

FINAL REPORT

P116: Recycled Materials in Roads – Queensland State of Play (2019/2020)

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FINAL

SUMMARY

This report provides a summary of the current state of play for the use of recycled materials across the Queensland Department of Transport and Main Roads' (TMR) network, including materials that are covered by TMR's standard specifications and those emerging materials under investigation by the National Centre of Excellence (NACOE) research program.

A summary of materials is provided and includes barriers to current use and feasible pathways to overcome these barriers, as well as opportunities for future research.

Currently, the recycled materials covered by TMR standards and specifications include crushed concrete, brick and glass, reclaimed asphalt pavement (RAP), crumb rubber, fly ash and ground granulated blast furnace slag (slag).

Additionally, TMR allows the in situ recycling of existing pavement materials.

Further research is underway on the use of crumb rubber in asphalt as well as the use of recycled plastics in road construction. Other emerging materials for Australia include bottom ash.

The incorporation of recycled materials into the construction, rehabilitation, and maintenance of road pavements, as well as the reduction of waste and greenhouse gas (GHG) emissions generated by these activities, are part of the strategies for TMR to deliver more sustainable road infrastructure. Road materials sourced from naturally occurring reserves are becoming an increasingly scarce resource; recycling and/or modification of in situ or readily available non-standard materials is an innovative and value for money solution for maintaining Queensland's road network.

The main barriers to the use of recycled materials across TMR's network are awareness, availability of materials, perceived health, safety and environment (HSE) concerns, perceived performance, procurement and potential cost. TMR has, and continues to, address these barriers through ongoing research and development (such as NACOE) and updates to standards and specifications; however, despite this the use of recycled materials in Queensland roads remains relatively low. Additional opportunities to address these barriers and to help improve the use of recycled materials include:

- developing policies and strategies to optimise the use of recycled materials
- embedding the use of recycled materials into TMR's procurement practices and decision making
- working with industry to build the capability to supply and construct infrastructure with recycled materials
- working with government partners to reduce 'green tape' and increase industry confidence
- knowledge sharing and dissemination of new findings.

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1 INTRODUCTION

Recycled materials in road construction can be an alternative to traditional (often non-renewable) materials or may be used to improve the properties of traditional materials (for example, fly ash used as a partial cement replacement in concrete or pavement stabilisation).

Recycled materials have been used by Queensland Department of Transport and Main Roads (TMR) for a long time to reduce waste and emissions to deliver sustainable and reliable transport infrastructure. Recently, the interest in increasing the use of recycled materials has been highlighted as part of TMR's commitment to work towards a circular economy.

The incorporation of recycled materials in the construction, rehabilitation, and maintenance of Queensland roads has several benefits, including:

- reducing the amount of waste sent to landfill
- reducing illegal dumping and littering
- reducing the GHG emissions generated by the production of new materials and the disposal of waste materials
- reducing our reliance on non-renewable resources
- developing a circular economy where materials are continually re-used in their highest and best use
- potentially reducing short and long-term costs
- potentially improving network performance.

The types and sources of recycled materials are diverse and of varying quality and consistency, with not all recycled materials being suitable for road construction. Recycled materials are often waste materials from other processes, with some materials requiring significant processing to ensure their properties are suitable for recycling or re-use into roads.

The requirements for recycled materials and their use are specified in TMR technical specifications. The intention of these requirements is to ensure that recycled materials perform to an equivalent or better standard when compared with 'traditional'/non-renewable materials in the intended application. Departing from these specifications may lead to a reduction in performance and/or an increase in whole-of-life costs which are not desirable.

It is important that both recycled and 'traditional'/non-renewable materials meet TMRs specified requirements when used on TMR projects, unless otherwise agreed for the purpose of research and development or trials/demonstration projects. Trials and demonstration projects are usually closely monitored following construction. This allows the impacts of any departure from specified requirements to be evaluated and considered before wider use and as part of future specification development.

Several of the recycled materials permitted or being considered by TMR have been developed through the National Asset Centre of Excellence (NACOE) research program. NACOE is a collaboration between TMR and the Australian Road Research Board (ARRB) and has a strong focus on sustainability and resilience. More information on NACOE can be obtained from the website¹.

In addition to this report, the outcomes of this project have included the development of TMR's technical note *TN193 Use of Recycled Materials in Road Construction* as well as a Recycled Materials factsheet, and both can be found at TMR's *Building Sustainable Roads* website². A separate internal position paper on the use of recycled plastics has also been produced as a deliverable from this project.

¹ <http://nacoe.com.au>

² <https://www.tmr.qld.gov.au/Buildingsustainableroads>

Table 1.1 provides a summary of where recycled materials are currently permitted in TMR technical specifications and a summary of further research that is underway.

Table 1.1: Overview of recycled material uses and relevant specifications

Application	Recycled material								TMR Specification
	Crushed concrete	Crushed brick	Crushed glass	RAP	Crumb rubber	Fly Ash and Slag	In situ material	Recycled plastic	
Unbound pavements	✓	✓	✓	✓	-	-	-	-	MRTS05, MRTS36
Stabilisation	✓	✓	✓	✓	-	✓	✓	-	MRTS07B, MRTS07C, MRTS08, MRTS09, MRTS10
Sprayed sealing	-	-	-	-	✓	-	-	R	MRTS11, MRTS18,
Asphalt	-	-	✓	✓	R/D	✓ (As filler)	✓	R	MRTS30, MRTS32, MRTS36, MRTS101, MRTS102, MRTS103, MRTS18, PSTS112
Concrete	R	-	R	-	-	✓	-	-	MRTS70*
Concrete Pavements	-	-	-	-	-	✓	-	-	MRTS39, MRTS40
Earthworks, drainage and backfill	✓ R	✓ R	✓ R	✓ R	-	-	✓	-	MRTS03, MRTS04
Geosynthetics	-	-	-	-	-	-	-	R	MRTS27 MRTS58 MRTS100 MRTS104
Crack & Seal/Rubblisation (Concrete pavements)	-	-	-	-	-	-	R	-	
Other (including road furniture)	-	-	-	-	-	-	-	R	

✓ = currently permitted within specified limits/uses R = Research underway D = Demonstration projects underway

Note: Crack & Seal/Rubblisation is now moving into the demonstration phase.

Source: TN193:2020

1.1 STRUCTURE OF THE REPORT

This report summarised the current state of play for the use of recycled materials across TMR's network and key next steps, and it is organised as follows:

- Section 2 provides a review of TMR's current approach to the use of recycled materials. The allowable uses and relevant standards, specifications and technical resources are discussed, for crumb rubber, RAP, construction and demolition (C&D) waste, recycled crushed glass, fly ash and ground granulated blast-furnace slag. In situ recycling of existing pavement is also discussed, as is recycled plastic as an emerging material.
- Section 3 discusses the barriers for using recycled materials in Queensland, including awareness, availability of materials, procurement, perceived inferior performance, perceived health, safety and environmental concerns, and cost.
- Section 4 provides an overview of the current and recent research undertaken via the NACOE research program, to further TMR's capabilities and knowledge in the use of recycled materials.
- Section 5 finalises the report, with discussion of the next steps for expanding recycled materials use in Queensland, including factors such as research and development, policy and strategy, procurement practices, capability building and knowledge sharing.

