Interim Guidelines for the Use of Recycled Waste Plastic in Local Government Road Surfacing Applications

Austroads

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Interim Guidelines for the Use of Recycled Waste Plastic in Local Government Road Surfacing Applications

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Abstract

As a result of the ban on the export of recycled waste plastic, there is increasing interest in repurposing recycled waste plastic for use in road surfacing applications. There is no guide for this purpose and until such time as a guide is available there is a need for interim guidance about how recycled waste plastic could be used in road surfacing applications.

This document provides interim guidance on the types of recycled waste plastic in Australia, what it has been used for in recent times, how it could be incorporated into asphalt or sealing work and flowcharts to assist in procuring products that use recycled waste plastic for road surfacing applications. The interim guidelines are intended for use by local governments for the surfacing of local roads that primarily provide access to abutting land (Austroads 2020). The interim guidelines are applicable to roads that are not used by a heavy volume of traffic or a high proportion of heavy vehicles and where applicable have a design traffic loading of no more than 1 x 10^6 equivalent standard axles (ESAs) for a 20 year design period. The interim guidelines offer no or limited guidance or technical information on health, safety or environmental matters, relative costs of products, procurement of proprietary products or performance of products being placed across Australia.

Consequently, asset owners considering the use of recycled waste plastic in road surfacing applications will need to make their own assessment of the impacts of doing so, particularly for health, safety and environmental aspects including compliance with relevant state or federal legislation and how any adverse impacts can be mitigated or managed.

Keywords

Recycled plastic, recycling, plastic modified bitumen, waste plastic, recycled waste plastic, sustainability, plastomers, polymer modified bitumen, PMB, plastic asphalt, pavements, road surfacings

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About Austroads

Austroads is the peak organisation of Australasian road transport and traffic agencies.

Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:

- Transport for NSW
- Department of Transport Victoria
- Queensland Department of Transport and Main Roads
- Main Roads Western Australia
- Department for Infrastructure and Transport South Australia
- Department of State Growth Tasmania
- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Department of Infrastructure, Transport, Regional Development and Communications
- Australian Local Government Association
- New Zealand Transport Agency.

This report has been prepared for Austroads as part of its work to promote improved Australian and New Zealand transport outcomes by providing expert technical input on road and road transport issues.

Individual road agencies will determine their response to this report following consideration of their legislative or administrative arrangements, available funding, as well as local circumstances and priorities.

Summary

Since Australian governments agreed to ban the export of specific recycled waste plastics in the near future, there has been an increased interest in repurposing recycled waste plastic in Australia. One potential avenue for this is to use recycled waste plastic in road surfacing applications. This is relatively a novel concept however the use of polymers is not new to road surfacing application and plastics are a type of polymer.

The interim guidelines assist users of recycled waste plastic in road surfacing applications through the current technologies and products and the likely applications. The interim guidelines are intended for use by local governments for the surfacing of local roads that primarily provide access to abutting land (Austroads 2020). The interim guidelines are applicable to roads that are not used by a heavy volume of traffic or a high proportion of heavy vehicles and where applicable have a design traffic loading of no more than 1 x 10^6 equivalent standard axles (ESAs) for a 20 year design period. The interim guidelines offer no or limited guidance on health, safety and environmental (HSE) matters, relative costs of products, procurement of proprietary products and performance of products currently being placed across Australia.

Further, no independent or comprehensive research has been undertaken into the effect of incorporating recycled waste plastic in asphalt and bitumen including HSE impacts, potential microplastic generation, leaching, fuming, reuse of asphalt incorporating recycled waste plastic and whole of life sustainability. Research to assess such factors is currently under way through Austroads, National Asset Centre of Excellence (NACOE) and Western Australian Road Research and Innovation Program (WARRIP) projects. Asset owners considering the use of recycled waste plastic in road surfacing applications will receive information from an asphalt supplier proposing the use of a product incorporating recycled waste plastic but will still need to review the information and make their own assessment of all the impacts of doing so, particularly for HSE aspects including compliance with relevant state or federal legislation or regulations and how any adverse impacts can be mitigated or managed. There are broadly two types of polymeric materials used in road surfacing, polymers that are elastomeric providing flexibility and resilience, and plastomeric providing stiffness and strength. Without the addition of other polymers to produce a binder with significant elastomeric performance most of the recycled waste plastics fall under the plastomeric category. The interim guidelines recommend that a supplier of recycled waste plastic should have a documented management system to control receipt and processing of recycled waste plastic. This includes testing of the processed recycled waste plastic to ensure consistency of its properties and hence its impact on the asphalt or sprayed seal.

The approach taken in the preparation of the interim guidelines has been to summarise the types of recycled waste plastic that is currently used in road surfacing applications, what type of product or technology was used and where it was placed.

There are some HSE concerns (NAPA 2020) regarding the use of recycled waste plastic in road surfacing and more research in this space is warranted. Currently, there is no universal or widely accepted method of determining the HSE impacts for the use of recycled waste plastic in road surfacing applications. The interim guidelines include an assessment form including HSE matters, to be completed by an asphalt supplier and provided to a customer. This includes an asphalt supplier assessing the level of fuming in an asphalt incorporating a recycled waste plastic and undertaking independent assessments of aspects of its use including leaching, loss of microplastics and its future use as Reclaimed Asphalt Pavement (RAP). The information will assist an asset owner in the assessment of the HSE impacts of the product being proposed by an asphalt supplier.

A framework has been developed for comparing the properties of recycled waste plastic binders against the same properties of binders currently specified in Austroads specification ATS 3110 and AS 2008. Until such time as a specification for recycled waste plastic modified binders is in place suppliers are encouraged to use the current Austroads specification framework to assess and monitor/specify the properties of a specific recycled waste plastic binder that has been accepted by a customer for use on a project.

In addition, the interim guidelines include a framework for comparing the properties of Conventional Asphalt to Alternative Asphalt mixes containing recycled waste plastic. The framework is based on current state road authority (SRA) and local government asphalt specifications and include proposed tests to compare the performance properties of Conventional Asphalt against Alternative Asphalt mixes. The framework includes a recommendation to have an independent assessment of Alternative Asphalt mixes as a means of obtaining approval to use an Alternative Asphalt mix design, such as through the TIPES process.

It is advised that asset owners record the location and depth where asphalt and seal incorporating recycled waste plastic have been placed along with their details for future knowledge as many of these products have not yet been assessed as to whether asphalt with recycled waste plastic can be safely used as RAP in the future.

The interim guidelines include flow charts, forms for assessment criteria and some examples that will provide support in assessing the type of product and technology, additional information that should be provided from a binder, asphalt or sealing supplier before choosing to use a product or technology incorporating recycled waste plastic. The interim guidelines also include charts to assist in the procurement of binder or asphalt incorporating recycled waste plastic.

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1. Introduction

There is significant interest in the use of recycled waste plastic in road surfacing applications from a sustainability perspective. Several technologies are currently being utilised ranging from the addition of recycled waste plastic as pelletised/shredded material into asphalt to the addition of recycled waste plastic in the modification of bituminous binders.

Currently there is no guide or specification for the use of recycled waste plastic in road surfacing applications and in general these materials are currently promoted under a sustainability banner on specific projects undertaken mainly by local government on low traffic volume roads. The National Asphalt Paving Association (NAPA) of the USA produced a report (NAPA 2020) on the state of knowledge on the use of recycled waste plastic in asphalt. It identified many issues that require research, investigation and trialling. In its concluding thoughts, the NAPA report states:

> *While significant effort has gone into understanding the impacts of recycling plastics in asphalt, more research is required by the asphalt, plastics, and petrochemical industries in order to advance the infrastructure of low cost recycling of plastics. There is no silver bullet, but patience, partnership, and open communication are essential to determine if plastic in asphalt can be the next great recycling story.*

Research on the use of recycled waste plastics for road applications in Australia is in progress (refer Section 2.2) and it is likely that outcomes from this research will result in a better understanding of the collection, preparation and use of recycled waste plastic in asphalt and sprayed sealing applications.

1.1 Purpose

In August 2019, the Council of Australian Governments (COAG) agreed that Australia should establish a timetable to ban the export of specific recycled waste plastic amongst other waste products. At a later date a timeframe was set with the ban on the export of mixed recycled waste plastics effective 1st July 2021 and then the ban on export of single polymer recycled waste plastics from 1st July 2022.

As a result of the ban on the export of recycled waste plastic, there is increasing interest in the utilisation of recycled waste plastics and road surfacing applications have been identified as a potential use. This is a novel application and there is limited guidance on the use of recycled waste plastic in road surfacing applications. Austroads and some SRAs have various initiatives in place towards understanding the use of recycled waste plastic in road surfacing applications. These initiatives encompass activities ranging from the assessment of the types of recycled waste plastic used, HSE considerations, performance of various materials, asphalt mix designs and relevant technical specifications. These initiatives are likely to take up to 24 months to complete and the output is expected to provide information for updated guidelines on the use of recycled waste plastic in road surfacing applications. Until this is achieved, the purpose of this publication is to provide practitioners interim guidelines for the use of recycled waste plastic in road surfacing applications.

1.2 Scope

The interim guidelines generally cover the current understanding of the use of recycled waste plastic in dense graded asphalt (DGA) as a wearing course and sprayed sealing. The interim guidelines are intended for use by local governments for the surfacing of local roads that primarily provide access to abutting land (Austroads 2020). The interim guidelines are applicable to roads that are not used by a heavy volume of traffic or a high proportion of heavy vehicles and where applicable have a design traffic loading of no more than 1 x 10^6 equivalent standard axles (ESAs) for a 20 year design period.

The use of recycled waste plastic in asphalt and sprayed sealing applications for heavily trafficked/loaded roads needs further research and evaluation and is not addressed in the interim guidelines. The interim guidelines focus mainly on asphalt applications with less information on the use of recycled waste plastics for sprayed sealing and pavement preservation applications. As there is no guide or specification for the use of recycled waste plastic, this publication provides a methodical approach to consider in the selection of a recycled waste plastic technology or a product based on existing technologies, learnings from product application trials, findings from research work and laboratory testing along with feedback from stakeholders.

The interim guidelines are focused on engineering aspects and offer no or limited guidance or technical information on the following aspects of the use of recycled waste plastic:

- health and safety or environmental aspects of using recycled waste plastic
- the ability to reuse asphalt with recycled waste plastic in the future or the long-term performance of the product
- costs, including costs relative to conventional bitumen and polymer modified binder products and
- procurement of proprietary products.

Consequently, it is recommended that users of the interim guidelines assess the risks and impacts of using recycled waste plastic in asphalt and sprayed sealing applications including compliance with relevant legislation.

1.3 Health Safety and Environment

Suppliers undertaking the following operations need to be fully aware of the impact such operations may have on workers, the community and the environment for the present and the future:

- preparing recycled waste plastic
- blending recycled waste plastic with bitumen as required
- mixing recycled waste plastic with other materials in an asphalt manufacturing plant
- testing the recycled waste plastic modified binder and asphalt
- placing and compacting the modified asphalt and ultimately recovering the same asphalt for potential reuse.

The European Asphalt Pavement Association (EAPA) made the same points in its position statement (EAPA 2017) issued in 2017.

NAPA in its report (NAPA 2020) states there are significant HSE concerns regarding the heating of recycled waste plastic during the manufacture and placement of asphalt. Post-consumer recycled waste plastics typically contain chemical additives that were added in the manufacturing process and some of these recycled waste plastics can release hazardous air particles including polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) when subjected to elevated temperatures (Austroads 2019). In addition, NAPA raised specific points including the following:

- Recommending that for the dry mixing process that recycled waste plastic should be introduced through a RAP collar when used in a drum mixer or drum dryer to reduce risk of overheating if added elsewhere.
- Concern about the release of micro (<5mm) or nano plastics (<1000nm) from weathering and trafficking of the surface of asphalt in service and cold planing at the end of life of the asphalt. The plastic would be washed off the road in rainfall with the risk of it entering water systems.
- Concerns relating to the leaching of materials from the recycled waste plastic especially with the use of PET and that suppliers should be looking at means of how this can be assessed.

- There could be a move to higher asphalt manufacturing temperatures to manage the higher viscosity of recycled waste plastic binder used in the wet process which would lead to higher emissions of PAHs, VOCs and total organic compounds (NAPA 2020). In addition, this may lead to increased odours and suppliers should therefore undertake monitoring at the production and paving sites and consider how manufacturing temperatures can be reduced.

Further work is needed to evaluate the health and safety effects of worker exposure to chemical components in recycled waste plastic, any impacts of those components on the operation of asphalt mixing plants, placement of the asphalt and its impact on the environment during its life cycle and its reuse. Initial investigations have commenced and is further reported in Section 2.2.

As there is no other guidance on how to manage HSE impacts on the use of recycled waste plastic in road surfacing applications the interim guidelines include an assessment form referenced in Section 6 for suppliers to respond to questions on HSE matters on the use of an asphalt or seal binder incorporating recycled waste plastic. The supplier should be thorough in responding, providing evidence-based responses and be cognisant of any statutory requirements in Australia with regard to issues associated with health, safety and environment when using recycled waste plastic, and possibly any other added materials in asphalt, or when used in sprayed sealing operations.

RAP is one of the most recycled materials in Australia and its use is increasing. Whether asphalt modified with recycled waste plastic can be used as RAP at the end of its life is unknown so it is very important that the location and thickness of this modified asphalt be logged in an asset management/maintenance system that it can be readily identified in the future.

1.4 Methodology

The preparation of the interim guidelines for the use of recycled waste plastic in road surfacing applications is based on collation of information from a wide range of sources currently engaged in the research, development, promotion, specification and use of recycled waste plastic for road surfacing applications.

The following approach was taken to collate the information presented in this publication:

- investigate the status of the use of recycled waste plastic in road surfacing applications.
- collection of information and learnings from:
  - road trials with the use of recycled waste plastic
  - experiences with the use of recycled waste plastic internationally
- review of literature, reports, committee work and recommendations
- consultations with academia and research institutions on key early findings
- consultations with stakeholders on any input that will assist in the preparation of the interim guidelines
- noting the links or source information in relation to the above tasks and highlight an extended list of relevant papers of interest.

1.5 Deliverables

The scope of the project was to produce a document titled “Interim guidelines to the use of recycled waste plastic in road surfacing application”, broadly covering the following areas:

- types of recycled waste plastic used in road surfacing applications
- recommended levels of modifications
- use of recycled waste plastic in pelletised form in asphalt applications

- use of bituminous binders manufactured using recycled waste plastic for asphalt and sprayed sealing applications
- use of bituminous binders manufactured as composite binders using recycled waste plastic and other polymers such as elastomers or crumb rubber in asphalt and sprayed sealing applications
- use of recycled waste plastic in pavement preservation applications such as joint sealants and emulsified mastics
- storage and handling guidelines of the various products incorporating recycled waste plastic used in road surfacing applications.

