practitioners.

The purpose of the engagements was also to raise awareness of the products and ultimately encourage practitioners to seek and utilise more recycled materials, to support the state's aims to recover and reuse waste products.

A large list was created of potential suppliers of recycled products and recycling services that were identified during the desktop study, as reported in Section 5. The term 'suppliers' is broad, covering any type of road construction product suppliers whether or not they were known to be incorporating recycled materials or using sustainable practices. The term 'suppliers' also covers the organisations with potential sources of recycled products including waste transfer stations, coal fired power stations, and any known secondary materials processors. The suppliers were categorised into 9 service and facility types, including:

1. Concrete services
2. Asphalt and spray seal providers
3. Organics recycling
4. C&D Waste recycling
5. Materials recovery facilities
6. Rubber recycling
7. Plastics reprocessing
8. Pavement products
9. Glass reprocessing.

The desktop study was able to identify information through internet and library searches. However, it was necessary to engage with practitioners and suppliers to ensure that the information was current, and to identify any prospective or potential future materials and methods.

6.1.3 Methods

The method of engagement with suppliers was through online surveys and phone calls, as further described in Section 6.2.

In conjunction with the supplier surveys, the practitioners were engaged by first requesting nominations from local governments and MRWA for an expert reference group. A workshop was then arranged, which:

- presented the findings of the literature review, desktop study and supplier survey
- informed practitioners of the range of materials and methods available
- sought feedback from the practitioners across the range of materials and methods
- sought why practitioners were using certain products, or were not, and what were the main impediments.

The workshop and results are further described in Section 6.3.

6.2 Supplier Engagement

To further understand the availability of recycled materials and recycling services in WA, suppliers were contacted to provide details about the specifics of their services and products and the range they can deliver in WA. As the information being sought could be provided in a structured format, the selected method of engagement was to use an online survey through SurveyMonkey. An extract of the survey is provided in Appendix B.

Using the list of suppliers of recycled materials generated as part of the desktop study, and after further liaison with WALGA and MRWA, a survey was developed as described below. The survey was sent out to the suppliers, and many were contacted directly to discuss the survey.

A summary of product information that has been received from respondents is provided in Appendix C.

6.2.1 Supplier Survey

Survey design

The supplier survey was created in SurveyMonkey, and a link to the survey was sent to identified suppliers via email, along with an explanation of the project and the objectives of the survey. Over 70 companies and organisations were contacted to provide responses to the survey.

The survey format was to initially request details of the respondent and their organisation. The subsequent pages requested the following product or service details, with the respondent able to include up to 10 different products or services:

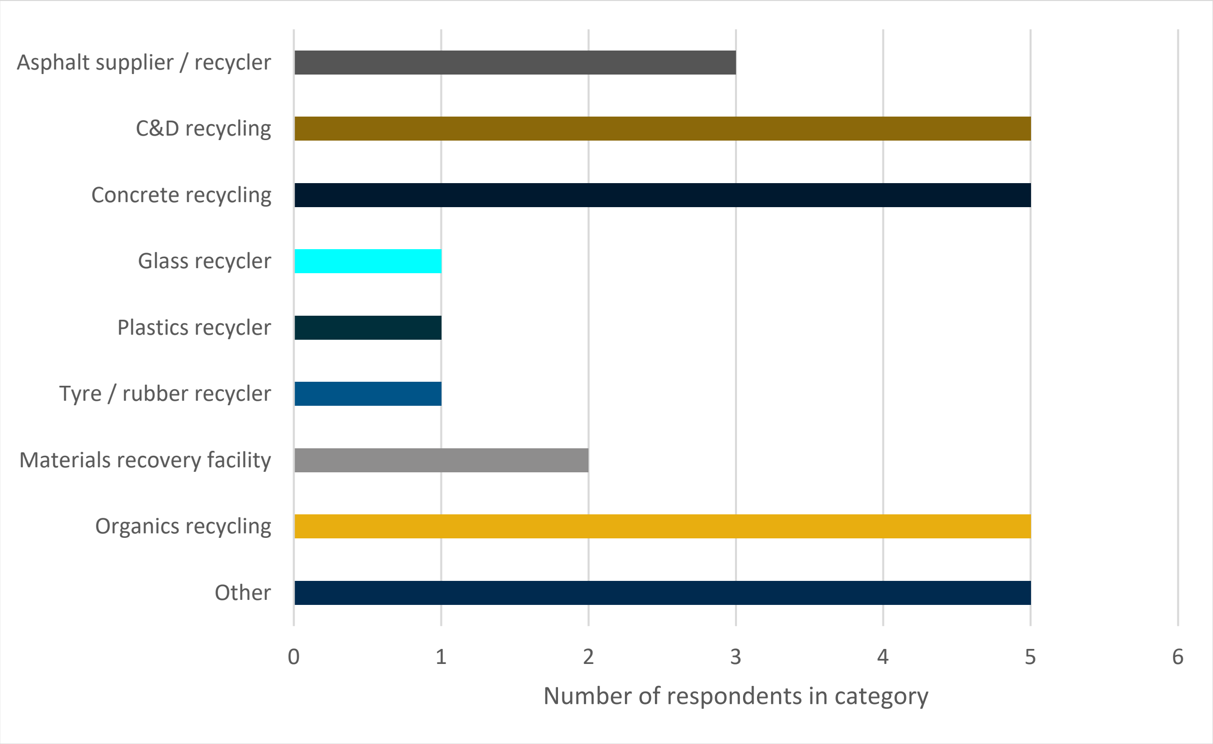
- name of product or service
- description of the product or service
- the recycled material produced or used
- applications of the product
- the specifications involved
- the amount of the product that is recycled material and the virgin materials it replaces
- the capacity and range of the product or service.

Results

A diverse range of products and services were determined from 15 responses. As this represents a small portion of the identified suppliers, the results of this survey may not accurately represent the size and scale of the market for each material.

Figure 6.1 shows the types of organisations that responded to the survey. The 'other' option included responses such as crushed rock quarry, landfill, recycled fill, liquid waste and green waste. The low numbers of responses from glass, plastic and rubber recyclers meant that additional effort was needed to contact these types of suppliers directly to discuss their products.

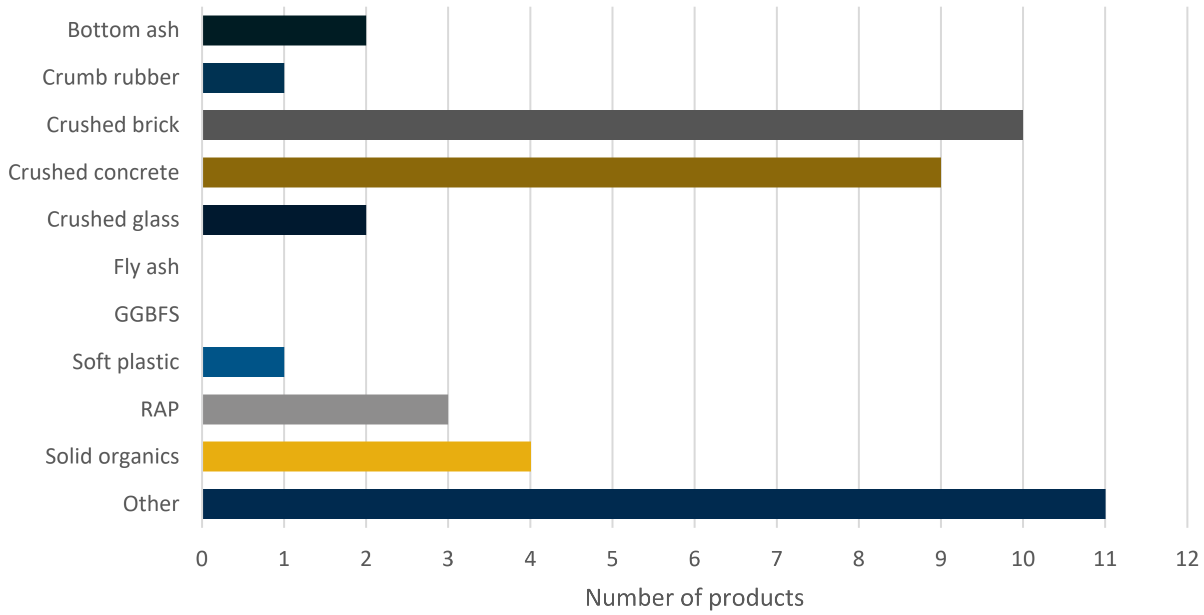
Figure 6.1: Type of supplier from survey



Note: Respondents were able to select multiple answers.

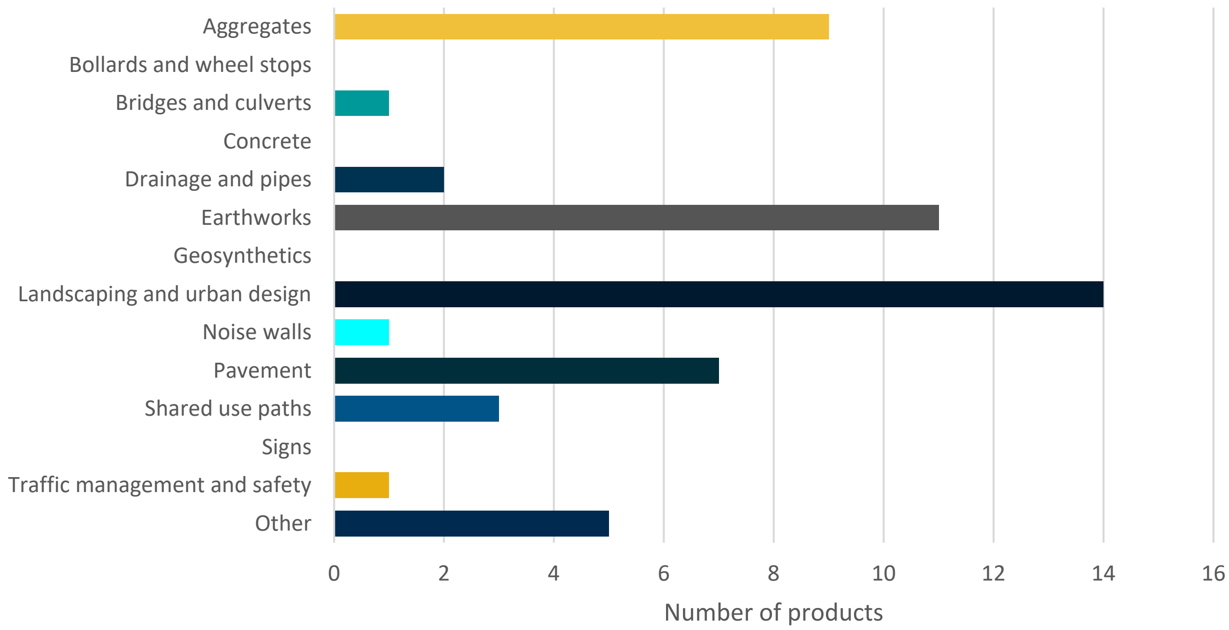
The product details of the suppliers also contained a diverse range of recycled materials and applications. Shown in Figure 6.2 is the number of products that include each recycled material. Crushed concrete and crushed brick were the most common. Again, respondents were provided with the option to add 'other' and the other materials used in the respondents' products includes sand, green waste, aggregates, soils, ballast and limestone.

Figure 6.2: Recycled materials in supplier's products from survey



Respondents also provided the common applications of their products (Figure 6.3. The common products were landscaping, earthworks and aggregates.

Figure 6.3: Application of suppliers' recycled products from survey

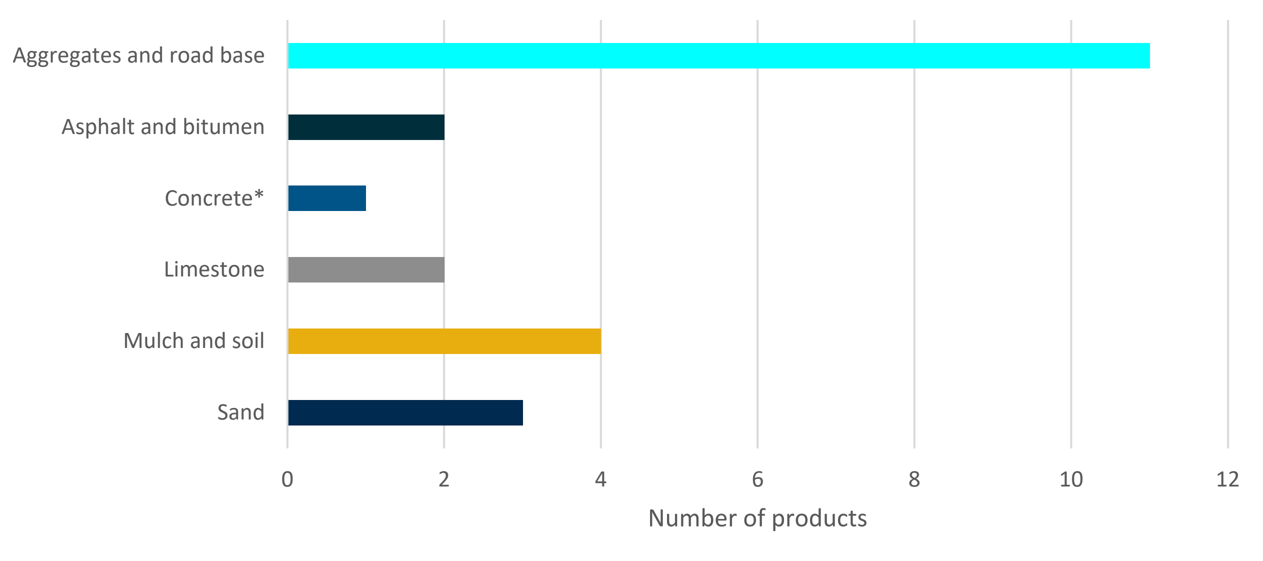


Additionally, respondents provided other details about their products including:

- product description
- current specifications that the product meets
- virgin materials the product replaces
- distribution range for the product
- capacity to supply the product.

Of the products surveyed, approximately 50% meet the criteria of MRWA or WALGA specifications, with the other products not having an applicable standard for their product. Figure 6.4 shows the virgin materials that products are replacing, with most products being suitable to replace virgin aggregates in road base. Details about product capacity and distribution are detailed in the database of identified products and services in Section 6.2.2 and Appendix C.

Figure 6.4: Virgin materials replace by products from survey



Note: *This refers to concrete used as a block, not crushed concrete

In addition to the survey answers, respondents were contacted directly to gain further insight into supplier recycling processes, challenges and opportunities that further inform the desktop study in Section 5.

Direct engagement

As only 15 responses were received from over 70 potential suppliers, further attempts were made to contact other suppliers by phone and follow-up emails. Suppliers were selected to ensure there were respondents from all recycler types and material types as well as covering the whole state. Although many suppliers were called, not all suppliers responded to the direct engagement. Each additional response added more products to the recycled products database, with ultimately 30 suppliers providing responses.

6.2.2 Recycled Product and Services Database from Supplier Engagement

From the supplier consultation, a list of recycled products and services was put together to begin a recycled product and services database. The database lists products and includes the recycled materials involved, the distribution range and the capacity. This list can be seen in Appendix C. It contains only the suppliers who responded through either the survey or the direct contact.

6.3 Practitioner Workshop

Due to the technical nature of the project, and the lack of published information regarding use of recycled materials and sustainable construction practices by local governments, a higher level of engagement was required with the practitioners. They needed to be involved in the project to help set the content for the technical report and guide. The aims were to seek information on current practices and perceptions, raise awareness in the different products and options, and generate engagement towards supporting the state's Waste Strategy.

The selected methodology for engagement was to seek nominations to form an expert reference group, which would then attend a workshop to assist with the development of the guide. Nominations were sought through notices in the WALGA newsletter, targeting local governments and MRWA employees. An online video conference workshop was then arranged, which:

- presented the findings of the literature review and desktop study
- informed practitioners of the range of materials and methods available
- sought feedback from the practitioners across the range of materials and methods
- sought why practitioners were using certain products, or were not, and what were the main impediments
- sought contributions towards any other aspects that needed to be included.

A copy of the presentation is available from WALGA.

6.3.1 Workshop Development

Being delivered online, the workshop was structured into 5 main phases:

1. Introduction to participants, sustainability and Waste Strategy targets, and feedback from the participants on current understanding of recycled materials and related road construction practices.
2. Information from the literature review, introducing the many types of recycled materials and sustainable road construction practices.
3. Information from the desktop study on availability of the many materials and products, with maps.
4. The implementation plan, the production of a practitioners' guideline and a technical report, showing some of the intended content.
5. Breakout discussions in 2 groups, to get further feedback.

Throughout the workshop, polling was conducted via Mentimeter (www.menti.com), enabling the participants to rate, select options, and add text information.

6.3.2 Outcomes of the Workshop

The workshop was conducted on 11 May 2023, with 11 practitioners from local government and MRWA attending online. The workshop was facilitated by Christine Howland from NTRO as the main presenter. Contributing to the presentation also from NTRO were Craig Manton, Dr James Grenfell, and Danny Feigen, and Mark Bondietti from WALGA.

The main outcomes were via:

6. Mentimeter live polling
7. breakout session discussion items
8. responsiveness and feedback during the presentation.

There was no further feedback after the workshop.

Live polling

To elicit engagement during the presentation, and collect meaningful information, 22 polls were run using Mentimeter during the workshop. The questions asked in the polls are listed below, with the corresponding graphs and explanation provided later.

1. 'Can you start by telling us about yourself, including your name, role, organisation, jurisdiction?'
2. 'When thinking about "sustainable road construction", what words come to mind?'
3. 'What area are you from?'
4. 'What are the 3 most common road construction project types completed in your area?'
5. (to 13) 'What are the biggest reasons you would not use <the recycled material>?'
14. 'In your work and local government area, which recycled materials are you most likely to use?'

15. ‘In your work and local government area, which sustainable road construction practices are you most likely to use?’
16. ‘How often have you used or requested the use of the following recycled materials in road construction?’
17. ‘What challenges do, or would, you have in recycling these waste materials?’
18. ‘What do you perceive is the local availability of these recycled materials in your area?’
19. ‘What issues have you encountered in accessing recycled materials and sustainable road construction equipment?’
20. ‘What do you consider to be the most important consideration for using recycled materials or sustainable road construction practices?’
21. ‘Are there any specific example scenarios you would like to see included in the documents?’
22. ‘Are there any additional discussion items that you would like to raise?’.

