DELIVERING FOR QUEENSLAND

Technical Note 193

Use of recycled materials in road construction

December 2025

Queensland Government

1 Background

The Department of Transport and Main Roads' vision is to become a zero-waste organisation and transport industry leader through circular economy practices (see Section 2 of Transport and Main Roads' *Waste 2 Resource Strategy*).

While research is continuing, the department already has a long history of using recycled materials to reduce waste and emissions to deliver sustainable and reliable transport infrastructure, however, in recent years, the importance of, and interest in, using recycled materials has increased. For example, in addition to the department's own strategy (see Section 2 of this document):

- Queensland currently has a *Waste Management and Resource Recovery Strategy* (Waste Strategy)
- A draft new *Queensland Waste Strategy 2025-2030 – Less Landfill, More Recycling* has been developed and consulted, with the final version expected to be finalised in mid to late 2025, and
- Infrastructure and Transport Ministers agreed in June 2023 to establish a national working group to undertake specific work related to decarbonisation of transport infrastructure (Communique For Infrastructure and Transport Ministers' Meeting Friday, 9 June 2023 – see https://www.infrastructure.gov.au/infrastructure-transport-vehicles/transport-strategy-policy/infrastructure-and-transport-ministers-meetings).

The appropriate use of recycled materials supports the creation of a circular economy and is one way of helping decarbonise and improve the sustainability of transport infrastructure.

This document provides guidance on the use of recycled materials in road construction using Transport and Main Roads Technical Specifications, as well as a brief summary of some of the current areas of research and where demonstration projects have been done or are desired to progress a particular use case.

The benefits of incorporating recycled materials in the construction, rehabilitation and maintenance of Queensland roads include:

- reducing the amount of waste sent to landfill
- reducing illegal dumping and littering
- reducing the greenhouse gas emissions generated by the production of new materials and the disposal of waste materials (and so helping to decarbonise transport infrastructure)
- reducing our reliance on non-renewable resources

- helping to develop a circular economy where materials are continually reused in their highest and best use
- supporting jobs and growing the economy through the development of new products, industries and employment derived from waste and recycling resources
- potentially reducing short- and long-term costs, and/or
- maintaining and potentially improving network performance.

2 Waste 2 Resource Strategy

Transport and Main Roads recognises that reducing Queensland's waste generation while maximising resource recovery is a priority and has published its *Waste 2 Resource (W2R) Strategy* to outline its approach in this area. It sets the department's strategic direction and intent to minimise waste and ensure sustainable use of resources across the department.

This document supports the department's W2R Strategy as does implementation the W2R tender schedule (see Section 2.1 of this document) on selected contracts and the use of the department's W2R calculator (see Section 2.2 of this document). Together they indicate to industry the department's commitment to circular economy practices.

2.1 W2R tender schedule

Transport and Main Roads has developed a C7810.S12.TIC Tender Schedule S12 *Waste to Resource Plan* (W2R tender schedule) that needs to be completed for all tenders on Transport Infrastructure Contracts (TICs) and Minor Infrastructure Contracts (MICs). It identifies where there is potential for recycled materials to be used (as per the department's Technical Specifications). Each tenderer for a TIC and MIC contract needs to complete the W2R tender schedule as part of its tender. The tenderer, for each listed product must:

- nominate the quantity / percentage of recycled materials proposed for use to complete the works, and
- if not proposing to use the maximum quantity / percentage of recycled materials permitted by the department's Technical Specifications, providing reasons as to why this is the case.

(The W2R tender schedule also includes a table where tenderers provide an estimate of waste that will be generated by the project.)

The W2R tender schedule supports the department's W2R Strategy.

2.2 W2R calculator and waste reporting

The data collected from Transport and Main Roads' W2R calculator directly supports the department's W2R Strategy by tracking progress against diversion targets. It assists infrastructure projects to fulfil waste reporting requirements and to better plan, manage and reduce waste disposed to landfill. (The W2R calculator was previously known as the Waste and Recycling Calculator.)

The W2R calculator must be used to fulfil the waste reporting requirements under the department's MRTS51 *Environmental Management* technical specification. Contractors are required to use the W2R calculator to record the actual amounts of waste generated and how must of that was reused, recycled or sent to landfill. Contractors should also record the actual amounts of recycled material used on the project as this will allow the department to track the actual use of recycled materials.

More information about it and its use, including associated requirements, the template to use and a user guide, is available on the department's Project waste reporting website.

2.3 Development of Sustainability Assessment Tool for Pavements

Through a joint National Asset Centre of Excellence (NACOE) and Western Australian Road Research and Innovation Program (WARRIP) project a sustainability assessment tool for pavements to support decarbonisation and sustainability improvements has been developed. This web-based tool will allow users to conduct comparative analyses of pavement lifecycle costs and greenhouse gas emissions data using various pavement configurations and material types. A key benefit of having the tool is that it will facilitate more informed, long-term investment decisions regarding the use of alternative pavement designs, materials and maintenance strategies. This tool will be released for use later in the 2025 / 2026 financial year with information about how to access and use the tool provided at that time.