2 RECYCLED MATERIALS IN QUEENSLAND

2.1 TMR'S CURRENT APPROACH

TMR's current approach for the use of recycled materials in road construction is to facilitate their use as an alternative to the currently used 'conventional' materials (i.e. it is a choice of the contractor/supplier to choose to use either the conventional or recycled materials).

TMR aims to specify the use of recycled materials that:

- provide as good, if not better, performance than conventional materials (in the appropriate application)
- do not harm the environment, the community or workers
- do not cause operational issues in the longer term (such as contaminated land)
- are 're-recyclable' at the end of their life.

Materials that do not meet these criteria would not be permitted for use by TMR.

Typically, TMR has not mandated the use of recycled materials, the exception being the use of either fly ash or slag in concrete. Doing so without adequate research or before industry capabilities are sufficiently mature would likely increase the risk of undesirable outcomes (e.g. environmental issues, early failures). If these risks are realised early on, it may compromise the future use of these materials.

Mandating the use of recycled materials is undesirable for various reasons, including:

- The availability of the right quality/types of recycled materials varies over time and within the state. Mandating recycled materials may result in an increase in both costs and greenhouse gas (GHG) emissions as a result of them having to be transported from significant distances or imported.
- The availability of the right quantities of recycled materials is not always present. This includes materials being available at all as well as in the required quantities to complete medium to large scale construction projects.
- The capacity and capability of industry varies throughout the state. Mandating recycled materials may reduce competition for TMR work and lead to local suppliers being unable to tender on TMR projects.
- Mandating recycled materials reduces competition from conventional materials.
- Underdeveloped supply chains may experience significant pressure, which in turn may impact the long-term sustainable use of recycled materials.

TMR is currently considering opportunities to further optimise and encourage the use of recycled materials where they are:

- viable alternatives to conventional materials
- cost-competitive with conventional materials
- covered by TMR's standard specifications.

TMR allows the use of certain recycled materials in some road infrastructure applications. These include the use of crumb rubber, RAP, construction and demolition (C&D) waste, recycled crushed glass, fly ash, ground granulated blast-furnace slag, and in situ recycling of existing pavements. These materials are discussed further in Sections 2.2, 2.3, 2.4, 2.5 and 2.6. Recycled plastic as an emerging material is discussed in Section 2.7.

2.2 CRUMB RUBBER

Crumb rubber is recycled rubber derived from end-of-life tyres (Figure 2.1). At present, predominantly truck tyres are used as a source of crumb rubber.

End-of-life tyres are shredded (Figure 2.1) then further processed into a crumb (below 2.36 mm) to create crumb rubber (Figure 2.2). Crumb rubber for use in roads is ambiently ground, graded to conform to a specified particle size distribution and free of contaminants and moisture. A high-value application for these materials is in crumb rubber modified (CRM) binders for use in road construction (Figure 2.3). An estimated 1.1 million equivalent passenger units (equivalent weight of one passenger car tyre at end of life; 8kg) will be saved from landfill in TMR projects by June 2021, though the use of crumb rubber.

Figure 2.1: Shredded tyre stockpile



Figure 2.2: Crumb rubber



Figure 2.3: Crumb rubber modified binder



2.2.1 ALLOWABLE APPLICATIONS

Crumb rubber modified binder is currently included in TMR standards and specifications for use in Queensland in both sprayed sealing and asphalt applications, up to a maximum nominal concentration of 18% in some sealing applications.

Relevant specifications for the use of crumb rubber in Queensland are as follows:

- MRTS11, *Sprayed Bituminous Treatments (Excluding Emulsion) (July 2019)*
- MRTS18, *Polymer Modified Binder (Including Crumb Rubber) (July 2020)*
- Austroads ATS-3110-20, *Supply of Polymer Modified Binders*
- PSTS112, *Crumb Rubber Modified Asphalt*.

MRTS11 provides an approach to binder selection in which contractors may choose alternative binder classes (providing equivalent performance) to the specified class without the need for principal or contract administrator's approval. The approach enables contractors to select preferred binder classes based on financial and operational considerations, working to facilitate an increased use of alternative binders such as CRM binders.

Acceptable binder classes for sprayed sealing secondary treatments and re-treatments are outlined in Table 2.1.

Table 2.1: Acceptable binder classes for secondary treatments and re-treatments

Treatment type	Treatment label	Technical specification	Acceptable binder class
High stress single/single seal for medium traffic loadings	HSS1-M	MRTS18	S10E, S35E, S45R or S15RF
High stress single/single seal for heavy traffic loadings	HSS1-H	MRTS18	S15E, S45R or S15RF
High stress double/double seal for medium traffic loadings	HSS2-M	MRTS18	S10E, S35E, S45R or S15RF
High stress double/double seal for heavy traffic loadings	HSS2-H	MRTS18	S15E, S45R or S15RF
Extreme stress double/double seal	XSS	MRTS18	S20E, S45R , S15RF

Treatment type	Treatment label	Technical specification	Acceptable binder class
Strain alleviating membrane for slow moving cracks	SAM-S	MRTS18	S10E, S35E, S45R or S15RF
Strain alleviating membrane for rapid moving cracks	SAM-R	MRTS18	S15E, S45R or S15RF
Strain alleviating membrane interlayer	SAMI	MRTS18	S25E or S18RF
Waterproofing seal under asphalt	WP-A	MRTS18	S20E, S25E, S45R, S15RF or S18RF

Note: S45R, S15RF and S18RF are the binder classes in which crumb rubber is utilised.

Source: Adapted from MRTS11:2019

TMR has also developed a project-specific technical specification (PSTS) for open graded and gap graded asphalt that utilises a CRM binder containing approximately 18–20% crumb rubber. Several demonstration projects have been undertaken by TMR and local government using PSTS112. Further research regarding the use of crumb rubber modified asphalt is ongoing.

2.3 RECLAIMED ASPHALT PAVEMENT

When asphalt is removed for reconstruction or resurfacing (Figure 2.4), the materials generated containing bitumen and aggregates are processed (mainly through crushing and screening). The resulting material known as RAP (Figure 2.5) can be re-used for pavement construction.

Figure 2.4: Asphalt removal



Figure 2.5: Reclaimed asphalt pavement



As RAP contains residual binder, it is generally preferable to recycle RAP into asphalt as the residual binder reduces the quantity of virgin binder needed, leading not only to improved sustainability outcomes but also cost savings.

The use of RAP in asphalt has become standard practice in Australia and around the world. The use of RAP provides cost savings, reduces our reliance on raw aggregate and bitumen and diverts waste from landfill. In 2016–17 asphalt was the second most recycled material, behind concrete, across Queensland (Queensland Government 2018).

During removal, if care is not taken or removal of the existing pavement needs to happen quickly, RAP is often mixed with other material such as unbound granular pavement or subgrade. This 'second class' RAP is not suitable for re-use in asphalt; however, it can be incorporated into granular materials or used as fill.

2.3.1 ALLOWABLE APPLICATIONS

Current TMR specifications allow the incorporation of RAP into dense graded asphalt base, corrector and surfacing courses (but not in open graded and stone mastic asphalt), as well as in unbound materials

(including subtype 2.2, 2.3, 2.4 and 2.5 as well as UM2 and UM3 material used in plant-mixed foamed bitumen).