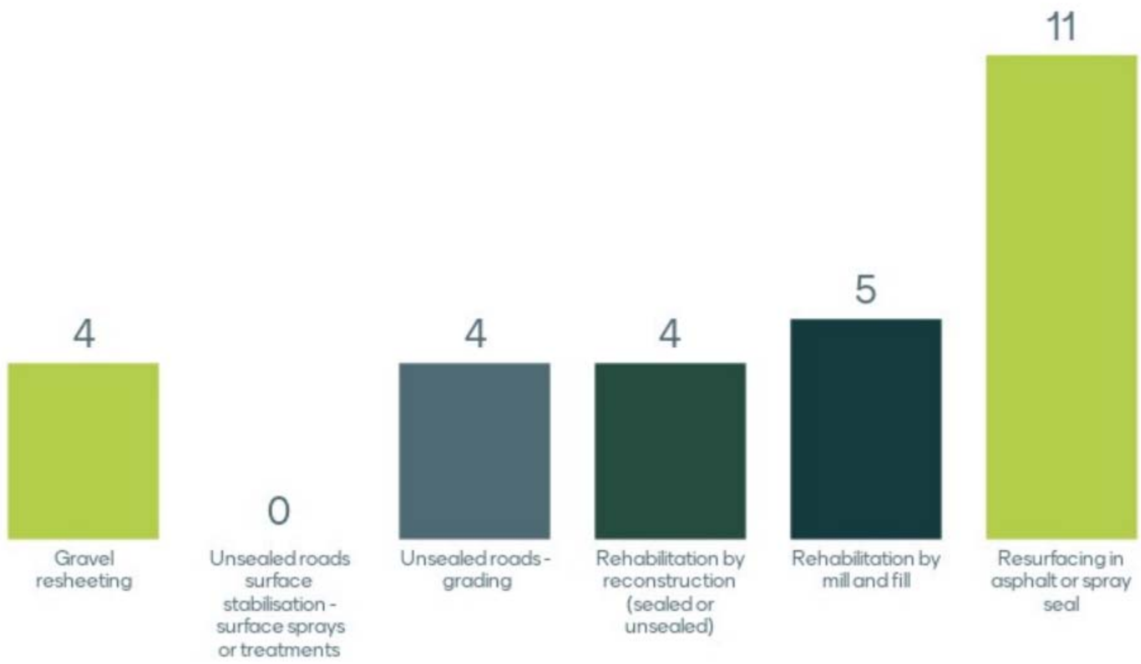
Poll 2 produced a word cloud showing the popularity of different words selected from the participants. Shown in Figure 6.5, the most popular words were ‘reuse’ and ‘availability’, noting that participants could see the words appearing as they typed them in, thus responses may have been influenced.

Figure 6.5: Word cloud for ‘sustainable road construction’ – Mentimeter output from poll 2

Poll 3 showed that participants were from metropolitan areas (6), regional areas (3) and very remote areas (2).

Poll 4, represented in Figure 6.6, showed that resurfacing was the most common activity, which reflects the number of metropolitan local governments represented. Resurfacing is known by the authors to be a common road construction activity for local governments in urban areas.

Figure 6.6: Most common activity – result for poll 4



Feedback on recycled materials and sustainable road construction methods

Polls 5 to 13 asked about the biggest reasons the participants would not use the different recycled materials products. Participants could select any number of the answers:

- Not available in my area.
- Not familiar with its use in construction or application.
- Construction or application safety concerns.
- Not sure of its life, durability, effect on the product.
- User safety concerns and usability concerns.
- Not tested or certified by appropriate authority.
- I'm already using it.
- Other (please write in teams chat, include the material).

As an example, Figure 6.7 shows the response to poll 5 on the use of RAP (reclaimed asphalt pavement).

Figure 6.7: Reasons participants would not use RAP – results for poll 5

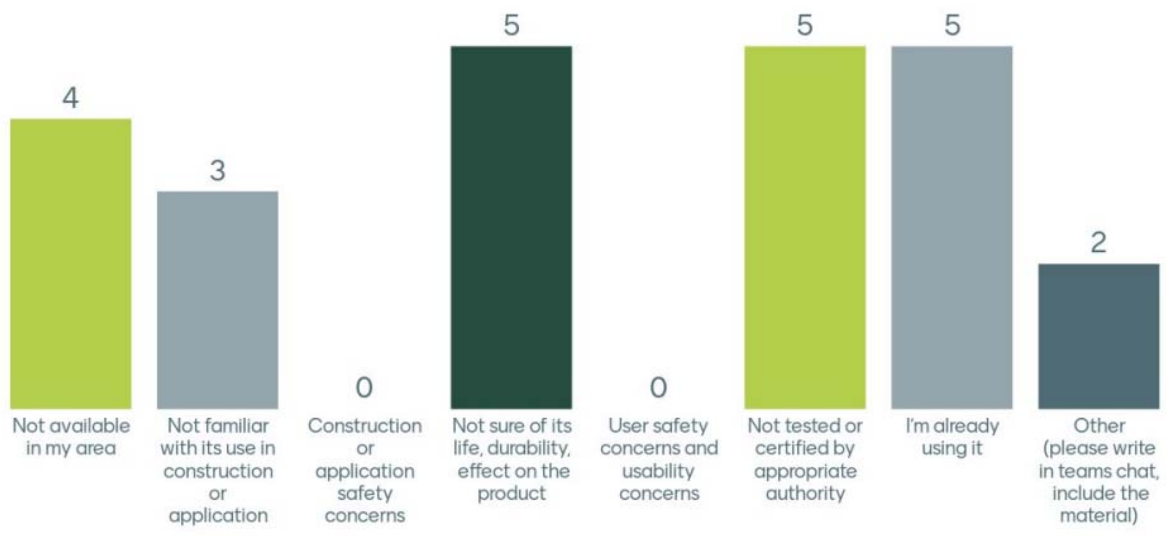
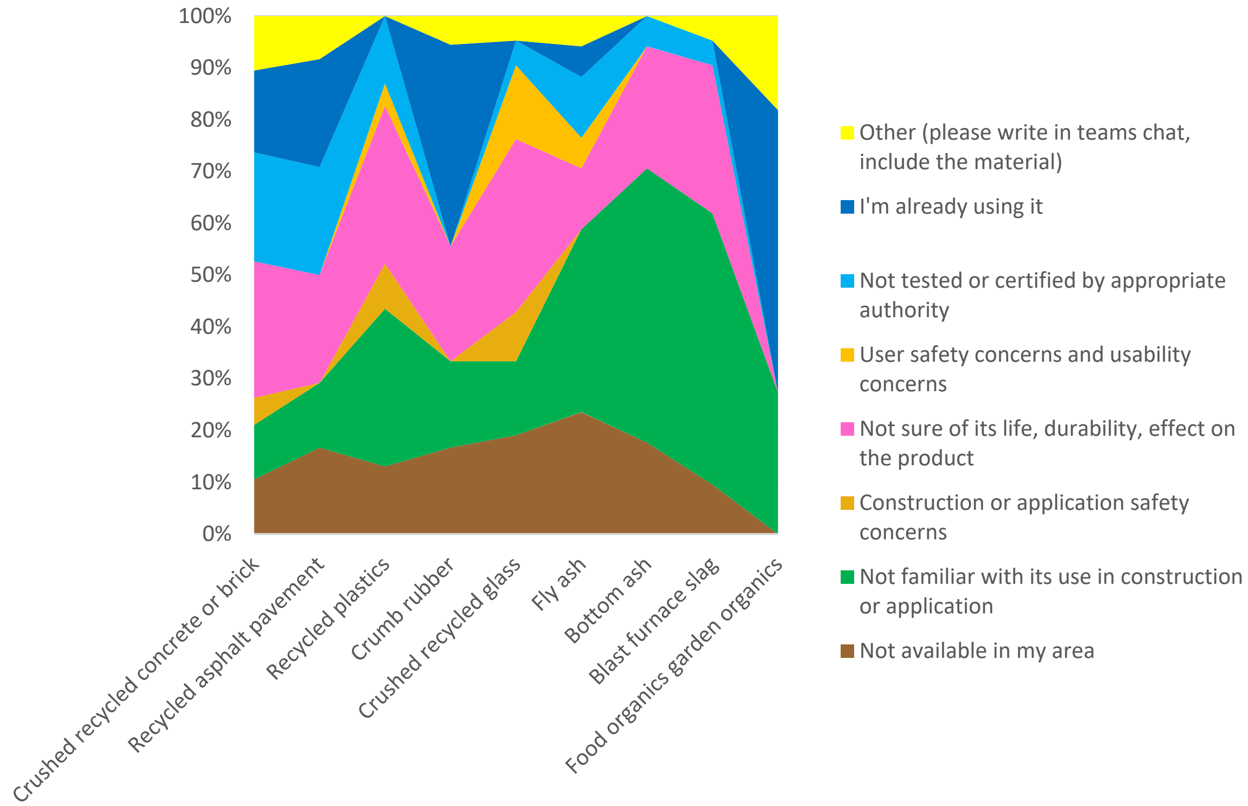


Figure 6.8 shows the responses to the 9 materials and 8 reasons, collated and stacked. The purpose of this chart is to show the influence of the responses which is indicated by the size of the coloured areas, or bands. The larger pink band across the middle of the chart, for instance, represents a common theme whereby participants were not sure of recycled materials' life, durability and effect. In this type of chart, the types of reasons are in no particular order, so their position higher or lower in the chart carries no importance.

Figure 6.8: Reasons participants would not use recycled materials



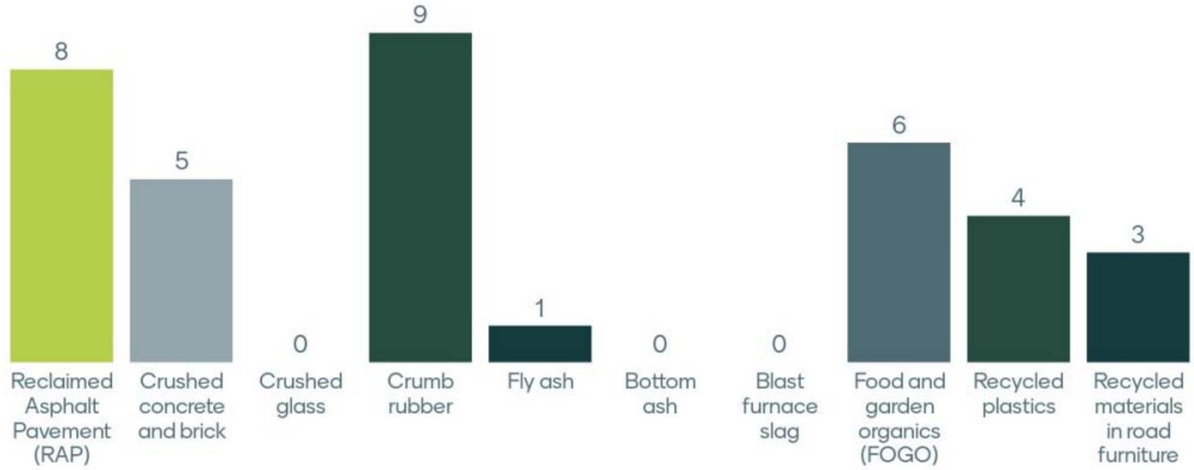
Across the 9 materials, the poll results indicated:

- The most unfamiliar materials were the blast furnace slag and ashes,

- The common themes were being unsure of the material life, durability and effect on the product, and the materials not being available in the area,
- The most common already used material was FOGO (as expected as the secondary processing industry is mature and well distributed), followed by crumb rubber.
- Crushed recycled glass rated the greatest concern for user safety and usability.
- The materials most needing certification and testing were RAP and crushed recycled concrete or brick.

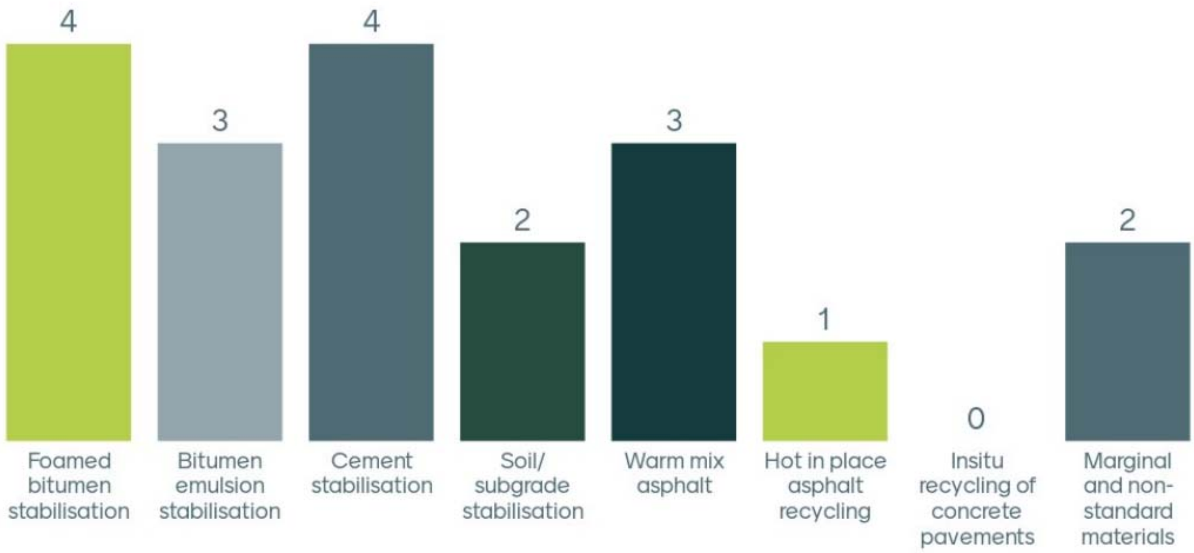
Poll 14 in the workshop asked 'In your work and local government area, which recycled materials are you most likely to use?' This produced the results in Figure 6.9, showing that crumb rubber and recycled asphalt pavement (RAP) were the most likely materials (of those presented).

Figure 6.9: Materials most likely to use – result from poll 14



This second phase of the workshop continued with the introduction of 'Sustainable road construction practices', describing foamed bitumen, bitumen emulsion and cement stabilisation, soil and subgrade stabilisation, warm mix asphalt, hot-in-place asphalt recycling, in situ recycling of concrete pavements, and marginal and non-standard materials. Only one poll (number 15) was conducted after introducing these methods, with the results shown in Figure 6.10.

Figure 6.10: Sustainable road construction practices most likely to use – result from poll 15



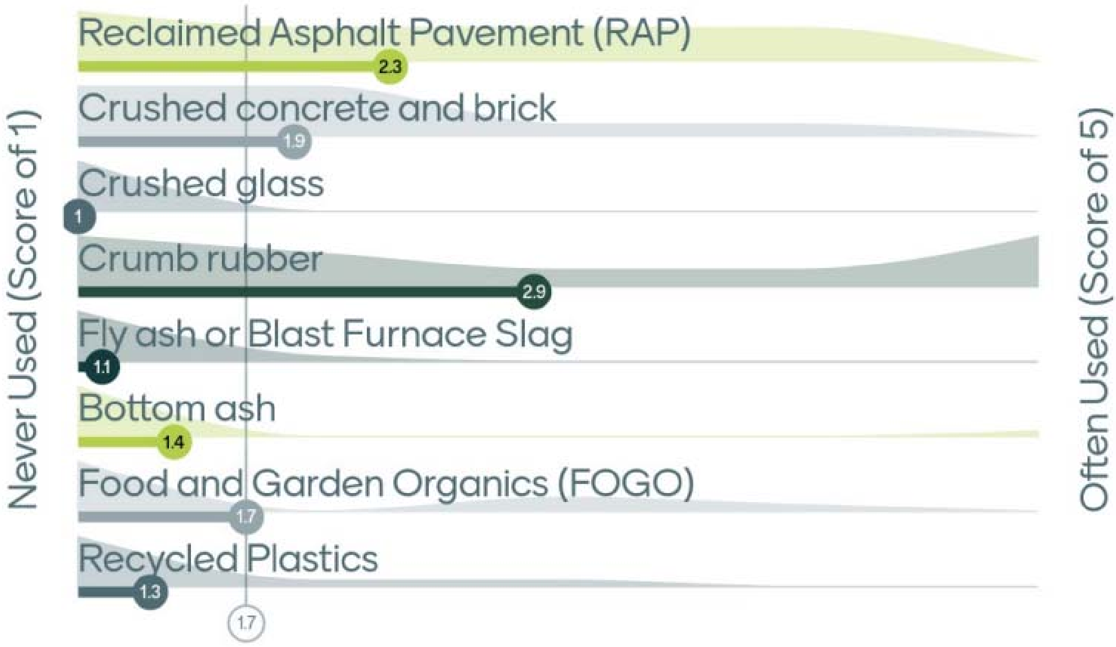
The results indicate that in situ concrete pavements recycling and hot-in-place asphalt recycling are the least likely methods to be used, with possible reasons being that concrete pavements are very rare in Western Australia, and the equipment required for hot-in-place asphalt recycling may not be available.

Feedback on supplier and materials availability

The maps were presented showing the distribution of suppliers of the many materials and services, as provided in Section 5. Poll 16 was then asked: 'How often have you used or requested the use of the following recycled materials in road construction?'.

Participants were able to select a rating from never used (1) to often used (5). This provided a dynamic display of the frequency of requests, shown in Figure 6.11. As identified in the previous polls, RAP and crumb rubber were the most often used overall. The response to FOGO is not consistent with the previous polls, indicating perhaps that although participants were familiar with the product, they had not used it often.