3 Recycled materials

3.1 General

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

The types and sources of recycled materials are diverse, and of varying quality and consistency, with not all recycled materials being suitable for use in transport infrastructure. Recycled materials are often derived from waste materials, with some waste materials requiring extensive processing to ensure their properties are suitable for recycling or reuse in road construction. For example, crushed concrete must undergo the removal of contaminants such as plastics, steel and timber in addition to crushing and screening. In other cases further research is needed to confirm whether it is appropriate to use certain recycled materials in roads.

The requirements for products that can include recycled materials and for their use are detailed in Transport and Main Roads Technical Specifications. These requirements are intended to ensure that products that include recycled materials perform to an equivalent or better standard in the intended application when compared with products that use 'traditional' / non-renewable materials. Departing from the requirements in the department's Technical Specifications may lead to a reduction in performance and/or an increase in whole of life costs which is not desirable.

It is important that products comprised of 'traditional' / non-renewable materials and/or recycled materials (e.g. recycled material blends (RMBs) used in unbound granular pavements) meet specification requirements when used on departmental projects, unless otherwise agreed by the department for the purposes 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 potentially becoming part of future specification update.

Several of the applications where recycled materials currently permitted in the department’s Technical Specifications have been enabled by research completed through NACOE. Potential future cases where more or different recycled materials may be used are also being explored through NACOE. NACOE is a collaboration between Transport and Main Roads and the Australian Road Research Board (ARRB) (now known as the National Transport Research Organisation (NTRO)) and has a strong focus on decarbonisation, sustainability and resilience. More information on NACOE can be obtained from the NACOE website.

Table 3.1 provides a summary of:

- where use of recycled materials is currently permitted in the department's Technical Specifications
- research that is underway or planned, and
- where trials or demonstration projects have been completed (and are being monitored / assessed) or are needed to progress an assessment about the application of recycled materials in the application.

Table 3.1 – Overview of recycled material uses and relevant specifications and technical publications

Application	Recycled Material (RM)											Transport and Main Roads Technical Publications
	Recycled Crushed Concrete (RCC)	Recycled Crushed Brick (RCB)	Recycled Glass Aggregate (RGA)	Reclaimed Asphalt Pavement (RAP)	Reclaimed aggregate	Crumbed rubber (recycled tyres)	Fly Ash and Ground-Granulated Slag (GGBFS)	Insitu recycling	Recycled plastic	Site won material	Coal Combustion Products (CCPs)	
Unbound pavements	☑	☑	☑	☑	-	-	-	-	-	-	**R**	MRTS05 and MRTS36. Pavement Design Supplement.
Stabilisation*	☑	☑	☑	☑	-	-	☑	☑ **R**	-	☑	**R**	MRTS07A, MRTS07B, MRTS07C, MRTS08, MRTS09, MRTS10 and MRTS115. Pavement Design Supplement. *Pavement Rehabilitation Manual*. Structural design procedure for lime stabilised sub-base.
Sprayed sealing	-	-	-	-	-	☑	-	-	-	-	-	MRTS11, MRTS17 and MRTS18
Asphalt	-	-	☑	☑	-	☑ **D** (as hybrid binder)	☑ (as filler)	-	**R**	-	-	MRTS17, MRTS18, MRTS30, MRTS32, MRTS36, MRTS101, MRTS102 and MRTS103. PSTS112 (contact Transport and Main Roads). Pavement Design Supplement. *Pavement Rehabilitation Manual*.
Normal-Class Concrete (excluding pavements)	☑	-	☑	-	☑	-	☑	-	☑ (as fibre)	-	-	MRTS70 and MRTS273.
Special-Class Concrete (excluding pavements)	-	-	-	-	-	-	☑	-	☑ (as fibre)	-	-	MRTS70 and MRTS273.

Application	Recycled Material (RM)											Transport and Main Roads Technical Publications
	Recycled Crushed Concrete (RCC)	**Recycled Crushed Brick (RCB)**	**Recycled Glass Aggregate (RGA)**	**Reclaimed Asphalt Pavement (RAP)**	**Reclaimed aggregate**	**Crumbed rubber (recycled tyres)**	**Fly Ash and Ground-Granulated Slag (GGBFS)**	**Insitu recycling**	**Recycled plastic**	**Site won material**	**Coal Combustion Products (CCPs)**	
Concrete pavements	-	-	☑ (ancillary works only)	-	-	-	☑	**R / D** ('crack and seat, 'rubblisation')	-	-	-	MRTS39, MRTS40 and MRTS41. Pavement Design Supplement. *Pavement Rehabilitation Manual*.
Earthworks	-	-	☑	☑^	-	-	-	☑	-	☑	**R**	MRTS04 and MRTS36.
Drainage Material	☑	-	☑	-	-	-	-	☑	-	☑	**R**	MRTS03 and MRTS36.
Landscaping and fauna furniture	-	-	-	-	-	-	-	☑	-	☑	-	MRTS16.
Other, including road furniture	-	-	-	-	-	-	-	-	**R**	-	-	-
☑ = currently permitted within specified issues / uses					**R = research topic / underway**				**D = demonstration projects done / underway / planned / required**			

Notes:

*Using cementitious, lime or foamed bitumen binders or mechanical without agents.

