Technical Note TN193

Use of recycled materials in road construction

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Queensland Government

Feedback

Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

1 Background

The Department of Transport and Main Roads is committed to working towards a circular economy.

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 times, the importance of, and interest in, using recycled materials has increased.

This Technical Note 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.

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 greenhouse gas 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 reused in their highest and best use
- potentially reducing short and long-term costs, and
- potentially improving network performance.

2 Recycled materials

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).

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 reuse into roads.

The requirements for recycled materials and their use are specified in Transport and Main Roads Technical Specifications. These requirements are intended 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 is not desirable.

It is important that both recycled and 'traditional' / non-renewable materials meet the department's specified requirements when used on Transport and Main Roads 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 the department have been developed through the National Asset Centre of Excellence research program (NACOE). NACOE is a collaboration between Transport and Main Roads 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 website http://nacoe.com.au/.

Table 2 provides a summary of where recycled materials are currently permitted in Transport and Main Roads Technical Specifications, and a summary of further research that is underway.

Table 2 – 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	Insitu 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 & Seat/Rubblisation (Concrete pavements)	-	-	-	-	-	-	R	-	
Other (including road furniture)	-	-	-	-	-	-	-	R	

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

Note

* Recycled crushed concrete and crushed glass are currently only being considered as partial aggregate replacements for non-structural concrete.

2.1 Crumb rubber

Crumb rubber is derived from end-of-life tyres. Rubber and carbon black represent approximately 70% of the weight of a tyre. To make crumb rubber, end-of-life tyres are shredded, then further processed into a crumb. A high-value application for these materials is as crumb rubber modified (CRM) bitumen for use in road construction.

Figure 2.1 – Crumb rubber used in CRM binder

CRM binder is used extensively in sprayed sealing, with MRTS11 *Sprayed Bituminous Surfacing (Excluding Emulsion)* being updated to permit Contractors to substitute a CRM binder in many cases where a conventional polymer modified binder (PMB) is specified. CRM sealing binders can be either field or factory blended products and usually contain approximately 15% crumb rubber.

Experience has shown that CRM sealing binders:

- can be successfully transported for extended distances and still conform at the point of use without segregation problems
- perform as well as, if not better than, conventional binders when stored, handled and used correctly, and
- can often be a lower-cost alternative to conventional binders.

Transport and Main Roads 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 the department and local government using PSTS112. It is expected that these mixes will provide superior performance to conventional asphalt mixes that otherwise conform with MRTS30 *Asphalt Pavements* (the departments general asphalt specification). A copy of PSTS112 *Crumb Rubber Modified Asphalt* can be made available for project specific usage by contacting Transport and Main Roads Director (Pavements, Research and Innovation).

Table 2.1 – Specifications for the use of crumb rubber

Specification		Application
MRTS11	*Sprayed Bituminous Treatments (Excluding Emulsion)*	Sprayed sealing
MRTS18	*Polymer Modified Binder (including Crumb Rubber)*	Binder manufacture and supply
PSTS112	*Crumb Rubber Modified Asphalt*	Gap graded and open graded asphalt

2.2 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).

Due to the residual bitumen (binder) contained in RAP, it is generally preferable to recycle RAP (where it is not mixed with other material) into asphalt, whereby the amount of new binder needed can be reduced.

Figure 2.2 – Reclaimed asphalt pavement

Current Transport and Main Roads specifications allow the incorporation of RAP into dense graded asphalt mixes for surfacing, intermediate, base and corrector courses. MRT30 *Asphalt Pavements*, MRTS32 *High Modulus Asphalt (EME2)* and MRTS102 *Reclaimed Asphalt Pavement Material* set out the requirements for RAP that is used in asphalt.

RAP can be used in asphalt within the following limits – up to:

- 20% in dense graded surfacing courses
- 40% in dense graded asphalt in other applications, and
- 15% in high modulus asphalt (EME2 – Enrobés á Module Elevé).

The use of RAP in stone mastic and open graded asphalt is not permitted.

Transport and Main Roads allows the incorporation of up to 15% RAP into asphalt mixes without any additional requirements; however, for the use of higher percentages of RAP, the requirements specified in Technical Note 183 *Use of High Percentages of Reclaimed Asphalt Pavement (RAP) Material in Dense Graded Asphalt* must be followed.

In some circumstances, it may be desirable to use RAP in other applications, such as unbound pavements or fill – for example, where the greenhouse gas emissions and/or costs to remove RAP and imported fill are higher or the RAP is mixed with other material.

'Second class' RAP that is mixed with granular, subgrade or other materials should not be used in asphalt.

RAP can be incorporated into unbound pavement material as detailed in MRTS05 *Unbound Pavements* and may be considered as a fill material in accordance with MRTS04 *General Earthworks*.