Figure 6.11: How often used recycled materials – result from poll 16



The workshop continued with presentations on the waste streams that could form sources for the recycled materials and methods. The 3 main waste streams presented were municipal solid waste (MSW), commercial and industrial waste (C&I), and construction and demolition waste (C&D). Poll 17 asked for comments in response to the question 'What challenges do or would you have in recycling these waste materials?' The individual responses were:

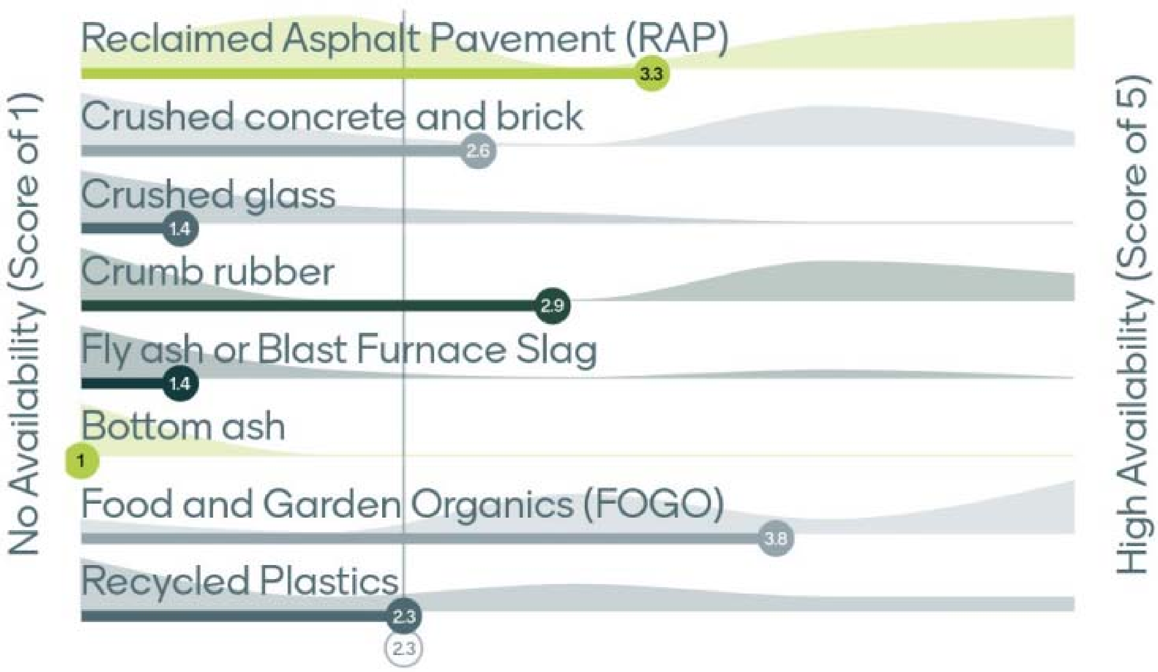
- 'Cost implications and locations of processing/separation plants.'
- 'Resource constraints,'
- 'Facilities to accommodate production, processing.'
- 'Little access to the research and the specifications.'
- 'Green waste: spread of dieback[1], weeds (seeds).
- RAP: experience shows does not perform well when exposed to traffic (before final seal).'

Poll 18 asked: 'What do you perceive is the local availability of these recycled materials in your area?'. Participants were able to select a rating from no availability (score 1) to high availability (score 5). This

[1] Refers to a plant disease of the Phytophthora species.

provided a dynamic display of the perception of availability, shown in Figure 6.12Figure . This shows a split perception of availability for most products with crumb rubber, crushed concrete products, and RAP being either a one or 5 score. This would be representative of the reality of availability as experienced from regional and remote participants versus metropolitan.

Figure 6.12: Perception of local availability – result from poll 18



The workshop continued with presentations on large scale material recyclers and processing facilities, such as materials recovery facilities, asphalt plants, and C&D recycling facilities. Maps of Western Austalia were presented, showing the locations of these facilities, as provided in Section 5.3. Poll 19 then asked ‘What issues have you encountered in accessing recycled materials and sustainable road construction equipment?’ Participants provided the following comments:

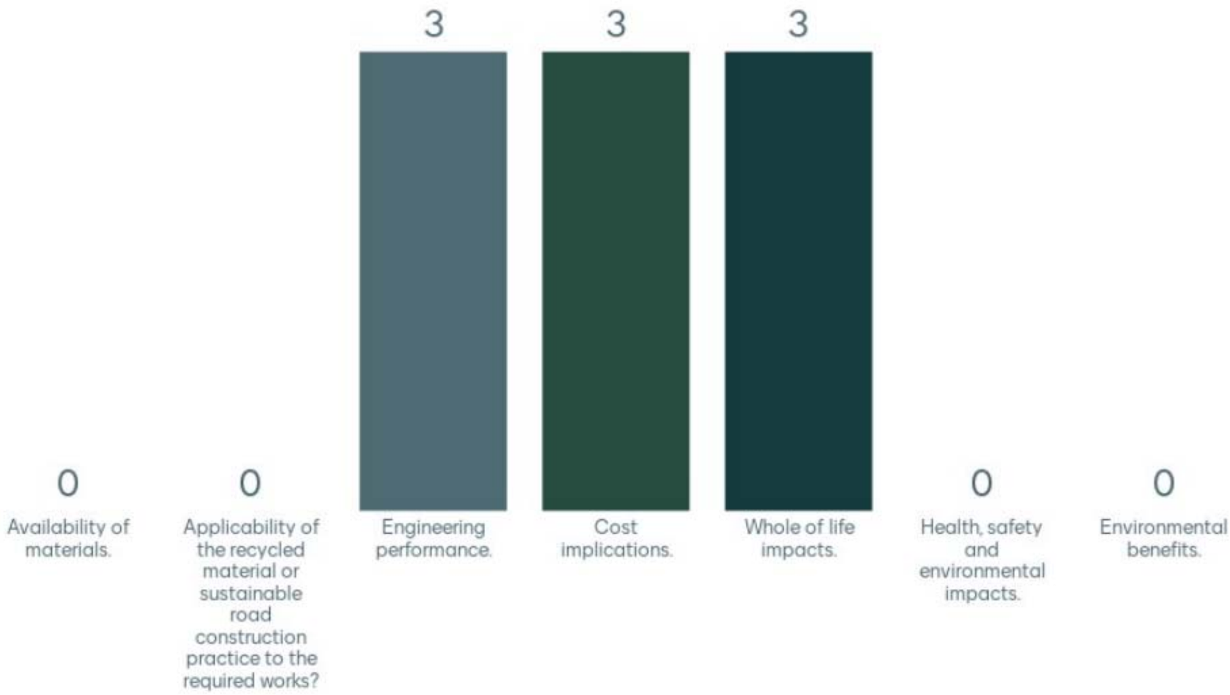
- ‘Significantly higher costs in remote locations.’
- ‘Limited knowledge and the cost.’
- ‘The ability to ensure that they are compliant for use, and the cost to transport.’
- ‘Quality assurance and availability.’
- ‘Supply/availability can be an issue with new products. Most that we are using are readily available now though.’

Feedback on the implementation plan

The implementation plan was presented, whereby a practitioners guideline would be prepared, for everyday use by local government practitioners, and a technical report would include the more complex and detailed information. This is explained in Section 1.3.

Further feedback was sought through 2 polls. Poll 20 asked ‘What do you consider to be the most important consideration for using recycled materials or sustainable road construction practices?’ This provided a common response that the 3 aspects of engineering performance, cost implications, and whole-of-life impacts were the most important considerations. For emphasis, This feedback is included also in Figure 6.13 below.

Figure 6.13: The most important considerations – results of poll 20



Participants were also asked polls 21 and 22 as listed earlier, however no further responses were received.

Feedback from the breakout sessions

The final phase of the workshop was to separate the participants into breakout sessions for further discussion, before bringing everyone back together to close the workshop. With the small number of participants, 2 sessions were created. The group raised a number of issues and provided commentary on a variety of matters regarding the workshop content and their individual experiences. The participant comments have been included below in Table 6.1. To provide context to and to ensure clarity on any perceived risks, a response has been included for each comment.

Table 6.1: Participant comments and responses

Participant comment	Response
RAP should be limited to 10% to ensure it is not too stiff as are using only on resurfacing.	Asphalt mixes containing RAP have been found to be comparable in tensile strength, however, they may show an increase in stiffness compared to virgin asphalt (Hall et al. 2022). RAP is approved for use through Main Roads, however these specifications limit the use of up to 10% RAP to be incorporated into the structural layers (i.e. not surface layers) of full-depth asphalt without additional mix design requirements (MRWA 2022). MRWA (2022) notes that several local suppliers in Perth have approved mix designs containing 20–25% RAP. The WALGA specification for the supply of recycled road base (IPWEA & WALGA 2016) includes provisions for the use of RAP in base and subbase materials in proportions of up to 10% or 15% by mass. RAP that is highly variable in nature and physical properties may be more suited for use in granular pavement or fill applications (Nguyen et al. 2021).
Participant is interested in cold emulsion from a local supplier.	Noted. The supplier recycled product and services database in Appendix C provides some additional information on suppliers. It is envisioned that as momentum grows for recycled materials in road infrastructure, additional suppliers will be locally available.
Potential for block cracking depending on bitumen or cement content in stabilisation, especially when stabilising with crushed recycled concrete.	The potential cause of block cracking is due to the reactivation of cement. Some mitigation measures include: • use as a subbase under full depth asphalt

Participant comment	Response
	• do not use as basecourse under heavy traffic • apply geofabric seal if used as basecourse.
Accessibility to the products is important.	Noted and agreed. Accessibility and availability have been key elements in the production of this guide.
Participant was unable to get material tested, but willing to reuse milled materials. Participant has used RAP in basecourse.	Noted. There is an opportunity for the supplier recycled product and services database (refer Appendix C) to include appropriate testing organisations. It is envisaged that as momentum grows for recycled materials in road infrastructure, additional suppliers will be locally available.
Participant is using recycled concrete.	Noted. Additional recycled materials for consideration have been included within these documents.
Participant is based in inner metro so does not have much new construction, mostly mill and fill.	This aligns with the project types nominated for Metropolitan areas within these documents, including: • upgrade widening • asphalt overlay • rehabilitation (mill and re-mill) – base rehabilitation.
There is an issue if the developer uses recycled materials, and who wears the future liability?	Whilst no comment can be made on liability, the information contained within the documents includes specifications related to recycled materials. Similar to any other material used, the developer should be made aware of and required to comply with specifications pertaining to the use of recycled materials (e.g. maximum % by weight requirements, pavement layers, etc.). Practitioners can also refer to the Local Government Guidelines for Subdivisional Development for further guidance on how to manage defect liability periods and maintenance bonds.
Need confidence that local governments can use the materials (RAP, crushed concrete) for basecourse and wearing course.	The WALGA specification for the supply of recycled road base (IPWEA & WALGA 2016) includes provisions for the use of recycled materials in base and subbase layers and the wearing course.
Would like examples of uses in eastern states or anywhere.	Some examples (both in WA and interstate) have been provided for each material within the documents.
RAP performance is low without a seal, and pavement does not last under traffic loads.	The quantity of RAP used within the asphalt mix can have an impact on overall engineering performance. Quantities of up to 20% (above currently accepted limits in WA) are reported to be comparable to a virgin asphalt mix, with little impact noted on properties such as ravelling, fatigue cracking, rutting and weathering (Hall et al. 2022). Asphalt mixes containing RAP have been found to be comparable in tensile strength.
Use of RAP is difficult due to trees in the area, and high application heats means contractors do not want to do works due to fire risk	The main use of RAP is as a component in the manufacture of new hotmix asphalt, however other processes that incorporate RAP include: • in situ hot asphalt (hot-in-place asphalt recycling (HIPAR)) • in situ cold asphalt recycling • cold plant (pug mill) mixing of RAP material (Rice et al. 2020). Typically RAP in asphalt should be able to be laid at a similar temperature to standard asphalt, however it is noted that there are other processes available that can incorporate RAP.
PMB is performing very well.	Further information would be required on this item to provide a suitable response. If related to crumb rubber, additional information on crumb rubber is available within the documents.
Remote town has limited suppliers, and one asphalt supplier has a monopoly on what materials to include. The supplier can also beat the cost of transporting from any other locations.	Noted. The supplier recycled product and services database in Appendix D provides some additional information on suppliers. It is envisaged that as momentum grows for recycled materials in road infrastructure, additional suppliers will be locally available.
Asphalt mixes with recycled materials are certified by the lab that makes it, not MRWA or ARRB, so the participant is awaiting further specs.	Noted. Additional details on specifications for all recycled materials have been included within the documents.
Crumb rubber has good potential and participant is seeking further specs and testing on CR mixes.	Noted. Additional details on crumb rubber and the associated specifications have been included within the documents.

Participant comment	Response
Costs are even greater for including recycled materials as in addition to transport to very remote areas, pavements do not last and need more maintenance or earlier renewal. Crumb rubber in seals worked well for a metropolitan local government.	Noted. The supplier recycled product and services database in Appendix C provides some additional information on suppliers. It is envisioned that as momentum grows for recycled materials in road infrastructure, additional suppliers will be locally available. Additional recycled materials for consideration have been included within these documents.
Not much new pavement [metropolitan], mostly using in situ methods including foamed bitumen stabilisation.	This aligns with the project types nominated for Metropolitan areas within these documents, including: • upgrade widening • asphalt overlay • rehabilitation (mill and re-mill) – base rehabilitation.
Tested RAP on unsealed laneways and it did not go well, but could if compacted properly.	It is indicated that this issue is not related to the RAP itself, but with the construction methodology. Further information on compaction requirements can be found in MRWA *Specification 515 In-situ Stabilisation of Pavement Materials*.
Used lots of crumb rubber, the organisation uses common asphalt suppliers to do this, and it has worked well in all but one case.	Noted. Additional details on specifications for all recycled materials have been included within the documents.
No assurance from asphalt suppliers that the road will meet the quality and last.	Noted. Additional details on specifications for all recycled materials have been included within the documents.
Dense graded asphalt – need assistance and guidance on what to do with this, none available.	Additional information on dense graded asphalt is available through MRWA Specifications *504 Asphalt Wearing Course* and *510 Asphalt Intermediate Course*.
Trialling other asphalt mixes that use crushed recycled glass and crushed recycled concrete on different parts of the same road – Presentation on this is available for more information.	Additional details for all recycled materials have been included within the documents.
They do not have that much RAP because they don't have full depth pavements.	Noted. Other recycled materials for potential reuse are included within this guide.
What grants are available to assist with implementing recycled materials?	Different organisations often provide grant opportunities for sustainability initiatives (e.g. Tyre Stewardship Australia, WA Department of Transport, etc.). The opportunity exists for WALGA to promote applicable grants to local governments.
There is a feeling that the road construction industry is being forced to use recycled materials when it could/should be taken up more by other industries.	It is noted that there is significant movement generally in the engineering and construction space with respect to the circular economy. In order to progress from a linear economy, all industries must invest in and implement the principles of the circular economy. The investment by the road construction industry in the use of recycled materials provides the opportunity to promote the improved sustainability outcomes.

It should be noted that the above commentary is from the workshop participants and reflects their views only. None of the statements should be interpreted as advice.

6.4 Outcomes of Stakeholder Engagement

6.4.1 Feasibility of Acquiring Recycled Materials and Services from Suppliers

With only 30 of the suppliers responding to the survey and follow-up contacting, a complete picture cannot be developed of supplier capability. The following learnings arose from the engagement:

1. Many suppliers provided at least one product that included recycled materials.
2. Some suppliers had extensive supply capability, while others had very limited capability (volumes)
3. Similarly, some suppliers could deliver state-wide (at a cost), while others were only delivering locally (due to cost or capability)
4. There were niche suppliers engaged in various recycled materials in different areas.
5. Some materials have already been developed and tested to meet standards.
6. Some suppliers indicated regulatory problems with storing or processing the various materials.

7. Some suppliers reprocess waste from their operations and supplied materials, as they can manage their waste quality and reduce operational costs.

Opportunities arising

With the industry already familiar with different recycled materials, the opportunity exists for engagement between waste processing companies, secondary processors, and suppliers of the final road construction products.

The cost of transport in regional and remote areas due to the distances involved is an obvious impediment to the use of recycled materials. In one case, even separating materials for local transport was too expensive, as stated by one remote area landfill operator.

Item 4 above suggests that some regional suppliers have been able to develop an effective business model for the inclusion of recycled materials in their products. Suppliers looking to explore different materials can contact these successful ventures and learn how to repeat the success.

To address regulatory compliance and quality control testing, communication could be developed between the regulatory agencies (particularly DWER) and suppliers. Communication could also be arranged between suppliers and local governments to understand and apply appropriate quality control standards.

6.4.2 Feasibility of Local Governments Using Recycled Materials and Services

During the workshop, it was not entirely clear how familiar the 11 practitioners were with all the materials and methods presented. With only roughly 12 of 137 local governments being represented (some practitioners had experience in more than one local government), no clear conclusion can be reached on the acceptance and understanding by local governments. However, the breakout session discussion, and polls taken in the workshop provided a number of learnings, summarised here:

1. The most common road construction activities were resurfacing, mill and fill, and gravel resheeting.
2. The most unfamiliar materials were blast furnace slag and ashes.
3. The most commonly used materials, with a higher perception of availability were organics, crumb rubber and reclaimed asphalt pavements (RAP).
4. The common themes in why participants would not use recycled materials were: being unsure of the material life, durability and effect on the product, and the materials not being available in the area.
5. Crushed recycled glass rated the greatest concern for user safety and usability.
6. The materials most needing certification and testing were RAP and crushed recycled concrete or brick.
7. Participants were likely to use most sustainable construction methods, relevant to the type of construction needs, so the method is not a limiting factor.
8. A poll on the use of different waste streams elicited various responses, noting that the practitioners were likely to be from the road construction industry and may not be familiar with waste management facilities.
9. There is a range of reasons why participants are not engaging to a greater degree with recycled materials and methods, centred on: cost implications, local availability, and knowledge of the product and its performance.
10. There is a diversity of experiences, and each practitioner appears to have used at least one of the listed recycled materials and methods.

Opportunities arising

In response to the feedback from the polls and discussions, to increase the uptake of recycled materials and associated methods the industry (local governments, agencies, and suppliers) could pursue actions shown in Table 6.2.

Table 6.2: Opportunities to increase uptake of materials and services arising from stakeholder engagement

Material, method or factor	Local governments	WALGA, DWER and state agencies	Suppliers
RAP and crushed concrete and brick products	Seek improved testing and certification processes and availability.	Support further testing of materials and develop efficient certification processes.	Seek further opportunities to provide tested, quality products that are perceived well by local governments.
Crumb rubber	Seek increased supply within existing product needs.	Facilitate improved regulatory approvals for suppliers and offer incentives where suitable.	Expand the production of crumb rubber products as they have a higher acceptance level,
All materials	Develop a structured method of introducing recycled materials, and testing performance in road construction projects, for all desired materials	Facilitate good project trial methods and communication of same across the industry. Facilitate supplier panels.	Support trial and project quality management in local government projects, with the aim of increasing recycled materials and methods.
Fly ash, bottom ash and blast furnace slag.	Advocate for funding for research and development in the reuse of these materials.	Facilitate funding for research and development in the reuse of these materials.	Assist with waste product testing and handling requirements, and trials by secondary suppliers.
Distance and transport costs	Be aware of costs of transport for all recycled materials within jurisdiction, and advocate for funding support. Be aware of what local recycled materials sources are available in the area.	Consider incentives to offset costs of transport and logistics, and facilitate logistics industry opportunities to reduce costs.	
Cost of materials or services	Develop cost feasibility methods as provided in the documents, to better understand local and life cycle costs.	Continue to research and monitor cost factors of different materials and services to enable more uptake.	Continue to seek cost effective methods of producing, processing and applying materials and services.
Existing familiarity of various materials and methods by industry	Share local experiences, for example through regional road groups, IPWEA seminars and Waste Net.	Facilitate knowledge sharing of industry developments across local governments and suppliers, and create forums.	Share materials and methods through industry forums.