2. Literature Review and Findings

Where information has been provided by product suppliers and from liaison with industry representatives it is important to note that there has been no independent testing or assessment to verify the information or to assess the effects on the performance of a product or technology.

2.1 Literature and Reports Survey

There is an abundance of research work being conducted worldwide about the use of recycled waste plastic for road construction applications. Overall, the salient points from the literature and report survey are:

- Dalhat and Wahhab (2015) claim that soft recycled waste plastics are preferable for use in bitumen and asphalt modification and that the melting point of the recycled waste plastic plays an important part in blending. They state that typically, recycled waste plastics with melting points >110 °C and <160 °C are used.
- A number of publications claimed that selection of the type of recycled polymer component and controlled metering of the pellets is critical to ensure a consistent distribution of recycled waste plastic in the asphalt matrix, particularly if used in a dry process (White and Reid 2018, and MacRebur n.d.(a)).
- White and Hall (2020 and 2021), and Mishra and Gupta (2020) advised that there are two processes for the introduction of the recycled waste plastic into asphalt. The Wet Process is where the recycled waste plastic is blended in bitumen and the Dry Process is where the recycled waste plastic in a pellet/shredded form is directly introduced into the asphalt mixing chamber. The Wet Process requires specialized mixing and storage facilities but is generally recognised as providing more complete and reliable mixing than the Dry Process. In contrast, the Dry Process is economical and logistically simpler for asphalt production in small quantities and in remote locations, where bitumen blending facilities are not generally available. The extracted binder and the performance of the asphalt statistically indicated little difference between the two processes.
- Generally, the existing products and technologies using recycled waste plastic in asphalt in Australia and New Zealand are used in combination with one or more of another recycled material such as glass, toner, RAP, slag, or crumb rubber in asphalt mixes. In the case of binders, the recycled waste plastic is either used singularly or as a composite with crumb rubber (see Table 3.1).
- Some literature states that soft plastics melt and blend with bitumen and therefore all of the plastic will completely melt into the bitumen thus reducing the likelihood that there would be free plastic in the asphalt that could leach chemicals or have microplastics issues. Papers suggest that suppliers of recycled waste plastic have management systems to control the processing of the recycled waste plastic to achieve consistent product. With these controls in place, it is argued that the environmental concerns are no different than for other PMBs made from virgin elastomers and plastomer (Lim et al 2020, Hunsuckar et al 1994, White 2019, Sustainability Victoria 2018, MacRebur n.d.(b) and MacRebur n.d.(c)). It is acknowledged that there is limited information around the effects of recycled waste plastic in road surfacing applications on HSE. Considerable research effort is being targeted in this important area and several studies are already underway (refer Section 2.2).
- NAPA (NAPA 2020) produced a report on the state of knowledge on the use of recycled waste plastic in asphalt and it includes gaps in knowledge and where research is required. Highlighted comments in the report include:
  - There is a lack of studies conducted in the HSE area and opinions may vary around the content of the limited studies, particularly the potential of leaching chemicals and microplastics, and worker exposure risks.

– Research is needed to specify the source and recycling process of recycled waste plastic for use in asphalt. Specific gravity, melting temperature, particle size, melt flow index, degree of crystallinity, and ash content are properties of recycled waste plastic that are considered important and thus, should be specified for asphalt applications.

– Standardisation guidelines are needed to define the scope and details of the different methods of incorporating recycled waste plastic in asphalt.

– Research is needed to:

  - mitigate the phase separation of recycled waste plastic modified binder (RPMB)
  - evaluate the impact of recycled waste plastic on the fatigue and cracking resistance of asphalt binders
  - verify the applicability of laboratory asphalt binder tests to RPMB
  - assess the compatibility between recycled waste plastic and other additives used in asphalt binders
  - develop new solvent and testing technologies for RPMB
  - identify the impact of the dry process of adding recycled waste plastic on the volumetric mix design and texture characteristics of asphalt mixtures.

– Plant operations - Agitated storage tanks are needed to prevent the phase separation of terminal blended RPMB. There are major barriers to the large-scale implementation of the plant blending approach of preparing RPMB during mixture production. Production trials are needed to determine safe and effective methods of introducing recycled waste plastic into the asphalt plant using the dry process. There is a plant operation safety concern that certain recycled waste plastic could jeopardize the operation efficiency of the baghouse and possibly cause a baghouse fire. It remains unknown how quality assurance testing could be conducted for the dry process of adding recycled waste plastic during plant production. This would mean agitation is required in road tankers associated with haulage and storage of RMPBs in Australia as well as fixed tanks.

– Field demonstration projects are needed to identify the potential changes in the construction practice of asphalt containing recycled waste plastic.

– There are significant health and safety concerns about the occupational exposure of asphalt workers to hazardous air pollutants (HAPs) from the heating of recycled waste plastic during plant production and construction. NAPA states that post-consumer recycled plastics typically contain chemical additives that were added in the manufacture of the plastic and these could release HAPs when heated to higher temperatures.

  Note: There is a process further into the interim guidelines where an asphalt supplier must measure and assess emissions during the manufacture and placement of asphalt containing recycled waste plastics.

– Research is needed to evaluate and verify the recyclability of recycled waste plastic modified asphalt (RPMA).

– There are major environmental concerns about the potential release of microplastics and nanoplastics as well as the leaching of harmful materials and pollutants from asphalt pavements containing recycled waste plastic. Research is needed to establish upstream life cycle assessment (LCA) data for asphalt pavements containing recycled waste plastic.

  Note: There is a process further into the interim guidelines where an asphalt supplier must measure and assess, using an independent professional, the issue of leaching of chemicals and microplastics into the environment.

– Long-term pavement performance data is needed for field projects constructed using RPMA.

- The European Asphalt Pavement Association (EAPA) issued a position statement (EAPA 2017) on the use of secondary materials, by-products and waste in asphalt mixtures. In its conclusion EAPA recommends that as a first, priority be given to the use of RAP in hot and warm mixed asphalt as this represents a very significant potential to save on the overall consumption of bitumen in Europe. Secondly, EAPA recommends that waste, or waste derived materials offered to the asphalt industry can only be incorporated into asphalt if it can be shown through a risk assessment process that:
  – there are no disadvantages with respect to health and safety of workers and the general public, during processing, use and application, now or in the future
  – there are no environmental impacts and/or liability problems during processing, use and application, now or in the future
  – the future reuse and recyclability of asphalt is not endangered
  – the value for money analysis remains positive for our clients
  – there is no negative impact on the technical product performance of asphalt now or in the future
  – the introduction of waste should not affect the competitiveness of asphalt solutions versus alternative pavements
  – that the health and environment classification of bitumen or asphalt is not affected by the addition of the waste.

2.2 Australian Research Work and Early Findings

There are two research projects funded by Austroads and NACoE / WARRIP in progress described in Sections 2.2.1 and 2.2.2. It is anticipated that at the conclusion of the research work, there will be an increase in understanding of the use of recycled waste plastic in road surfacing applications that will contribute to an update of the interim guidelines to the use of recycled waste plastic in road applications.

Austroads has published the following reports that can provide further information on the use of recycled materials:

- AP-T351-19 – *Viability of Using Recycled Plastics in Asphalt and Sprayed Seals*. This report examines the viability of using recycled waste plastics in asphalt and sprayed seals by Australian and New Zealand road authorities.
- AP-T353-20 – *Sustainable Roads Through Fit-for-purpose Use of Available Materials: Evaluation Tool and User Guide*.

2.2.1 Austroads

Austroads has commissioned RMIT University to deliver project APT6305 titled *Use of road-grade recycled plastics for sustainable asphalt pavements*, to provide guidance to government and industry in Australia and New Zealand on the types of recycled waste plastic that are most suitable for use in roads.

This project will provide evidence-based research that will allow the road industry to respond to an increasing push to reduce waste to landfill and better harness the use of recycled materials and return them to productive use, supporting the economy and achieving sustainable outcomes for communities. In particular, the project outcomes will provide guidance and clear information to the road industry regarding best practices for identifying, handling and using ‘road-grade’ recycled waste plastics in asphalt. One deliverable is to develop evidence-based and performance-based specifications around the road-grade recycled waste plastic polymer/s identified through the research undertaken.

The project commenced in September 2020 and will provide four reports as follows:

- *Use of Road-grade Recycled Plastics for Sustainable Asphalt Pavements: Overview of the Recycled Plastic Industry and Recycled Plastic Types* (Austroads 2021) which covers the type, volume and price of recycled waste plastic and its possible use as road-grade recycled waste

- an initial performance and environmental assessment on blending recycled waste plastics with bitumen and aggregates
- a final performance assessment based on experimental activities relating to the blending of recycled waste plastics with bitumen and aggregates
- a final environmental assessment based on experimental activities relating to blending recycled waste plastics with bitumen and aggregates.

2.2.2 NACoE / WARRIP

The National Asset Centre of Excellence (NACoE) was established by the Queensland Department of Transport and Main Roads (DTMR) and the Australian Road Research Board (ARRB) to strengthen specialist technical capability and capacity and achieve cost savings in road infrastructure expenditure through targeted research.

The Western Australian Road Research and Innovation Program (WARRIP) is a co-operative research initiative between Main Roads Western Australia (MRWA) and ARRB that reflects a strategic commitment to research and development, technology transfer and capability development.

WARRIP in collaboration with NACoE has a project titled, *Investigating the use of recycled plastic in future sustainable road infrastructure,* with an aim to gain a full understanding of how best to use recycled and reclaimed materials in road infrastructure without adversely affecting service life, connectivity-enabling ability, workplace health and safety, user safety and environmental impact. The project is not necessarily limited to exploring the use of recycled waste plastic in asphalt and bitumen, other potential beneficial uses may be identified and explored.

The project will be conducted in stages with the project being flexible with the scope of Stage 2 and beyond being developed based on the findings from the previous stage.

2.3 Stakeholder Consultation

Consumers (SRAs and Local Government) and producers (plastic recyclers, binder producers and asphalt suppliers) were consulted in the process to establish different perspectives in the sourcing, manufacturing and application of road surfacing binders and asphalt using recycled waste plastic. A list of those stakeholders can be found at Appendix C.

Overall, there were common themes in the feedback obtained on experiences and on the concerns with the use of recycled waste plastic as follows:

- health safety and environmental effects including the presence of odour or fuming, leaching of chemicals, release of microplastics (tiny pieces of degraded plastic, synthetic fibres, and plastic beads, collectively called microplastics) into the environment
- uniform distribution of the recycled waste plastic when added as dry material to asphalt and the resultant consistency of the asphalt
- cost and performance data on comparison of road surfacing using recycled waste plastic in relation to bitumen and in some cases against other PMBs
- ability to recover and reuse asphalt incorporating recycled waste plastic as RAP
- understanding the recycled waste plastic technologies and the complexities built around the types of plastic and the delivery systems needed to incorporate recycled waste plastic into asphalt during manufacture.

3. Technologies and Products

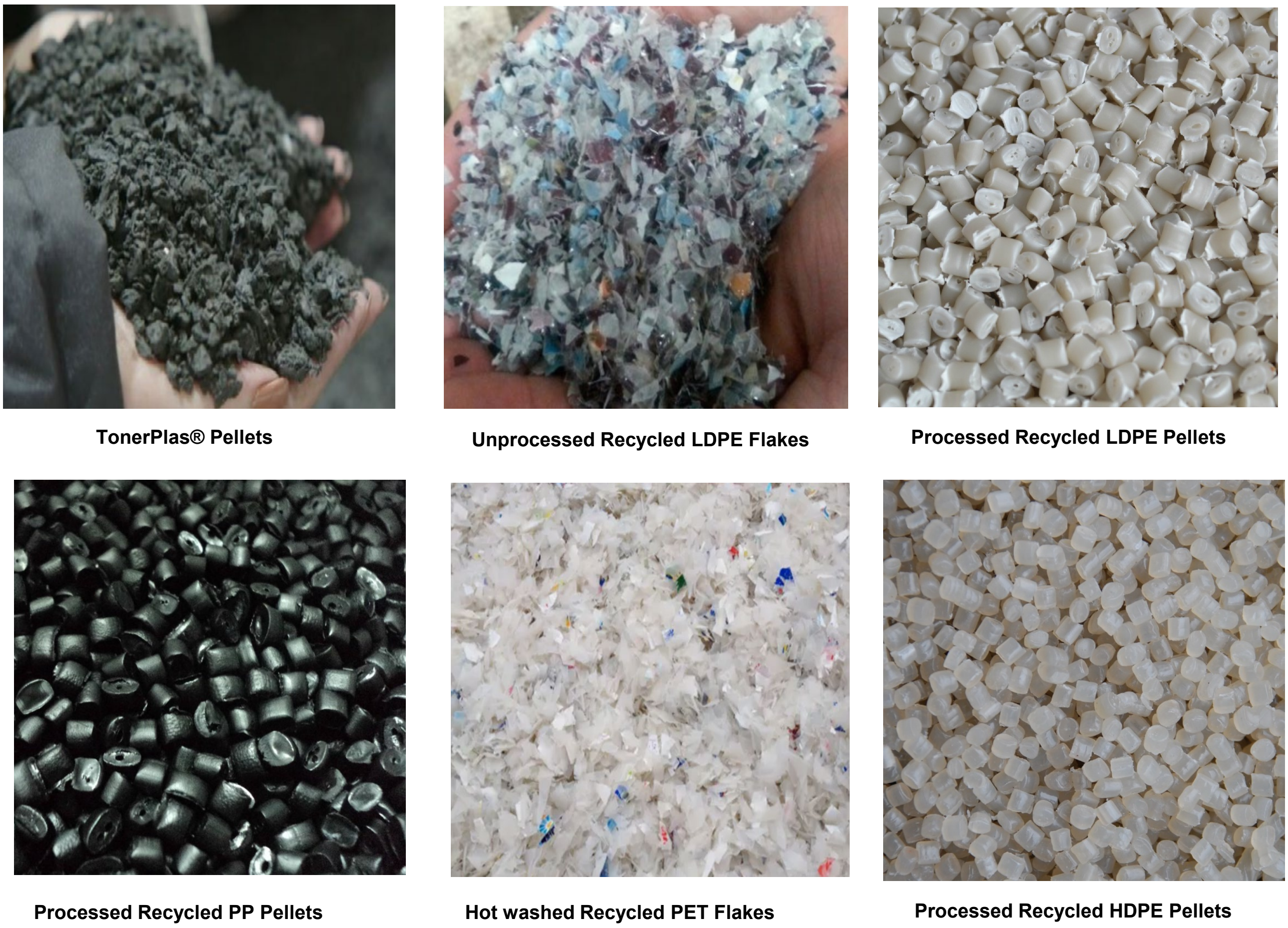
3.1 Types of Recycled Waste Plastic

Depending on the desired performance outcome of the road surfacing application, recycled waste plastic can be used in a singular form or as a composite with other recycled waste plastics, polymers or additives.