Relevant specifications for the use of RAP in Queensland are as follows:

Unbound pavements

- MRTS05, *Unbound Pavements*. (November 2020).

Stabilised pavements

- MRTS07B, *Insitu Stabilised Pavements using Cement or Cementitious Blends* (July 2020)
- MRTS07C, *Insitu Stabilised Pavements using Foamed Bitumen* (July 2020)
- MRTS08, *Plant-mixed Heavily Bound (Cemented) Pavements* (July 2020)
- MRTS09, *Plant-mixed Foamed Bitumen Stabilised Pavements* (July 2020)
- MRTS10, *Plant-mixed Lightly Bound Pavements* (July 2020).

Asphalt

- MRTS30, *Asphalt Pavements* (July 2020)
- MRTS32, *High Modulus Asphalt (EME2)* (October 2017)
- MRTS102, *Reclaimed Asphalt Pavement Material* (March 2019).

2.3.2 ASPHALT PAVEMENTS

RAP material may be utilised in dense graded asphalt; however, it shall not be utilised in stone mastic or open graded asphalt. Maximum allowable percentages of RAP in asphalt are outlined in Table 2.2.

While there are often calls to increase the use of RAP in asphalt with up to 100% RAP mixes being proposed, consideration needs to be given to the long-term sustainability of using very high levels of RAP in asphalt. In most of Queensland there is not enough RAP available to consistently produce very high RAP mixes, meaning that to facilitate very high levels of RAP in some asphalt, other asphalt would contain little to no RAP. Very high RAP mixes also require specialised asphalt plants and RAP handling processes. A more sustainable outcome may be to encourage the increased use of higher 'business as usual' levels of RAP in all asphalt.

Table 2.2: Allowable percentages of RAP material in dense graded asphalt

RAP approval level	Maximum percentage (%)
Surfacing course	
1S	15
2S	20
Other than surfacing course	
1	15
2	25
3	30
4	40

Source: Adapted from MRTS30:2020.

For dense graded asphalt mixes containing > 15% RAP, the contractor shall manage the viscosity of the binder blend by complying with one of two available methods outlined in MRTS30.

2.3.3 EME2 ASPHALT

Up to 15% (by mass of total mix) of RAP material may be utilised in high modulus asphalt (EME2). RAP material shall comply with MRTS102, as well as meeting additional binder requirements and a maximum aggregate particle size.

2.3.4 RECYCLED MATERIAL BLENDS FOR UNBOUND AND STABILISED PAVEMENTS

TMR allows the use of RAP in recycled material blends for unbound and stabilised pavements. The allowable percentages are shown in Table 2.3.

In these applications, RAP is blended with a combination of quarried, crushed concrete, crushed brick or crushed glass material and is sourced from a registered supplier.

Table 2.3: Allowable percentages for reclaimed asphalt pavement material in asphalt

Unbound material type 2	Maximum limit of RAP (per cent by mass of final mix)
Subtype 2.1	0
Subtype 2.2	15
Subtype 2.3	20
Subtype 2.4	20
Subtype 2.5	45

Source: Adapted from MRTS05:2020.

2.3.5 PLANT-MIXED PAVEMENT LAYERS STABILISED USING FOAMED BITUMEN

RAP may be included in unbound material Types UM2 and UM3, in the following percentages.

- Type UM2 – maximum 10% by mass
- Type UM3 – maximum 15% by mass.

RAP shall not be used in Type UM1 material. RAP material shall not contain tar binder or contaminants such as unbound granular base material, concrete, clay, soil or organic matter.

2.4 RECYCLED AGGREGATES

In addition to RAP, various recycled aggregates including concrete (Figure 2.6), glass (Figure 2.7) and brick (Figure 2.8) can be used as substitutes for natural and quarried aggregates and for sand. The allowable percentages are outlined in Table 2.4.

Figure 2.6: Crushed concrete



Figure 2.7: Crushed glass



Figure 2.8: Crushed brick



2.4.1 CRUSHED CONCRETE

This material is typically sourced from reclaimed concrete from buildings and other large structures. It principally consists of rock fragments coated with cement, crushed concrete mortar, and cementitious fines derived from cement mortar. Processing of crushed concrete involves the removal of contaminants such as steel, plastics, and timber as well as crushing and screening.

2.4.2 CRUSHED GLASS

Recycled crushed glass (RCG) is a product made from mixed recycled glass sourced from manufacturing and post-consumer waste; glass shall be sourced only from food and beverage container glass. The fragmented material comes in colour or colourless forms and its size varies depending on the chemical composition and method of production.

2.4.3 CRUSHED BRICK

Crushed material commonly obtained from C&D activities principally consists of crushed brick and may also include some crushed concrete and concrete mortar. TMR's current specifications set material property requirements that need to be managed during the crushed brick production for it to be suitable in pavements. Crushed brick is permitted to be used in unbound pavements subtypes 2.2, 2.3, 2.4 and 2.5.

Table 2.4: Allowable percentages of recycled aggregates

Application	Recycled material (maximum allowable percentage (%))			
	Crushed concrete	RCG	Crushed brick	RAP
Unbound pavement				
Subtype 2.1	100	0	0	0
Subtype 2.2	100	0	15	15
Subtype 2.3	100	20	20	20
Subtype 2.4	100	20	45	20
Subtype 2.5	100	20	45	45
Asphalt				
Dense graded asphalt (other than surfacing)	0	10	0	40
Dense graded asphalt (surfacing)	0	2.5	0	20
Bedding & backfill				
Bedding & backfill material	0	100	0	0

Source: Adapted from MRTS04, MRTS05 and MRTS30

Relevant specifications for the use of recycled aggregates in Queensland are as follows:

Unbound pavements

- MRTS05, *Unbound Pavements* (November 2020)
- MRTS36, *Recycled Glass Aggregate* (November 2020).

Stabilised pavements

- MRTS07B, *Insitu Stabilised Pavements using Cement or Cementitious Blends* (July 2020)
- MRTS07C, *Insitu Stabilised Pavements using Foamed Bitumen* (July 2020)

- MRTS08, *Plant-mixed Heavily Bound (Cemented) Pavements* (July 2020)
- MRTS09, *Plant-mixed Foamed Bitumen Stabilised Pavements* (July 2020)
- MRTS10, *Plant-mixed Lightly Bound Pavements*. (July 2020).

Asphalt

- MRTS30, *Asphalt Pavements* (July 2020)
- MRTS36, *Recycled Glass Aggregate* (November 2020)
- MRTS101, *Aggregates for Asphalt* (July 2020).

Backfill

- MRTS04, *General Earthworks* (November 2020)
- MRTS36, *Recycled Glass Aggregate* (November 2020).

2.5 FLY ASH AND GROUND GRANULATED BLAST-FURNACE SLAG

Fly ash (Figure 2.9) is an industrial by-product of coal combustion and can be used as a replacement for Portland cement in concrete production. Currently, it is permitted to be used as a supplementary cementitious material in concrete and pavements, as well as an asphalt filler. The use of fly ash improves the concrete's resistance to chlorides, sulphates, and carbonation. The use of fly ash is fundamental to the supply of economic and durable concrete in Queensland, especially to mitigate the risk of alkali-silica reactions.