6.4.3 Effectiveness of Engagement Methods

The effectiveness of engagement with local government practitioners was demonstrated through the workshop attendance. Although only eleven practitioners attended from the 137 local governments in WA there was a some diversity of representation from metropolitan, regional and rural areas.

The method of notifying the practitioners was through the WALGA newsletter, which is considered to be effective in reaching the relevant staff. It is noted that additional marketing and communications may have been conducted via some applicable industry associations. The lack of attendance was therefore most likely due to practitioners being unable to allocate time or not having sufficient interest in the subject.

Due to the low level of attendance, the poll results should be interpreted as providing indications of preference and are not necessarily a fair representation of all local government practitioners.

Regarding the quality of engagement within the workshop, it is believed that the Mentimeter polling and the breakout sessions provided very valuable information for the project, as well as enabling the participants to be actively engaged in the content. Additional benefits may have been realised if the results of the polling were able to differentiate between responses and the locality of the participants in some areas.

The breakout sessions were timed to 15 minutes, and both sessions could have continued for longer to elicit more information.

On release of the new documents, it is recommended that a participation survey be conducted along the same lines as the Mentimeter polls and that follow-up surveys, in subsequent years, be conducted to gauge the effectiveness of the documents and related promotional activities.

. The number of surveys received from suppliers was unexpectedly low, as the authors expected that suppliers would take the opportunity to advertise their capabilities. The survey was not overly lengthy, however the method of surveying may need to be revised in future to ensure that the survey itself was not an impediment to a company or person responding.

The follow-up calls and emails were only partly successful, with an appropriate person at some suppliers being hard to contact and in some cases phones not being answered. A number of successful phone contacts did not then result in a response to the follow-up emails. The final count was 29 responses received from 70 suppliers. This still did not include all asphalt or potential C&D suppliers.

To acquire a greater number of responses, much more time would need to be allocated to contact each supplier and the surveyor would need to demonstrate the value to the supplier of contributing to the study.

To facilitate the development of the industry, an online register could be established. Linked to the WALGA Vendorpanel, there may be the facility for suppliers to list recycled materials and methods and indicate capability and availability. Local government practitioners could then reference the site when planning their road construction projects.

7 Availability of Materials

7.1 Availability from Suppliers

Section 5.3 presented the locations of recycling facilities in Western Australia. As expected, the facilities are concentrated in the Perth metropolitan area with the remaining facilities based at population centres. Maps showing the locations of suppliers of recycled materials, were not prepared for the reasons explained below.

As part of the literature review and desktop study reported in Sections 4 and 5, potential suppliers of the many types of recycled materials and sustainable construction methods were identified. Some suppliers had multiple sites that they operated from, and their internet sites did not always clearly identify what products and services were provided from which locations. Some suppliers offered services across a region or area. In other cases, the addresses of facilities were not provided.

To help with the locations and confirm products, suppliers were surveyed and directly contacted as reported in Section 6.1. The suppliers who responded have been listed in Appendix C. This unfortunately represents less than half of known suppliers due to low numbers of responses.

Feedback from suppliers indicated that there are a number of materials and methods available in different locations that use recycled materials, and also that there are a number of new products being created.

Overall, however, there was insufficient certainty in availability of materials and methods to make a definitive statement for any of the areas. For these reasons, the documents cannot reflect all current availability. What may be available in the metropolitan, regional, remote and very remote areas based on what is known is discussed in Section 8.2.

To manage the shortage of information, it is recommended that local governments establish a 'Recycled materials and methods availability matrix'.

The matrix can be developed after local government has identified the potential quantities of recycled materials and methods for upcoming projects and programs of work as explained in Section 8.1.

To create the matrix:

- prepare a list of known suppliers of similar materials to those identified for the project
- conduct a search for other suppliers such as through WALGA Preferred Supplier panels, industry lists (like the DCCEEW Waste and Resource Recovery Data Hub) and internet searches
- contact the potential suppliers to identify what products and services are available
- update the local supplier listing, including where appropriate:
  - capacity (quantity that they are able to supply)
  - any limits to supply including seasonal factors
  - haulage and delivery requirements
  - minimum quantities
  - range of supply and locations of suppliers,
  - availability of test results
  - what specifications are being complied with
  - safety data sheets (SDS)
  - any handling aspects
  - risks in the materials' availability
  - notable questions and responses identified during the project feasibility checks in Section 8.3.

This information can be stored as a local list of suppliers of recycled materials and methods.

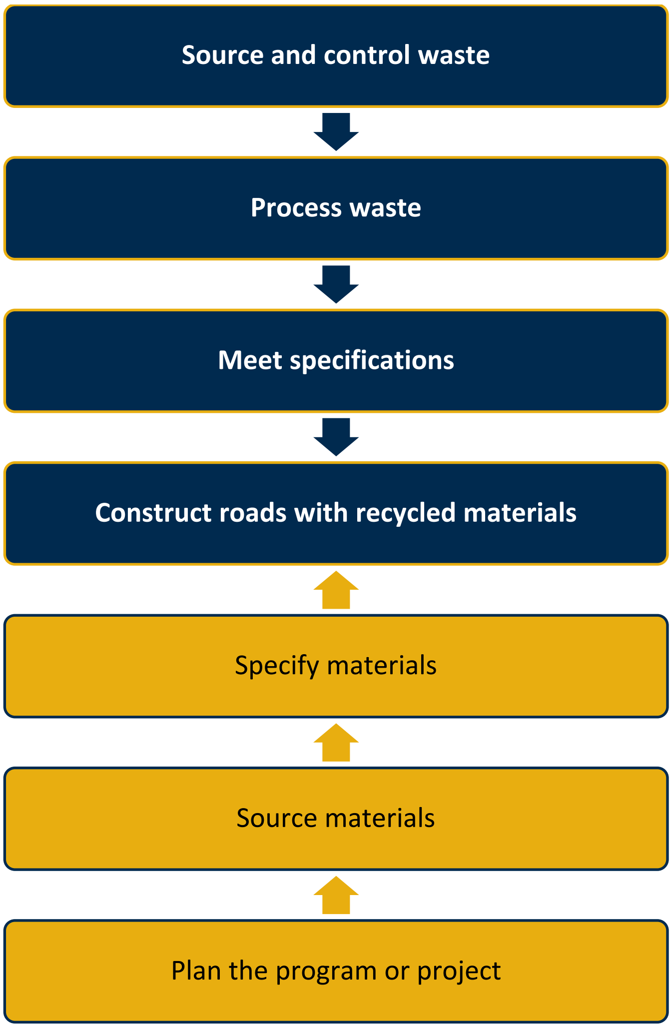
The next steps are to specify and arrange procurement by project or program, as explained in Section 8.

7.2 Availability from Local Government Managed Waste

In this section we look at the sources of waste available to local governments and provide guidance on turning the waste into a product suitable for road construction.

Figure 7.1 represents the path from waste materials to the eventual road construction materials. As will be presented in Section 8 the path also works from the other direction, with the works program and project needs leading to road construction materials with recycled content.

Figure 7.1: Path from waste to recycled materials in road construction



Local governments are uniquely placed to increase the volume of waste being recycled into road construction products. This is because they have access to a significant waste resource, in many cases have a high level of control on the quality of the waste streams and can specify material requirements.

7.2.1 Managing Waste Resources to Produce Road Construction Materials with Recyclables

As a local government managing its waste resources, and wanting to produce road construction materials with recyclables, the broad steps to follow are presented in Figure 7.2 with further guidance in the following pages.

Figure 7.2: The process for managing waste to produce recycled materials for local government projects

Step 1 Source and control waste

Understanding the legislation and waste strategy

The Waste Authority's *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Strategy) provides guidance for local government on sustainable road construction practices. As discussed in Section 2.1.3, three targets were identified in the Waste Strategy:

- increase MSW material recovery (in this case, plastics and glass as potential reusable materials) to;

  - 67% in Perth and Peel, 55% in major regional centres, by 2025
  - 70% in Perth and Peel, 60% in major regional centres by 2030
- increase material recovery in C&D sector to 77% by 2025, and 80% by 2030
- for all waste facilities to adopt resource recovery better practice.

The *Factsheet – Assessing Whether Material is Waste* (DWER 2018) provides definitions for waste in terms of the regulations and generally.

Section 2.2.2 discusses who determines if the material is waste, and when the waste becomes the property of local government.

Premises that process waste may need to be licensed as provided by the *Environmental Protection Regulations 1987* (EP Regulations). A levy may also be payable under the *Waste Avoidance and Resource Recovery Act 2007* (WARR Act) and WARR Levy Regulations 2008 (Section 3.2.3).

Local governments will need to seek advice from DWER as to whether the waste they are processing, and the resulting recycled materials will be considered waste and require licensing of their premises and activities (Section 3.2.3)..

Understand the waste resources available

Waste resources in a local government area may arise from:

- public and commercial operators delivering waste directly to a transfer station or waste receiving site managed by the local government
- local government managed collection services
- third party waste collection, receiving and processing, which may not involve local government.

Any waste not able to be recycled by local government leads to a high cost of disposal to landfill, and so there is typically a large financial incentive to avoid waste-to-landfill.

Local governments should assess the quantities of wastes generated that may be available for secondary processing in their areas. Information such as tonnages of materials may be sourced from waste facility records and waste collection company records.

Local governments should also assess their costs of landfill disposal to determine the potential cost saving benefits of being able to recycle any waste materials they receive. Such an assessment can assist to derive the cost effectiveness of any proposed road construction materials that contain recycled materials, for example a cost saving of $120 per tonne of avoided waste-to-landfill by recycling materials may offset an increased (net) construction material cost of $50 per tonne, resulting in an overall saving to the local government and the community.

Understand the types of materials that could be produced from waste

Refer to the factsheets provided in the Practitioners Guideline and for more information see also Section 4.

Step 2 Understand the types of road construction materials and quantities that are needed

Prior to considering how to control the types of waste materials and consequently the types of recycled materials that can be separated, the local government should evaluate what types of materials may be needed.

This may consist of:

- work with the operations and projects teams to identify projects in the works program for the coming budget year and future years

- estimate the approximate quantities of key road construction materials
- derive the quantities of recycled materials that could be incorporated into the road construction material
- assess the local government's waste sources, and if necessary contact product suppliers, and recycled materials suppliers, to determine if the required quantities of recycled materials are available and viable for inclusion in the project(s)

a. The mix of recycled glass in asphalt, for example, may be less than 0.1% by mass, so smaller quantities of asphalt may not be viable for batching with glass.

Step 3 Check feasibility and acquire approvals

A feasibility check is needed to determine the costs, constraints and risks of processing waste to produce recycled materials for road construction. Factors to consider in assessing the cost of processing include:

- waste facility site and operating costs to separate materials, or costs for a waste collection company to separate materials off site
- storage space and lease or land cost
- cost of specialised plant and equipment such as a mobile crushing plant
- mixing costs with other materials
- transport costs, which may include the cost of transporting waste to the facility, and the cost of transporting the processed materials to the user.

It is expected that local governments will have methods of deriving the various fixed and variable cost elements and apportioning them to the recycled materials project. A suggested calculation is to:

1. confirm the tonnes of the nominated waste received in a year (W for waste, tonnes)
2. Evaluate the total site operating costs and assign a proportion (percentage) of cost to the nominated waste, based on perceived effort, space, and handling costs (S for site costs)
3. from previous experience, or by quotation, determine the cost over a year for batch processing of the waste on site by suitable plant (P for plant costs). C&D waste processing, for example, may be undertaken through a mobile crushing plant. There may need to be a number of visits of larger plant required for batch crushing to optimise time and cost for the plant. This cost also needs to include separation of waste streams if needed for processing
4. evaluate the losses, the tonnage of material that cannot be processed and so remains as waste (L for losses in tonnes)
5. evaluate the cost of the mixing of materials if the processed material will be mixed with raw road construction materials (such as aggregates), as well as the cost of the raw material itself (M for mixing and raw materials cost)
6. evaluate quality testing costs depending on the desired material specification (Q for quality test costs)
7. Evaluate additional site costs that may arise to accommodate the plant and processed materials (S2 for additional site costs)
8. Evaluate the cost of transporting to the user if this will not be covered by the receiving project (T for transport).

The resulting equation is:

Cost per tonne of recycled material (C) = Operational and Production Costs / Recyclable Waste

$$C = (S + P + M + Q + S2 + T) / (W - L)$$

Note that this equation is suggested only, and local governments will need to ensure they have considered all appropriate costs in their assessment.

This calculation can be undertaken on a batch basis, for a specific (large) road construction project, or over a longer term if plant costs are to be considered.

The resulting cost per tonne can then be compared with the project raw material costs, and evaluated against landfill costs to determine if the processing would be financially viable for the organisation and the community.

Financial viability example

In a hypothetical case, a local government has an established waste transfer facility with annual operating costs (as per the budget)of $500,000. It receives C&D waste of concrete and brick of 5,000 tonnes annually, typically only through the summer months. Concrete comprises 80% of the C&D waste. The material is currently stockpiled until it can be transported to landfill. The waste is transported to landfill in 3 batches per year and costs $20,000 overall. Landfill cost per tonne is charged at $150, so the disposal of the waste costs the local government $770,000.

After discussion with the construction project team, it is identified that if all the concrete was separated and crushed and added to pavement aggregates at 95% by mass, the team could use it all. The concrete waste available before processing (W) is 5,000 x 80% = 4,000 tonnes.

The waste facility site is quite large, so the apportionment of site costs of the C&D waste (S) is only 10%, so $50,000. Separating the concrete can be done on delivery, so no additional cost is incurred for the waste facility. The cost of wet-hiring a mobile crushing plant is evaluated at $20,000 a visit. Three visits are still needed, so the total cost (P) is $60,000. Testing the material (Q) is $1,000. Around 5% of the material is expected to be unrecoverable so (L) is 200 tonnes.

Mixing the materials can be done as an extension to the crushing process, costing an additional $2,000 per batch. The local quarry can produce raw aggregates for the pavement at $15/tonne. Adding 5% by mass of raw aggregates to the waste of 4,000 tonnes will cost $3,000 so (M) is $9,000. As the site is large, no additional costs will arise to accommodate the plant. It is expected that the road construction project will pay for transport to the project site.

The cost to process the recycled materials into a viable road construction aggregate is ($50,000 + $60,000 + $9,000 + $1,000 + $0 + $0) = $120,000.

The cost per tonne of recycled material is = ($120,000) / (4,000 tonne – 200 tonne) = $31.58 per tonne.

This is more than double the cost of the raw material, however, in doing so the local government has saved over $600,000 (4,000 tonnes x $150 per tonne plus transport costs).

On the basis of the hypothetical results, this example presents as a significant cost saving to the organisation and community, despite the increase in cost to the construction projects.

Once it has been determined that the processing is financially viable, the local government needs to check for non-financial feasibility (see Section 8.3) and confirm that it can acquire the correct licences to process the waste. Refer to Section 2.2.3 for more information on licences.

Step 4 Manage the waste streams to get the desired quality and waste types

WALGA's Waste Net, the Waste Authority and DWER can provide guidance to local governments on how to manage waste facilities (such as transfer stations), and how to improve separation of waste streams to enable easier production of the desired recycled products.

Local governments may also refer to the following guides which provide information on managing waste facilities:

- DWER *Guidance Document Local Government Waste Plans* (2019b)
- DWER *Guideline: Better Practice Organics Recycling* (2022)
- Waste Authority *Roads to Reuse: Product Specification – Recycled Road Base And Recycled Drainage Rock* (2021), covering the receipt of C&D waste
- Waste Authority *Guidelines for Local Government Vergeside and Drop-Off Services* (2022b), including guidance on operating drop-off services at a transfer station.

In addition, a guidance document is being prepared by WALGA for planning, siting, operating and closure of small rural landfills (WALGA n.d.b.).

Mechanisms that may be used include:

- education and awareness programs with the public
- controlled separation at the point of collection, for example metals are commonly collected separately during bulk verge collections
- controlled separation at transfer stations or similar sites, such as providing separate bins and spaces, and drop-off services

- financial or service incentives for the community to separate waste before delivery or on receipt
- controls through a Waste Local Law and active enforcement (refer to Section 2.2.2 and the template Waste Local Law available from WALGA)
- private partnerships to process or even collect and process certain waste types, as is commonly arranged for mattresses
- other legislative mechanisms such as in land use development approvals requiring materials to be recycled (subject to the planning schemes and the *Planning and Development Act 2005* (WA)).

Note that if the waste processing is being undertaken in-house, the local government must ensure the waste processing site has been licensed in accordance with the EP Act. Refer also to Section 2.2.3

Problems in transforming bulk and organic waste

It is noted that there are a number of problems specific to bulk waste processing that may prevent the local government from engaging in secondary processing. These problems can include:

- approvals and operating licences under the EP Act (see also Section 2.2.3)
- processing plant (especially crushing plants) noise and dust
- scale and cost of the operation
- storage risks such as material flammability and contaminant leakage
- risk of intended recyclable material having other materials that contaminate the desired material
- organics processing odours.

Local governments should consult with DWER, the Waste Authority and Waste Net for advice on how to proceed with secondary processing.

Third party waste collection and processing

A mechanism to control waste separation and quality is for the local government to enter a contractual arrangement with a private operator to collect certain materials. This can provide benefits to the local government through:

- simplifying the product handling by the local government so it is only handling a limited number of waste streams
- outsourcing the risks of secondary processing
- enabling a specialised supplier to produce specified materials at higher productivity and economic quantities
- enabling processed, recycled materials to be available for use by the local government with third party quality controls
- enabling recycled materials to be available to the wider industry and community
- the private operator may be able to access grants schemes and levies not available to the local government.

Use of fill materials

Local governments should be advised that the use of fill materials that are received as waste and placed into local government projects, for example as subgrade or fill material, may be considered 'waste disposed of to landfill' within the meaning of the WARR Levy Regulations (DWER 2018). Local governments therefore need to ensure that any fill material they receive as waste is first processed at an appropriate facility and transformed to a viable fill material before being used in projects.

The above would not arise should the local government excavate the fill material themselves and use directly in their own projects, however they need to be careful to ensure the material meets the use specifications and is not mixed with other waste products. For more guidance on this, the practitioner should refer to the Factsheet *Amendments to the Environmental Protection Regulations 1987 Clean Fill and Uncontaminated Fill* (DWER 2019a).

Step 5 Process the waste into recyclables and then into road construction materials

This step involves processing materials into the new raw products that can then be substituted into other products (such as crushed glass into concrete). There are a significant number of specifications that govern how recycled materials need to be produced. The local government needs to ensure the chosen road construction material meets specifications prior to applying the product into their projects.

The local government should seek compliance with the relevant materials standard through appropriate quality control tests.

Refer to the individual materials and construction methods in Section 4 for the relevant specifications, materials and the testing and compliance that should be undertaken.