Types of recycled waste plastic used in road surfacing applications in Australia and New Zealand include the following and are shown in Figure 3.1.

- Low density polyethylene (LDPE), linear low density polyethylene (LLPDE) and high density polyethylene (HDPE). These plastics are typically used in asphalt applications as a composite with one or more recycled materials such as toner (shown in Figure 3.1 as TonerPlas® pellets), glass or RAP.
- Polyethylene terephthalate (PET) has been used as a composite with one or more recycled materials such as glass, crumb rubber, slag and RAP in an asphalt application or just as recycled waste plastic in asphalt.
- LDPE with styrene butadiene styrene (SBS) and LDPE with crumb rubber (CR). The blended binder is used as a plastomer / elastomer composite in sprayed sealing and asphalt applications.
- Polypropylene (PP) has been used as a composite with RAP in asphalt.

Figure 3.1: Various types and forms of recycled waste plastic



TonerPlas® Pellets | **Unprocessed Recycled LDPE Flakes** | **Processed Recycled LDPE Pellets**

Processed Recycled PP Pellets | **Hot washed Recycled PET Flakes** | **Processed Recycled HDPE Pellets**

Source: Downer, n.d.

3.2 Status on the Use of Recycled Waste Plastic

An overview of this subject has been addressed in the Austroads Technical Report AP-T351-19, *Viability of Using Recycled Plastics in Asphalt and Sprayed Seals*. The use of recycled waste plastic in road surfacing applications in Australia and New Zealand is an emerging technology. However, the use of plastomers such as LDPE derived as virgin or a reprocessed recycled waste plastic, in combination with other polymers have been in use in Australia for some time for both sprayed sealing and in asphalt applications.

The forthcoming ban on the export of certain types of recycled waste plastic has resulted in an interest about potential ways to repurpose the recycled waste plastic and investigate its use in road surfacing applications. These plastics derived from the waste stream can generically be termed as plastomers, examples of which are EVA, PE (of varying molecular weight), and PP amongst others. They exhibit plastic behaviour as opposed to an elastic behaviour from an elastomer such as SBS, SEBS, PBD and CR amongst others. Elastomers are the most common polymer currently used to manufacture modified binders used in Australia.

3.2.1 Placements in Australia and New Zealand

There have been several placements of recycled waste plastic modified asphalt with different approaches to the use of various types of recycled waste plastic. These are proprietary products that are being used particularly by local governments.

Below is a synopsis of the various proprietary products using recycled waste plastic that have been placed or are being used in Australia and New Zealand. These are further summarised in Table 3.1 for ease of comparing the various attributes. There may be other products available now or in the future and the listing of products in the interim guidelines is not intended to limit use or assessments to these products or imply that other products are not suitable. Other products can be assessed when they are offered for use. The inclusion of this information does not mean that the listed products have been evaluated or are endorsed for use by Austroads and users of the interim guidelines will need to assess the products before considering their use. Advice to assist in making this decision is available in further sections of the interim guidelines.

The information on the various proprietary products and technologies has come from the respective suppliers of the products, either through consultation with them or with information available in the public domain and has not been verified by an independent review. It is early days with the use of recycled waste plastic in road surfacing applications and a lot of the claimed benefits have not been rigorously tested and details or outcomes of the placed recycled waste plastic modified asphalt is not known.

Alex Fraser: PolyPave™

PolyPave™ is a proprietary asphalt including recycled waste plastic, glass and RAP. It was first used in a resurfacing project in September 2018 for the City of Yarra in Victoria. The PolyPave™ contained recycled glass, RAP, and HDPE derived from hard recycled waste plastic bottles (Alex Fraser n.d., City of Yarra).

In Queensland one kilometre of road in Princess Street, Cleveland was resurfaced with PolyPave™ for the Redlands Council. Since this placement, announced in October 2019, additional PolyPave™ proprietary asphalt has been used to resurface roads in Queensland (Alex Fraser 2019, Redlands).

Boral: Innovo™

Innovo™ is a proprietary asphalt that includes glass, recycled waste plastic, crumb rubber, RAP and slag. The recycled waste plastic is substituted for the fine aggregates (Boral 2020a).

Boral placed Innovo™ on Carlisle Road in the suburb of Westbourne Park for the City of Mitcham in Adelaide in April 2020 (Boral 2020b).

Close the Loop: TonerPlas®

TonerPlas® is an additive for asphalt and is manufactured from recovered waste printer toner and post-consumer recycled waste soft plastics dropped into the RedCycle bins in supermarkets around Australia. Their main supply has been to Downer for use in Reconophalt**™.**

Downer Australia: Reconophalt™

Reconophalt™ is a proprietary asphalt containing recycled waste plastic derived from postconsumer waste streams, such as recycled waste soft plastics and toner and includes other recycled products such as RAP, glass, toner and at times crumb rubber. The first placement was conducted in May 2018 on a local road in Craigieburn, Victoria and subsequently, Reconophalt™ has been placed in other states. The plastic component of Reconophalt™ originates from supermarkets around Australia through the RedCycle program run by the Red Group. The recycled waste soft plastics include postconsumer plastic shopping bags and food packaging. The resultant type of recycled waste plastic is predominantly LDPE with some HDPE. It is introduced during the manufacture of asphalt in a dry granulated form comprising of recycled waste soft plastics, toner obtained from used printing cartridges and a binding agent. The granulated material is an additive for asphalt marketed as TonerPlas®.

Following 18 months of testing under a program designed in conjunction with the New South Wales Environment Protection Authority (EPA), on the potential leaching of bisphenol-A (BPA) from the recycled waste plastic in the asphalt and the release of microplastics, the EPA has granted a Resource Recovery Order and Exemption for Reconophalt™, applicable in NSW, to use recycled waste plastic derived from a waste stream (Downer 2020, EPA 2020).

Reconophalt™ currently has approval for conditional use as an alternative to a dense grade wearing course asphalt containing Class 320 binder by the DoT, Victoria. This is referred to as Conventional Asphalt in Section 4.1.1 of the interim guidelines.

Downer New Zealand / Road Science: Plas Mix

Plas Mix is raw shredded recycled waste plastic added into asphalt through the dry mixing process. Downer New Zealand has developed a process for the sorting and sizing of the recycled waste plastic ready for use in Plas Mix. A trial was done using 0.5% of recycled waste plastic of the total mix in a dense graded asphalt application on 1455 m^2 of Liardet Street, a road leading to Pukekura Park in New Plymouth (Radio NZ 2019).

Fulton Hogan Australia: PlastiPhalt®

PlastiPhalt® is a proprietary asphalt produced using recycled waste plastic from specially selected single sourced polymer from automotive recycled waste plastic which is shredded and dissolved into bitumen.

Castle Road in Glanville was resurfaced for the City of Port Adelaide with PlastiPhalt® that included 20% RAP. The project was the first large-scale use of PlastiPhalt® in South Australia. PlastiPhalt® was placed in Mozart Street in St Kilda and the City of Port Phillip and Fulton Hogan will monitor the performance of the asphalt for 2 years. Frankston City Council has placed PlastiPhalt® in Seaford and the City of Greater Dandenong has resurfaced a section of road in Westall using PlastiPhalt® (Roads Online 2020). Work with PlastiPhalt® has also taken place in Queensland, South Australia and Western Australia.

Fulton Hogan New Zealand: PlastiPhalt®

PlastiPhalt® New Zealand is a proprietary asphalt made with the polymers from recycled waste plastic oil containers collected as part of a recovery of used oil each year through the R.O.S.E. (Recovering Oil Saves the Environment) scheme. The inaugural placement was on Christchurch International Airport and PlastiPhalt® was subsequently laid at Auckland Airport (Fulton Hogan NZ n.d.(a)) and (Fulton Hogan NZ n.d.(b)).

The supply of PlastiPhalt® New Zealand is currently limited to Auckland and Christchurch because of the nature of the production process, requiring proximity of the bitumen plant and the sourcing of the recycled waste plastic polymer.

MacRebur: MR6, MR8 and MR10

MacRebur products are currently manufactured in the United Kingdom and imported to Australia. There are three grades of the product available in pellet form. They are used as binder extenders to reduce the volume of bitumen required in asphalt and/or as a modifier to achieve an improvement in asphalt performance in comparison to bitumen used in asphalt. All products are made from 100% recycled waste plastic with MR6 and MR10 offering modification whilst MR8 only extends the bitumen.

Trials were conducted by the Brisbane City Council using two grades of the MacRebur product alongside asphalt manufactured with multigrade bitumen and C320 bitumen. The findings of the laboratory evaluations are reported in detail in a University of Sunshine Coast paper (White and Magee 2019).

Road Maintenance Pty Ltd: Maxi-Binder and Maxi-Seal

Road Maintenance has three binders, Maxi-Binder B06, B07 and B08. The technology is based on combination of a high dosage of crumb rubber and a low dosage of recycled waste plastic. B06 and B07 are used in a wet process for dense graded asphalt in high and low traffic asphalt applications. B08 is used in various sprayed sealing applications.

Maxi-Binder B08 was trialled as a S45R binder for a High Stress Seal (HSS) on a DoT Victoria site on the Wimmera Highway. The product was placed in April 2020 alongside an S35E binder as a performance comparison. Both seals were designed as a 14 mm HSS, with binder application rates of 2.05 L/m^2 for the running lane and 1.4 L/m^2 for the shoulders using 7 mm aggregate.

Road Maintenance has also adopted the use of recycled waste plastic in pavement preservation. In its joint and crack sealing product, Maxi-Seal Class 2, recycled waste plastic is combined with crumb rubber. It has been used mainly in Victoria with various local councils including Wyndham, Maroondah, Dandenong, Kingston and Banyule.

State Asphalt: PAKPave

PAKPave is a proprietary asphalt that has been designed to use a selected waste stream of recycled waste plastic from automotive and food packaging sources with the recycled waste plastic being primarily polypropylene (PP). It is introduced into the asphalt in a dry mixing process at a high dosage rate.

Table 3.1: Summary of proprietary recycled waste plastic products and technologies

Organisation	Product Name	Description	Primary Type of Recycled Waste	Primary Source of Recycled Waste Plastic	Form Used	Application / Usage	Launch / Field Placements
Alex Fraser	PolyPave™	PolyPave is asphalt incorporating recycled waste plastic, glass and RAP	HDPE	Recycled waste hard plastic bottles	Dry Process via addition of pellets	Current application is mostly in DGA	First use Stanley and Margaret Streets, City of Yarra and Princes St, Cleveland, Redlands Council Qld
Boral	Innovo™	Asphalt consisting of the addition of hard recycled waste plastic as a replacement of the aggregate plus glass, RAP and crumb rubber	PET	Recycled waste plastic bottles and containers	Dry Process direct into asphalt mixer	Local council residential mixes	Willetton, City of Canning, Perth WA Carlisle Rd, City of Mitcham, Adelaide SA
Close the Loop	Toner Plas®	Pellets incorporating soft recycled waste plastic and toner from printer cartridges	Mainly LDPE some HDPE Toner	Post-consumer recycled waste plastic shopping bags and food packaging	Dry Process direct into asphalt mixer	Dense graded asphalt	Raw material to Downer's Reconophalt™
Downer (AUS)	Reconophalt™	Reconophalt™ is asphalt incorporating soft recycled waste plastic, toner, glass, RAP and at times crumb rubber	Mainly LDPE some HDPE Toner	As above	Dry Process via addition of Pellets	Current application is DGA	First use in May 2018 on local road in Craigieburn, VIC
Downer / Road Science (NZ)	Plas Mix	Plas Mix is asphalt incorporating hard recycled waste plastics and glass	HPDE PET PP	Sorted hard recycled waste plastic from domestic waste	Dry Process via addition of Pellets	Dense graded asphalt on local roads	Local road leading to Pukekura Park, New Plymouth District Council
Fulton Hogan (AUS)	PlastiPhalt®	PlastiPhalt is asphalt using specially selected single sourced recycled waste plastic and RAP	PP LDPE	Recycled automotive waste plastic	Wet process by modifying bitumen	Current application is mostly in DGA	Castle Rd, Glanville, City of Port Adelaide Enfield SA Mozart St Port Phillip Council VIC
	PlastiPhalt®	Modified binder incorporating crumb rubber and recycled waste plastics	PP LDPE	Recycled automotive waste plastic	Wet process by modifying bitumen	Current application is mostly in DGA	Brendale Street, Moreton Bay Regional Council

Organisation	Product Name	Description	Primary Type of Recycled Waste	Primary Source of Recycled Waste Plastic	Form Used	Application / Usage	Launch / Field Placements
Fulton Hogan (NZ)	PlastiPhalt®	PlastiPhalt is asphalt using specifically sourced recycled waste plastic	Likely PET	Recycled waste plastic oil containers	Wet process by modifying bitumen	Current application is mostly in DGA	Auckland and Christchurch Airports NZ
MacRebur (UK)	MR6, MR8 & MR10	Recycled waste plastic pellets	Proprietary selected type	Not known	Dry Process via pellets or Wet process by modifying bitumen	As binder extender or as a modifier for DGA	Trial with Brisbane City Council, Queensland
Road Maintenance	Maxi-Binder B06 & Maxi-Binder B07	Modified binder incorporating crumb rubber and recycled waste plastic	Proprietary selected type	Selected and processed household recycled waste plastic	Wet Process	Dense graded asphalt	
	Maxi-Binder B08	Modified binder incorporating crumb rubber and recycled waste plastic	Proprietary selected type	Selected and processed household recycled waste plastic	Wet process as per normal PMBs	Sprayed Sealing in HSS, SAM, or SAMI	Trial on Wimmera Hwy 83kms before Horsham including control with S35E binder
	Maxi-Seal Class 2	Proprietary modified binder incorporating recycled waste plastic and /or elastomers & crumb rubber	Proprietary Selected type	Selected and processed household recycled waste plastic	As a packaged modified binder joint sealant	Joint and crack sealing	Various councils
State Asphalt	PAKPave	Asphalt with dosage of plastic pellets	Mainly PP	Automotive and packaging sources	Designed for dry addition direct into asphalt mixer	Dense graded asphalt	

3.2.2 International Experience

The use of recycled waste plastic in road surfacing applications is limited around the world, however current trends are not dissimilar to the ones used in Australia and New Zealand. For example, the use of MacRebur recycled waste plastic products has been trialled and commercialised in several countries including the UK, USA, Australia, Turkey, Bahrain, Slovakia, New Zealand and South Africa (MacRebur, n.d.(d)).

The use of MR6, MR8 and MR10 from MacRebur is being promoted with MR6 being used more frequently. This has followed the initial trials of the MacRebur products in Australia and work done by the University of Sunshine Coast (White and Reid 2018, White and Magee 2019).