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

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

Table 2.2 – Specifications for the use of RAP

Specification		Application
MRTS05	*Unbound Pavements*	Unbound pavement materials
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Stabilised 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 Pavement Layers Stabilised Using Foamed Bitumen*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS30	*Asphalt Pavements*	Asphalt
MRTS32	*High Modulus Asphalt (EME2)*	
MRTS102	*Reclaimed Asphalt Pavement Material*	

2.3 Recycled aggregates

In addition to RAP, a range of recycled aggregates including concrete, brick and glass can be used as an alternative to natural and quarried aggregates and sand.

Some of the benefits of using recycled aggregates include:

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

Figure 2.3 – Recycled concrete, brick and glass

2.3.1 Crushed concrete

Crushed concrete is typically sourced from construction and demolition waste, including returned hardened concrete and concrete washout. It principally consists of aggregate coated with hydrated cement, 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.

Crushed concrete can be used in bound and unbound pavements. NACOE research is underway to consider its use as a partial aggregate replacement in non-structural concrete as well as in earthworks, drainage and backfill materials.

2.3.2 Crushed brick

Crushed brick 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.

Crushed brick can be used in unbound and bound pavements.

2.3.3 Crushed glass

Recycled crushed glass (RCG) used in road construction is produced from food and beverage containers that are typically not suitable (or processing is uneconomical) for being recycled back into glass. Typically, this glass is sourced from municipal kerbside recycling (yellow-topped bins).

RCG can be used within the following limits – up to:

- 20% in unbound pavements
- 10% in dense graded asphalt layers (other than surfacings), and
- 2.5% in dense graded asphalt surfacings.

NACOE research is currently underway to investigate the use of recycled glass as a partial sand replacement in non-structural concrete and as drainage / bedding media.

The removal of potential contaminants such as plastic and metal lids, paper from bottle labels, sugar residue, and other contaminants from co-mingled recycling is a potential issue for the use of RCG. Suppliers need to ensure that material is sufficiently clean for the intended use.

Table 2.3.3 – Specifications for the use of recycled aggregates

Specification		Application
MRTS05	*Unbound Pavements*	Unbound pavement materials
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Stabilised 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 Pavement Layers Stabilised Using Foamed Bitumen*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS36	*Recycled Glass Aggregate*	Unbound pavements and asphalt
MRTS30	*Asphalt Pavements*	Asphalt
MRTS101	*Aggregates for Asphalt*	

2.4 Fly ash and blast furnace slag

Fly ash and blast furnace slag are industrial by-products of coal combustion and steel production, respectively. Both products can be blended with and used as a partial replacement for General Purpose (GP) cement in concrete and pavements. Silica fume, which is a by-product of certain high-end metal processing operations is also used in more aggressive environments for structural concrete.

The use of fly ash, ground granulated blast-furnace slag (slag) and silica fume as supplementary cementitious materials (SCM) is well-proven to increase the durability and sustainability of concrete.

MRTS70 *Concrete* (the department's specification for structural concrete) requires the replacement of GP cement with a minimum of 25% fly ash or with 60–70% slag to meet Alkali Silica Reaction (ASR)-mitigation requirements. In more aggressive 'Exposure Class C' environments, typical of salt water or acid sulphate soil exposure, MRTS70 *Concrete* requires up to 50% cement replacement with a combination of fly ash and slag, up to 40% replacement with fly ash and silica fume, or 60–70% replacement of cement with slag alone.

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

Figure 2.4 – Fly ash

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

Up to 70% of the stabilising agent used in plant-mixed or insitu stabilised lightly and heavily bound pavements can be made up of fly ash or slag. 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.

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

As slag is not produced in Queensland, it is not commonly used as an aggregate by the department.

Some of the benefits of using fly ash and slag include:

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

Table 2.4 – Specifications for the use of fly ash and slag

Specification		Application
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	Pavement stabilisation
MRTS08	*Plant-Mixed Heavily Bound (Cemented) Pavements*	
MRTS09	*Plant-Mixed Pavement Layers Stabilised Using Foamed Bitumen*	
MRTS10	*Plant-Mixed Lightly Bound Pavements*	
MRTS39	*Lean Mix Concrete Sub-base for Pavements*	Concrete
MRTS40	*Concrete Pavement Base*	
MRTS70	*Concrete*	
MRTS103	*Fillers for Asphalt*	Fillers in asphalt

2.5 Recycled plastic

The use of recycled plastics in roads is a current area of focus for the department.

NACOE research is underway to identify and develop the potential uses for recycled plastics in road construction. Potential uses may include:

- asphalt and sprayed seals
- geosynthetics
- 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 equipment (such as traffic cones)
- 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.