Step 6 Provide test results and SDS to users

As a producer of a material with recycled content, the local government will need to arrange quality control testing and produce a safety data sheet (SDS) prior to using the product in-house or on-selling. There may be other requirements set out by DWER as part of the site operating licences.

Step 7 Transfer the materials into projects and monitor performance

Road construction materials that contain recycled portions (in whole or part) may have different safe handling and transport requirements. The materials provider (in this process, being the local government or their agent), needs to ensure the product SDS has been provided to the construction project manager and that they are familiar with the content, prior to delivering the materials to the project.

To ensure the recycled materials will continue to be accepted and usable, the local government should identify the performance of the materials in the final project assets and establish ways of monitoring the performance over the asset life cycle. More information on this is provided in Section 8.

Step 8 Recognise and celebrate the quantities of materials recycled

Whatever the final use of the materials, as long as they have not ended up in landfill (or unusable stockpiles) then there has been a net contribution to Western Australian sustainability and the environment.

Celebrate and let the community know the great work that has been done!

7.2.2 Future Planning

As each of the previous main processes are tested and used, the organisation can incorporate these into their waste plan or maintenance/asset management plans to:

- increase the conversion of waste into usable road construction materials
- increase the use of road construction materials in works programs.

Refer to the DWER *Guidance Document Local Government Waste Plans* (DWER 2019b), and appropriate guidance for maintenance and asset management plans such as the Institute of Public Works Engineering Australasia's (IPWEA) *International Infrastructure Management Manual*.

8 Process for Selecting Appropriate Recycled Materials and Sustainable Road Construction Practices

8.1 The Overall Process

The selection of recycled materials and sustainable road construction practices is one element of a greater road construction project. For each project type, the steps outlined in Figure 8.1

Figure 8.1: and in Table 8.1 are intended to enhance a local government's project management processes to improve sustainability outcomes.

Figure 8.1: Sustainable road construction overall project process

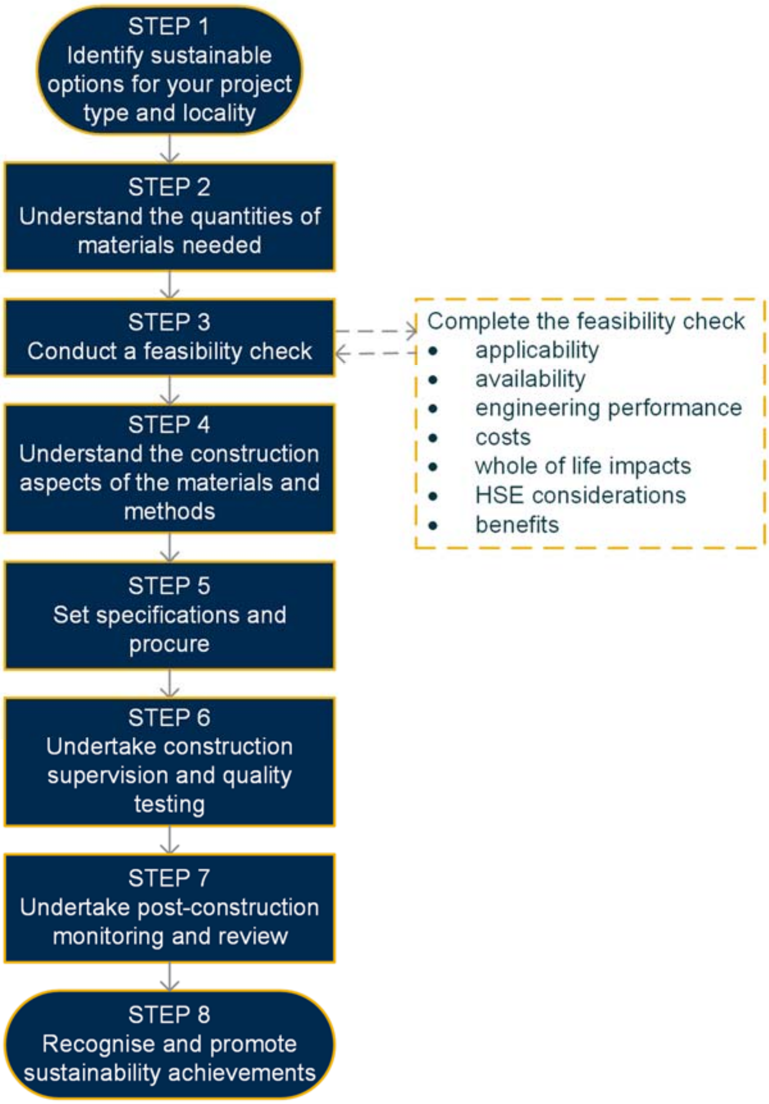


Table 8.1: Sustainable road construction overall project flow

Step	Purpose
1. Identify sustainable options (refer Section 3.2)	For the specific project type completed within the locality of the local government, identify possible recycled materials or sustainable road construction practices that could be included for each road infrastructure component.

Step	Purpose
	Each component (e.g. seals, asphalt, embankments, etc.) may have several different types of recycled materials that could be incorporated. The following information in Section 8.2 and the factsheets included within the Practitioners Guideline provide guidance for identifying possible recycled materials and sustainable road construction practices.
2. Understand the quantities of materials needed	This is from the perspective of the construction manager. To increase the portion of recycled materials that are used in road construction, The local government needs to have an understanding of the materials quantities that are going to be needed from its capital and maintenance works programs. The local government may estimate these quantities from: • gravel resheeting and grading done in the past, and future plans • depot stocks such as gravels issued over a financial year • asphalt tonnages procured in the past from panel contract suppliers • road resurfacing programs • larger road construction projects. Some examples of estimating the materials quantities are: • If the local government typically resheets 50 km of gravel road at 6 m wide and 75 mm depth, then they would estimate the need for 12,500 tonnes of gravel wearing course (at 1.8 t/m^3). • If the local government aims to rehabilitate 800 m of distributor road 7 m wide and the work includes 30 mm depth of asphalt, then they would estimate the need for 72 tonnes of asphalt (as well as basecourse materials). • For projects that have a formal design, the quantities can be extracted from the design drawings. This exercise can be continued across a number of projects or programs of works, to identify the total volumes and tonnages of different materials that are needed. Local governments with a capital works program that spans many future years may consider forecasting future materials quantities to inform a strategy of recycled materials procurement.
3. Conduct a feasibility check (refer Section 8.3 and the Practitioners Guideline factsheets)	The feasibility check will be conducted to identify the most appropriate sustainable options. The feasibility check will include, but not be limited to, a review of the following key aspects: • applicability • availability: • engineering performance • cost implications • whole-of-life factors • health, safety and environmental considerations • environmental benefits. Where a significant concern is identified, a risk assessment should be undertaken and include in the feasibility check. Information on these key aspects has been summarised within the factsheets in the Practitioners Guideline and detailed within this report.
4. Understand construction aspects of using the materials and methods	As local governments plan for construction, they may need to consider: • Are there any handling or use characteristics of the material that are different to ‘standard’ or unmodified materials? • Who in the supply chain and construction project needs to know about the products, for site safety, safe working practices, quality and efficiency? • Will traffic passing the work site need any different standard of care? • Will the ultimate users need information about using the constructed products that is different to standard materials? • What type of information should be provided to the public, and should this be presented as an opportunity (saving the environment), cautious (mind the hazards), or both? Where a significant concern is identified, undertake a risk assessment and include it in the feasibility check.

Step	Purpose
5. Set specifications for the material and works and procure	Refer to the individual materials and construction methods in Section 4 for the specifications that should be quoted. The following template can be used: Supply <product> and product test results demonstrating compliance with the specifications: • <ref and title> • <ref and title>. Provide material safety data sheets, safe transport and handling procedures for the products prior to delivery. The <product> test results, SDS and procedures are to be provided at least 10 working days before delivery. The local government should arrange procurement and delivery as per normal procedures. They should also ensure that the SDS, transport and handling procedures are reviewed by the receiving officer prior to receiving the products.
6. Undertake construction supervision and quality testing	The next actions for the local government are to: • Review safe work method statements, job safety analyses and similar work procedures as required so that they include the recycled materials. • Supervise the works and arrange quality control tests. • Maintain appropriate diary and job records on the aspects of working with the recycled materials products, in anticipation of future project reviews. At this stage it is important to keep good records to monitor the life of the assets over the long term. • Arrange project practical completion and handover of records to the asset management teams, ensuring that the recycled materials information is clearly identified.
7. Undertake post-construction monitoring and review	As part of the materials life cycle plan that was developed earlier, the organisation should arrange post-construction inspections, testing and assessment. This may include: • periodic inspections of the constructed product during the defects liability period, and post construction at 12 and 24 months • enhanced inspections as part of routine asset condition inspection cycles, to identify the effect of the recycled materials on condition • further quality control testing at 12 and 24 months, suited to the usual testing regime of the product type, and then assessment of the test results • user surveys and feedback. The organisation also needs to include recycled materials as an agenda item in project review meetings. The project review meetings should include experiences related to the recycled materials products such as: • the procurement of the products • supplier capability • transport and delivery • quality control by inspection and testing • site works productivity • site and public safety • communications and engagement results • planning of additional communications if considered appropriate • cost.
8. Recognise and promote sustainability achievements	Having successfully incorporated recycled materials into the construction project, materials have been prevented from ending up in landfill (or unusable stockpiles which has contributed to Western Australian sustainability and the environment. Celebrate and let the community know about the project.

8.2 Selection Process for Improved Sustainability

These documents have been structured to align with the requirements associated with the WA specific locality constraints and project types. Recycled materials and sustainable road construction practices will be highlighted where applicable for the infrastructure components associated with each project type (e.g. seals). The availability of those materials in each locality will then be discussed.

Additional key aspects for consideration during the feasibility check (e.g. engineering performance, health, safety and environmental impacts) for recycled materials and sustainable road construction practices will be described in the following factsheets in the Practitioners Guide:

Recycled materials

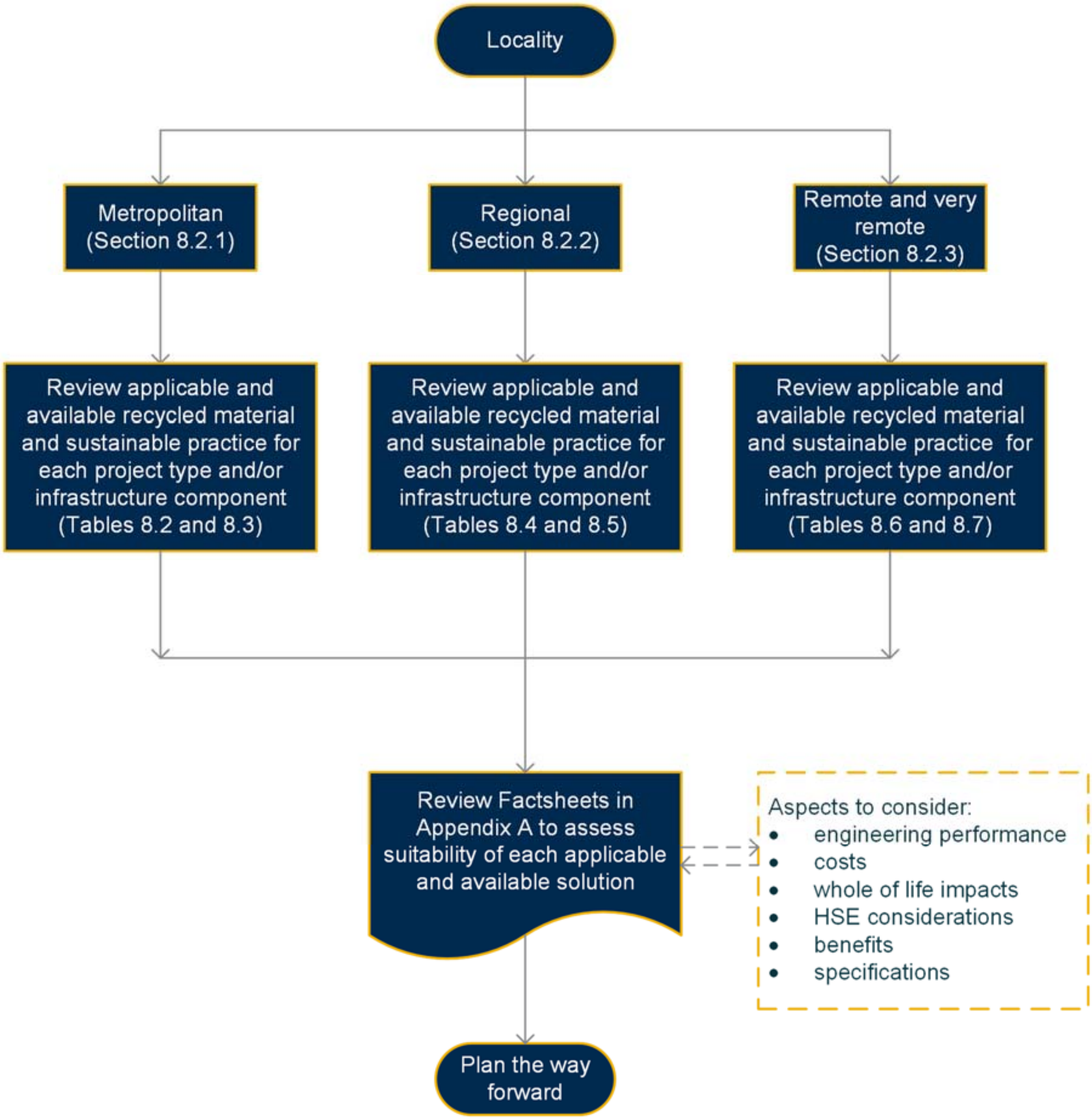
- Reclaimed asphalt pavement (RAP)
- Crushed recycled concrete and crushed brick
- Recycled crushed glass
- Crumb rubber
- Fly ash
- Bottom ash
- Blast furnace slag
- Food and garden organics
- Recycled plastics
- Recycled materials in road furniture.

Sustainable road construction practices

- Foamed bitumen stabilisation
- Bitumen emulsion stabilisation
- Cementitious stabilisation
- Soil/Subgrade stabilisation
- Warm mix asphalt
- Hot-in-place asphalt recycling
- In situ recycling of concrete pavements
- Marginal and non-standard materials.

A flow chart outlining the implementation process has been included in Figure 8.2. Additional details on each of the localities is included in Section 3.2.

Figure 8.2: Implementation flow chart



8.2.1 Metropolitan

As the majority of WA's population resides in and around the metropolitan area, the majority of local government areas are also metropolitan based. In accordance with the MRWA *Operational Procedure 112 – Operational Boundaries and Asset Responsibilities* (MRWA 2020b), the following local government areas are listed as metropolitan local government: City of Armadale, Town of Bassendean, City of Bayswater, City of Belmont, Town of Cambridge, City of Canning, Town of Claremont, City of Cockburn, Town of Cottesloe, Town of East Fremantle, City of Fremantle, City of Gosnells, City of Joondalup, Shire of Kalamunda, Town of Kwinana, City of Melville, Town of Mosman Park, Shire of Mundaring, City of Nedlands, Shire of Peppermint Grove, City of Perth, City of Rockingham, Shire of Serpentine-Jarrahdale, City of South Perth, City of Stirling, City of Subiaco, City of Swan, Town of Victoria Park and Town of Vincentand City of Wanneroo.

There are challenges and opportunities with respect to road construction in metropolitan areas. For example, the high volume of road users may present a significant challenge during construction and may influence higher engineering performance requirements. However, the greater availability of recycled materials suppliers within close proximity presents a valuable opportunity. Further details on the challenges and opportunities for road construction within the metropolitan area are detailed in Table 3.1.

Limited or no new road construction works typically occur as metropolitan areas are generally significantly developed. The following key project types have been identified as being relevant for road construction works within the metropolitan area:

- upgrade widening
- asphalt overlay
- rehabilitation (mill and re-mill) – base rehabilitation
- improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.

Each project type has nominated infrastructure components which may be redeveloped during construction. Recycled materials applicable to each project and infrastructure component are shown in Table 8.2. The potential availability of the materials, based on the desktop study and supplier engagement process is also shown.

Table 8.2: Recycled materials in metropolitan areas

Project type	Infrastructure component	Recycled materials(1)								
		RAP	Crushed recycled concrete and crushed brick	Recycled crushed glass	Crumb rubber	Fly ash	Bottom ash	Blast furnace slag	Food and garden organics (FOGO)	Recycled plastics
Upgrade widening	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓
Asphalt overlay	Asphalt	✓		✓	✓	✓		✓		R
Rehabilitation (mill and re-mill) – base rehabilitation	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
Improvement projects – e.g. new carriageways,	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R

Project type	Infrastructure component	Recycled materials[1]								
		RAP	Crushed recycled concrete and crushed brick	Recycled crushed glass	Crumb rubber	Fly ash	Bottom ash	Blast furnace slag	Food and garden organics (FOGO)	Recycled plastics
turning lanes, traffic circles etc.	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/Embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.

IS = Specifications available in other states.

R = Research underway.

Availability Key:

= Available in metropolitan WA.

= Available in metropolitan WA and LG sustainable waste management opportunities are available.

Sustainable construction practices applicable to each project and infrastructure component are shown in Table 8.3.

Table 8.3: Sustainable practices in metropolitan areas

Project type	Sustainable road construction practices[1]							
	Foamed bitumen stabilisation	Bitumen emulsion stabilisation	Cementitious stabilisation	Soil/Subgrade stabilisation	Warm mix asphalt	Hot-in-place asphalt recycling	In situ recycling of concrete pavements	Marginal and non-standard materials
Upgrade widening	✓	✓	✓	✓	✓			✓
Asphalt overlay					✓	✓		
Rehabilitation (mill and re-mill) – base rehabilitation	✓	✓			✓	✓		
Improvement projects - e.g. new carriageways, turning lanes, traffic circles etc.	✓	✓	✓	✓	✓	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.

Availability Key:

To be determined by local practitioners.

8.2.2 Regional

Regional WA surrounds the greater Perth metropolitan region. These areas are not within metropolitan areas and hence recycled materials suppliers are not present to the same extent, however the distances from regional areas to these suppliers are not likely to hinder their usage.

There are challenges and opportunities with respect to road construction in regional areas. For example, the higher cost for transport of recycled materials and sustainable construction equipment may present a challenge. However, there is a greater opportunity for regional local governments to conduct their own waste sourcing and separation. Further details on the challenges and opportunities for road construction within regional areas are detailed in Table 3.2.

The following key project types have been identified as being relevant for road construction works within regional areas:

- granular resheeting/stabilisation
- seal/reseal
- rehabilitation base and seal
- upgrade widening.
- improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.