A product from Close the Loop, TonerPlas®, used in the Downer Reconophalt™ proprietary asphalt is now in the process of being introduced in the USA and in Belgium.

As is the case in Australia, the use of soft recycled waste plastic is preferential for ease of blending in bitumen and for consistent blending in asphalt when added as a dry additive. The harder recycled waste plastics are often promoted for use as part substitution of the aggregate component.

Other key technologies include the manufacture of a polymer modified binder using the combination of soft recycled waste plastic and another reactive elastomeric polymer. Another technology is to reprocess by reverse engineering PET to a liquid polymer that becomes a binder that is subsequently used in asphalt applications. The economic costs of a reactive additive and the processing of PET would have to be considered in the overall cost performance of these technologies.

Dow Chemicals: RPMA

Recycled waste plastic modified asphalt (RPMA) is manufactured by adding post-consumer recycle content of polyethylene-rich recycled waste plastics with a reactive elastomeric polymer in bitumen. Great understanding and precise control of the materials and process are needed to help ensure high quality results.

Pilot projects in several countries around the world (see Figure 3.2) have placed more than 107 km of pavement with RPMA, diverting more than 100 metric tons of recycled waste plastic from landfill. The pilot projects were done in coordination with waste management associations, local governments, asphalt suppliers and universities (Dow Chemicals n.d.).

Figure 3.2: Recycled polymer modified asphalt trials across several countries

Source: Dow Chemicals (n.d.).

4. Recycled Waste Plastic in Asphalt

4.1 Use of Recycled Waste Plastic in Asphalt

4.1.1 Terminology Used in Interim Guidelines

The term Conventional Asphalt will be used along with the term Alternative Asphalt with each defined below for the context of the interim guidelines. Section 4.1.3 introduces two terms used for how recycled waste plastic is added to asphalt at the time of manufacture, being the “Wet Process” and “Dry Process”.

Conventional Asphalt - is the asphalt the local government asset owner would typically place on the type of road as defined in Section 1.2 of the interim guidelines. The asphalt would be a 10mm DGA or 14mm DGA with C320 bitumen designed to a Marshall 35 or 50 blow mix design or a 50 or 80 cycle Gyratory compacted mix design.

A customer may choose to nominate Conventional Asphalt with a different binder including a polymer modified binder. If so, then the asphalt supplier will need to undertake comparison testing between the two types of asphalt using the different binder in the Conventional Asphalt. The comparison process is detailed further into the interim guidelines.

Alternative Asphalt – is the mix design that an asphalt supplier has offered to a local government asset owner as an alternative to the placement of the asset owner’s Conventional Asphalt. Selection of the Conventional Asphalt for comparison against the Alternative Asphalt is to be done by the representative of the asset owner.

4.1.2 Applications

Recycled waste plastic is typically added to asphalt for the following purposes.

- Recycled waste plastic may be used as an **aggregate extender** to replace some of the virgin aggregate in the asphalt mixture using the dry process to add the recycled waste plastic. During the dry and wet mixing stages at the asphalt plant not all of the recycled waste plastic melts and some remains as a solid aggregate in the mixture. The size and form of the recycled waste plastic particles being added into the asphalt may have an impact on the behaviour of the asphalt if it is too large, reducing workability of the asphalt.
- Recycled waste plastic may be used as a **binder extender** to offset a proportion of the virgin bitumen in the asphalt mix design. The dry or wet process can be used to add the recycled waste plastic to the asphalt mixture for this purpose. The recycled waste plastic should have a melting point sufficiently low enough to be able to totally melt into the binder. The addition of the recycled waste plastic in this application is not intended to improve the performance of the binder as happens in the next point “binder modifier”. This is regardless of the addition of other materials that may improve the performance of the bitumen such as crumb rubber.
- Recycled waste plastic may be used as a **binder modifier** to enhance the properties of the binder. In this application the recycled waste plastic completely melts in the bitumen and creates linkage with the bitumen. Typically, the means of achieving this outcome is to add the recycled waste plastic into the binder such that the recycled waste plastic modified binder is added to the asphalt by the wet process with the aim being to achieve improved performance of the asphalt. Adding recycled waste plastic using the dry process would require a recycled waste plastic with a low melting temperature along with an extended dry and wet mixing time to ensure complete melting of the recycled waste plastic into the bitumen. This process relies on good work practice however even then the efficacy of dry mixing may result in variable levels of melting of the recycled waste plastic to form strong bonds with the bitumen and hence not achieving improved performance of the asphalt. This process may not achieve good outcomes if the asphalt is manufactured at warm mix temperatures.

4.1.3 Mixing Processes

Dry Process

A method of adding recycled waste plastic to asphalt is adding the recycled waste plastic in a solid dry form direct to the mixing chamber of an asphalt plant and this method is referred to as the “Dry Process”. The recycled waste plastic comes in the form of flakes, pellets or shredded and can be a singular or multiple types of recycled waste plastic, or a composite of recycled waste plastic and other recycled material.

The use of the dry process requires vigilance in the mixing process to ensure that the recycled waste plastic is sufficiently mixed into the asphalt such that it bonds with the binder plus the aggregates and is completely coated with binder. Testing of the manufactured asphalt by Austroads test method AGPT-T232, *Stripping Potential of Asphalt - Tensile Strength Ratio*, should be undertaken to monitor for any reduction in the dry or wet strength of the asphalt, not just the ratio of the dry and wet strength. Asphalt suppliers should also look at other tests to assist in assessing the efficacy of the mixing of the recycled waste plastic into the asphalt.

Wet Process

This method adds the recycled waste plastic into asphalt by pre-blending the recycled waste plastic into bitumen and then using the recycled waste plastic modified binder to manufacture the asphalt and this method is referred to as the “Wet Process”.

The advantage of the wet process is the ability to test the binder for quality prior to its use and the process should ensure total melting and uniform distribution of the recycled waste plastic as part of the binder. This is important where the properties of the binder will result in enhanced performance of the asphalt. It is critical that the binder be manufactured using appropriate materials and a manufacturing process to ensure the binder is stable in its storage and does not segregate. Austroads test method AGPT-T108, *Segregation of Polymer Modified Binders*, will detect the propensity of a recycled waste plastic modified binder to segregation during storage, however this test may not be suitable for testing some hybrid binders. Sampling and testing of the recycled waste plastic modified binder (RPMB) at the point of use is recommended to check binder properties and segregation at or near the time and place of use of the binder.

4.1.4 Typical Levels of Modification

Given the different approaches to the incorporation of recycled waste plastic in products for use in road surfacing applications and the proprietary nature of the information, quantifying the mass of recycled waste plastic added can be difficult to understand, for example in some cases a supplier may provide information on the amount of recycled waste plastic in equivalent “numbers of plastic bags” or “number of plastic bottles”.

Australian experience to date has used recycled waste plastic in proprietary asphalt mixes of the order of 0.25% by mass of asphalt (based on 5% by mass of the binder added through the wet process) and up to 0.7% by mass of asphalt (added through the dry process). These values may change in the future depending on the type of recycled waste plastic and blending of binders but higher dosage may impact on the properties of the asphalt such as workability and stiffness. Similarly, the proportioning of recycled waste plastic if used in a spray sealing binder needs to be considered in terms of durability and lifetime of the seal.

4.2 Quality of Recycled Waste Plastic

In preparing recycled waste plastic for use in either an asphalt or sprayed sealing application a supplier should have a documented quality management system to detail:

- how it will receive the recycled waste plastic
- verify that the supplied materials are the correct type(s) of recycled waste plastic
- stockpile in the correct location
- manage stockpiles to ensure traceability of product and that contamination or damage does not occur
- process the recycled waste plastic in accordance with a specified process to the requisite size and shape
- storing the processed plastic to protect it from rain and contaminants.

The supplier should test on a regular basis the processed plastic for melting temperature and melting viscosity to ensure quality, including consistency in the properties of the processed plastic.

4.3 Recycled Waste Plastic Modified Binders

4.3.1 Properties

Recycled waste plastic modified binders may have complexities associated to the type of recycled waste plastic used and little is formally published on the properties of these binders. However, these binders may serve the same purpose as other modified bituminous binders. Thus, the binder properties and their methods of test in Austroads specification ATS 3110, or AS 2008 for bitumen, should be considered as the basis for any testing of recycled waste plastic modified binders, including those with other added materials.

Suppliers may be able to modify recycled waste plastic modified binders with SBS polymer or crumb rubber to meet the requirements of elastomeric or rubber binders already specified in ATS 3110.

Where recycled waste plastic modified binder is proposed to be used in an asphalt application using the wet process or as a sprayed sealing binder, Austroads specification ATS 3110 for polymer modified binders and AS 2008 for bitumen should be used as models for testing binder properties until such time as alternative specifications are developed. Test data on the properties of the proposed recycled waste plastic binder should be presented and monitored as a measure of quality and it should be recorded, preferably against the binder (PMB or bitumen) that would have been used otherwise.

This would assist in the creation of an ongoing database, which will prove useful in the development of future specifications. Forms attached in Appendices A.1, A.2 and A.3, can be used for recording and comparing the modified binder and bitumen properties, for sprayed sealing and asphalt applications, against the proposed recycled waste plastic modified binder. Examples of completed forms are included in Appendices B.1, B.2 and B.3.

4.3.2 Storage and Handling

Where used in the wet process the storage and handling aspects of recycled waste plastic modified binders needs to be understood. Most types of recycled waste plastic are generally incompatible within bitumen unless stabilised to make the binder homogenous. For this reason and as is the case with other PMBs, results on segregation of the binder using Austroads test method AGPT-T108 must be provided by the supplier of the binder, however this test may not be suitable for testing some hybrid binders. This data will highlight the capability of the binder to be transported and stored.

For binders where the recycled waste plastic is stabilised in the bitumen the segregation may be minimal thus storage stable and likely be held for a period of time. In other cases, the binder may require constant mixing and circulation to maintain the recycled waste plastic in suspension such as a hybrid binder with recycled waste plastic and crumb rubber. Alternatively, the binder is manufactured next to the asphalt mixing plant and the binder is used immediately; however suitable storage tanks with agitation to keep the binder mobile will be necessary.

Depending on the technology and the products being offered, a quality plan between the binder supplier and binder user is essential to manage any complexities around the homogeneity of the binder during transport and storage.

4.4 Assessment of Recycled Waste Plastic Modified Asphalt

Currently local government would typically specify Conventional Asphalt mix design by volumetric properties along with possibly prescriptive limits for particle size distribution (PSD) and binder content whilst some customers may specify simple recipe mixes. The modification of the properties of the Conventional Asphalt by adding recycled materials may result in an asphalt that is not fit for purpose that could lead to premature failure in service. Traditional tests measuring the basic strength of manufactured asphalt such as Marshall stability will not be sufficient to understand the influence recycled waste plastic has on the performance of asphalt.

Therefore, Section 4.4.1 of the interim guidelines proposes a testing system that will ascertain the properties of the asphalt incorporating all recycled materials, not just recycled waste plastic, such that decision makers can understand the relative performance of asphalt incorporating recycled materials and the impact that manufacturing and placement has on its field performance.

4.4.1 Properties of Recycled Waste Plastic Modified Asphalt

The use of an Alternative Asphalt mix design incorporating recycled waste plastic and possibly other recycled materials should not have a negative impact on the properties and performance of asphalt now or in the future. An Alternative Asphalt mix design should undergo a volumetric mix design as specified by a customer, whether the specification is local government, state road authority, AUS-SPEC Worksection 1144 or in AS 2150. The volumetric properties and limits such as voids in mineral aggregate, laboratory air void content (as a range of values or as a target air void content with a production tolerance), binder film index or stability and flow should be the same as the Conventional Asphalt mix design. Where such properties are not specified then the Alternative Asphalt mix design should comply with the volumetric properties and limits in AS 2150 for dense graded asphalt using the same level of laboratory compaction.

The performance of an Alternative Asphalt mix design should be benchmarked against a Conventional Asphalt mix design used by the customer as defined in Section 4.1.1. The basis for the benchmarking should follow the rationale and the methodology in Section 4.7 of the Austroads *Guide to Pavement Technology Part 4B: Asphalt (*Austroads 2014). The performance criteria will include workability, moisture sensitivity, deformation resistance, modulus and fatigue performance. In addition, an assessment of the durability and life expectancy of the placed asphalt needs to be considered by an asset owner. This approach allows for introduction of innovative technologies that would be difficult with the conventional ‘recipe’ based specifications.

Specified properties for the asphalt mix designs are shown Table 4.1. For the workability test the limit on the Alternative Asphalt is a maximum aimed to ensure that the asphalt is not too difficult to work. Further testing for fatigue performance and deformation resistance will ensure the mix design is sufficiently resistant to cracking and does not have too much binder making it prone to flushing or rutting.

Table 4.1: Asphalt properties for comparison testing

Property	Conventional Asphalt	Alternative Asphalt
Workability (AS/NZS 2891.2.2 and AS/NZS 2891.9.2)	Not tested	Maximum 6% air voids
Moisture sensitivity (Austroads AGPT-T232)	Minimum 80% TSR	Minimum 80% TSR
Deformation Resistance (Austroads AGPT-T231)	Report	Maximum rut depth no more than Conventional Asphalt
Fatigue Performance (Austroads AGPT-T274)	Report	Microstrain value to be greater than the value for Conventional Asphalt
Flexural Stiffness (Austroads AGPT-T274 preferred method) OR Resilient Modulus (AS/NZS 2891.13.1)	Report	Report

The form in Appendix A.4 shows these tests for Alternative Asphalt against Conventional Asphalt along with the mix components and proportions. This form, which provides a performance measure, can be used for all mixes using recycled waste plastic produced using various permutations and combinations of the wet or dry process for comparison against Conventional Asphalt. An example of a completed form is included in Appendix B.4.

A risk of leaving the comparison work to customers is that they may not be able to discriminate between the results to identify an appropriate outcome. Another means of assessing relative performance is to have the assessment of the Alternative Asphalt undertaken by an independent process such as TIPES (Transport Infrastructure Product Evaluation Scheme) which is managed by the Australian Road Research Board with more information available at www.arrb.com.au/tipes. This means that asphalt suppliers would have a one stop process to get their proprietary mix designs evaluated as to whether it meets specified requirements such as the mix design process in the interim guidelines, documented production and placement systems, safety data sheets and a placement trial.

4.5 Alternative Asphalt Mix Design Process

The system described in this section has two stages with the first stage being a typical mix design process using volumetric properties and the second stage is the mix undergoing further tests to compare the performance properties of both Conventional Asphalt and Alternative Asphalt mix designs. This is built on the process described in the Austroads *Guide to Pavement Technology Part 4B: Asphalt* (Austroads 2014) and is shown in Table 4.2.

Advice on a process for approval of an Alternative Asphalt mix design is provided in Section 6.1.1.