^Well graded material as specified in MRTS04.

3.2 Crumb rubber

Crumb rubber is derived from end-of-life tyres which are shredded, then further processed into a crumb. A high value application for these materials is as crumb rubber modified (CRM) binder for use in sprayed seals (see Figure 3.1) and asphalt.

Figure 3.1 – Crumb rubber used in CRM binder

(Source: P116 NACOE, 2021)

CRM binder is used extensively in sprayed seal applications, with MRTS11 *Sprayed Bituminous Surfacing (Excluding Emulsion)* permitting Contractors to use a CRM binder instead of a conventional (unmodified) bitumen or other type of polymer modified binder (PMB) in most cases. CRM binders for seals can be either field or factory blended products with the proportion of crumb rubber differing depending on the binder grade / treatment.

Experience has shown that CRM binders for seals:

- can be successfully transported for extended distances and still conform at the point of use without segregation problems (provided the contractor implements appropriate transport, storage, handling, and construction procedures for it)
- perform as well as, if not better than, the equivalent alternative binders (when transported, stored, handled, and used / sprayed correctly), and
- can often be a lower cost alternative to the equivalent alternative binders.

Transport and Main Roads allows the use of conventional polymer modified binders (such as A15E) in asphalt mixes that contain a combination of styrene-butadiene-styrene (SBS) and crumb rubber. These are often referred to as hybrid binders and may contain up to 10% crumb rubber.

The department has also developed a Project-Specific Technical Specification (PSTS112) for open graded and gap graded asphalt (OGA and GGA respectively) that uses a CRM binder containing approximately 18-20% crumb rubber. Several demonstration projects have been undertaken by the department and local government using PSTS112. It is expected that these mixes will provide superior performance (for some properties, e.g. better crack resistance for GGA) to the corresponding conventional asphalt mixes that otherwise conform with MRTS30 *Asphalt Pavements* (which is the department's general asphalt specification). A copy of PSTS112 *Crumb Rubber Modified Asphalt* can be made available for project-specific usage by contacting asphaltmixdesign@tmr.qld.gov.au.

Table 3.2 lists the Transport and Main Roads specifications relevant to the use of CRM binder.

Table 3.2 – Transport and Main Roads specifications related to the use of crumb rubber

	Specification	**Application**
MRTS11	*Sprayed Bituminous Treatments (Excluding Emulsion)*	Sprayed seals. (Note: MRTS11 *Sprayed Bituminous Treatments (Excluding Emulsion)* includes binder requirements for 5 parts (5%) CRM binder.)
MRTS18	*Polymer Modified Binder (including Crumb Rubber)*	Binder manufacture and supply (including transport and storage). (Note: MRTS18 *Polymer Modified Binder (including Crumb Rubber)* includes binder requirements for blend with more than 5 parts (5%) CRM binder.)
PSTS112	*Crumb Rubber Modified Asphalt*	Gap graded and open graded asphalt.

3.3 Reclaimed asphalt pavement (RAP)

When asphalt is removed for reconstruction or resurfacing, the processed material can be recycled back into pavements as reclaimed asphalt pavement (RAP) (see Figure 3.3).

Due to the residual bitumen (binder) contained in RAP, it is generally preferable to recycle RAP that is not mixed with other material such as unbound granular pavement or subgrade (i.e. pure RAP which is sometimes known as 'First-Class RAP') into asphalt, whereby the amount of new binder, raw aggregate, and new aggregates needed can be reduced leading to improved sustainability outcomes and cost savings.

Figure 3.3 – Reclaimed asphalt pavement

(Source: P116 NACOE, 2021)

Current Transport and Main Roads specifications allow the incorporation of RAP into dense graded asphalt mixes for surfacing, intermediate, base, and corrector courses. MRTS30 *Asphalt Pavements*, MRTS32 *High Modulus Asphalt (EME2)*, and MRTS102 *Reclaimed Asphalt Pavement Material* set out the department's requirements related to the use of RAP in asphalt.

RAP can be used in asphalt within the following limits (which are percentages by mass of the mix) – up to:

- 15% for dense graded asphalt with polymer modified binder when it is not the lowest asphalt layer in the pavement structure
- 20% for a dense graded asphalt surfacing course with a bitumen binder
- 40% for a dense graded asphalt non-surfacing course with a bitumen binder, and
- 15% in high modulus asphalt (i.e. EME2 – Enrobés á Module Elevé).