Figure 2.9: Fly ash



Slag is an industrial by-product of iron and steel making. Like fly ash, slag is a supplementary cementitious material used as a replacement for Portland cement in concrete and pavements. Replacing cement with slag in concrete production enhances a range of performance characteristics such as the reduction of the heat of hydration, reduction of concrete permeability and improvement of its resistance to aggressive environments.

2.5.1 ALLOWABLE APPLICATIONS

Fly ash and slag (supplementary cementitious materials (SCMs)) may be used to replace the cement in concrete and stabilised pavements. The use of SCMs is mandatory under MRTS70. Fly ash may be used as a filler for asphalt.

Relevant specifications for the use of fly ash and slag in Queensland are as follows:

Stabilised pavements

- MRTS07B, *Insitu Stabilised Pavements using Cement or Cementitious Blends* (July 2020)
- MRTS08, *Plant-mixed Heavily Bound (Cemented) Pavements*

- MRTS09, *Plant-mixed Foamed Bitumen Stabilised Pavements* (July 2020)
- MRTS10, *Plant-mixed Lightly Bound Pavements* (July 2020).

Concrete

- MRTS39, *Lean Mix Concrete Sub-base for Pavements* (November 2018)
- MRTS40, *Concrete Pavement Base* (November 2018)
- MRTS70, *Concrete* (November 2018).

Asphalt

- MRTS103, *Fillers for Asphalt* (July 2017).

2.5.2 STABILISATION

Stabilisation is a process by which the properties of granular materials or earthworks are changed through the addition of a stabilisation binder or granular material improve properties to meet performance requirements. The use of stabilisation technology for pavement construction and maintenance is widely accepted as a cost-effective method for improving long-term performance, whilst reducing whole-of-life costs of pavements structures (Austroads 2019).

- Up to 70% of general purpose (GP) cement can be replaced with fly ash to make general purposed blended **(GB) cement for stabilisation** (Austroads 2020, MRTS07B:2020).

Typically, 70:30 or 60:40 cement/fly ash blends are used in cement stabilisation to produce lightly bound materials (Austroads 2020). There has been increased usage of 50:50 blends in cement stabilisation, and fly ash can be used up to 70% by mass of cementitious binder.

- Fly ash can be used in **soil stabilisation** including triple blends (Volker 2020). There is the potential that ground granulated blast furnace slag could be used in soil stabilisation.

Triple blend stabilisation is a subbase or subgrade treatment typically carried out on materials of medium plasticity by incorporating cement, fly ash and lime. This process increases the strength, and reduces plasticity index, permeability and shrink swell characteristics. Typical binder blends ratios are 40:30:30 and 30:30:40 of cement, fly ash, and lime, respectively. A technical note is currently under development by TMR to reflect best practice and advice on the use of triple blend stabilisation.

- Slow setting binders improve working times and mix designs for **lightly bound materials** (Austroads 2020).

The addition of fly ash to GP cement leads to longer setting times, without compromising the long-term performance of these materials. This allows longer working times for these materials, which can aid construction, especially where materials are needed to be transported from further afield. Ground granulated blast furnace slag can also be used to provide slow setting binders in combination with cement or hydrated lime.

The use of higher proportions of fly ash can increase the target binder contents needed to produce stabilised materials. This is especially relevant for lightly bound pavement materials which are designed to achieve a unconfined compressive strength (UCS) between 1 and 2 MPa at 28 days, and typically only require a very small amount of GP or low fly ash blend GB stabilising agents to meet this requirement, making the blend impractical to produce. Typically, industry reports needing a minimum of 1–1.5% stabilising agent (by mass) to ensure effective blending.

- Use in **foamed bitumen** can improve the properties of stabilised materials.

In situations where foamed bitumen stabilised materials have struggled to meet the mix design requirements, fly ash has been added as an additional supplementary binder. The addition of fly ash has been used where certain aggregate geologies have been found to be incompatible with the standard

binder combinations. This approach has been found to improve the strength gain and enable mix design curing requirements to be met for problematic geologies.

2.5.3 FILLERS FOR ASPHALT

When used as a filler in asphalt, fly ash shall comply with AS/NZS 3582.1:2016, *Supplementary Cementitious Materials: Fly Ash*.

2.5.4 CONCRETE PAVEMENT BASE

Aggregates for base concrete shall consist of clean, durable materials sourced from natural gravel, crushed stone, air-cooled iron blast furnace slag and sand. Supplementary cementitious material shall be fly ash and/or ground granulated blast furnace slag from the production of molten iron. Usage limits are outlined in Table 2.5.

Table 2.5: Supplementary cementitious material

Blend	Alkali-silica reactivity (ASR) class	Limits*	
		Minimum (%)	Maximum (%)
Fly ash (FA)	Non-reactive	15 – (0.5 x GGBFS%)	40 – (0.5 x GGBFS%)
	Reactive	20 – (0.5 x GGBFS%)	
Ground granulated blast furnace slag (GGBFS)	Non-reactive	10 – (2.0 x FA%)	65 – (2.0 x FA%)
	Reactive	40 – (2.0 x FA%)	

*By mass relative to total cementitious material.

Source: Adapted from MRTS40:2018.

Fly ash for use in concrete pavement base shall comply with:

- AS/NZS 3582.1:2016, *Supplementary Cementitious Materials: Fly Ash*
- ATIC-SPEC SP43:2017, *Cementitious Materials for Concrete*.

Slag for use in concrete pavement base shall comply with:

- AS 3582.2:2016, *Supplementary Cementitious Materials: Slag Ground Granulated Blast-furnace*
- ATIC-SPEC SP43:2017, *Cementitious Materials for Concrete*.

2.5.5 LEAN MIX CONCRETE SUBBASE FOR PAVEMENTS

The use of a minimum of 40% fly ash is mandatory in lean mix concrete subbase for pavements. Fly ash shall comply with AS/NZS 3582.1:2016.

2.5.6 CONCRETE

Fly ash and slag may be used in cementitious blends. The allowable percentages are outlined in Table 2.6.

Table 2.6: Cementitious blends

Blend	General purpose (GP) Cement	Fly ash	Slag	Amorphous silica
a	65–75%	25–35%		
b	50–55%	25–30%	20–25%	
c	65–71%	25–31%		4–8%
d	30–40%		60–70%	

Source: Adapted from MRTS70:2018.

Fly ash for use in concrete shall comply with:

- AS/NZS 3582.1:2016, *Supplementary Cementitious Materials: Fly Ash*
- ATIC-SPEC SP43:2017, *Cementitious Materials for Concrete*.

Slag for use in concrete shall comply with:

- AS 3582.2:2016, *Supplementary Cementitious Materials: Slag Ground Granulated Blast-furnace*
- ATIC-SPEC SP43:2017, *Cementitious Materials for Concrete*.

2.6 IN SITU RECYCLING

TMR has been utilising in situ recycling for decades; however, it is often overlooked as a form of recycling. TMR uses in situ recycling to continually maintain the road network, and it offers benefits as a cost-effective approach, reducing material haulage, generation of waste and use of virgin materials.