Table 4.2: Asphalt mix design procedure

<table>
<tr><th colspan="2">Volumetric Mix Design</th></tr>
<tr><td>Conventional Asphalt Mix Design C320 Bitumen
Marshall 35 or 50 blow compaction or Gyratory 50 or 80 cycles compaction
Using a laboratory made mix
Properties in accordance with client’s specification, typically as below:
PSD, binder content, BFI, VMA (or where specified VFB in lieu of VMA), % air voids, stability and flow. Air voids would either be a range or a target value.</td><td>Alternative Asphalt Mix Design
Must include recycled waste plastic(s) and may include other recycled materials
Marshall 35 or 50 blow compaction or Gyratory 50 or 80 cycles compaction
Can be wet or dry mixed process using a laboratory made mix
Compaction temperature for Marshall or Gyratory specimens to be determined in accordance with Appendix B in AS/NZS 2891.2.2 or AS/NZS 2891.5
Target PSD and/or binder content may differ from the Conventional Asphalt mix design
Volumetric design properties same as the Conventional Asphalt mix design</td></tr>
<tr><th colspan="2">Comparison Testing</th></tr>
<tr><td colspan="2">Can be undertaken using laboratory or plant manufactured mix using the same formulation as that for the volumetric mix design. For comparative testing the method for preparation of test specimens must be the same for both mixes. Therefore, test specimens must be prepared using either of the following:
Hot plant mix, all specimens must be prepared without the mix cooling to less than 30 °C below plant temperature.
Hot plant mix placed in sample containers and allowed to cool to ambient temperature. Mix to be reheated following time and temperature limits below:
Oven temperature maximum 160°C.
Maximum time in oven 3 hours for loose mix and 1 hr for mix in a compaction mould.
Reheat asphalt only once.</td></tr>
<tr><td>Voids after 250 Cycles Gyratory Compaction
Not required</td><td>Voids after 250 Cycles Gyratory Compaction
Compact at same compaction temperature for volumetric specimens. Compaction in accordance with AS/NZS 2891.2.2, SSD bulk density by AS/NZS 2891.9.2, maximum density by AS/NZS 2891.7.1 and air voids by AS/NZS 2891.8</td></tr>
<tr><td>Deformation Resistance (Austroads AGPT-T231)
5% air voids, 10,000 passes at 60°C</td><td>Deformation Resistance (Austroads AGPT-T231)
5% air voids, 10,000 passes at 60°C</td></tr>
<tr><td>Moisture Sensitivity
Tested in accordance with test method Austroads AGPT-T232</td><td>Moisture Sensitivity
Tested in accordance with test method Austroads AGPT-T232</td></tr>
<tr><td>Fatigue Performance (Austroads AGPT-T274)
At 20°C and 10Hz, Micro strain level at 10^6 cycles to 50% of initial modulus</td><td>Fatigue Performance (Austroads AGPT-T274)
At 20°C and 10Hz, Micro strain level at 10^6 cycles to 50% of initial modulus</td></tr>
<tr><td>Flexural Stiffness (Austroads AGPT-T274)
Recommended Test
5% air voids
OR
Resilient Modulus (AS/NZS 2891.13.1)
5% air voids standard reference conditions</td><td>Flexural Stiffness (Austroads AGPT-T274)
Recommended Test
5% air voids
OR
Resilient Modulus (AS/NZS 2891.13.1)
5% air voids standard reference conditions</td></tr>
</table>

4.6 Testing of Asphalt

4.6.1 Production Tolerances

The finished Alternative Asphalt mix design should have tolerances applied to the target grading and binder content to be applied during manufacture of the asphalt. The tolerances should be in accordance with the customer's specification and where not specified be in accordance with AS 2150. In addition, where the customer does not specify volumetric properties and limits such as voids in mineral aggregate, laboratory air void content (as a range of values or as a target air void content with a production tolerance), binder film index or stability and flow then the Alternative Asphalt mix design should comply with the volumetric properties and limits in AS 2150 for dense graded asphalt with the same level of laboratory compaction.

4.6.2 Laboratory Practice

Testing of any asphalt manufactured with a recycled waste plastic modified binder poses challenges for testing laboratories in the development of sound practices as to how samples are taken and prepared. For example, the test for maximum density of asphalt where clumps of asphalt have to be taken down to a small size to lessen entrapment of air in clumps of asphalt fines resulting in an incorrect measurement of maximum density. With modified binders and especially crumb rubber modified binder the task is more difficult and a laboratory should provide effective training to its technicians. Another test is determining binder content by wet extraction where the use of a routine solvent may not be effective enough to wash all of the plastic polymer off the aggregate particles. Similarly use of an ignition oven is likely to remove the plastic polymer and crumb rubber from the asphalt and a laboratory needs to develop processes to calibrate the ignition test to take into account the loss of materials from ignition. A key area for all laboratories to consider is the temperature to be used for the compaction of Marshall or Gyratory specimens.

Standard temperatures in the applicable test methods do not apply as they are intended for specified grades of bitumen or PMB intended for use in Conventional Asphalt. Recycled waste plastic modified binders or the addition of recycled waste plastic by the dry process will require laboratory compaction temperatures in excess of that used for C320 bitumen and likely in excess of the laboratory compaction temperature for some PMBs. Both AS/NZS 2891.2.2 and AS/NZS 2891.5 have an appendix to describe a process as how to determine an alternative compaction temperature.

4.7 Manufacture, Storage and Transport of Asphalt

The addition of recycled waste plastic to Conventional Asphalt is likely to increase the stiffness of the asphalt and could result in the asphalt being less workable at typical manufacturing temperatures for DGA of 165-170 °C when made with C320 bitumen. This would result in an increase in the manufacturing temperature and especially if used with crumb rubber and possibly RAP. An increase in temperature is not desirable as this will increase emissions of fumes and use more energy to manufacture the asphalt. More fuming may have health implications, is not comfortable for the paving crew and can have an impact on road users and the community living or working close to a road. Various means of reducing the manufacturing temperature could be considered including reducing a base binder grade and/or the use of a warm mix additive to improve workability of the asphalt and facilitate reduced production temperatures. This depends on the feasibility of a warm mix additive being functional in the asphalt including whether use of a dry process remains feasible at a lower production temperature. The effect of storage of the asphalt made from recycled waste plastic is unknown, therefore it would be prudent to avoid prolonged storage of the asphalt before discharge from the mixing plant. Transfer of asphalt manufactured with recycled waste plastic to a paver or materials transfer vehicle (MTV) could be more problematic than Conventional Asphalt.

An asphalt supplier should have a documented management system of how it will manage processes for the manufacture, storage and transport of asphalt containing recycled waste plastic.

5. Recycled Waste Plastic in Sprayed Sealing and Crack Sealing

5.1 Binder Properties, Storage and Use

Recycled waste plastic must be pre-blended into bitumen when used as a binder for sprayed sealing, either on site or at a manufacturing facility away from the site of the works. Section 4.3.1 provides information on the properties of recycled waste plastic modified binders. It is critical that the binder be manufactured using appropriate materials and a manufacturing process to ensure the binder is stable in its storage and does not segregate. Austroads test method AGPT-T108, *Segregation of Polymer Modified Binders*, will detect the propensity of a modified binder to segregation during storage, however this test may not be suitable for testing some hybrid binders.

In the design of a binder application rate for a sprayed seal a binder factor is applied to the design with the factors being between 1.0 and 1.6 (*Austroads Guide to Pavement Technology Part 4K, Section 6.3*). The binder factor varies for the type of seal treatment and the type of binder, using binder classes from AS 2008 and Austroads ATS 3110, with the factors having been derived from many years history of using modified binders across Australia for various seal treatments. The interim guidelines assume that in general recycled waste plastic modified binders will be manufactured to comply with the properties for modified binders in Austroads specification ATS 3110, however the behaviour of a recycled waste plastic binder in a seal application may not be the same as that for the same ATS 3110 class of binder without recycled waste plastic. It is recommended that a seal designer seek advice from the supplier of a recycled waste plastic binder on the application of a binder factor.

Suppliers storing or transporting a recycled waste plastic modified binder must have a documented management system detailing how the binder should be stored and heated to ensure the product has minimal deterioration in properties and does not segregate or settle during storage or transport.

Tankers used for storage and transport must be suitable to ensure the binder is fit for purpose for its intended application at the time of use. Inspection of the binder for segregation in the tanker at the point of use is recommended along with sampling of the recycled waste plastic modified binder for subsequent testing to determine properties of the binder at the time and place of use. Binder samples are best taken during transfer of the binder from the site storage tanker to the bitumen sprayer where a sample can be taken before the addition of additives in the bitumen sprayer.

5.2 Recycled Waste Plastic in Pavement Preservation Applications

As pavement preservation techniques are used on road surfacing applications, the suitability of recycled waste plastics on their own in the binder would impact on the performance of the binder resisting cracking. Recycled waste plastic is intrinsically a stiff material, good for deformation resistance but poor for crack resistance. To mitigate the stiffness of a recycled waste plastic modified binder, recycled waste plastic can be used in combination with an elastomer to improve performance of the modified binder.

One area in pavement preservation that is already using recycled waste plastic is in crack and joint sealing. In this case the recycled waste plastic is combined with crumb rubber and it is claimed to give a resilient and an elastic product suitable for providing waterproofing, adhesion and crack resistance.

6. Selection and Application

There are numerous considerations in what type of recycled waste plastic is introduced in the road surfacing material. As indicated, there are a diverse range of approaches, different types of recycled waste plastic, some of them used singularly and others used as a composite with other polymers or other recycled materials. Furthermore, it needs to be established whether the addition of the recycled waste plastic is via the dry or the wet process.

To facilitate these complexities the approach taken is to flow chart the applications and thereby the considerations for the selection of the technology or a product type, bearing in mind, that this is an early stage of adopting the use of recycled waste plastic. Many of the suggestions made in the interim guidelines are based on the approach stated in the methodology and at the best are experiential and generic in nature.

The following categories and subsequent sub-categories were identified as considerations in the assessment process towards selection (technology) and use (application) of recycled waste plastic.

1. Technology category:
    a. type of product
    b. product specification
    c. product storage and handling
    d. product health, safety and environmental considerations
2. Application category:
    a. performance data and design
    b. field experience and trial data.

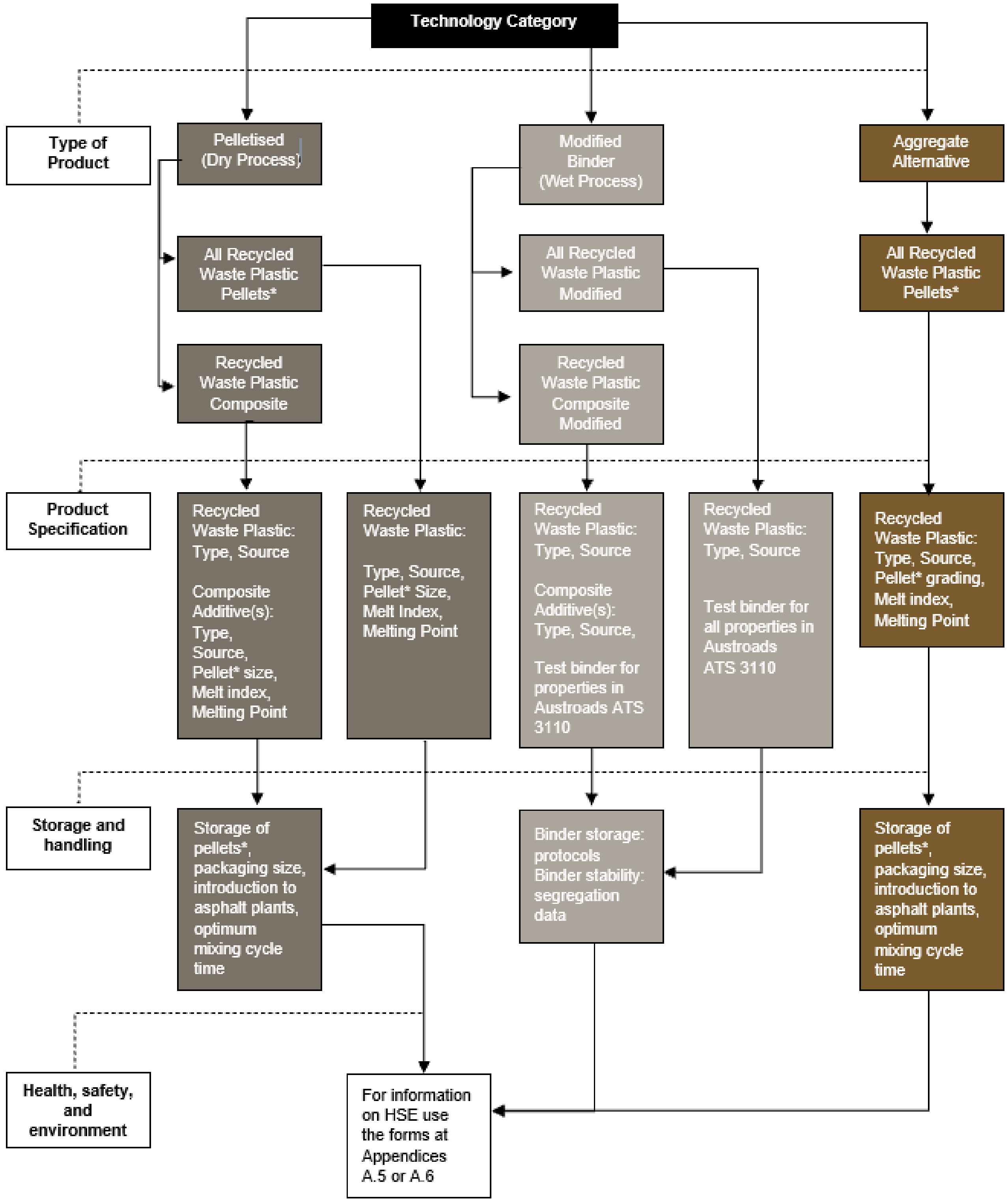
The flow chart shown in Figure 6.1 shows the processes by which recycled waste plastic is added to a binder by the wet process, into asphalt by the dry process or into asphalt as an alternative to virgin aggregates. It shows that the recycled waste plastic should be tested before use for properties including melt index, particle size distribution and other properties critical to ensure the recycled waste plastic has consistent properties and hence performance for the asphalt or sprayed seal.

Forms in Appendix A.5 and A.6

At the end of the process is information on health, safety and environment which directs the user to the form at Appendix A.5 for asphalt or Appendix A.6 for sprayed sealing. A supplier that is proposing the use of an Alternative Asphalt or seal binder incorporating recycled waste plastic must complete the appropriate form and submit it to the customer. The form should have information to support claims including written specialist advice from appropriately qualified professionals.

The customer can review the Supplier's responses in the form and decide whether the supplier has undertaken a thorough assessment of the risks of using recycled waste plastic and developed processes to manage those risks. The customer may engage the services of appropriately qualified professionals to assist in a review of the Supplier's responses.