The use of RAP is not permitted in:

- dense graded asphalt with polymer modified binder when it is the lowest asphalt layer in the pavement structure
- stone mastic asphalt; and
- open graded asphalt.

For use of higher percentages of RAP, the requirements specified in TN183 *Use of High Percentages of Reclaimed Asphalt Pavement (RAP) Material in Dense Graded Asphalt* and MRTS30 *Asphalt Pavements*, MRTS32 *High Modulus Asphalt (EME2)*, and MRTS102 *Reclaimed Asphalt Pavement Material* must be followed. TN148 *Asphalt Mix Design Registration* also contains some information about registration requirements for asphalt mixes containing RAP.

'Second-Class' RAP (i.e. RAP that is mixed with unbound granular pavement, subgrade, or other materials) cannot be used in asphalt manufacture, however, it can be incorporated into unbound granular pavement material. Ideally, 'First-Class' RAP should not be used as unbound granular pavement material or earth fill. The highest and best use of 'First-Class' RAP is for the manufacture of asphalt.

Up to 45% of 'Second-Class' RAP can be incorporated into unbound pavement material as detailed in MRTS05 *Unbound Pavements*. Research is underway on the potential use of RAP as an earth fill material in embankment construction.

In summary, some of the benefits of incorporating RAP into pavements include:

- reducing cost (especially in asphalt where the amount of new binder and aggregate required can be reduced)
- providing equivalent performance to traditional materials when used in the appropriate applications
- reducing the consumption of non-renewable materials (e.g. aggregate and binder), and
- reducing the amount of waste sent to landfill.

Table 3.3 lists the Transport and Main Roads specifications relevant to the use of RAP.

Table 3.3 – Transport and Main Roads specifications related to the use of RAP

	Specification	**Application**
MRTS05	*Unbound Pavements*	Unbound pavement materials.
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Stabilised / bound pavements. Note: These specifications refer to MRTS05 *Unbound Pavements* for recycled material requirements.
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*	
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*	
MRTS09	*Plant-Mixed Foamed Bitumen Stabilised Pavements*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS115	*Insitu Stabilised Subbases using Triple Blend*	
MRTS30	*Asphalt Pavements*	Asphalt
MRTS32	*High Modulus Asphalt (EME2)*	
MRTS102	*Reclaimed Asphalt Pavement Material*	

3.4 Recycled and reclaimed aggregates (excluding RAP)

In addition to RAP, a range of recycled aggregates including concrete, brick and glass (e.g., see Figure 3.4) can be used as an alternative to natural and quarried aggregates and sand.

Figure 3.4 – Recycled crushed concrete, brick and glass (from left to right respectively)

(Source: P116 NACOE, 2021)

Reclaimed aggregates can also be used in concrete. Reclaimed aggregates are:

- produced from fresh concrete by washing out cement paste to separate the aggregates, and
- balls of hardened cement paste and aggregate formed by use of a chemical admixture which absorbs the free water in the mix to form.

The mechanical properties of reclaimed aggregate vary according to the strength, durability, grade (of the concrete) and the type of the natural and quarried aggregate used in the concrete. Australian Standards' AS 2758 *Aggregates and rock for engineering purposes* series outlines the criteria for aggregate properties such as particle size distribution, durability and strength.

Some of the benefits of using recycled and reclaimed aggregates include:

- potential cost savings
- reducing the use of non-renewable resources
- reducing the amount of waste sent to landfill
- reducing greenhouse gas (GHG) emissions, and
- realising equivalent performance to traditional materials when used in the appropriate applications.

Table 3.4 lists the Transport and Main Roads specifications relevant to the use of recycled aggregates.

Table 3.4 – Transport and Main Roads specifications for the use of recycled aggregates

	Specification	Application
MRTS03	*Drainage Structures, Retaining Structures and Slope Protections*	Recycled Glass Aggregate (RGA) in Type D subsoil drains as coarse sand. Note: This specification refers to MRTS04 *General Earthworks* for coarse sand requirements. MRTS04 *General Earthworks* allows RGA to be used for coarse sand.
MRTS04	*General Earthworks*	Allows RGA as: 'sand,' 'coarse sand' and 'well graded bedding material' where a free draining granular material must be used.
MRTS05	*Unbound Pavements*	Allows Recycled Crushed Concrete (RCC), Recycled Crushed Brick (RCB) and RGA in Type 2 and Type 3 unbound pavement materials. Note: Where a Type 3 material is specified, a Type 2 material of the same subtype may be used in its place. Type 2 recycled blend is also suitable for use as a Type 3 material.
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Stabilised / bound pavements. Note: These specifications refer to MRTS05 *Unbound Pavements* for recycled material requirements.
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*	
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*	
MRTS09	*Plant-Mixed Foamed Bitumen Stabilised Pavements*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS115	*Insitu Stabilised Subbases using Triple Blend*	
MRTS36	*Recycled Glass Aggregate*	As noted for individual specifications in this table.