2.6.1 IN SITU STABILISATION

In situ stabilisation is the blending of existing materials with stabilising agents (including fly ash, slag, lime, foamed bitumen, and cement) to strengthen and rejuvenate the soil and/or pavement structure without removing the material. The benefits of this process may include reduced use of non-renewable resources, reduced waste, reduced material haulage requirements, improved performance of existing materials, improved durability and flood resistance of existing pavements and reduced construction time.

Relevant specifications for in situ stabilisation in Queensland are as follows:

- MRTS07A, *Insitu Stabilised Subgrades using Quicklime or Hydrated Lime (July 2020)*
- MRTS07B, *Insitu Stabilised Pavements using Cement or Cementitious Blends (July 2020)*
- MRTS07C, *Insitu Stabilised Pavements using Foamed Bitumen (July 2020)*.

2.6.2 HOT-IN-PLACE ASPHALT RECYCLING

Hot-in-place asphalt recycling (HIPAR) is used to recycle an existing asphalt pavement. A mobile recycling plant heats, scarifies, remixes, re-lays and compacts the top asphalt layer. New binder, asphalt mix or aggregate, recycling additives, or combinations of these may be added to obtain an end product with the desired characteristics. The benefits of HIPAR may include reduced consumption of virgin materials, reduced waste, minimised traffic disruptions and reduced costs.

Currently, there is no TMR standard specification for HIPAR; however, guidance may be found in TMR's *Pavement Rehabilitation Manual* (Section 4.4.14) (Queensland Department of Transport and Main Roads 2020a).

2.6.3 IN SITU RECYCLING IN CONCRETE PAVEMENTS

Rubblisation and 'crack and seat' are two methods intended to rehabilitate concrete pavement with substantial fault cracks, loss of load transfer with associated faulting, shearing of longitudinal tie bars or any combination of these. Currently, there is no TMR standard specification for in situ concrete pavement recycling; however, guidance is provided in TMR's *Pavement Rehabilitation Manual* (Section 4.8.2) (Queensland Department of Transport and Main Roads 2020a) and trials are currently underway.

Rubblisation

The rubblisation method is used to rehabilitate and recycle existing concrete pavements by fracturing the pavement into small, interlocking pieces. The fractured pieces are compacted with a roller, onto the underlying pavement layer. If required, the rubblised material may be removed for further processing. Lastly, a thick asphalt overlay is applied.

Crack and seat

The 'crack and seat' method involves fracturing concrete pavements at regular intervals. The pieces are then rolled to 'seat' on to the underlying pavement layer. A thick asphalt overlay is subsequently applied. This method fractures the pavement into larger pieces than rubblisation and therefore requires less effort to achieve; however, associated challenges may include the fracture segments reflecting through the asphalt overlay.

2.7 PLASTICS

TMR is investing in research to understand the opportunities for incorporating recycled plastics into road infrastructure. Across Australia, recycled plastics (Figure 2.10) in roads is emerging as a point of focus for research, as well as within industry with a number of proprietary products already being developed and marketed commercially.

Figure 2.10: Recycled plastic



Early research has shown that addressing the waste plastics problem in Australia (and internationally) is complex. There is significant variability in the waste streams for plastics, and there is a need for industry to develop sorting and handling processes to produce 'road grade' recycled plastics. There is reluctance from industry, however, to invest in these initiatives until end uses and markets have been established.

The recycled plastics targeted for use in roads, such as polyethylene terephthalate (PET), high-density polyethylene (HDPE) and low-density polyethylene (LDPE), are typically sourced from post-consumer waste. Post-consumer waste is usually co-mingled and often contains a large amount of contamination. There is also a significant post-industrial waste stream which is more likely to be single-resin plastics with lower levels of contamination. Care needs to be taken to ensure that waste plastics are recycled into their highest and best use in line with circular economy principles.

Prior to allowing the widespread use of recycled plastics in roads, there are a number of aspects that need to be addressed – these include:

- ensuring that any use of recycled plastic provides performance and durability that is equal to or better than the equivalent conventional material
- managing the risks of causing harm to the environment, community and workers during both construction and in operation
- ensuring storage stability and handling (when used in bitumen and asphalt)
- ensuring the materials are suitable for re-recycling at end of life without excessive additional requirements
- developing standards and guidelines to procure these materials, since conventional specifications and procurement policies may not be applicable as a result of the materials' predominantly proprietary nature at present.

Key steps recommended to address these areas of concern are to:

- better understand the plastic waste stream and the plastics that may be most suitable for use in roads
- identify 'priority uses' for waste plastics in roads – noting the importance of establishing multiple opportunities (rather than just in asphalt as has been the current focus)
- collaborate with industry to improve the waste streams for the types of plastics that are beneficial for use in roads
- develop a holistic assessment framework for the use of recycled materials in roads and related infrastructure, and by doing so, provide a way to assess asphalt products that include recycled plastic
- investigate sustainability, environment, and safety issues
- investigate cost and performance impacts
- test and ascertain the performance and durability of materials containing recycled plastics – benchmark this against current materials, including polymer modified bitumen
- develop an implementation plan.

These steps need to be completed so that TMR can use recycled plastics responsibly, balancing risks to the community and environment against community needs related to recycling and sustainability. As part of the next steps, TMR, in collaboration with Main Roads Western Australia (MRWA) and ARRB under the NACOE and Western Australian Road Research and Innovation Program (WARRIP³) agreements, are investigating the use of recycled and reclaimed plastics in safe and sustainable future road infrastructure to address the areas of concern listed above.

2.7.1 POTENTIAL APPLICATIONS

Recycled plastics are currently not covered under TMR standards and specifications. However, some potential uses may include:

- asphalt and sprayed seals
- geosynthetics and geogrids
- railway sleepers
- bike paths and footpaths
- noise and retaining walls
- pipes, conduits, and pits
- fencing, barriers, bollards, wheel stops and kerbs
- signage and other roadside furniture
- safety accessories (such as traffic cones)
- drinking fountains, bins, tables, seats, artwork, garden edging, tree stakes, and architectural screens
- structural and non-structural lumber – including for formwork, wharves, jetties, decking, etc.

2.7.2 RECYCLED PLASTICS IN ASPHALT

The use of recycled plastics in asphalt has become a high-profile potential use due largely to the development of a number of proprietary products and the trialling of these products on projects across Australia.

To date no agreed approach has been developed for the use of these products; however, research is underway under both a joint NACOE/WARRIP project and a project being undertaken by RMIT on behalf of Austroads (APT6305 *Use of Road-grade Recycled Plastics for Sustainable Asphalt Pavements*).

³ WARRIP is a research partnership between ARRB and Main Roads Western Australia (MRWA).

A number of key considerations for this research include:

- health, safety and environmental impacts, such as potential fuming, microplastic generation, leaching and re-recyclability
- techniques for incorporating waste plastics – including wet, dry and hybrid methods
- performance and durability compared to conventional and polymer modified asphalt
- GHG emissions and whole-of-life cost comparisons
- the development of a specification that facilitates the procurement of suitable products, recognising that many will be proprietary (this is likely to be a performance-based specification benchmarked against conventional and polymer modified asphalt).