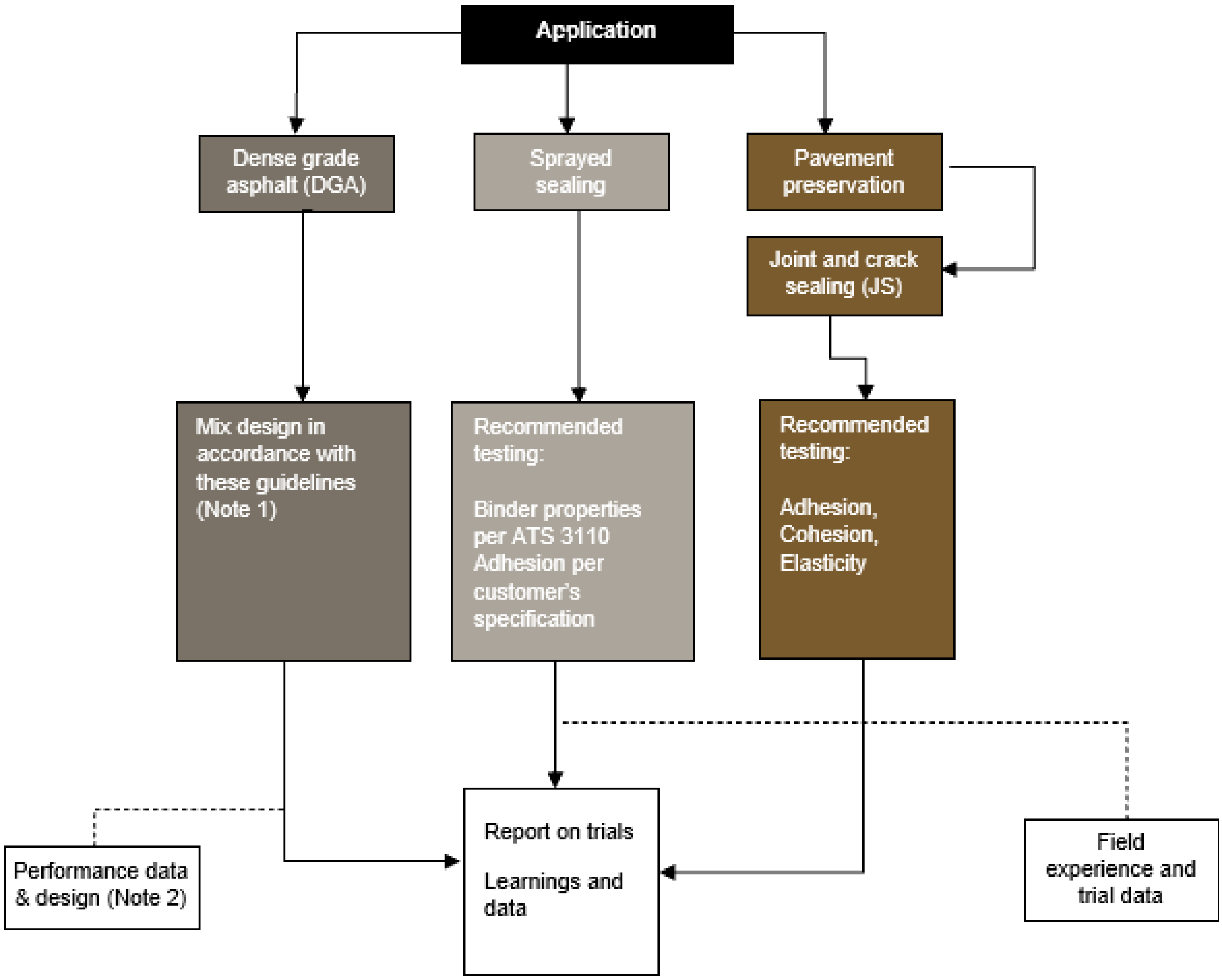
Figure 6.1: Technology and product flow chart



*reference to pellets also includes flake and shredded forms

The flow chart shown in Figure 6.2 shows the application of recycled waste plastic in asphalt and sprayed sealing and summarises what testing should be done. Forms at Appendices A.1 to A.3 should be used by a supplier to show the properties of a recycled waste plastic binder proposed for use in asphalt or sprayed sealing work, regardless of whether the binder meets the requirements of AS 2008 or Austroads ATS 3110. Results of any testing not shown in the forms should also be provided to the customer. Form A.4 compares the results of performance testing of an Alternative Asphalt against a Conventional Asphalt and requires the supplier to show the proportions of each virgin and recycled component in its asphalt mix design.

Figure 6.2: Application and performance flow chart



Note 1: Sections 4.4 and 4.5 of the interim guidelines detail the asphalt properties and the process for mix design to enable comparison between a Conventional Asphalt against a proposed Alternative Asphalt mix design using the form at Appendix A.4. Section 6.1.1 details the process for the customer to approve the Alternative Asphalt mix design.

Note 2: Performance data can be ascertained for an Alternative Asphalt from the form at Appendix A.4.

6.1 Procurement of Alternative Asphalt

6.1.1 Approval of an Alternative Asphalt Mix Design

Section 6.1.3 describes a process to procure the use of an Alternative Asphalt and a step in that process is that the customer should assess the properties of the Alternative Asphalt and approve use of the mix design for the Alternative Asphalt for the proposed works. The first stage of the approval process is that the asphalt supplier designs the Alternative Asphalt to meet the requirements for volumetric and other properties in Section 4.4 and provide National Association of Testing Authorities (NATA) accredited test results, for all properties, to show that the Alternative Asphalt mix design meets specified requirements.

The second stage of the mix design process for an Alternative Asphalt involves performance related testing as specified in Section 4.4 with the process detailed in Section 4.5. These properties are not included in current specifications used by local government so this clause is important for a customer to require that an asphalt supplier's Alternative Asphalt mix design meet the requirements of the interim guidelines. The asphalt supplier or their external testing laboratory must undertake all required testing in a laboratory that is accredited by NATA for all of the specified tests and results provided on NATA endorsed test reports. A customer may choose to ask the asphalt supplier to have the performance testing, or all testing of the mix design, undertaken by an independent laboratory that is NATA accredited for all of the specified tests. A customer should ask the asphalt supplier of cost implications of such a request and any time delays.

The form at Appendix A.4 requires the asphalt supplier list the component materials used in its Alternative Asphalt mix design and their proportions by percentage of the total mass of aggregate. This is the mix design that is compared to the Conventional Asphalt mix design therefore any changes to the components or proportions in the Alternative Asphalt mix design will have an impact on the properties of the asphalt used in the comparison testing. Whenever the Alternative Asphalt mix design is used it must include the same component materials and proportioning, thus ensuring that the Alternative Asphalt will deliver performance no less than that delivered by Conventional Asphalt. A supplier must not change the formulation without submitting new data to the customer or through TIPES.

An example of how this may occur is where an asphalt supplier has different types of asphalt plants around Australia that may vary as to how much of a recycled product can be added in a specific plant. In addition, the availability of recycled products may vary such as glass or slag not be available or the source of RAP varying between plants.

Application of Alternate Asphalt Mix Design

When reviewing test results for an Alternative Asphalt in Appendix A.4 the Alternative Asphalt mix design proposed for use on the network must be the mix design to be placed on the network and not a mix design from another city/town with varying/different components, sources and/or proportions of materials. The mix design proposed for the network must have been used in the comparison testing against a Conventional Asphalt. When the customer has approved use of the Alternative Asphalt mix design the asphalt supplier must not change the formulation for the Alternative Asphalt mix design without submitting new mix design and comparison testing data to the customer or seek a new approval through TIPES.

The customer or their agent should review the information on Form A.4 returned by the asphalt supplier and ascertain whether the reported results for the performance tests deliver results that meet the requirements of Section 4.4.1 of this document. Along with Form A.4 the asphalt supplier should provide a covering letter showing the target grading and binder content with the applicable production tolerances. If the performance results comply with Section 4.4.1 and the asphalt supplier has provided the covering letter the customer can approve the Alternative Asphalt mix design for use on the works or for a specified period of time for use on that customers network.

6.1.2 Specification and Testing of Alternative Asphalt

At the time of manufacture the approved alternative asphalt should be sampled in accordance with AS/NZS 2891.1.1, or as specified by a customer, and tested during production. Unless otherwise specified the approved Alternative Asphalt must be tested for the properties and testing frequencies shown in Table 6.1. Advice on the testing of asphalt incorporating a recycled waste plastic is available in Section 4.6 of this document. The asphalt supplier must manufacture the Alternative Asphalt to comply with specified properties of the approved mix design. This includes the use of all materials shown in the approved mix design and addition of those materials in the specified proportions. If this is achieved then the manufactured Alternative Asphalt should replicate the properties of the asphalt at the mix design stage.

Table 6.1: Asphalt properties for production testing

Property	Frequency of Sampling and Testing
Binder Content and PSD (AS/NZS 2891.3.1 / 2891.3.2 / 2891.3.3) (AGPT-T234)	As specified in contract or in accordance with testing frequencies used by the state road agency in your state or territory
Maximum density (AS/NZS 2891.7.1)	As specified in contract or in accordance with testing frequencies used by the state road agency in your state or territory
Air void content of laboratory compacted specimens (AS/NZS 2891.5 or AS/NZS 2891.2.2, AS 2891.9.2 and AS/NZS 2891.8)	As specified in contract or in accordance with testing frequencies used by the state road agency in your state or territory
Voids in Mineral Aggregate (AS/NZS 2891.8)	As specified in contract or in accordance with testing frequencies used by the state road agency in your state or territory
Stability and flow for Marshall compacted specimens (AS/NZS 2891.5)	As specified in contract or in accordance with testing frequencies used by the state road agency in your state or territory

In addition to the testing in Table 6.1, or in a customer's specification, the tests shown in Table 6.2 must be undertaken or commenced during production of the approved Alternative Asphalt.

Table 6.2: Other asphalt properties for production testing

Property	Limits	Frequency of Sampling and Testing
Moisture content of asphalt (AS/NZS 2891.10)	Maximum 0.5%	One per day of plant production of the approved alternative asphalt
Moisture sensitivity (AGPT-T232)	Minimum 80% TSR	One test per 5,000 tonnes of the approved alternative asphalt
Uniform coating of binder (AS/NZS 2891.11)	Minimum 95%	One test per 5,000 tonnes of the approved alternative asphalt

6.1.3 Procurement of Alternative Asphalt

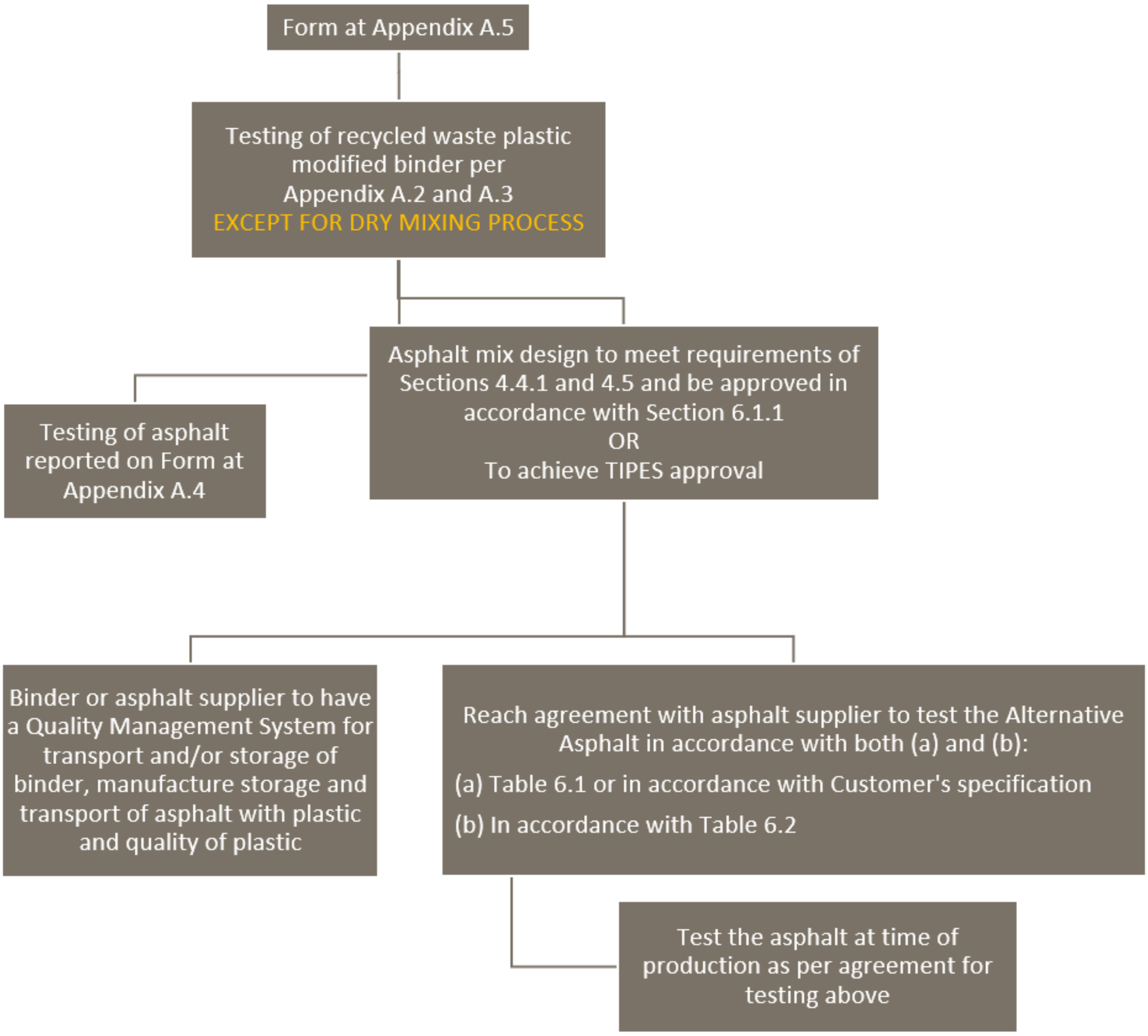
Typical specifications for the supply and placement of asphalt would not cater for the use of a product not described or specified by a customer. Where a supplier proposes the use of an Alternative Asphalt there are processes described in the interim guidelines to assess the technical impact of using the Alternative Asphalt however a user will need to make a value assessment where the cost of placing the Alternative Asphalt is more than that for Conventional Asphalt.

Factors for consideration in a value assessment include:

- the performance of the Alternative Asphalt compared against Conventional Asphalt
- expected maintenance requirements
- expected life before replacement is required
- potential sustainability benefits through a reduction in the use of raw materials
- recyclability and other potential impacts on the environment
- cost.