Each project type has nominated infrastructure components which may be redeveloped during construction. Recycled materials applicable to each project and infrastructure component are shown in Table 8.4. The potential availability of the materials, based on the desktop study and supplier engagement process is also shown.

Table 8.4: Recycled materials in regional areas

Project type	Infrastructure component	Recycled materials(1)								
		RAP	Crushed recycled concrete and crushed brick	Recycled crushed glass	Crumb rubber	Fly ash	Bottom ash	Blast furnace slag	Food and garden organics (FOGO)	Recycled plastics
Granular resheeting/ stabilisation	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
Seal/reseal	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
Rehabilitation base and seal	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R

Project type	Infrastructure component	Recycled materials(1)								
		RAP	Crushed recycled concrete and crushed brick	Recycled crushed glass	Crumb rubber	Fly ash	Bottom ash	Blast furnace slag	Food and garden organics (FOGO)	Recycled plastics
	Concrete		✓	✓		✓	R	✓		R
Upgrade widening	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/Embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓
Improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.
IS = Specifications available in other states.
R = Research underway.

Availability Key:

= Available in regional WA.
= Not available in regional WA, however LG sustainable waste management opportunities are available.

Sustainable construction practices applicable to each project and infrastructure component are shown in Table 8.5.

Table 8.5: Sustainable practices in regional areas

Project type	Sustainable road construction practices(1)							
	Foamed bitumen stabilisation	Bitumen emulsion stabilisation	Cementitious stabilisation	Soil/Subgrade stabilisation	Warm mix asphalt	Hot-in-place asphalt recycling	In situ recycling of concrete pavements	Marginal and non-standard materials
Granular resheeting/stabilisation	✓	✓	✓					✓
Seal/reseal					✓	✓		
Rehabilitation base and seal	✓	✓		✓	✓	✓		✓
Upgrade widening	✓	✓	✓	✓	✓			✓
Improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.	✓	✓	✓	✓	✓	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.

Availability Key:

To be determined by local practitioners.

8.2.3 Remote/Very Remote

Remote WA surrounds the greater WA regional area, with a small isolated regional zone along the northwest coastline. Very remote WA includes the remaining areas within WA not included in the sections above. The majority of WA (by area) is considered very remote.

There are challenges and opportunities with respect to road construction in remote and very remote areas. For example, the limited suppliers within close proximity and long distances of transport supplies may present a challenge. However, there is a greater opportunity for remote and very remote local governments to conduct their own waste sourcing and separation. Further details on the challenges and opportunities for road construction within remote and very remote areas are detailed in Table 3.3 and Table 3.4.

The following key project types have been identified as being relevant for road construction works within remote and very remote areas:

- granular resheeting/stabilisation
- seal/reseal
- rehabilitation base and seal
- upgrade widening
- improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.

Each project type has nominated infrastructure components which may be redeveloped during construction. Recycled materials applicable to each project and infrastructure component are shown in Table 8.6. The potential availability of the materials, based on the desktop study and supplier engagement process is also shown.

Table 8.6: Recycled materials in remote and very remote areas

Project type	Infrastructure component	Recycled materials[1]								
		RAP	Crushed recycled concrete and crushed	Recycled crushed glass	Crumb rubber	Fly ash	Bottom ash	Blast furnace slag	Food and garden organics (FOGO)	Recycled plastics
Granular resheeting/ stabilisation	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓
Seal/reseal	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
Rehabilitation base and seal	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
Upgrade widening	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓
Improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.	Seals				✓					R
	Asphalt	✓		✓	✓	✓		✓		R
	Unbound pavements	✓	✓	✓		✓	IS	✓		R
	Concrete		✓	✓		✓	R	✓		R
	Earthworks/embankments	✓	✓	✓		✓	R	✓		
	Ancillaries	✓	✓	✓	✓	✓	R	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.
IS = Specifications available in other states.
R = Research underway.

Availability Key:

= Available in remote WA.
= Not available in remote WA, however LG sustainable waste management opportunities are available.
= Not available in remote WA.

Sustainable construction practices applicable to each project and infrastructure component are shown in Table 8.7.

Table 8.7: Sustainable practices in remote areas

Project type	Sustainable road construction practices[1]							
	Foamed bitumen stabilisation	Bitumen emulsion stabilisation	Cementitious stabilisation	Soil/Subgrade stabilisation	Warm mix asphalt	Hot-in-place asphalt recycling	In situ recycling of concrete pavements	Marginal and non-standard materials
Granular resheeting/stabilisation	✓	✓	✓					✓
Seal/reseal					✓	✓		
Rehabilitation base and seal	✓	✓		✓	✓	✓		✓
Upgrade widening	✓	✓	✓	✓	✓			✓
Improvement projects – e.g. new carriageways, turning lanes, traffic circles etc.	✓	✓	✓	✓	✓	✓	✓	✓

1. Recycled materials are linked to the product factsheets in the Practitioners Guide.

Applicability Key:

✓ = Application in specifications in WA.

Availability Key:

To be determined by local practitioners.

8.3 Feasibility Check

A feasibility check is needed to determine the costs, factors and risks of introducing recycled materials or methods into road construction.

The feasibility check will be conducted to identify the most appropriate sustainable options. The feasibility check will include, but not be limited to, a review of the key criteria outlined in Table 8.8. It is expected that the practitioner will consider these criteria as part of their normal project planning processes.

The feasibility check and processes are presented from the perspective of the works, project or construction manager. To understand financial viability from the perspective of the waste manager refer to Section 7.2.1.

Table 8.8: Feasibility aspects to consider

Item	Summary
Applicability	• Refer Step 1. • Identify any project constraints such as time and quality that may prevent a recycled materials product from being utilised.
Availability	• Refer Step 1. • Seek advice from the local government's waste operations, and contact product suppliers and recycled materials suppliers, to determine the availability of alternative materials for inclusion in the project(s).
Engineering performance	• Consider the durability requirements for the project (e.g. is the road highly trafficked, an unsealed road, etc.).
Cost implications	• Undertake a cost analysis of the impact of using the different recycled materials in the projects and programs.

Item	Summary
	• Elements to consider may include a comparison of virgin materials vs recycled materials, transportation costs, etc.
Whole-of-life factors	• At the end of the pavement life, can the road be recycled or used as clean fill?
Health, safety and environmental considerations	• Is the road being constructed in a particularly sensitive location? • Are there any potential contamination, workplace exposure, cultural or community considerations that need to be taken into account? • Identify project risks that may be increased or reduced as a result of using the recycled materials products
Environmental benefits	• Identify the local benefits of using each recycled material, which may include tangible savings from reductions of waste-to-landfill, and intangible benefits such as life of products, local employment and sustainability objectives.

8.3.1 Availability

Step 1 of the overall process (Table 8.1) and Section 8.2 provided guidance on the potential recycled materials and methods that could be used. As part of the feasibility check, the practitioner needs to identify the availability of the materials and methods.

As covered in Section 7.1, due to the variability in suppliers and locational needs, the local government is recommended to establish a recycled materials and methods availability matrix. The suggested content for the matrix is covered also in Section 7.1.

When considering a specific project or program of work, the practitioner can refer to the organisation's matrix to identify likely suppliers, and from there to determine which suppliers are able to supply the needed materials and methods.

Practitioners are advised to be mindful of their organisation purchasing procedures and tender regulations under the *Local Government Act 1995* and ensure that the procurement of the resulting materials and methods meets the regulations.

8.3.2 Cost

The cost impacts of a recycled material or method can be reflected directly, indirectly, or through economic measures.

To evaluate the direct cost impact, practitioners will need to know the gross cost of current materials and methods (C), and the gross cost of the proposal (P). The simple assessment is to compare which is higher. The gross cost is evaluated by considering all the inputs and activities needed to undertake the project with or without the recycled materials and methods. This may include increases or decreases that arise from:

9. transport of the materials
10. mobilisation and demobilisation of the supplier and plant and equipment
11. time on site for support staff and contractor staff
12. placement and compaction work
13. site safety requirements
14. quality control tests and supervision
15. community education and awareness programs to manage perceptions as identified in Section 8.3.6
16. environmental controls for items identified from Section 8.3.7.

Indirect costs to the organisation can include waste management savings and life cycle costs. The waste management savings can arise from reduced landfill costs where the material is saved from landfill through the organisation’s waste management as covered in Section 7.2.1. This could be an important factor that makes an otherwise higher cost material viable.

Life cycle costs can increase or reduce, as the useful life of the asset and its acquisition costs change, and through operations and maintenance costs as identified in Section 8.3.8.

8.3.3 Time

The introduction of recycled materials and methods may have an impact on the time elements of a project. Practitioners will need to consider whether the following aspects will be manageable within the timeframes provided to deliver the project or program of work:

- Is there additional time required for the supplier or waste facility to receive and process the recycled materials?
- Is there readily available stock and reliability of supply of the required quantities?
- Can the materials and methods be applied in shorter construction times thus potentially saving site costs and reducing risks?
- Is there specialised plant required, how available is it, and is there a need to program the work?
- Are there seasonal effects such as the suitability of a material or method in wet periods and summer or winter?
- Can the project be completed within the target financial year?

Practitioners can include the effects on project time elements as part of project scheduling and budgeting.

8.3.4 Engineering Performance

The project designer needs to be confident that the materials and methods will produce an asset that meets engineering performance standards. Aspects that may be considered, when comparing recycled materials and methods with previous materials and methods can include:

- Are the new materials and methods producing an equivalent or better durable asset and design life?
- Do the materials and methods support future growth in asset demand (flexibility in function and usage)?
- Are the maintenance requirements similar or easier?
- What quality control tests and inspections are required during construction?
- What are the specifications that should be adhered to?
- Are there any aspects of the materials and methods that do not comply with or align to design standards?

Methods to manage the risks that arise from this process can include undertaking trials, communicating with neighbouring local governments to understand their experiences, increasing defects liability periods or applying maintenance bonds, and requesting information from suppliers.

The answers to the under-construction questions need to be forwarded to the construction manager for consideration as part of steps 5 and 6 in Table 8.1.

8.3.5 Constructability and Work Health and Safety

There are aspects of construction with some recycled materials and methods that may require a review of project constructability (the practical ability to undertake the construction). This is most likely to occur when the plant and equipment are very different to what has normally been used, or the safety and environmental management requirements are more stringent.

The practitioner should review the supplier information, material specifications and SDS', and consider:

- Are there substantially different product handling requirements for the materials and methods?
- Are the plant and equipment required substantially different?

- Is there sufficient information available to understand the practical impact on the project including safety risks?
- Will the organisation job safety analyses or safe work procedures need to be developed or updated?
- Are there impacts to how the construction site will be managed?
- Are different traffic management controls needed, and can these be amended easily?
- Are different environmental controls needed for noise, dust, lighting and stormwater?
- Will the plant and equipment cause an increase in vibration that may require dilapidation surveys?

The answers to the questions need to be forwarded to the construction manager for consideration as part of steps 4 and 6 in Table 8.1. Additional information is also included in Section 2.3 Health, Safety and Environment.

8.3.6 Community Health and Safety

The introduction of a new recycled material or method may lead to a potential health and safety impact on the community. This is separate to the normal work health and safety management that will be undertaken during construction. Community health and safety can become at risk due to the type of recycled material and whether it is released from the source material as the material ages and wears.

The types of questions to consider for health and safety, as the asset ages and wears are:

- If particles of the recycled material come out of the asset, do they cause a risk and if so how and to what extent?
- Is the risk different if the particles are wind-blown than if carried by water such as in stormwater?
- Are the particles of recycled material soluble?
- Will the particles persist in the environment and are they within standard thresholds?

To understand this risk, practitioners need to refer to the factsheets and applicable specifications (refer the Practitioners Guide) and acquire the safety data sheets (SDS) from suppliers. Additional information on potential contaminants is included in Section 2.3 Health, Safety and Environment.

Where it is known that the community has safety concerns regarding a material, the practitioner should arrange community engagement with the aim of ensuring the community understands and can manage their perceived risks.

8.3.7 Environment and Heritage

Where there is positive and strong community or political support towards the use of recycled materials and methods or towards protecting the environment, this can be seen as a benefit towards feasibility. See also Section 2.1.3 for Drivers of Sustainability and Section 2.3 Health, Safety and Environment.

Benefits can arise from:

- diversion of materials from landfill, as an environment measure
- potential for reduced carbon dioxide emissions for recycled materials when compared to the work needed to extract raw materials
- reduction in the use of non-renewable materials
- the ability to process and bind materials into long lasting assets, thus ensuring the materials do not become contaminated in their unprocessed form
- reducing the need for non-renewable materials may enhance the protection of land from clearing and enable the protection of heritage values.

Practitioners may be able to report the environmental benefits through organisation climate change action plans, environmental management plans or the International Council for Local Environmental Initiatives (ICLEI).

The method of scoring or valuing the benefits or risks to the environment is beyond the scope of this guide. Practitioners should seek advice from their environmental management and statutory planning teams to identify the relative values.

The introduction of a new recycled material or method may lead to an environmental impact. Practitioners should refer to the factsheets and suppliers and acquire the recycled materials and methods SDS to identify the risk of contamination to the environment over the life of the constructed asset. Where uncertainty remains with respect to potential environmental impacts, further assessment should be conducted by suitably qualified and experienced consultants.

The types of questions to consider for environmental impact are the same as for community health and safety. As the asset ages and wears consider:

- If particles of the recycled material come out of the asset, do they cause a risk and if so how and to what extent?
- Is the risk different if the particles are wind-blown than if carried by water such as in stormwater?
- Are the particles of recycled material soluble?
- Will the particles persist in the environment, and are they within standard thresholds?
- Subject to the organisation environmental policy and practices, practitioners can also consider: Is there a life cycle benefit to the environment in having the recycled material built into the assets?
- Are there energy and emissions savings from the recycled materials processes that provide a net benefit to the community?

These considerations are to be made in comparison to the previously used materials. For example, where fly ash can be used to decrease the amount of cement in concrete, then there may be a reduced environmental impact overall by reducing the impact from manufacturing cement.

8.3.8 Whole-of-life and Asset Management

In a feasibility assessment, the whole-of-life considerations for the practitioner can include:

- Can the materials be subsequently reused or recycled at the end of the asset's life?
- What are the estimates of useful life for the recycled materials and methods compared to those previously used?
- What is the impact on the asset valuation and depreciation costs?
- Are there ongoing operational and maintenance requirements that differ from the previous materials?

While a smaller individual project may not result in a significant increase in annual depreciation for the organisation, there may be situations where a very large project or program of work, that introduces higher cost or shorter life recycled materials in assets, will lead to a higher depreciation charge. This can affect the organisation's financial ratios, loan capacities and funding.

The method of assessing these factors is beyond the scope of this guide. Practitioners should refer to the organisation's asset management and finance teams for advice.

Practitioners should refer to suppliers and acquire the recycled materials and methods SDS to identify if there are operational and maintenance requirements to manage.

8.3.9 Risk Management

As part of normal project planning, the practitioner will undertake a risk assessment using their organisation's risk management procedures. Example risks relating to the use of recycled materials and sustainable construction methods are provided in Table 8.9 below. This shows examples of the types of risks that could arise and how the practitioner could manage the risks. This aspect of feasibility is provided separately to ensure that the practitioner has undertaken their due diligence and applied suitable mitigation.

By reference to the organisation's risk matrix, and mitigation measures, the practitioner can determine if the risks can be avoided or mitigated sufficiently to enable the recycled materials or methods to be used.

Table 8.9: Examples of risks in using recycled materials and sustainable construction methods

Typical risk element	Example risks	Example mitigation
Financial	• Risk of unknown costs arising from the product handling and placement methods, increasing the cost of the project. • Risk of construction budget not being able to support the use of the different materials (that would otherwise offset a cost to landfill for example).	• Ensure the materials and methods are understood before procuring and using. Arrange job safety analyses or safe work instructions. • Liaise with finance team to identify organisation savings to offset increases in product costs.
Environmental	• Risk of a contaminant being introduced within a recycled material and then being released to the environment from a road construction project.	• Arrange quality control tests of recycled materials prior to delivery and ensure suppliers are appropriately licensed.
Work health and safety	• Workers or public become exposed to recycled materials from the product leading to injury or health effects.	• Ensure SDS and specifications are understood by all workers and apply effective safety practices in handling the products.
Legal	• Supplier product or method does not perform as intended or as specified, leading to contractual compliance problems.	• Ensure specifications are clear and based on adopted standards, follow effective construction and contract management practices in quality control, site supervision and correspondence.
Reputational	• Community decline in satisfaction arising from smell, noise, odour or some other aspect of the material or method.	• Identify areas where the community may be exposed and inform or mitigate as needed.
Political	• Failing to implement a material or method that is promoted by local political leader may cause disfavour towards the local government.	• Ensure feasibility assessments are communicated with the political leader.
Operational	• Risk of the material or method application delaying a project and affecting the allocation of resources.	• Ensure the materials and methods are understood before procuring and using.

9 Implementation Opportunities

These documents have been prepared with the intent of providing local governments with the support and guidance required to make informed decisions about integrating sustainable solutions in road construction. The challenges for local governments in improving sustainability outcomes are compounded by the geographical constraints of WA. These documents have been tailored to focus on solutions associated with both locality (i.e. metropolitan, regional, remote/very remote), and the project types typically undertaken in those areas.

Improving the sustainability of a road construction project can take many forms. For the purposes of these documents, the focus has been on waste and energy reduction and the circular economy. This focus aligns with current local, national and international policies and strategic plans. The use of recycled materials in road construction will aid in transforming the circular economy within WA. This can be supplemented by sustainable road construction practices which primarily focus on improving in situ materials or the technologies currently used. Twelve recycled materials and 8 sustainable practices have been reviewed and presented within these documents. Many of these recycled materials and sustainable practices can be utilised now under current MRWA and WALGA specifications.

A review of availability identified that, as expected, many types of recycled materials for use in road construction are predominantly situated or accessible within metropolitan and surrounding regional areas. However, increasing the uptake of recycled materials and sustainable practices in road construction is anticipated to aid in improving availability. Local governments also have opportunities to take control of waste management within their jurisdictions by improving facilities and processes to transform waste (e.g. C&D waste) into valuable construction materials.

The selection and implementation process for the integration of sustainable practices in road construction has been outlined in the practitioners guide. The practitioners guideline includes a methodology for selecting potential sustainable options and identifying which option will best suit the project. A practitioner can use the guideline by entering the project type and locality into a chart that will provide a range of applicable recycled materials and methods for consideration. Each of the recycled materials and methods options are supported by a detailed fact sheet providing comprehensive advice including availability, engineering performance and technical specifications, from which a practitioner can decide whether to adopt the option. These parameters provide the information required to enable a feasibility check specific to individual project works. Example scenarios are provided to guideline the user through the process to aid in achieving best practice outcomes.