Research to date has also shown that the use of recycled plastics in asphalt alone will have a limited impact on the waste stream and needs to be developed in line with other applications. For example, if 6% (by mass) waste plastic were added to the 800,000 tonnes of bitumen used annually in Australia, this would use approximately 48,000 tonnes of waste plastic. This would total less than 2% of the waste plastic generated annually in Australia. In reality, a significant proportion of Australia's bitumen use is in sprayed seals, which is less likely to be suited to the inclusion of waste plastics and better suited to the increased use of other recycled materials such as crumb rubber. Much of the remaining bitumen, used in asphalt, may not be suitable for the incorporation of waste plastics. A more realistic assumption on the use of waste plastic in asphalt would be significantly less than 1%.

The use of polymer modified binders (PMBs) in asphalt and sprayed seal surfacings is widely used across the TMR road network. The use of these high-performance binders, as opposed to unmodified bitumen binders, has become increasingly necessary due to the ever-increasing number of heavy vehicles using the road network. The use of these binders also increases the time between resurfacing treatments, as well as providing better performance (i.e. reduced risk of premature failures) – especially in situations where improved resistance to cracking, ravelling or deformation is required.

Most research into the use of recycled plastic in asphalt to date has compared the performance benefits to unmodified binders.

When making comparisons regarding performance, cost, etc., it is important to consider how these mixes (which contain recycled plastic) compare to mixes containing:

- unmodified bitumen binder
- conventional polymer modified binders.

The suitability of mixes containing recycled plastics will need to be compared against the default standard design solution (i.e. unmodified bitumen binder or conventional PMB) to determine its appropriateness for a specific application.

3 BARRIERS FOR THE USE OF RECYCLED MATERIALS

The main barriers to the use of recycled materials across TMR's network include:

- awareness
- availability of materials
- procurement
- perceived inferior performance
- perceived health, safety and environmental concerns
- cost.

3.1 AWARENESS

As mentioned earlier, TMRs current approach to the use of recycled materials is to facilitate their use as alternatives to conventional materials. Essentially this means that contractors must choose when and if to use recycled materials on projects rather than being specifically asked to do so by TMR.

As such, contractor awareness of the allowable uses of recycled materials is a barrier that may inhibit use. This barrier can emerge where contractors lack awareness around the types of materials that may be used for various applications, the allowable percentages and how to utilise materials. Furthermore, different processes may arise for recycled materials, compared to conventional materials, that may require subtle adjustments in contractor processes, additional awareness, or training.

Similarly, disconnect within the levels of the supply chain can reduce access to recycled material resources – for example, if head contractors do not ask for recycled material alternatives, suppliers will not develop their capability to offer them. Adequate dissemination of new knowledge and results from demonstration trials of new products, such as through technical notes, webinars and presentations, is key to developing and improving industry awareness.

NACOE places a large amount of focus on knowledge dissemination and building awareness around the research and development efforts of the program, to enable implementation of new products and processes. One of the NACOE strategic objectives is development, including developing the capabilities of staff and disseminating learnings to regions. Webinars, presentations, and training are regularly undertaken, enabling this necessary sharing of knowledge. NACOE research reports and guides are also readily available online⁴.

The implementation of Infrastructure Sustainability Council of Australia (ISCA) ratings on TMR projects larger than \$100 million has created an increase in contractors' interest into the use of recycled materials; however, usage still remains relatively low especially outside of south-east Queensland.

3.2 AVAILABILITY OF MATERIALS

Further to awareness, availability is also a key barrier for Queensland. TMR's network is expansive, while Queensland's population is generally concentrated in the south-east corner of the state and along the east coast, with inland and northern parts of the state being quite isolated. As such, the collection and recycling of waste can be logistically difficult or even uneconomical outside of the larger population centres; therefore, access to recycled material sources within adequate distance may be a barrier. Furthermore, the materials sourced also need to meet the contamination and quality requirements in place within TMR's suite of standards and specifications. For example, the removal of potential contaminants such as plastic and metal

⁴ <https://www.nacoe.com.au/publications/>

lids, paper bottle labels, sugar residue, and other contaminants may be required for the use of recycled aggregate.

Additionally, where materials are recycled, available quantities will be limited by local waste generation. Given the significant quantities of materials required for most road construction projects, the use of 100% recycled materials may not be feasible without needing to import material leading to both a less sustainable and more costly outcome. It is crucial that transport of all materials be reduced and that local materials are used where suitable. Therefore, it is crucial to outline that the use of recycled materials may not always be the most appropriate nor most sustainable approach if local sources are not available.

3.3 PROCUREMENT

Procurement can also be a significant barrier to the use of recycled materials, that is somewhat aligned with awareness. TMR's current approach is to facilitate the use of recycled materials as an alternative to conventional materials; however, this relies on contractor awareness. Embedding the use of recycled materials into TMR's procurement practices and decision making would help move from an approach that facilitates the use of recycled materials to an approach that optimises the use of recycled materials. This has recently been demonstrated by the Victorian government's *Recycled First* policy which requires that:

- bidders must demonstrate how they will optimise the use of recycled and re-used materials
- contractors must report on the types and volumes of recycled and re-used products they use.

The *Recycled First* policy will not set mandatory minimum requirements or targets. Instead, a project-by-project approach will allow contractors to liaise with recycled materials suppliers to determine if there are adequate supplies of the necessary products for their project.

To facilitate an effective procurement approach, TMR would also need to work with:

- industry to build the capability to supply and construct infrastructure with recycled materials
- government partners to reduce green tape and increase industry confidence.

3.4 PERCEIVED INFERIOR PERFORMANCE

Perceived inferior performance is another barrier that may impact the use of recycled materials across TMR's network. This barrier is tackled through TMR's specification and research approach. TMR aims to specify the use of recycled materials to ensure equivalent if not better performance. It is crucial, when having a sustainable approach, that materials used do not reduce service life. Furthermore, the dissemination of research findings and new knowledge through NACOE's research program and the variety of available publications, webinars and presentations, provide contractors and the public with the adequate resources to make informed decisions about the use of emerging materials and their performance.

3.5 PERCEIVED HEALTH, SAFETY AND ENVIRONMENTAL CONCERNS

Work health and safety concerns are another perceived barrier associated with recycled materials. This may include the environmental impacts, such as leaching, and health and safety considerations for workers and the community. For example, environmental and health impacts were a concern associated with the use of recycled glass. Through NACOE project P76 *The use of Recycled Glass in Pavements*, comprehensive research has been undertaken to determine the impacts of recycled glass, finding that when it is processed and handled correctly, recycled glass does not pose an increased risk of exposure to respirable crystalline silica, compared to natural and manufactured sand.

Managing environmental, health and safety concerns is achieved through sufficient research into new materials, i.e. emissions monitoring and leaching, demonstration trials with sufficient monitoring, the

appropriate use of personal protective equipment (PPE) and developing appropriate standards, specifications and safe working methods.

3.6 COSTS

Cost implications are another factor associated with recycled materials. Novel applications of materials are often more expensive, whereas over time, widespread use of materials as markets mature can offer reductions in costs. Investment from TMR, through research (i.e. the NACOE research program), financing of demonstration trials and acceptance of risk, ensures new markets are facilitated and emerging materials can be introduced into common practice.