Figure 6.3 shows an example of a process to assist a user of the interim guidelines evaluate and purchase Alternative Asphalt offered by an asphalt supplier. Where the customer decides to use an Alternative Asphalt, they must reach agreement with the asphalt supplier that it tests the Alternative Asphalt as shown in Section 6.1.2 of the interim guidelines.

Figure 6.3: Example procurement process for Alternative Asphalt



6.2 Procurement of Alternative Binder for Sprayed Sealing

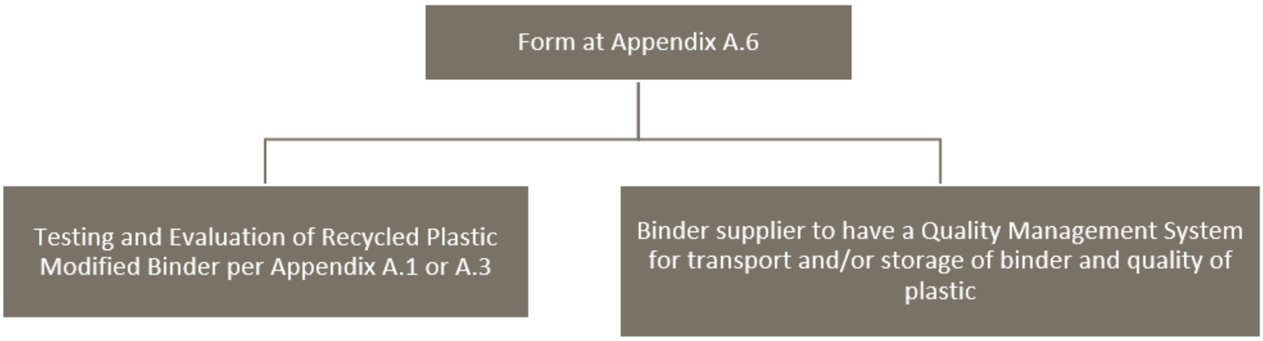
Evaluation of the performance of an alternative binder incorporating recycled waste plastic for use in a sprayed seal is more difficult as there is no assessment process like that used for asphalt where the performance of the relative asphalt mix designs can be compared. Incorporation of bitumen and recycled waste plastic by itself is most likely going to increase the viscosity and stiffness of the binder making it more difficult to achieve an optimal spray outcome and may result in a shortened life expectancy. Suppliers may combine recycled waste plastic with crumb rubber or SBS polymer to result in a binder with more elastic type of performance than just combining recycled waste plastic with bitumen. For a customer to make a decision on whether to use a RPMB the supplier should complete the forms at Appendices A.1 or A.3 so the customer can compare the properties of the RPMB and a similar binder from Austroads ATS 3110 or AS 2008. It would be preferable for suppliers to manufacture a RPMB to comply with Austroads ATS 3110 specified limits but there may be variations for some properties.

As a guide to assist in the evaluation of a recycled waste plastic modified binder, notes on some test properties are listed below:

- Viscosity at 165 °C – where the RPMB includes crumb rubber the viscosity should not exceed that of S45R, being 4.5 Pa.s, where an SBS polymer is added the viscosity should not exceed 0.55 Pa.s for a SAM seal binder or 0.8 Pa.s for a SAMI seal binder.
- Softening Point – should not exceed the maximum for the class of binder from ATS 3110 that would have been used instead of the RPMB. If the softening point is too high this will have an impact on application of the binder to the road surface.
- Segregation – must not exceed 8%. Critical that a RPMB not segregate or settle whilst in transport or storage to ensure homogeneity of the binder at the time of application. Note that this test may not be suitable for testing some hybrid binders.

Figure 6.4 shows an example of a process to assist a user of the interim guidelines evaluate and purchase an offer to use a recycled waste plastic modified binder for sprayed sealing. The supplier should complete the form at Appendix A.6 and submit it to the customer along with the form from Appendix A.1 or A.3.

Figure 6.4: Example procurement process for alternative seal binder



7. Conclusions

The interim guidelines provide information to users about the use of recycled waste plastic in road surfacing applications including a review of current technologies and products and the likely applications. The interim guidelines are intended for use by local governments for the surfacing of local roads that primarily provide access to abutting land (Austroads 2020). The interim guidelines are applicable to roads that are not used by a heavy volume of traffic or a high proportion of heavy vehicles and where applicable have a design traffic loading of more than 1 x 10^6 equivalent standard axles (ESAs) for a 20 year design period. The interim guidelines provide no or limited guidance or technical information on health, safety and environmental (HSE) matters, relative costs of products, procurement of proprietary products and performance of products being placed across Australia. Further, no independent or comprehensive research has been undertaken into the impacts of incorporating recycled waste plastic in asphalt and bitumen, including HSE impacts, potential microplastic generation, leaching, fuming, use of RAP with recycled waste plastic and whole of life considerations.

Research to assess such factors is currently under way through Austroads, National Asset Centre of Excellence (NACOE) and Western Australian Road Research and Innovation Program (WARRIP) projects. Consequently, asset owners considering the use of recycled waste plastic in road surfacing applications need to make their own assessment of all the impacts of doing so, particularly for HSE aspects including compliance with relevant state or federal legislation/regulation and how any adverse impacts can be mitigated or managed.

With the completion of these projects more information will be available on the use of recycled waste plastic in road surfacing applications. The preparation of the interim guidelines was based on input from a number of stakeholders (refer to Appendix C) involved in recycled waste plastic technologies and products, field placements to date, literature survey, international experiences and early findings of research in this area. It recommends that a supplier of recycled waste plastic should have a documented management system to control receival and processing of recycled waste plastic. This includes testing of the processed plastic to ensure consistency of properties and hence its impact on the asphalt or sprayed seal.

Until specifications for recycled waste plastic modified binders are in place the interim guidelines propose that the binder properties in Austroads specification ATS 3110 be a template for binder or asphalt suppliers to test the properties of the recycled waste plastic binders used in the wet process to manufacture Alternative Asphalt or used for sprayed sealing. Suppliers should also develop a plan how to manage the handling and storage of a recycled waste plastic modified binder.

The interim guidelines include a section on asphalt mix design for dense graded asphalt where the Austroads *Guide to Pavement Technology Part 4B: Asphalt* is the basis for the design and evaluation of Alternative Asphalt mix designs. In addition, it is suggested that assessment of an Alternative Asphalt mix design could be undertaken by an independent organisation such as the TIPES system administered by ARRB.

The interim guidelines provide a series of assessment tools to assist users in the selection of the type of recycled waste plastic product or technology to consider for a given application. These include:

- technology and product flow chart
- application and performance flow chart
- flow charts to show a procurement process for recycled waste plastic products
- procurement forms for Alternative Asphalt or a recycled waste plastic binder in sprayed sealing and
- forms and examples for assessing the binders and asphalt mixes.

For procurement there are two forms for asphalt and sprayed sealing applications at Appendices A.5 and A.6. The forms request suppliers for HSE information, safety data sheet, compliance with government regulations on use of waste materials, preparation and testing of waste materials, asphalt mix design and binder properties. Suppliers of asphalt incorporating recycled waste plastic should assess the level of fuming and are encouraged to undertake independent assessments of aspects of its use including leaching, loss of microplastics and its future use as RAP.

It is advised that asset owners record the location where asphalt incorporating recycled waste plastic has been placed for future knowledge, as it is yet to be determined whether it can be safely used as RAP in the future. Location can be recorded by GPS coordinates at start and end along with the supplier’s name and proprietary name of the product.

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Appendix A Example Forms

A.1 Form for Assessing Recycled Waste Plastic Binder Against PMB in Sprayed Seals

Supplier				
Product Name				
Specification	Austroads ATS 3110 for PMB			
Application				
Test method	**Binder Property**	**Normal Class of Polymer Modified Binder**	**Specified Limits for Class of PMB Being Compared**	**Alternative Recycled Waste Plastic Modified Binder**
AS/NZS 2341.4 or AGPT-T111	Viscosity at 165 °C (Pa.s) max.			
AGPT/T122	Torsional recovery at 25 °C, 30 s (%)			
AGPT/T131	Softening point (°C)			
AGPT/T125	Stress ratio at 10 °C min.			
AGPT/T121	Consistency 6% at 60 °C (Pa.s) min.			
AGPT/T121	Stiffness at 15 °C (kPa) max.			
AGPT/T132	Compressive limit at 70 °C, 2 kg (mm) min.			
AGPT/T108	Segregation (%) max.			
AGPT/T112	Flash point (°C) min.			
AGPT/T103	Loss on heating (% mass) max.			
Comments:				

A.2 Form for Assessing Recycled Waste Plastic Binder (Wet Process) Against PMB in Asphalt

Supplier				
Product Name				
Specification	Austroads ATS 3110 for PMB			
Application				
Test method	**Binder Property**	**Normal Class of Polymer Modified Binder**	**Specified Limits for Class of PMB Being Compared**	**Alternative Recycled Waste Plastic Modified Binder**
AS/NZS 2341.4 or AGPT/T111	Viscosity at 165 °C (Pa.s) max.			
AGPT/T122	Torsional recovery at 25 °C, 30 s (%)			
AGPT/T131	Softening point (°C)			
AGPT/T125	Stress ratio at 10 °C min.			
AGPT/T121	Consistency 6% at 60 °C (Pa.s) min.			
AGPT/T121	Stiffness at 25 °C (kPa) max.			
AGPT/T108	Segregation (%) max.			
AGPT/T112	Flash point (°C) min.			
AGPT/T103	Loss on heating (% mass) max.			
Comments:				

A.3 Form for Assessing Recycled Waste Plastic Binder (Wet Process) Against Bitumen in Sprayed Seals and Asphalt

Supplier	
Product Name	
Specification	AS 2008 for bitumen
Application	

Test method	**Bitumen Property**	**Class of Bitumen**	**Specified Limits for Bitumen Class**	**Alternative Recycled Waste Plastic Modified Binder**
AS 2341.2	Viscosity at 60 °C (Pa.s)			
AS 2341.2/3/4	Viscosity at 135 °C (Pa.s)			
AS 2341.12	Penetration at 25 °C (100 g, 5 s) [0.1 mm]			
AS 2341.14 ASTM D92	Flash point (°C) min.			
AS 2341.8 or AS/NZS 2341.20	Matter insoluble in toluene, % mass			
AS/NZS 2341.10 AS2341.2	Viscosity at 60 °C, % of original after RTFO treatment			
ASTM D2872 AS2341.2				
AS/NZS 2341.10 AS2341.2	Viscosity at 60 °C, after RTFO treatment, Pa.s			
ASTM D2872 AS 2341.2				
AS/NZS 2341.10 ASTM D2872 AS 2341.12	Penetration at 25 °C, after RTFO treatment (100 g, 5 s) [0.1 mm]			
AS/NZS 2341.13, AS/NZS 2341.5	Long-term effect of heat and air, days			
AS 2341.7	Density at 15 °C, kg/m^3			
AS/NZS 2341.10 ASTM 2872	Mass change, % mass			
Comments:				

A.4 Form for Assessing Alternative Asphalt Against Conventional Asphalt

Asphalt Mixes Using Dry or Wet Process		**Conventional Asphalt**	**Alternative Asphalt**
Supplier			
Product Name			
Mix Type and Size			
Manufacturing process		Conventional Asphalt	Alternative Asphalt (Wet or Dry Process)
Proportioning of Aggregates	*Must show every component and percent by mass of total aggregates. This must not change each time the mix is manufactured other than small changes to manage variability in material properties*		
Binder type and bitumen content			

Asphalt Property	**Test method**	**Performance measure**	**Performance criteria**	**Conventional Asphalt**	**Alternative Asphalt**
Workability	AS/NZS 2891.2.2 AS/NZS 2891.9.2	Air voids after 250 cycles gyratory compaction	Maximum air void content 6%		
Moisture Sensitivity	AGPT-T232	Tensile Strength Ratio	Minimum 80%		
Deformation Resistance	AGPT-T231	Rut depth after 10,000 passes	Maximum rut depth in Alternative Asphalt to be lower		
Flexural Stiffness Resilient Modulus	AGPT/T274 OR AS/NZS 2891.13.1	Flexural Modulus at 50 ± 3 με OR Resilient Modulus	Report modulus values		
Fatigue Performance	AGPT/T274	Micro strain level at 10^6 cycles to 50% of initial modulus	Strain value of Alternative Asphalt to be greater		
Resistance to ravelling	AGPT-T236	Asphalt particle loss (open-graded asphalt only)	Alternative Asphalt to have a lower value		
Handling and durability	AGPT-T235	Asphalt binder drain-off (open-graded asphalt and SMA only)	Maximum 0.3%		
Comments					

A.5 Procurement Form for Alternative Asphalt

	Question	Response from Supplier	Name of Customer's Reviewer and Comments
1	Name of Supplier and Product Name *The response must be based on the alternative asphalt mix design being proposed to the customer as shown on the form at Appendix A.4*		
2	**What are the HSE implications in the manufacture and use of the Alternative Asphalt?**	*A detailed response is required supported by testing and analysis. The supplier should engage suitably qualified people to assist in completion of the detailed response*	
2a	What has been done to reduce fuming / odour at placement and emissions during production of the asphalt?		
	Provide data and an analysis of appropriate testing of emissions during paving operations and of plant emissions. The analysis should consider amongst others the impact of hazardous substances, comparison to relevant limits and comparison to the emissions of conventional asphalt at normal operating temperature.		
2b	Provide data and analysis of an independent testing of leaching of chemicals and particulates to the environment		
2c	Provide data and analysis of an independent assessment of microplastics and loss of fine particulate through dislodgement into the environment		
2d	Provide data and analysis of an independent assessment of the recyclability of the asphalt in the future		
2e	Provide written advice from an independent and suitably qualified person that use of the alternative asphalt is consistent with all relevant government legislation and regulations.		

	Question	Response from Supplier	Name of Customer’s Reviewer and Comments
	Are there regulations that require a form of approval to manufacture and place the Alternative Asphalt? If yes has this been obtained and provide evidence?		
2f	Provide a Safety Data Sheet for the Alternative Asphalt		
2g	Is the supply and processing of recycled materials used in the Alternative Asphalt subject to government regulations? If yes what is the requirement and provide evidence of compliance through the supply chain		
3	Does the supplier and their material suppliers have documented management systems to manage the supply and preparation of waste materials to be used in the Alternative Asphalt?		
4	Have the management systems been assessed by a third party certifier against ISO 9001?		
5	Does the Alternative Asphalt mix design comply with the requirements of Sections 4.5 and 4.4.1 of the interim guidelines?		
6	At what asphalt plants can the Alternative Asphalt be manufactured in accordance with the mix design being proposed to the customer as shown on the form at Appendix A.4		
7	Has the in-situ performance of the mix design being proposed to the customer as shown on the form at Appendix A.4 been assessed?		
	If yes provide details of the road being assessed and results of the in-situ performance		
8	What is the cost at the asphalt plant in $/tonne of the Alternative Asphalt versus Conventional Asphalt used for comparison testing?		
9	Will the Alternative Asphalt require different thickness, placement requirements or another treatment not used when placing Conventional Asphalt?		