	Specification	Application
MRTS30	*Asphalt Pavements*	RGA permitted as a partial replacement of fine aggregate in dense grade asphalt (DGA) mixes only. Up to 2.5% of RGA by mass of total mix is permitted in the surfacing course, and up to 10% of RGA by mass of total mix is permitted in courses other than the surfacing course.
MRTS101	*Aggregates for Asphalt*	
MRTS41	*Concrete Pavement Base (Ancillary Works)*	RGA as partial replacement of up to 20% of the fine aggregate component.
MRTS70	*Concrete*	RGA as partial replacement of up to 20% of the fine aggregate component in normal-class concrete.

3.4.1 Recycled Crushed Concrete

Recycled Crushed Concrete (RCC) (see Figure 3.4) is typically sourced from construction and demolition waste, including returned hardened concrete and concrete washout waste from machinery and equipment. It principally consists of aggregate coated with hydrated cement, and cementitious fines derived from cement mortar. Processing of crushed waste concrete includes the removal of building waste and contaminants such as metal, plastics, timber, brick etc, as well as crushing and screening.

The properties of RCC can vary considerably, as the material properties vary according to the strength, durability, grade and the type of the quarry aggregates that were used to produce the original concrete. Australian Standards' AS 2758 outlines the criteria for aggregate properties such as particle size distribution, durability, and strength.

RCC can be used in unbound and stabilised pavements. In these applications up to 100% of RCC can be used or RCC can be blended with natural gravel, quarried material or other recycled materials to produce Type 2 materials as specified in MRTS05 *Unbound Pavements*.

MRTS70 *Concrete* allows up to 20% of the coarse aggregate component for normal class concrete to be recycled crushed concrete and/or reclaimed aggregate.

In addition, NACOE research is underway to consider the use of RCC in earthworks, drainage and backfill materials.

3.4.2 Recycled Crushed Brick

Recycled Crushed Brick (RCB) (see Figure 3.4) is typically sourced from construction and demolition waste. It principally consists of hardened clay bricks but may also include some crushed concrete and cement / lime mortar.

RCB can be used in unbound and stabilised pavements. In these applications up to 45% of RCB can be blended with natural gravel, quarried material, or other recycled materials to produce Type 2 materials as specified in MRTS05 *Unbound Pavements*.

3.4.3 Recycled Glass Aggregate (recycled crushed glass)

Recycled Glass Aggregate (RGA) (sometimes also known as Recycled Crushed Glass (RCG)) used in road pavements is produced from food and beverage containers or window glass. Typically, this glass is sourced from municipal kerbside (commingled) recycling (i.e. from yellow topped bins) – glass from this source is typically unsuitable for being recycled back into glass.

RGA that complies with Transport and Main Roads' Technical Specification MRTS36 *Recycled Glass Aggregate* can be used within the following limits (which are percentages by mass of the mix) – up to:

- 20% in unbound pavements
- 10% in dense graded asphalt layers (other than surfacings)
- 2.5% in dense graded asphalt surfacings, and
- 100% as sand, coarse sand, free draining granular material, well-graded bedding, and haunch zone material.

MRTS70 *Concrete* (for normal class concrete) and MRTS41 *Concrete Pavement Base (Ancillary Works)* allow partial replacement of up to 20% of the fine aggregate component with recycled crushed glass. Recycled crushed glass in such concrete needs to comply with Austroads Technical Specification (ATS) 3050 *Supply of Recycled Crushed Glass Sand*.

The removal of potential contaminants such as plastic and metal lids, paper from bottle labels, sugar residue, and other contaminants from the waste glass used is a potential issue for the use of RGA in some applications (e.g. in concrete). Suppliers need to ensure that material is sufficiently clean for the intended use (and that it complies with the relevant specifications).

3.5 Ground-granulated blast furnace slag and amorphous silica

Ground-granulated blast furnace slag (GGBFS) is an industrial by-product of iron production. It can be blended with and used as a partial replacement for General Purpose (GP) cement in special and normal class concrete and stabilised pavements.

Amorphous silica including silica fume, which is a by-product of certain high end metal processing operations, is also used in more aggressive environments for special class concrete.

GGBFS (slag) and amorphous silica are known as Supplementary Cementitious Materials (SCMs) and are well proven products that improve the durability and sustainability of concrete.

Both GGBFS (slag) and amorphous silica need to conform with Australian Standards' AS 3582.2 *Supplementary cementitious materials Slag – Ground* granulated blast-furnace and AS 3582.3 *Supplementary cementitious materials Amorphous silica*, respectively.

MRTS70 *Concrete* requires the cementitious material used to manufacture concrete to include minimum amounts of fly ash, ground granulated blast furnace slag, amorphous silica or combinations of these materials which are blended with GP cement. Such requirements help mitigate issues relate to Alkali Silica Reaction (ASR) and meet durability requirements.

While all these SCMs improve concrete durability, there are also significant environmental and economic benefits from the use of these materials.