As materials become more common place cost benefits may be realised. For example, across Queensland the use of CRM binder is often found to provide a cost saving compared to conventional PMBs typically used on the network. As aforementioned, TMR does not mandate the use of recycled materials under majority circumstances, allowing contractors to choose materials that may provide a beneficial cost outcome.

4 KEY AREAS FOR ONGOING AND FUTURE RESEARCH

Currently, much of the potential to use recycled materials is in road pavements. However, some potential uses exist in other areas, such as geotechnical (e.g. earthworks) or structural engineering (e.g. concrete) applications. Future use in other applications (e.g. road furniture) may be possible following further research.

The NACOE development program incorporates assessment of engineering feasibility, workplace and community health and safety, environmental risks and the end of life uses of the materials, i.e. re-recyclability.

Current NACOE projects associated with the use of recycled materials include:

- *O20 Recycled Materials Assessment Framework*
 - This project involves implementing a wholistic recycled materials assessment process to assist in the use of new or innovative recycled materials. The project has a specific focus on reviewing Queensland's WHS and environmental legislation and on supporting Queensland Government's Waste Reduction and Resource Recovery Strategy's objective to become a zero-waste society.
- *O25 Use of Recycled Materials in Earthworks and Drainage*
 - This research focuses on ways to re-utilise waste materials as road embankments and drainage materials. The project will review local and international literature, existing practice across Australian state road agencies and will look to provide a specification framework. Materials to be assessed include C&D waste, glass, recovered pavement materials, railway ballast and bottom ash.
- *P75 Transferring Crumb Rubber Modified Gap Graded Asphalt Technology to Queensland*
 - In this project, NACOE is working alongside the City of Gold Coast, implementing a crumb rubber modified gap graded asphalt demonstration trial.
- *P76 The use of Recycled Glass in Pavements*
 - This project focuses on optimising the use of glass across TMR's network. The research includes environmental and performance-based research, and outcomes have included amendments to *MRTS30 Asphalt Pavements* and *MRTS101 Aggregates for Asphalt*, as well as advice on the development of *MRTS36 Recycled Glass Aggregate*, which now applies to unbound granular pavements, backfill and asphalt.
- *P94 Optimising the use of Recycled Materials in Unbound and Stabilised Pavements in Queensland*
 - This project is reviewing the best practice approach for specifying recycled unbound pavement materials, including reviewing national standards and undertaking laboratory characterisation and performance testing of recycled material blends. The outcomes of this project have already led to specification updates to produce a single specification for natural, quarried and recycled materials and optimised the use of secondary recycled materials, including up to 20% recycled crushed glass.
- *P106 (Part 2) Assessing the Potential Greenhouse Gas Emissions Reductions and Sustainability Benefits of Innovative Pavement Solutions*
 - This project is extending the outcomes from P106 (Part 1) to assess the GHG and economic benefits of using warm mix asphalt and recycled glass in pavements.
- *P111 Improved Crumb Rubber Modified Binder Sprayed Sealing Practices*
 - This project aims to review and develop best practice guidelines for sealing with CRM binders. This research will support improved practice around the use of crumb rubber in sprayed sealing and work toward further improving performance. This work will investigate sprayer calibration practices, construction practices (including quality control and assurance) and sealing equipment (e.g. sprayers, tankers).

- *P116 Recycled Materials in Roads – Queensland State of Play*
 - In addition to this report, the outcomes of this project have included the development of TMR's Technical Note 193 *Use of Recycled Materials in Road Construction* (TN193) as well as the Recycled Materials factsheet which can both be found on TMR's *Building Sustainable Roads* website⁵.
- *P117 Sustainability Assessment Tool*
 - This joint venture project between NACOE and WARRIP is developing a user-friendly sustainability assessment tool that may be used to calculate GHG emissions and life-cycle cost benefits of various pavement technologies. The tool will facilitate the comparison of innovative technologies against traditional materials, quantify sustainability outcomes providing value for money indicators, and support procurement decisions.
- *P120 Investigating the use of Recycled and Reclaimed Plastic in Safe, Sustainable Future Road Infrastructure*
 - This joint venture project between NACOE and WARRIP is working to identify and develop the potential uses for recycled plastics in road construction.
- *S51 Suitability of the Use of Recycled Aggregate in Concrete*
 - This project is examining the feasibility of using recycled aggregates, including recycled crushed concrete and glass in non-structural concrete.

Completed NACOE projects associated with the use of recycled materials include:

- Completed 2019: *P106 (Part 1) Assessing the Potential Greenhouse Gas Emissions Reductions and Sustainability Benefits of Innovative Pavement Solutions*
 - This project (Brownjohn et al. 2019) modelled the economic and environmental benefits of alternative and innovative pavement materials and technologies, with a focus on GHG emissions. The technologies studied included high modulus asphalt (EME2), RAP, crumb rubber modified asphalt and crumb rubber modified sprayed seals, stabilisation practices (including foamed bitumen stabilisation) and marginal materials.
- Completed 2018: *P57 Implementing the use of Reclaimed Asphalt Pavement (RAP) in TMR Registered Dense Grade Asphalt Mixes*
 - This research (Yousefdoost et al. 2018) worked to facilitate the increased usage of RAP, through greater confidence in the design and performance of asphalt mixes containing higher proportions of RAP. The work also included laboratory analysis, evaluating the variability of RAP supplied to TMR.
- Completed 2018: *P31 and P32 Optimising the use of Crumb Rubber Modified Bitumen in Seals and Asphalt*
 - The aim of this research (Denneman et al. 2015, Grobler et al. 2017) was to identify the opportunities available to Queensland for using crumb rubber technologies in sprayed seal and asphalt applications. Queensland has successfully implemented widespread use of crumb rubber in sprayed seals and is continuing to conduct research in the asphalt space.

4.1 EMERGING TECHNOLOGIES

Additional to the existing research program encompassing a broad range of recycled and reclaimed materials, there are some emerging materials that are arising in Australia and worldwide, which are of interest in terms of future research scopes.

Bottom ash is a material output generated from coal power stations and Energy from Waste (EfW) facilities. EfW is a growing technology across Australia in the waste management sector, whereby waste is processed

⁵ <https://www.tmr.qld.gov.au/Buildingsustainableroads>

via incineration, gasification or pyrolysis. EfW bottom ash is common in Europe, with its greatest potential for use as an unbound granular material. There are a number of projects in progress across Australia, with the most progressed projects including a 400,000-tonne facility under construction in Kwinana, south of Perth, and another facility set for construction in the Latrobe Valley, east of Melbourne. The technology is similarly emerging in Queensland, with a project proposed near Ipswich, west of Brisbane.

As well as generating bottom ash, such plants will generate fly ash, which has potential uses as a supplementary binder. The plants are also likely to generate biochar which could have potential for use as a bitumen or asphalt modifier, or even for use in the creation of rejuvenating oils for facilitating incorporation of RAP in asphalt. The by-products generated by EfW plants will need to be fully characterised, especially as their composition is likely to be dependent on the input waste stream. Particular attention will have to be paid to the WHS and environmental impacts from the use of these by-products. As more experience in the Energy from Waste sector is generated, it is likely there will be the opportunity to tailor the outputs to suit potential road infrastructure applications. This could be related to the ratio of biochar to bottom ash produced, or the resultant properties of the by-product constituents themselves. This is likely to be a function of the input stream, but also processing techniques, durations, and temperatures.