To support the implementation of these documents, it is recommended that local government practitioners undertake a review of the recycled materials and equipment available in their local area. The process to undertake this has been included within the technical report. It is recommended that local governments establish a recycled materials and methods availability matrix. It is anticipated that this would be a live document/database that would increase in value as more recycled materials and methods are adopted in local projects.

This process would also be suitable for the conversion of waste into resources at local government owned waste facilities. As each of the main processes are tested and used, the organisation can incorporate these into their waste plan or maintenance/asset management plans to:

- increase the conversion of waste into usable road construction materials
- increase the use of road construction materials in works programs.

As practitioners become familiar with the many specifications for recycled materials and sustainable construction practices, there will be a need for the specifications to be reviewed and updated. Practitioners can liaise with their Regional Road Groups, industry associations, WALGA and Main Road WA as needed.

Sustainability innovation within the road construction space is constantly evolving to address the requirements of international goals, government policy and strategic plans and societal expectations. These documents provide information on the current status of the use of recycled materials and sustainable road construction practices. Future reviews and revisions of these documents may be required to align with emerging technologies and emerging recycled materials.

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Standard specification section 306 2019, *Cementitious treated pavement subbase*.

Standard specification section 307 2008, *In-situ stabilisation of pavements with cementitious binders*.

Standard specification section 405 2014, *Regulation gap graded asphalt*.

Standard specification section 407 2022, *Dense graded asphalt*.

Standard specification section 408 2017, *Sprayed bituminous surfacings.*

Standard specification section 421 2020, *High binder crumb rubber asphalt*.

Standard specification section 422 2019, *Light traffic crumb rubber asphalt*.

Standard specification section 423 2021, *Lean mix asphalt* (withdrawn).

Standard specification section 520 2018, *Materials and construction plant for roller compacted concrete pavement courses*.

Standard specification section 610 2020, *Structural concrete*.

Standard specification section 702 2019, *Subsurface drainage*.

Standard specification section 703 2021, *General concrete paving*.

Standard specification section 705 2021, *Drainage pits and covers*.

Standard specification section 801 2018, *Material sources for the production of crushed rock and aggregates*.

Standard specification section 802 2006, *Bituminous cold and warm mixes*.

Standard specification section 812 2016, *Production of crushed rock for pavement base and subbase*.

Standard specification section 813 2021, *Base and subbase for lower trafficked roads*.

Standard specification section 815 2013, *Cementitious treated crushed rock for pavement subbase*.

Standard specification section 820 2019, *Crushed concrete for pavement subbase and light duty base* (archived).

Standard specification section 821 2019, *Cementitious treated crushed concrete for pavement subbase* (archived).

Technical note TN 107 2019, *Use of recycled materials in road pavements*.

Main Roads Western Australia (MRWA) Specifications

Specification 302 2020, *Earthworks.*

Specification 404 2021, *Culverts.*

Specification 410 2021, *Low strength infill.*

Specification 501 2022, *Pavements* (superseded).

Specification 502 2022, *Stone mastic asphalt.*

Specification 503 2018, *Bituminous surfacing.*

Specification 504 2022, *Asphalt wearing course.*

Specification 507 2017, *Microsurfacing*.

Specification 510 2022, *Asphalt intermediate course.*

Specification 511 2023, *Materials for bituminous treatments.*

Specification 515 2021, *In-situ stabilisation of pavement materials.*

Specification 516 2020, *Crumb rubber open graded asphalt.*

Specification 602 2020, *Guide posts.*

Specification 820 2018, *Concrete for structures*.

Specification 901 2018, *Concrete: general works.*

Specification 904 2018, *Noise walls.*

Queensland Department of Transport and Main Roads (TMR) Specifications

MRTS04 2022, *General earthworks*.

MRTS05 2022, *Unbound pavements*.

MRTS07B 2022, *In-situ stabilised pavements using cement or cementitious blends*.

MRTS07C 2022, *In-situ stabilised pavements using foamed bitumen*.

MRTS08 2022, *Plant-mixed heavily bound (cemented) pavements*.

MRTS09 2022, *Plant-mixed foamed bitumen stabilised pavements*.

MRTS10 2022, *Plant-mixed lightly bound pavements*.

MRTS11 2022, *Sprayed bituminous treatments (excluding emulsion)*.

MRTS18 2020, *Polymer modified binder (including crumb rubber)*.

MRTS30 2022, *Asphalt pavements*.

MRTS32 2022, *High modulus asphalt (EME2)*.

MTRS35 2010, *Recycled material blends for pavements* (superseded).

MTRS36 2020, *Recycled glass aggregate*.

MRTS39 2018, *Lean mix concrete sub-base for pavements*.

MRTS40 2018, *Concrete pavement base*.

MRTS70 2022, *Concrete*.

MRTS101 2022, *Aggregates for asphalt*.

MTRS102 2019, *Reclaimed asphalt pavement material*.

MRTS103 2017, *Fillers for asphalt*.

PSTS112 2019, *Crumb rubber modified asphalt*.

Technical note TN193 2020, *Use of recycled materials in road construction*.

Transport Canberra and City Services (TCCS) Municipal Infrastructure Technical Specifications

MITS 02C 2019, *Stabilisation.*

MITS 04 2019, *Flexible pavements.*

MITS 10 2019, *Concrete works*.

Transport for NSW (TfNSW)

Design & Construct Specification D&C R116 2021, *Heavy duty dense graded asphalt.*

Design & Construct Specification D&C R117 2022, *Light duty dense graded asphalt.*

Design & Construct Specification D&C R121 2020, *Stone mastic asphalt.*

Design & Construct Specification D&C 3051 2020, *Granular pavement base and subbase materials.*

Design & Construct Specification D&C 3211 2015, *Cements, binders and fillers.*

D&C 3256 2020, *Crumb rubber.*

QA Specification R118 2020, *Crumb rubber asphalt*.

QA Specification 3051 2020, *Granular pavement base and subbase materials.*

QA Specification 3201 2021, *Concrete supply for pavement maintenance.*

QA Specification 3252 2023, *Polymer modified binder for pavements.*

Technical Direction PTD 2015/00, *Foamed bitumen stabilisation*.

Appendix A Recycled Materials Specifications for Road Construction

The following list of interstate specifications and guidance materials have been sourced from Hall et al. (2022).

A.1 Reclaimed Asphalt Pavement

Table A.1: Specifications for the use of recycled aggregates in road infrastructure (including aggregates other than concrete and brick); summary table

Specification/Standards	Agency/Institution	Application
ACT		
TCCS MITS 04 *Flexible Pavements*	TCCS	
NSW		
TfNSW Specification D&C 3051 *Granular Pavement Base and Subbase Materials*	TfNSW	Base and subbase
NT		
Standard Specification for Roadworks v5.1	DIPL	
Standard Specification for Road Maintenance	DIPL	
Materials Testing Manual	DIPL	
Qld		
MRTS05 *Unbound Pavements*	TMR	Unbound pavement materials
MRTS07B *In situ Stabilised Pavements using Cement or Cementitious Blends*		Stabilised pavements
MRTS07C *In situ Stabilised Pavements using Foamed Bitumen*		
MRTS09 *Plant-mixed Foamed Bitumen Stabilised Pavements*		
MRTS10 *Plant-mixed Lightly Bound Pavements*		
MRTS30 *Asphalt Pavements*		Asphalt
MRTS32 *High Modulus Asphalt*		
MRTS101 *Aggregates for Asphalt*		
MTRS102 *Reclaimed Asphalt Pavement Material*		
SA		
RD-PV-S1-2022 *Supply of Pavement Materials*	DIT	
Tas		
Section 812 *Production of Crushed Rock for Pavement Base and Subbase*		Base and subbase
Vic		
Section 407 *Dense Graded Asphalt*	VicRoads	
Section 405 *Regulation Gap Graded Asphalt*		
Section 423 *Lean Mix Asphalt*		
Section 802 *Bituminous Cold and Warm Mixes*		
Section 801 *Material Sources for the Production of Crushed Rock and Aggregates*		
Section 812 *Production of Crushed Rock for Pavement Base and Subbase*		Base and subbase
Section 821 *Cementitious Treated Crushed Concrete for Pavement Subbase*		
Code of Practice RC 500.02 *Registration of Crushed Rock Mixes*		
Code of Practice RC 500.20 *Assignment of CBR and Percent Swell to Earthworks Fill and Pavement Materials*		
Code of Practice RC 500.01 *Registration of Bituminous Mix Designs*		Class 1–4 crushed rock (as supplementary material)
TN 107 *Use of Recycled Materials in Road Pavements*		

Table A.2: Allowable contents of RAP in asphalt layers for each state and territory in Australia; summary table

RAP content limit		
NSW		
Surface	Up to 20% in wearing course and up to 40% for other than wearing course in heavy duty dense graded asphalt	TfNSW QA R116
	Up to 25% by mass in wearing course and up to 40% by mass for other than wearing course in light duty dense graded asphalt	TfNSW QA R117
Mix type	RAP is not allowed in CRA, SMA or OGA mixes. For PMB mixes, up to 10% RAP could be used	
NT		
Surface	In dense graded asphalts, up to 10% by mass in the wearing course, and up to 15% by mass in base layers	*Standard Specification for Roadworks v5.1*
Qld		
Surface	In dense graded asphalt, up to 20% by mass RAP is allowed in surfacing course. Maximum allowable limit is 15% if the dense graded asphalt contains PMB and multigrade bitumen In dense graded asphalts, up to 40% (by mass) RAP is allowed in base, intermediate and corrector courses	MRTS30
	The maximum allowable RAP in EME2 is 15% by mass	MRTS32
Mix type	RAP is not allowed in SMA and OGA mixes	
SA		
Surface	RAP is allowed to be used for wearing courses up to 10% (by mass) in coarse dense mix asphalt and up to 20% in fine dense mix asphalt Up to 50% (by mass) RAP is allowed in asphalt pavement layers (other than wearing course). In asphalt mixes containing PMB, the maximum allowable is 20%	RD-BP-S2
Mix type	RAP is not allowed in SMA and OGA mixes	RD-BP-S2
Tas		
Surface	Aligned with Vic	
Mix type		
Vic		
Surface	Up to 40% (by mass) RAP content is allowed for dense graded asphalt depending on traffic volume. (Maximum 25% for RAP Level 1 and maximum 40% for RAP Level 2)	Section 407 Code of Practice RC 500.01
	Up to 10% (by mass) RAP in regulation gap graded asphalt	Section 405
Mix type	RAP is not allowed in SMA, OGA and high binder crumb rubber asphalt (HBCRA) mixes and mixes containing PMBs or EME2 binders	

Table A.3: Allowable contents of RAP in granular layers for each state and territory in Australia; summary table

RAP content limit		
NSW		
Base and subbase	Up to 40% by mass in unbound, modified and bound base and subbase	TfNSW QA 3051
NT		
Base and subbase	Not specified	
Qld		
Base and subbase	Up to 20% RAP is allowed in base and subbase of unbound pavements. In lower subbase and subgrade (Subtype 2.5 unbound pavement), up to 45% by mass is allowed	MRTS05

RAP content limit		
SA		
Base and subbase	Up to 20% (by mass) RAP is allowed in granular pavement materials	RD-PV-S1
Tas		
Base	Aligned with Vic	
Vic		
Base and subbase	Up to 15% for unbound base (Class 3), and up to 40% for unbound and bound subbase (Class 4)	Code of Practice RC 500.02
	Up to 20% in lower trafficked base and up to 50% in lower trafficked subbase	Section 813

A.2 Crushed Concrete and Brick

Table A.4: Specifications for the use of recycled aggregates in road infrastructure (including aggregates other than concrete and brick): summary table

Specification/Standards	Agency/Institution	Application
ACT		
MITS 04 *Flexible Pavements*	TCCS	
NSW		
TfNSW Specification D&C 3051 *Granular Pavement Base and Subbase Materials*	TfNSW	Base and subbase
NT		
Standard Specification for Roadworks v5.1	DIPL	
Standard Specification for Road Maintenance	DIPL	
Materials Testing Manual	DIPL	
Qld		
MRTS05 *Unbound Pavements*	TMR	Unbound pavement materials
MRTS07B *In situ Stabilised Pavements using Cement or Cementitious Blends*		Stabilised pavements
MRTS07C *In situ Stabilised Pavements using Foamed Bitumen*		
MRTS08 *Plant-mixed Heavily Bound (Cemented) Pavements*		
MRTS09 *Plant-mixed Foamed Bitumen Stabilised Pavements*		
MRTS10 *Plant-mixed Lightly Bound Pavements*		
MRTS30 *Asphalt Pavements*		Asphalt
MTRS35 *Recycled Material Blends for Pavements*		
MRTS101 *Aggregates for Asphalt*		
SA		
RD-PV-S1 2022 *Supply of Pavement Materials*	DIT	
Tas		
Section 306 *Cementitious Treated Pavement Subbase*	DSG	Cementitious subbase
Section 812 *Production of Crushed Rock for Pavement Base and Subbase*	DSG	Base and subbase
Section 304 *Unbound Flexible Pavement Construction*	DSG	

Specification/Standards	Agency/Institution	Application
	Vic	
Section 407 *Dense Graded Asphalt*	VicRoads	Asphalt
Section 423 *Lean Mix Asphalt*		
Section 802 *Bituminous Cold and Warm Mixes*		
Section 703 *General Concrete Paving*		Footpaths
Section 801 *Material Sources for the Production of Crushed Rock and Aggregates*		
Section 812 *Production of Crushed Rock for Pavement Base and Subbase*		Base and subbase
Section 820 *Crushed Concrete for Pavement Subbase and Light Duty Base*		
Section 821 *Cementitious Treated Crushed Concrete for Pavement Subbase*		
Code of Practice RC 500.02 *Registration of Crushed Rock Mixes*		
Code of Practice RC 500.20 *Assignment of CBR and Percent Swell to Earthworks Fill and Pavement Materials*		
Section 175 Referenced Documents for Standard Specifications for Roadworks and Bridgeworks		
TN 107 *Use of Recycled Materials in Road Pavements*		

A.3 Recycled Crushed Glass

Table A.5: List of specifications and standards available per state and Australia-wide: summary table

Specification/Standard	Agency/Institution	Application
	ACT	
MITS 04 *Flexible Pavements*	TCCS	Granular base and subbase
	NSW	
TfNSW D&C R116 *Heavy Duty Dense Graded Asphalt*	TfNSW	Asphalt
TfNSW D&C R117 *Light Duty Dense Graded Asphalt*		
TfNSW D&C R121 *Stone Mastic Asphalt*		
TfNSW QA Specification R3051 *Granular Pavement Base and Subbase Materials*		Granular base and subbase
TfNSW QA Specification 3201 *Concrete Supply for Pavement Maintenance*		Slab replacement work for concrete pavements
	NT	
Standard Specification for Roadworks v5.1	DIPL	Bedding for drainage works

Specification/Standard	Agency/Institution	Application
		Qld
MRTS30 *Asphalt Pavements*	TMR	Dense-graded asphalt layers (other than surfacings) and dense-graded asphalt surfacings
TN193 *Use of Recycled Materials in Road Construction*		Unbound pavements (subtypes 2.3, 2.4 and 2.5)
MRTS05 *Unbound Pavements*		
MRTS04 *General Earthworks*		Bedding and backfill material
MTRS36 *Recycled Glass Aggregate*		Unbound pavements and asphalt
		SA
RD-LM-S1 *Materials for Pavement Marking*	DIT	Anti-skid mixtures for pavement markings
		Tas & Vic
Section 407 *Dense Graded Asphalt*	DoT	Intermediate and base course layers in dense-graded asphalt
TN 107 *Use of Recycled Materials in Road Pavements*		Granular base and subbase
RC 500.02 *Registration of Crushed Rock Mixes*		
Section 702 *Subsurface Drainage*		Subsurface drainage – granular filter material
Section 204 *Earthworks*		Type A, B and C fill

A.4 Crumb Rubber

Table A.6: List of specifications for use of crumb rubber

Specification/Standard	Agency/Institution
Crumb Rubber Modified Open Graded and Gap Graded Asphalt (AAPA 2018b)	Australian Flexible Pavement Association (AfPA) (formerly AAPA)
QA specification R118 *Crumb Rubber Asphalt*	Transport for New South Wales (TfNSW)
QA specification 3252 *Polymer Modified Binder for Pavements*	
D&C Specification 3256 *Crumb Rubber*	
MRTS11 *Sprayed Bituminous Treatments (Excluding Emulsion)*	Queensland Department of Transport and Main Roads (TMR)
MRTS18 *Polymer Modified Binder (Including Crumb Rubber)*	
PSTS112 *Crumb Rubber Modified Asphalt*	
Master Specification RD-BP-S1 *Supply of Bituminous Materials*	Department for Infrastructure and Transport (DIT)
Section 408 *Sprayed Bituminous Surfacing*	Department of Transport Victoria (DoT Vic)
Section 421 *High Binder Crumb Rubber Asphalt*	
Section 422 *Light Traffic Crumb Rubber Asphalt*	

A.5 Fly Ash

Table A.7: List of specifications for use of fly ash by jurisdiction

State	Road agency	Application	Material/Product	Max limit (% by mass)	Reference
NSW	TfNSW	Concrete work for bridges	SCM in binary blended cement(1)	40	TfNSW D&C 3211

State	Road agency	Application	Material/Product	Max limit (% by mass)	Reference
		Shotcrete work Shotcrete work without steel fibres Concrete for general works No fines concrete subbase	SCM in ternary blended cement(2)	30	
		Lean-mix concrete subbase	SCM in binary and ternary blended cement	75	
		Concrete pavement base	SCM in binary and ternary blended cement	40	
		Stabilisation of earthworks Construction of unbound and modified pavement course Construction of plant mixed heavily bound pavement course In situ pavement stabilisation using slow setting binders Roller compacted concrete subbase Roller compacted concrete	Binder	Not specified	
		Heavy duty dense graded asphalt Light duty dense graded asphalt Crumb rubber asphalt Open graded asphalt Stone mastic asphalt Thin open graded asphalt surfacing High modulus asphalt (EME2)	Added filler	Not specified	
Qld	TMR	In situ stabilisation	Binder (stabilising agent)	Not specified	MRTS07B
		Plant-mixed heavily bound (cemented) pavements			MRTS08
		Plant-mixed foamed bitumen stabilised pavements			MRTS09
		Plant-mixed lightly bound pavements			MRTS10
		Lean mix concrete subbase for pavements	SCM in blended cement	Not specified(3)	MRTS39
		Concrete pavement base		40	MRTS40
		Concrete road and bridge structures	SCM in binary blended cement	40	MRTS70
			SCM in ternary blended cement	32	
		Asphalt	Added filler	Not specified	MRTS103
Vic	DoT	Cementitious treated pavement subbase	SCM in blended cement	30	Section 306, Section 815
		In situ stabilisation of pavements		30	Section 307
		Dense graded asphalt	Added filler	Not specified	Section 407
		Concrete pavement courses	Fine aggregate	Not specified	Section 520
			SCM in blended cement	20	
		Structural concrete	SCM in blended cement	25	Section 610
		Concrete for paving (including geopolymer concrete)		Not specified	Section 703
		Geopolymer binder		100	Section 703
		Concrete for drainage pits and covers (including geopolymer concrete)		Not specified	Section 705
Tas	DSG	Aligned with DoT			
SA	DIT	Controlled low strength material	SCM	Not specified	RD-EW-C4

State	Road agency	Application	Material/Product	Max limit (% by mass)	Reference
		Stabilisation	SCM in binder	67(4)	RD-PV-S1
		Stabilised pavement	SCM in blended cement	Not specified	RD-PV-S2
		Geopolymer concrete (for structures)	Binder	Not specified	ST-SC-S2
NT	DIPL	Stabilisation Miscellaneous concrete works Drainage work structures (e.g. culverts)	SCM in blended cement	Not specified	*Standard Specification for Roadworks v5.1*
ACT(5)	TCCS	Subgrade stabilisation	Binder (stabilising agent)	Not specified	MITS 02C
		Base and subbase	Filler and/or binder	Not specified	MITS 04
		Grout for concrete works	Grout material	Not specified	MITS 10

1. Blended cements containing cement and one SCM.
2. Blended cements containing cement and 2 SCMs.
3. Minimum 40% by mass of total cementitious material.
4. The total binder content is 3% consisting of 2% fly ash and 1% lime.
5. ACT has the Municipal Infrastructure Technical Specifications (MITS) in place. ACT follows the TfNSW specifications for its trunk road infrastructure under Trunk Road Infrastructure Technical Specifications (TRITS).