	Question	Response from Supplier	Name of Customer's Reviewer and Comments
10	Will this increase the cost of placing the Alternative Asphalt?		
11	Has the Alternative Asphalt mix design been approved in accordance with Section 6.1.1?		

A.6 Procurement Form for Alternative Binder for Sprayed Sealing

	Question	Response from Supplier	Name of Customer's Reviewer and Comments
1	Name of Supplier and Product Name *The response must be based on the alternative binder being proposed to the customer as shown on the form at Appendix A.1 or A.3*		
2	**What are the HSE implications in the manufacture and use of the RPMB?**	*A detailed response is required supported by testing and analysis. The supplier should engage suitably qualified people to assist in completion of the detailed response*	
2a	What has been done to reduce fuming / odour at time of spraying and emissions during production and transport of the RPMB?		
	Provide data and an analysis of appropriate testing of emissions during production, transport and spraying of the RPMB. The analysis should consider amongst others the impact of hazardous substances and comparison to relevant limits.		
2b	Provide data and analysis of an independent testing of leaching of chemicals and particulates to the environment.		
2c	Provide data and analysis of an independent assessment of microplastics and loss of fine particulate through dislodgement into the environment.		
2d	Provide written advice from an independent and suitably qualified person that use of the alternative binder is consistent with all relevant government legislation and regulations.		

	Question	Response from Supplier	Name of Customer's Reviewer and Comments
	Are there regulations that require a form of approval to manufacture and place the Alternative Binder? If yes has this been obtained and provide evidence?		
2e	Provide a Safety Data Sheet for the RPMB.		
2f	Is the supply and processing of recycled materials used in the RPMB subject to government regulations? If yes, what is the requirement and provide evidence of compliance through the supply chain.		
3	Does the supplier and their material suppliers have documented management systems to manage the supply and preparation of waste materials to be used in the RPMB?		
4	Have the management systems been assessed by a third-party certifier against ISO 9001?		
5	Has the RPMB been tested for all properties in AS 2008 or Austroads ATS 3110?		
6	Has the performance of a seal with the RPMB being proposed to the customer been assessed		
	What are the results of the performance of the seal?		
7	What is the cost at the binder plant in $/tonne of the RPMB versus the binder specified by the customer?		
8	Will the RPMB require a different BAR or transport requirements in comparison to the binder specified by the customer?		
9	Will this increase the cost of spraying a seal with the RPMB?		

Appendix B Examples of Completed Forms

B.1 Example for Assessing Recycled Waste Plastic Binder Against PMB in Sprayed Seals

Supplier	Innovative Binders Pty Ltd (hypothetical supplier)
Product Name	PlasSeal Plus (hypothetical name) Recycled waste plastic/crumb rubber blend designed to meet requirements for a S45R binder
Specifications	Austroads ATS 3110 for PMB
Application	Sprayed Sealing 14 mm XSS

Test method	Sealing Binder Property	Normal Class of PMB	Specified Limits for Normal Class of PMB	Alternative Recycled Waste Plastic Modified Binder
		S45R		PlasSeal Plus
AS/NZS 2341.4 or AGPT/T111	Viscosity at 165 °C (Pa.s) max.	1.3	4.5	2.2
AGPT/T122	Torsional recovery at 25 °C, 30 s (%)	42	25 - 55	34
AGPT/T131	Softening point (°C)	62	55 - 65	77.2
AGPT/T125	Stress ratio at 10 °C min.	-	Report	1.87
AGPT/T121	Consistency 6% at 60 °C (Pa.s) min.	1666	800	2304
AGPT/T121	Stiffness at 15 °C (kPa) max.	179	180	144
AGPT/T132	Compressive limit at 70 °C, 2 kg (mm) min.	0.2	Min. 0.2	0.2
AGPT/T108	Segregation (%) max.	5	8	0.5
AGPT/T112	Flash point (°C) min.	292	250	>300
AGPT/T103	Loss on heating (% mass) max.	<0.1	0.6	0.06
Comments:	PlasSeal Plus does not meet the Austroads ATS 3110 specification for softening point for S45R.			

B.2 Example for Assessing Recycled Waste Plastic Binder (Wet Process) Against PMB in Asphalt

Supplier	**Innovative Binders Pty Ltd (hypothetical supplier)**
Product Name	PlasAsphalt (hypothetical name)
Specifications	Austroads ATS 3110 for PMB
Application	Binder for 14 mm DGA Wearing Course

Test method	**Asphalt Binder Property**	**Normal Class of PMB**	**Specified Limits for Normal Class of PMB**	**Alternative Recycled Waste Plastic Modified Binder**
		A35P		PlasAsphalt
AS/NZS 2341.4 or AGPT/T111	Viscosity at 165 °C (Pa.s) max.	0.45	0.6	0.55
AGPT/T122	Torsional recovery at 25 °C, 30 s (%)	16	6 – 21	8
AGPT/T131	Softening point (°C)	65	62 – 74	60*
AGPT/T125	Stress ratio at 10 °C min.		Report	
AGPT/T121	Consistency 6% at 60 °C (Pa.s) min.	1800	1000	1600
AGPT/T121	Stiffness at 25 °C (kPa) max.	110	120	130*
AGPT/T108	Segregation (%) max.	0.5	8	8
AGPT/T112	Flash point (°C) min.	>250	250	>250
AGPT/T103	Loss on heating (% mass) max.	0.2	0.6	0.2
Comments:		* These properties are outside the specified limits for an A35P binder in the Austroads ATS 3110 specification.		

B.3 Example for Assessing Recycled Waste Plastic Binder (Wet Process) Against Bitumen in Sprayed Seals and Asphalt

Supplier	Innovative Binders Pty Ltd (hypothetical supplier)
Product Name	PlasSeal(hypothetical name)
Specifications	AS 2008 for bitumen
Application	Binder for DGA Wearing Course and High Stress Seals

Test method	Bitumen Property	Normal Class of Bitumen	Specified Limits for Normal Class of Bitumen	Alternative Recycled Waste Plastic Modified Binder
		C320		PlasSeal
AS 2341.2	Viscosity at 60 °C (Pa.s)	302	260 – 380	850*
AS 2341.2/3/4	Viscosity at 135 °C (Pa.s)	0.55	0.40 – 0.65	0.9*
AS 2341.12	Penetration at 25 °C (100 g, 5 s) [0.1 mm]	65	Min. 40	45
AS 2341.14 ASTM D92	Flash point (°C) min.	>250	Min. 250	>250
AS 2341.8 or AS/NZS 2341.20	Matter insoluble in toluene, % mass	0.1	Max. 1.0	1.0
AS/ NZS 2341.10 AS2341.2	Viscosity at 60 °C, % of original after RTFO treatment		Max. 300	
ASTM D2872 AS2341.2			Max. 340	
AS/NZS 2341.10 AS2341.2	Viscosity at 60 °C, after RTFO treatment, Pa.s		NA	
ASTM D2872 AS2341.2			NA	
AS/NZS 2341.10 ASTM D2872 AS 2341.12	Penetration at 25 °C, after RTFO treatment (100 g, 5 s) [0.1 mm]		NA	
AS/NZS 2341.13, AS/NZS 2341.5	Long-term effect of heat and air, days		NA	
AS 2341.7	Density at 15 °C, kg/m^3	1.035	Report	1.025
AS/NZS 2341.10 ASTM 2872	Mass change, % mass		NA	
Comments:	* These properties are outside specified limits for C320 bitumen. *Example of response to non-conforming binder – this is where performance based testing of the asphalt can be used to highlight that asphalt may achieve satisfactory outcomes where a recycled waste plastic binder does not meet specified limits. In this case a supplier should propose alternative limits for the properties of the recycled waste plastic binder.* However, asphalt performance results (available on request) show that the asphalt using PlasSeal results is an improvement in deformation and fatigue performance. PlasSeal has binder properties closer to those of an A35P binder in Austroads ATS 3110			

B.4 Example for Assessing Alternative Against Conventional Asphalt

		Conventional Asphalt	Alternative Asphalt
Supplier	XYZ Asphalt Services (hypothetical supplier)		
Product Name	XYZphalt (hypothetical name)		
Mix Type and Size	14 mm Dense Graded Asphalt Wearing Course 50 blow Marshall		

Manufacturing process		Conventional Hotmixed Asphalt	Alternative Asphalt (Dry Process)
Proportioning of Aggregates	• 14mm aggregate • 10mm aggregate • 7mm aggregate • 5mm aggregate • Dust • RAP (passing 9.5mm) • Recycled waste plastic pellets • Crushed recycled glass	• 16% • 14% • 16% • 16% • 38% • 0% • 0% • 0%	• 13% • 11% • 12% • 10% • 31% • 20% • 0.5% • 2.5%
Binder type and bitumen content		C320 Bitumen 4.8%	C170 Bitumen 4.8%

Asphalt Property	Test method	Performance measure	Performance criteria	Conventional Asphalt	Alternative Asphalt
Workability	AS/NZS 2891.2.2 AS/NZS 2891.9.2	Air voids after 250 cycles gyratory compaction	Maximum air void content in Alternative Asphalt		5.0
Moisture Sensitivity	AGPT-T232	Tensile Strength Ratio	Minimum 80%	87	88
Deformation Resistance	AGPT-T231	Rut depth after 10,000 passes	Maximum rut depth in Alternative Asphalt to be lower	3.7	3.2
Flexural Stiffness	AGPT/T274 OR	Flexural Modulus at 50 ± 3 με OR	Report modulus value		
Resilient Modulus	AS/NZS 2891.13.1	Resilient Modulus	Report modulus value	4,760	4,540
Fatigue Performance	AGPT/T274	Micro strain level at 10^6 cycles to 50% of initial modulus	Strain value of Alternative Asphalt to be greater	172	208
Comments:	The results show that for the Alternative Asphalt the air voids after 250 cycles complies, the TSR complies with the specified limits for both mixes, deformation resistance is better than the Conventional Asphalt, resilient modulus is similar to the Conventional Asphalt and the Alternative Asphalt is more fatigue resistant than the Conventional Asphalt				

Appendix C Consultation List

	Name	Position	Organisation
1	Alex Let	Technical Manager	State Asphalt Services
2	Andrew Papacostas	Principle Engineer Pavements, Geotech & Materials	Department of Transport Victoria
3	Anna D'Angelo	Executive Director, Technology & Leadership	AfPA
4	Bevan Sullivan	National Technical Manager	Fulton Hogan Industries
5	Brendan Camilleri	General Manager	Alex Fraser
6	Chris Skantzos	Bituminous Products Consultant	Main Roads Western Australia
7	Darcy Rogers	Technical Development Manager	Road Science NZ
8	David Alexander	R&D Projects Manager	Road Science NZ
9	David Hallett	Chief Executive Officer	IPWEA Victoria
10	David Hitzler	Technical Manager	Close the Loop
11	David Smith	Sales and Business Development Manager - Road Services	Downer
12	Erik Denneman	Global Technical Manager	PUMA Bitumen
13	Filippo Giustozzi	Senior Lecturer, Road and Airport Pavement Materials	RMIT University
14	George Panagiotou	General Manager Bituminous Products, Road Services	Downer
15	Graham Henderson	Manager Pre Contracts & Development, Road Services	Downer
16	Grant Bosma	Principle Surfacings Engineer	NZ Transport Agency
17	Greg Stephenson	Senior Engineer, Civil Infrastructure	Brisbane City Council
18	Greg White	Independent Airport Pavement Engineering Specialist	University of Sunshine Coast
19	Hugo Van Loon	Senior Asphalt Engineer	DIT SA
20	Iulian Man	Technical Support Manager	SAMI Bitumen Technologies
21	Jason Jones	Principle Engineer, Asphalt & Surfacings	DTMR QLD
22	Jerry Tan	Blended Products Manager, Infrastructure Services	Downer
23	John Arvanitidis	Technical Development Manager	Bituminous Products
24	Jothi Ramanujam	A / Chief Engineer	DTMR QLD
25	Les Marchant	Manager Materials Engineering	Main Roads Western Australia
26	Max Fitzgerald	Owner and Director	Road Maintenance
27	Mike Pickering	Director Pavements, Research & Innovation	Department of Transport and Main Roads Queensland
28	Paul Keech	Director Assets and Works	Shoalhaven City Council
29	Paul Morassut	Technical and Innovation Manager	Fulton Hogan Industries
30	Peter Thompson	Project Manager	Transport Canberra and City Services
31	Pravin Narayan	Divisional Manager, Technical (NSW)	Fulton Hogan Industries
32	Rob Vos	State Executive Director Qld / NT	AfPA
33	Ross Guppy	Transport Infrastructure Program Manager	Austroads

	Name	Position	Organisation
34	Russell Lowe	Senior Technologist - Pavement Surface	Department of Transport and Main Roads Queensland
35	Ryan Jansz	Manager, Asphalt & Pavement Technology	Boral
36	Sebastien Chatard	General Manager	SAMI Bitumen Technologies
37	Stephen Hulme	Principle Engineer, Pavements & Materials Development	Department of Transport and Main Roads Queensland
38	Stephen Scherer	General Manager	Recycling Plastics Australia
33	Su Tao	Specialist Materials Scientist	Transport for NSW
34	Trevor Distin	Technical and Marketing Manager	Colas
35	Warren Carter	National Technical Manager, Road Services	Downer
36	BSTG	Austroads Bituminous Surfacings Technology Group (Binders)	Austroads
37	NTLC	National Technology and Leadership Committee	AfPA

Appendix D Terminology

Acronym	Definition
ABS	Acrylonitrile Butadiene Styrene
ARRB	Australian Road Research Board
BPA	Bisphenol A
CR	Crumb Rubber (End of life tyre derived)
DGA	Dense Grade Asphalt
DOT	Department of Transport (Victoria)
DTMR	Department of Transport and Main Roads (Queensland)
EVA	Ethylene Vinyl Acetate
HDPE	High Density Polyethylene
HSE	Health Safety and Environment
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
MRWA	Main Roads Western Australia
NACOE	National Asset Centre of Excellence
OGA	Open Grade Asphalt
PBD	Polybutadiene
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene Terephthalate
PMB	Polymer Modified Bitumen
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl Chloride
RAP	Reclaimed Asphalt Pavement
RMIT	Royal Melbourne Institute of Technology
RPMA	Recycled Waste Plastic Modified Asphalt
RPMB	Recycled Waste Plastic Modified Binder
SBS	Styrene Butadiene Styrene
SEBS	Styrene Ethylene Butylene Styrene
SMA	Stone Mastic Asphalt
SRAs	State Road Authorities
TfNSW	Transport for New South Wales
WARRIP	Western Australian Road Research and Innovation Program

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