PLASTICS

As previously mentioned, work is also underway covering more emerging materials such as recycled plastics. P120 *Investigating the use of Recycled and Reclaimed Plastic in Safe, Sustainable Future Road Infrastructure* is progressing, identifying and developing the potential uses for recycled plastics in road construction. This project is a joint venture between NACOE and WARRIP. The key objectives of this research include:

- identifying plastic waste streams that may be viable for recycling into road infrastructure applications
- encouraging the packaging industry to consider the types of plastics that are being produced and the potential to produce/recover more plastics that could be recycled into road applications
- understanding the performance of recycled plastics relative to conventional materials
- managing the risks of causing harm to the environment, community and workers during manufacture, construction and operation
- ensuring the materials are suitable for re-recycling without excessive additional requirements
- undertaking and monitoring trials and demonstrations of the use of recycled plastics in roads
- where appropriate, developing standards and guidelines to procure these materials, noting that they are predominantly proprietary and may be difficult to address with conventional specifications.

5 NEXT STEPS FOR RECYCLED MATERIALS IN QUEENSLAND

Queensland is making strides in the implementation of recycled materials, with the use of crumb rubber in sprayed sealing; RAP, crushed concrete, brick, and glass in unbound pavements; and RAP, glass and fly ash in asphalt well established. TMR have, over the last few years, been updating specifications to facilitate the use of recycled materials. Furthermore, research is underway regarding emergent materials, such as bottom ash, and plastics, and into furthering recycled material usage for earthworks, drainage and backfill.

The main barriers to the use of recycled materials across TMR's network include awareness; availability of materials; perceptions of inferior performance; health, safety and environment issues; procurement; and cost.

Many of these barriers are being tackled through the research and implementation projects via the NACOE program, including environmental assessments, economic evaluation, knowledge dissemination, and TMR's work in standards and specification development. As part of this project, TMR has developed a summary of resources⁶ to outline the opportunities in standards and specifications where recycled materials may be used, including a Recycled Materials factsheet (Queensland Department of Transport and Main Roads 2020b) and technical note TN193.

Additional opportunities to address these barriers and to help improve the use of recycled materials include:

- developing policies and strategies to optimise the use of recycled materials
- embedding the use of recycled materials into TMR's procurement practices and decision making
- working with industry to build the capability to supply and construct infrastructure with recycled materials
- working with government partners to reduce green tape and increase industry confidence
- knowledge sharing and dissemination of new findings.

Queensland, like many other states, has committed to applying the ISCA ratings process on all new large-scale infrastructure projects. The ratings process awards an ISCA score for the level of sustainability and innovation achieved by the projects (in either the design or 'as-built' phases). Credits are awarded for the sustainable use of materials, reductions in GHG emissions and for innovation. Recycled materials are not the only way in which to achieve ISCA credits, therefore there is also a need to drive change in the use of recycled materials through targeted approaches.

In their 2020 Impacts Report (Infrastructure Sustainability Council of Australia 2020) ISCA discusses the development of 'EcologiQ' within the Major Transport Infrastructure Authority, the leader of major infrastructure projects in Victoria, which is being used to drive change in the use of recycled and re-used materials in both road and rail. EcologiQ is an initiative leading the implementation of the *Recycled First* policy, where major projects are required to demonstrate how optimisation of recycled and re-used materials will be achieved in their works. The policy does not mandate use of any one specific recycled material, nor are there minimum percentages in place, which provides the opportunity to use materials suitable for each individual application and project location.

This initiative is a benchmark of one approach that can tackle some of the barriers associated with recycled materials, such as contractor awareness and location, through policy and governance. Policy has a strong impact on the optimisation of recycled materials in the road industry moving forward and can be successfully engaged to encourage and support innovation and capability development within industry and collaboration along the supply chain.

⁶ Recycled Materials factsheet and TN193 *Use of Recycled Materials in Road Construction* may be accessed at <https://www.tmr.qld.gov.au/Buildingsustainableroads>

Additionally, to further the understanding of the overarching sustainability impacts of recycled material use, there are a number of initiatives that are underway to build industry capability.

The development of the Sustainability Assessment Tool (SAT) through NACOE project P117, will provide a resource for TMR to calculate GHG emissions and life-cycle cost benefits of pavement technologies. Resources such as the SAT are key in drawing together the economic and environmental factors when considering use of new, innovative materials, in comparison to traditional technologies.

Additionally, the Australian flexible Pavement Association (AfPA) is presently developing a Sustainability Framework for Asphalt (SF4A), providing a simplified resource for industry in assessing environmental factors (Global Asphalt Pavement Alliance 2020). Through the development of the toolkit, AfPA aims to simplify the changes required in industry as sustainability and recycled materials become increasingly important within the asphalt sector. The framework draws on guidance from Europe (European Asphalt Pavement Association's guidance on Environmental Product Declarations (EPDs)) and the United States (National Asphalt Pavement Association/ Federal Highway Administration Sustainable Pavements initiatives).

Two components of the SF4A have been developed and are part of the implementation phase. These are titled Plant and Organisation, respectively. A third component, Road Project, is in development. SF4A provides a way to assess and rank bituminous product plants, organisations and products across Australia and intends to support setting qualitative and quantitative metrics for reduction of GHG emissions and waste.

As research and development of innovative products continue, knowledge sharing, policy and governance, and the overarching tools for the evaluation of the sustainability impact, from an environmental and economic standpoint, will be ever important to the optimisation of recycled material use across TMR's road network.

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STANDARDS AND TEST METHODS

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- AS 3582.2:2016, *Supplementary cementitious materials: slag ground granulated blast-furnace*.
- ATC-SPEC SP43:2017, *Cementitious materials for concrete*.
- ATS-3110-20, *Supply of polymer modified binders*.
- MRTS04:2020, *General earthworks*.
- MRTS05:2020, *Unbound pavements*.
- MRTS07A:2020, *Insitu stabilised subgrades using quicklime or hydrated lime*.

MRTS07B:2020, *Insitu stabilised pavements using cement or cementitious blends.*

MRTS07C:2020, *Insitu stabilised pavements using foamed bitumen.*

MRTS08:2020, *Plant-mixed heavily bound (cemented) pavements.*

MRTS09:2020, *Plant-mixed foamed bitumen stabilised pavements.*

MRTS10:2020, *Plant-mixed lightly bound pavements.*

MRTS11:2019, *Sprayed bituminous treatments (excluding emulsion).*

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MRTS30:2020, *Asphalt pavements.*

MRTS32:2017, *High modulus asphalt (EME2).*

MRTS36:2020, *Recycled glass aggregate.*

MRTS39:2018, *Lean mix concrete sub-base for pavements.*

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MRTS70:2018, *Concrete.*

MRTS101:2020, *Aggregates for asphalt.*

MRTS102:2019, *Reclaimed asphalt pavement material.*

MRTS103:2017, *Fillers for asphalt.*

PSTS112:2019, *Crumb rubber modified asphalt.*

TN193:2020, *Use of recycled materials in road construction.*