MRTS40 *Concrete Pavement Base* allows cementitious materials to be comprised of up to 65% slag or 40% fly ash, or intermediate combinations of both.

MRTS39 *Lean Mix Concrete Sub-base for Pavements* allows cementitious materials to be comprised of slag, fly ash or intermediate combinations of both subject to suitability and submission of mix design.

Some of the benefits of slag in concrete can include:

- reduction in costs
- significant reductions in GHG emissions, and
- reduction of the heat of hydration as well as improved durability and alkali-silica resistance.

Table 3.5 lists the Transport and Main Roads specifications relevant to the use of GGBFS and amorphous silica.

Table 3.5 – Transport and Main Roads specifications for the use of GGBFS and amorphous silica

	Specification	Application
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Stabilised / bound pavements – ground granulated blast furnace slag (and other permitted materials). (Silica fume not permitted.)
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS39	*Lean Mix Concrete Sub-base for Pavements*	Large scale concrete pavements - ground granulated blast furnace slag (and other permitted materials). (Silica fume not permitted.)
MRTS40	*Concrete Pavement Base*	
MRTS41	*Concrete Pavement Base (Ancillary Works)*	Small scale concrete pavements – use of recycled materials as per MRTS70 *Concrete*.
MRTS70	*Concrete*	Concrete (other than large scale concrete pavements) – ground granulated blast furnace slag, and silica fume (and other permitted materials).

3.6 Coal combustion products

Coal combustion products (CCPs) include fly ash and furnace bottom ash materials, which are by-products from the generation of power in coal-fired power stations. The reuse of by-product 'waste' is a preferred practice to reduce the amount of waste disposed of to landfill.

Typically, up to 70% of the stabilising agent used in plant mixed or insitu cementitious stabilised pavements can be made up of fly ash (i.e. Special Grade or Grade 1 fly ash that complies with Australian Standards' AS/NZS 3582.1 *Supplementary cementitious materials Fly ash*) or slag (i.e. slag that complies with AS 3582.2 *Supplementary cementitious materials Slag – Ground granulated blast-furnace*). The use of fly ash and slag in these applications can extend working times and aids in the blending of low quantities of stabilising agents. While an upper limit is not specified, experience has shown that a minimum of 30% GP cement (in the cementitious binder blend) is typically required for effective stabilisation.

Transport and Main Roads is currently exploring the potential for use of another type of CCP that is a blend of fly ash and bottom ash, sometimes referred to as 'pond ash' or 'run of station ash,' through NACOE. This research is ongoing.

3.6.1 Fly ash

Fly ash is an industrial by product of coal combustion and can be used as a partial replacement for General Purpose (GP) cement in concrete and various pavement materials.

The use of fly ash as a SCM is well proven to increase the durability and sustainability of concrete.

Fly ash can also be used as an asphalt filler and as a component of the secondary stabilising agent in plant mixed and insitu stabilised foamed bitumen materials.

Fly ash used in concrete, stabilised pavements and as asphalt fillers need to comply with Australian Standards' AS 3582.1 *Supplementary cementitious materials Fly ash*.

MRTS70 *Concrete* mandates the cementitious material used to manufacture concrete to include minimum amounts of fly ash, ground granulated blast furnace slag, amorphous silica, or combinations of these materials which are blended with GP cement to meet Alkali Silica Reaction (ASR) resistance requirements.

While all these SCMs improve concrete durability, there are also significant environmental and economic benefits from the use of these materials.

MRTS40 *Concrete Pavement Base* allows cementitious materials to be comprised of up to 40% fly ash or 65% slag, or combinations of both.

MRTS39 *Lean Mix Concrete Sub-base for Pavements* requires the cementitious material to include a minimum of 40% fly ash.

Figure 3.6.1 – Fly ash

(Source: https://www.adaa.asn.au/uploads/default/files/aerial-view-of-ash-dam-4.jpg (aerial photo))

Fly ash can also be used in soil stabilisation binders, including triple blend binders.

Some of the benefits of using fly ash include:

- reduction in costs
- significant reductions in GHG emissions, and
- reduction of the heat of hydration as well as improved durability and alkali-silica resistance.

Table 3.6.1 lists the Transport and Main Roads specifications relevant to the use of fly ash.

Table 3.6.1 – Transport and Main Roads specifications for the use of fly ash

	Specification	Application
MRTS04	*General Earthworks*	Insitu stabilisation subgrade material.
MRTS07A	*Insitu Stabilised Subgrades using Quicklime or Hydrated Lime*	Stabilised / bound pavements. Note: These specifications refer to MRTS05 *Unbound Pavements* for recycled material requirements.
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*	
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*	
MRTS09	*Plant-Mixed Foamed Bitumen Stabilised Pavements*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS115	*Insitu Stabilised Subbases using Triple Blend*	
MRTS39	*Lean Mix Concrete Sub-base for Pavements*	Concrete.
MRTS40	*Concrete Pavement Base*	
MRTS41	*Concrete Pavement Base (Ancillary Works)*	
MRTS70	*Concrete*	
MRTS103	*Fillers for Asphalt*	Fillers in asphalt.