A.6 Blast Furnace Slag

Table A.8: Specified limits for BFS by different road agencies

State	Road agency	Application	Material/Product	Max limit (% by mass)	Reference
NSW	TfNSW	Concrete work for bridges Shotcrete work Shotcrete work without steel fibres Lean-mix concrete subbase Concrete for general works No fines concrete subbase	SCM in binary blended cement(1)	70	TfNSW D&C 3211
			SCM in ternary blended cement(2)	50	
		Concrete pavement base	SCM in binary and ternary blended cement	65	
		Stabilisation of earthworks Construction of unbound and modified pavement course Construction of plant mixed heavily bound pavement course In situ pavement stabilisation using slow setting binders Roller compacted concrete subbase Roller compacted concrete	SCM in binary and ternary blended cement	Not specified	
		Heavy duty dense graded asphalt Light duty dense graded asphalt Crumb rubber asphalt Open graded asphalt Stone mastic asphalt Thin open graded asphalt surfacing High modulus asphalt (EME2)	Binder	Not specified	
Qld	TMR	In situ stabilisation	Binder (stabilising agent)	Not specified	MRTS07B
		Plant-mixed heavily bound (cemented) pavements			MRTS08
		Plant-mixed lightly bound pavements			MRTS10

State	Road agency	Application	Material/Product	Max limit (% by mass)	Reference
		Lean mix concrete subbase for pavements	SCM in blended cement	Not specified	MRTS39
		Concrete pavement base		65	MRTS40
		Concrete road and bridge structures	SCM in binary blended cement	40	MRTS70
			SCM in ternary blended cement	25	
Vic	DoT	Cementitious treated pavement subbase	SCM in blended cement	50	Section 306, Section 815
			Cementitious binder in a slag-lime blend	90	Section 815
		In situ stabilisation of pavements	SCM in blended cement	50	Section 307
			Cementitious binder in a slag-lime blend	90	
		Dense graded asphalt	Added filler	Not specified	Section 407
		Structural concrete	SCM in blended cement	40	Section 610
		Concrete for paving (including geopolymer concrete)		Not specified	Section 703
		Geopolymer binder		100	Section 703
		Concrete for drainage pits and covers (including geopolymer concrete)		Not specified	Section 705
Tas	DSG	Aligned with DoT			
SA	DIT	Controlled low strength material	SCM	Not specified	RD-EW-C4
		Stabilisation	SCM in binder	80(3)	RD-PV-S1
		Stabilised pavement	SCM in blended cement	Not specified	RD-PV-S2
NT	DIPL	Stabilisation Miscellaneous concrete works Drainage work structures (e.g. culverts)	SCM in blended cement	Not specified	*Standard Specification for Roadworks v5.1*
ACT	TCCS	Subgrade stabilisation	Binder (stabilising agent)	Not specified	MITS 02C

1. Blended cements containing cement and one SCM.
2. Blended cements containing cement and 2 SCMs.
3. The total binder content is 5%, consisting of 4% GGBFS and 1% lime.

Appendix B Supplier Engagement Survey

Suppliers of recycled materials for road infrastructure in Western Australia

This survey applies to organisations that supply products containing recycled materials, for use in road infrastructure across Western Australia.

You will be asked to provide basic organisational information and then provided with the opportunity to detail up to 10 products that you presently have commercially available.

The data collected in this survey will be made publicly available, to provide local governments with a broader knowledge of available products, in an aim to drive uptake of recycled materials in road infrastructure.

* 1. Please provide the following details for your organisation:

Organisation name ______

ABN ______

Website ______

Organisation address ______

2. Please provide the following details for your organisation (optional):

Contact name ______

Phone number ______

Email address ______

* 3. Please provide your organisation type (select all that apply):

- ☐ Asphalt Recycling / Spray Seals
- ☐ C&D Recycling
- ☐ Concrete Recycling
- ☐ Glass Recycling / Reprocessing
- ☐ Plastics Recovery / Reprocessing
- ☐ Tyre / Rubber Recycling / Reprocessing
- ☐ Materials Recovery Facility
- ☐ Organics Recycling
- ☐ Other (please specify)

______

4. Do you wish to be contacted by ARRB directly to further discuss your involvement with recycled materials and their application to Local governments in WA? (Please ensure your contact details are entered above if answering 'Yes').

- ○ Yes
- ○ No

Next

Suppliers of recycled materials for road infrastructure in Western Australia

Product details (1)

Please provide details of your products containing recycled materials. You will have the opportunity to add up to 10 products.

* 5. What is the name of the product?

* 6. Provide a brief description of the product

* 7. Which of the following recycled materials are used in this product? Please select all that apply.

- ☐ Bottom ash
- ☐ Crumb rubber
- ☐ Crushed brick
- ☐ Crushed concrete
- ☐ Crushed glass
- ☐ Fly ash
- ☐ Ground granulated blast furnace slag (GGBFS)
- ☐ Reclaimed asphalt pavement (RAP)
- ☐ Soft plastic
- ☐ Solid organics
- ☐ Other (please specify)

* 8. Which of the following applications apply to this product? Please select all that apply.

- ☐ Aggregates
- ☐ Bollards and wheel stops
- ☐ Bridges and culverts
- ☐ Concrete
- ☐ Drainage and pipes
- ☐ Earthworks
- ☐ Geosynthetics
- ☐ Landscaping and urban design
- ☐ Noise walls
- ☐ Pavement
- ☐ Shared use paths
- ☐ Signs
- ☐ Traffic management and safety
- ☐ Other (please specify)

* 9. Does the product meet any current MRWA or WALGA Specifications? Please select all that apply.

- ☐ MRWA Specification 302 Earthworks
- ☐ MRWA Specification 501 Pavements
- ☐ MRWA Specification 504 Asphalt Wearing Course
- ☐ MRWA Specification 510 Asphalt Intermediate Course
- ☐ MRWA Specification 511 Materials for Bituminous Treatments
- ☐ MRWA Specification 515 Insitu Stabilisation of Pavement Materials
- ☐ MRWA Specification 516 Crumb Rubber Open Graded Asphalt
- ☐ MRWA Specification 820 Concrete for Structures
- ☐ IPWEA/WALGA Specification for the Supply of Recycled Road Base
- ☐ WALGA Earthworks and Pavement Construction Road Building Model Specification
- ☐ WALGA/GHD Sprayed Bituminous Surfacing: Road Building Model Specification
- ☐ IPWEA/AfPA Technical Specification, Tender Form and Schedule for Supply and Laying of Asphalt Surfacing
- ☐ Not applicable
- ☐ Other (please specify)

* 10. What percentage (by weight) of the product is comprised of recycled material? (Input answer with numbers only, e.g "20" or "100")

* 11. Which standard product or material is this recycled product intended to replace?

* 12. How far can this product be distributed in Western Australia? Please provide your response in km from supply, or by LGA/Region; for example, "within 50km of Perth" or "in the Pilbara region".

* 13. Please provide details of the capacity to supply this product; for example, stockpile tonnage or volumes of material available.

* 14. Do you have any additional products to add?

- ◯ Yes
- ◯ No

Prev Next

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Appendix C Recycled Product and Services Database

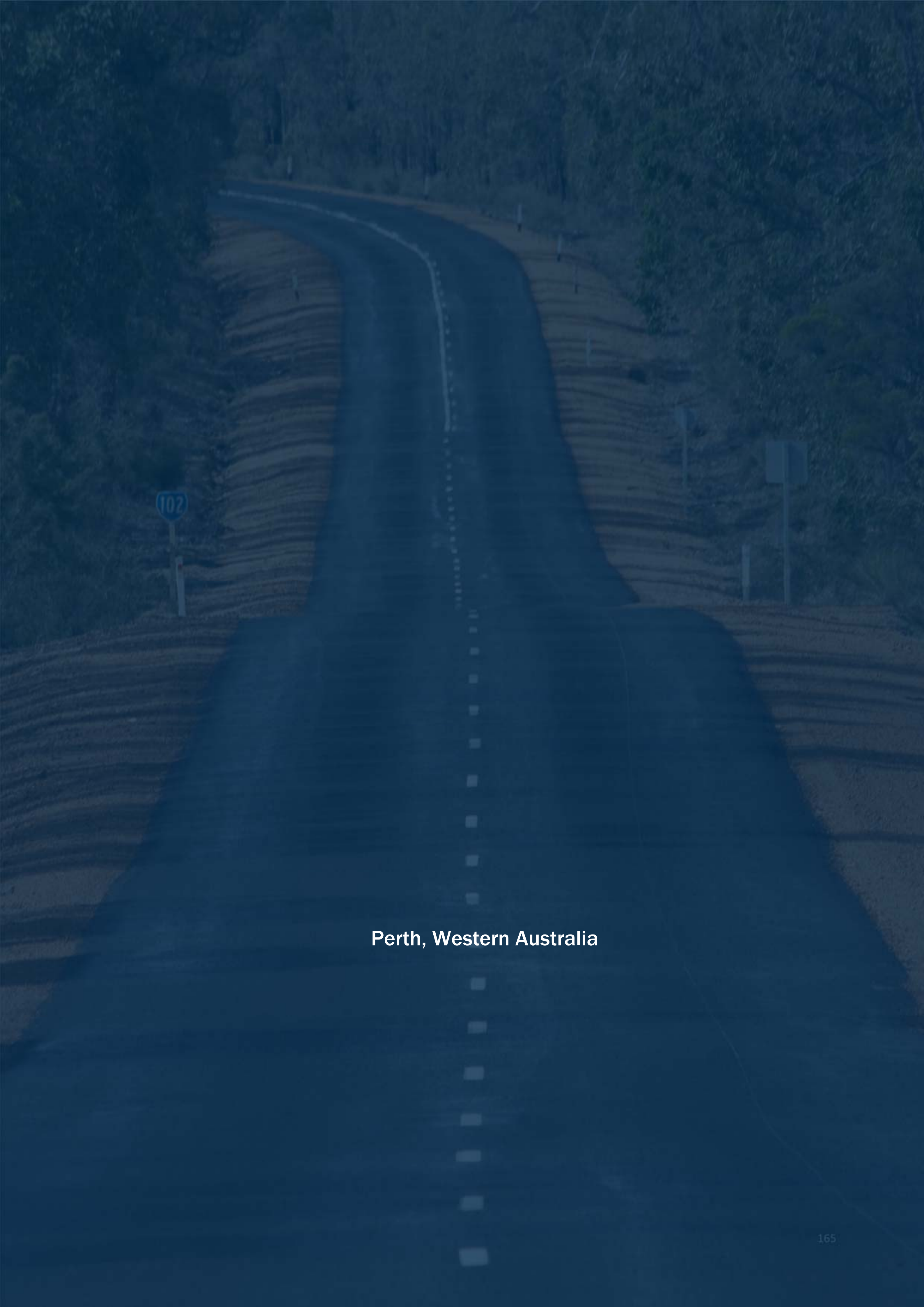
From the supplier consultation, a list of recycled products and services was put together to begin a recycled product and services database (refer Table C.1). The database lists products and includes the recycled materials involved, the distribution range and the capacity. It contains only the suppliers who responded through either the survey or the direct contact.

Table C.1: List of recycled products and services (as at August 2023)

Supplier name	Product or services	Recycled material(s)	Distribution range	Product/service capacity
Abbotts Liquid Salvage	Organic recycling – compost/soil conditioner	Organics	Great southern WA	7,500 tonnes/annum
Asphalt Recyclers Australia	Asphalt recycling, takes clean waste asphalt.	RAP (10%-60% into hot mix asphalt or 100% as cold placement)		
Aussie Organics Garden Supplies	Organic recycling – Premium fine black mulch	Organics	WA	5,000m^3/annum
	Organic recycling – landscape mulch	Organics	WA	10,000m^3/annum
Boral Asphalt	INNOVO asphalt	Glass, crumb rubber, RAP & plastics		
Broome Waste Management Facility	C&D waste recycling	Crushed concrete	Broome area	
Capital Recycling – Postans	C&D waste recycling	Crushed recycled glass, concrete and brick		
Cleanaway	Glass recycling	Glass		23,000 tonnes/annum
	Organic recycling – FOGO	Organics		35,000 tonnes/annum
Corps Environmental Pty Ltd	Asphalt recycling	RAP	Pilbara, Kimberley and Gascoyne	2,000 tonnes
CTS Tyre Recycling	Rubber recycling – crumb rubber 30 mesh suitable for bitumen (facility under construction, with production due late 2023)	Crumb rubber	WA	11,000 tonnes/annum
Downer Group	Asphalt recycling – 'Reconophalt™'	RAP	WA	
	C&D waste recycling	Glass, crumb rubber, RAP & plastics		
Eclipse Soils	Organic recycling – structural soil	Bottom ash, recycled rail ballast, organics and soils	Perth Metro	20,000 m^3/annum
	Organic recycling – 'Aquamor' mulch	Organics	Esperance to Pilbara	50,000 m^3/annum
	Organic recycling – blended topsoil	Bottom ash	Perth Metro	100,000 m^3 per annum
Encore Recycling & Resource Recovery	19 mm roadbase	Crushed concrete and brick	Within 50 km Perth GPO	100 tonnes per day
Everything Earth	Crushed concrete	Crushed concrete and brick	Port Hedland area	
Hastie Waste Pty Ltd	Organic recycling – mulch and compost supplies	Organics	WA	
Holcim Australia Pty Ltd	Concrete Products and Pavement Products	Recycled and crushed concrete waste from own supply 20% recycled concrete in low grade cement products Up to 50% recycled concrete in aggregates	WA	
Kimberley Contracting	Asphalt and Geolink masonry	Crumb rubber options under development	Not yet available	
Malatesta Group	Asphalt services – PMB asphalt	Crumb rubber	South West region	

Supplier name	Product or services	Recycled material(s)	Distribution range	Product/service capacity
	Granite/glass AC mixes	Crushed glass	South West region	
	Glass recycling	Crushed glass	Pilbara, Kimberley and Gascoyne	1,000 tonnes
	C&D waste recycling – Concrete Crushing	Crushed concrete	Pilbara, Kimberley and Gascoyne	10,000 tonnes
Peel Resource Recovery	C&D waste recycling – 0-20 mm road base	Crushed concrete and brick	Pinjarra, Bunbury & Vasse	100,000 tonnes/annum
	C&D waste recycling – 20–40 mm aggregate	Crushed concrete and brick	Pinjarra, Bunbury & Vasse	15,000 tonnes/annum
	Organic recycling – 0–100 mm mulch	Organics and timber	Pinjarra, Bunbury & Vasse	10,000 tonnes/annum
	C&D waste recycling – crushed asphalt	RAP	Pinjarra, Bunbury & Vasse	5,000 tonnes/annum
Poly Pipe Recycling	Plastics recycling	Plastic	WA	
Product Recovery Industries	Materials recovery facility – waste drop-off /recycling	Concrete, brick, glass & green waste	Postans, Bayswater & Neerabup	
	C&D waste recycling – recycled road base	Crushed concrete and brick	Postans, Bayswater & Neerabup	
	C&D waste recycling – recycled aggregate	Crushed concrete and brick	Postans, Bayswater & Neerabup	
Red Sand Supplies	Asphalt recycling	RAP	100 km of Perth	15,000 tonnes/annum
	C&D waste recycling – concrete road base	Crushed concrete	100 km of Perth	15,000–20,000 tonnes/annum
	C&D waste recycling – track material	Limestone, RAP & crushed concrete and brick	100 km of Perth	15,000–20,000 tonnes/annum
	C&D waste recycling – crushed brick 0–10 mm	Crushed brick	100 km of Perth	5,000 tonnes/annum
	C&D waste recycling – crushed brick 10–20 mm	Crushed brick	100 km of Perth	5,000 tonnes/annum
	C&D waste recycling – crushed brick 20–35 mm	Crushed brick	100 km of Perth	5,000 tonnes/annum
Richgro Composting Facility	Organic recycling – 'Rich Organic'	Organics	70 km of Perth	
Stabilised Pavements Australia	Pavement products	Foamed bitumen, fly ash, slag, CRC, RAP, brick	WA	1,500,000 m^2/annum
Stoneridge Quarries WA	C&D waste recycling – 'ECO Grey', 'ECO Cream', 'ECO Red' reconstituted construction block	Crushed concrete and brick	WA	
South32 (Worsley Alumina Power Station)	Coal power station ash	Fly ash		100,000 tonnes/annum
	Coal power station ash	Bottom ash		10,000 tonnes/annum
WA Limestone	C&D waste recycling – 'E-Blok' 19 mm	C&D waste, limestone		500,000 blocks/annum
WA Recycled Asphalt	Asphalt recycling	RAP		
WA Recycling	C&D waste recycling – recycled aggregates	Crushed concrete and brick	300 km of Hazelmere	

Supplier name	Product or services	Recycled material(s)	Distribution range	Product/service capacity
Wylie Bay MRF	C&D waste recycling	Brick, concrete, organics, metals, tyres, glass & plastic	Esperance	



Perth, Western Australia