The key objectives of this research include:

- identifying plastic waste streams that may be viable for recycling into roads
- encouraging industry to consider the types of plastics that are being produced and the potential to produce / recover more plastics that could be recycled in these applications
- understanding the performance of recycled plastics relative to conventional materials
- managing the risks of causing harm to the environment, community and workers during both 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, and
- 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.

The development of specifications for the use of recycled plastics in roads will be considered based on these research outcomes. In the interim, industry has begun developing materials under existing specification frameworks, for example geosynthetics.

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 developed to incorporate these products into Transport and Main Roads projects.

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 (such as footpaths and bikepaths). The department is currently developing a specification for the use of plastic fibres (both virgin and recycled) for use in concrete in these applications.

3 Insitu recycling

3.1 Insitu stabilisation

Insitu stabilisation is the process of blending 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.

Figure 3.1 – Insitu stabilisation works

Some of the benefits of using insitu stabilisation are the:

- Re-use of existing pavement materials without the need to use non-renewable resources
- reducing the amount of waste sent to landfill
- reducing the amount of material haulage required
- improving the properties and performance of existing materials
- improving the durability and flood resilience of existing pavement materials, and
- significant reductions in construction time and traffic impacts.

Table 3.1 – Specifications for insitu stabilisation

Specification		Application
MRTS07A	*Insitu Stabilised Subgrades using Quicklime or Hydrated Lime*	Insitu pavement stabilisation
MRTS07B	*Insitu Stabilised Pavements using Cement or Cementitious Blends*	
MRTS07C	*Insitu Stabilised Pavements using Foamed Bitumen*	

3.2 Hot-in-place asphalt recycling

Hot-in-place asphalt recycling (HIPAR) is an insitu process used to recycle an existing asphalt pavement. A mobile recycling plant heats, scarifies, remixes, re-lays and compacts the top asphalt layer. New binder, recycling additives, new asphalt mix, new aggregate, or combinations of these may be added to obtain an end product with the desired characteristics.

Some benefits of HIPAR include:

- reducing consumption of non-renewable materials
- minimising waste
- minimising disruptions to traffic, and
- potential to be more economical than resurfacing with a new layer of asphalt.

HIPAR was first used by Transport and Main Roads in 1990. In the first 10 years, an area of approximately 2 million m² was recycled.

Most of the early HIPAR projects involved recycling asphalt made with Class 320 bitumen. The demand for HIPAR declined during the 2000s due to the increased use of polymer modified bitumen in asphalt.

Since this time, local research and overseas experience has shown that the HIPAR process can be successfully used on polymer modified asphalts without adversely affecting the binder properties. To verify the possibility of recycling polymer modified asphalt, the department undertook a successful demonstration project on Southport Burleigh Road in December 2015.

Figure 3.2 – HIPAR recycling works

Currently, the department does not have a standard specification for HIPAR. Transport and Main Roads' *Pavement Rehabilitation Manual* (Section 4.4.14) provides guidance on the use of HIPAR including the required materials and design considerations.

Further information on HIPAR can be obtained by contacting Transport and Main Roads Director (Pavement Rehabilitation).

3.3 *Insitu recycling of concrete pavements*

3.3.1 Rubblisation

Rubblisation is a method used to rehabilitate and recycle existing concrete pavements by completely fracturing the existing concrete pavement into small, interlocking pieces. The rubblised pieces are then rolled to compact them firmly on the underlying pavement layer. A thick asphalt overlay is then applied over the rubblised pavement.

If required, the rubblised pavement can be removed for further processing prior to reuse.

Figure 3.3.1 – Rubblisation works

3.3.2 Crack & seat

The 'crack & seat' process involves fracturing existing concrete pavements at regular spacings. The cracked pieces are then rolled to 'seat' them firmly on the underlying pavement layer. A thick asphalt overlay is then applied over the cracked and seated pavement.

Compared to rubblisation, 'crack & 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 asphalt overlay.

Both methods are intended for a concrete pavement with a substantial number of fault cracks, a significant loss of load transfer with associated faulting, shearing of longitudinal tie bars or any combination of these.

Currently, the department does not have a standard specification for insitu concrete pavement recycling.

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

Further information on insitu concrete pavement recycling can be obtained by contacting Transport and Main Roads Director (Pavement Rehabilitation).

Figure 3.3.2 – Crack & seat works

4 Emerging recycled materials

The Department of Transport and Main Roads is continually researching innovative technologies and materials to construct sustainable, resilient infrastructure which benefits the environment, community, and economy. While several of the recycled materials detailed previously continue to be refined and developed through further research, new opportunities are also being explored.

A major focus with emerging recycled materials is ensuring long-term performance benefits for Queensland's roads. It is also important that these materials maintain the safety and sustainability of the environment, the community, and the workers now and in the future.