3.6.2 Bottom ash

Bottom ash is another CCP by-product produced in conjunction with fly ash. Unlike fly ash, bottom ash consists of coarse ash particles that are relatively heavy and so are not carried up with the flue gases during the combustion process.

There is a current NACOE research project that includes investigating the potential to use bottom ash, and bottom ash / fly ash mixtures in earthworks and pavements.

3.7 Recycled plastic

The potential to use recycled waste plastics in roads has been researched by Austroads and jointly by NACOE and WARRIP. The recycling of waste plastics into new road construction materials is complex due to supply chain / quality issues, intermingling of different plastics, environmental considerations, health and safety considerations and a need to understand performance impacts. It is also important to note that use of recycled waste plastics in roads alone is not going to solve the plastic waste problem. For instance, while the road infrastructure asset in Australia is very large even if all bitumen used in Australia included 6% plastic (an optimistic high-use scenario), this would still equate to less than 2% of the annually generated waste plastic. However, there still lies the potential to incorporate recycled plastics into transport infrastructure in some applications to help with the plastic waste problem.

Potential uses of recycled waste plastics in transport infrastructure include utilisation in:

- asphalt and bitumen
- geosynthetics
- railway sleepers
- noise and retaining walls
- pipes, conduits and pits
- fencing, barriers, bollards, wheel stops, and kerbs
- signage and other roadside furniture
- safety accessories / equipment (such as traffic cones or other temporary traffic management devices)
- drinking fountains, bins, tables, seats, artwork, garden edging, tree stakes, and architectural screens, and
- as structural and non-structural 'lumber' – including for formwork, wharves, jetties, decking, and so on.

Joint NACOE / WARRIP research to identify and assess some of the potential uses for recycled waste plastics in road construction, specifically in asphalt, bitumen, geosynthetics, and traffic management devices has essentially been completed. Some of the objectives of this research were to:

- identify plastic waste streams that may be viable for recycling into roads

- understand the performance of products that include recycled plastics relative to 'conventional' materials
- understand how to manage the risks of including recycled waste plastics with respect to causing harm to the environment, community and workers, and
- assess whether materials / products that include recycled waste plastics are suitable for re-recycling without excessive additional requirements.

For Transport and Main Roads, if or how to progress the use of recycled waste plastics in roads will in part be informed by the outcomes of the Austroads and NACOE / WARRIP research. In the interim, industry has begun developing materials under existing specification frameworks (e.g. geosynthetics that include recycled waste plastics and conform to current specifications).

In other cases, proprietary products have been developed that do not fit within current procurement practices or specifications, and non-standard processes may need to be considered to incorporate these products into departmental projects (e.g. registration of an asphalt mix as a 'non-standard asphalt mix' if supported by appropriate testing with results acceptable to the department).

There are also recycled plastic fibres currently in the market that can be used as a reinforcement for concrete in non-critical / non-structural slab on ground applications where normal-class concrete would normally be permitted (such as footpaths, bike paths, shotcrete, and precast concrete elements). Transport and Main Roads has published a specification (MRTS273 *Fibre-reinforced Concrete*) for the use of plastic fibres (both virgin and recycled) for use in concrete in these applications.

4 Landscape and Revegetation Reclaimed Material

Priority is typically given to the retention / salvage of stripped topsoils for reuse in landscape works on Transport and Main Roads projects. MRTS16 *Landscape and Revegetation Works* specifies the sampling, testing, amelioration, and site soil management procedures for the recycling of stripped, site-won soils for use in landscaping and revegetation. Under MRTS16 *Landscape and Revegetation Works*, Contractors are required to develop and implement a Soil Management Plan-Construction which sets out their intended soil management operations. By recycling site won soils, costs for importing topsoils to site are reduced as is the cost of removing or disposing stripped soils from site. Unused site soils may be removed and sold to topsoil manufacturers for further recycling opportunities.

Suitable cleared vegetation resulting from clearing and grubbing operations as specified in MRTS04 *General Earthworks* can be recycled as marketable timber. Cleared vegetation is also typically processed into mulch for reuse in landscape works, or as erosion and sediment control measures (such as mulch berms for example). Cleared timbers can also be used as recycled material for the construction of a range of fauna furniture (e.g. raised walkways and shelves in underpasses / culverts, escape poles, glider poles) and timbers containing hollows can be retained on site to provide refuge and habitat opportunities to enhance fauna sensitive road design measures.

5 Insitu recycling of road pavements

5.1 Insitu stabilisation using cementitious or foamed bitumen binders

Insitu stabilisation is the process of mixing existing materials in place with stabilising agents (that include fly ash, slag, lime, foamed bitumen and/or cement) to improve the properties of the materials (e.g. increase in strength and durability / resilience) (see Figure 5.1).

Figure 5.1 – Insitu stabilisation works

(Source: Transport and Main Roads)

Some of the benefits of using insitu stabilisation are the:

- re use of existing pavement materials without the need to use new non-renewable resources
- reduction in the amount of waste sent to landfill
- reduction in the amount of material haulage required
- improvement of the properties and performance of existing materials

- improvement of the durability and flood resilience of existing pavement materials, and
- significant reductions in construction time and traffic related impacts.

Table 5.1 lists the Transport and Main Roads specifications relevant to insitu stabilisation.

Table 5.1 – Transport and Main Roads specifications for insitu stabilisation

	Specification	Application
MRTS04	*General Earthworks*	Insitu stabilisation of subgrade material.
MRTS07A	*Insitu Stabilised Subgrades using Quicklime or Hydrated Lime*	Insitu stabilisation of pavement materials / pavements.
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*	
MRTS115	*Insitu Stabilised Subbases using Triple Blend*	

5.1.1 Insitu granular (or mechanical) stabilisation (without binders)

Insitu granular stabilisation is the process of in place mixing selected materials together in place to produce one material which has the required properties. The purpose of granular (or mechanical) stabilisation is to improve the engineering properties and performance of an existing material by blending with it with imported materials or soils (e.g. unbound granular / gravel materials, sands, clay). Granular stabilisation can be undertaken in conjunction with (and before) an overlay to provide additional pavement structural life.

Currently Transport and Main Roads does not have a standard specification for insitu granular stabilisation. However, Section 4.9.5 of the department's *Pavement Rehabilitation Manual* provides guidance on the use of granular stabilisation, including for material, design and construction considerations.

Further information and project-specific technical specifications on granular (or mechanical) stabilisation can be obtained by contacting Transport and Main Roads' Director (Pavement Rehabilitation).

5.2 Insitu recycling of concrete pavements

5.2.1 General

Rubblisation and 'cracking and seating' are 2 methods intended for use on an end-of-life concrete pavement (e.g. one with a substantial number of fault cracks, significant loss of load transfer capability with associated faulting, shearing of longitudinal tie bars, or any combination of these).

Currently Transport and Main Roads does not have a standard specification for insitu concrete pavement recycling but does have project-specific supplementary specifications.

Further information on insitu concrete pavement recycling and related project-specific supplementary specifications can be obtained by contacting Transport and Main Roads' Director (Pavement Rehabilitation).

5.2.2 Rubblisation

Rubblisation is a method used to rehabilitate and recycle existing concrete pavements by fracturing the existing concrete pavement into required sizes and interlocking pieces (see Figure 5.2.2). The rubblised pieces are then rolled to compact them firmly on the underlying layer(s). A full depth asphalt pavement (FDA) is then typically applied over the rubblised pavement. Alternatively, the rubblised concrete pavement materials can be removed for further processing and reuse (and a new pavement constructed).

Transport and Main Roads has successfully rubblised concrete pavements in Queensland where the existing concrete pavement was fully repurposed and reused as a lower sub-base layer. Further information can be obtained by contacting Transport and Main Roads' Director (Pavement Rehabilitation).

Figure 5.2.2 – Rubblisation works

Prior to rolling After rolling

(Source: Transport and Main Roads)

5.2.3 Cracking and seating

The 'cracking and seating' process involves fracturing existing concrete pavements at designed intervals to create the required patterns. The cracked pieces are then rolled to 'seat' them firmly on the underlying layer(s) (see Figure 5.2.3). Asphalt layers are then typically applied over the cracked and seated pavement and would typically include crack mitigation measures (e.g. include a SAMI or crumb rubber gap graded asphalt layer).

Compared to rubblisation, 'crack and seat' breaks the pavement into larger segments. This requires less effort to achieve, however, if not done properly, the cracked segments may reflect through the overlying layers (typically asphalt).

The department has successfully cracked and seated concrete pavements in Queensland where the existing concrete pavement was fully repurposed and reused as a lower sub-base layer. Further information can be obtained by contacting Transport and Main Roads' Director (Pavement Rehabilitation).

Section 4.8.2 of Transport and Main Roads' *Pavement Rehabilitation Manual* provides guidance on the use of the 'crack and seat' approach, including the required material and design considerations.

Figure 5.2.3 – Crack and seat works

(Source: Transport and Main Roads)

6 Potential use of other recycled waste materials

Transport and Main Roads is continually researching innovative technologies and materials to construct value-for-money, sustainable and resilient infrastructure that benefits the environment, community and economy. While several of the recycled waste material uses detailed previously continue to be refined and developed through further research, new opportunities are also being explored. NACOE research underway includes the development of a potential recycled material assessment framework that could be used to assess the use of recycled waste materials in pavements.

A major focus with emerging recycled materials is ensuring there are long term performance benefits, or at least no disbenefits, related to the use of recycled waste materials in state-controlled roads. It is also important impacts on the safety and sustainability of the environment, the community, and the workers now and in the future are considered.