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Recycled and Sustainable Materials at Main Roads

Reference Guide

November 2022

Contents

Version Control

Issue Number	Issue Date	Description of Key Changes
1	March 2021	Initial release
2	November 2022	Review and update

Introduction to the Reference Guide

This reference guide outlines different types of sustainable and recycled materials that are or potentially could be used for building and maintaining the Main Roads state road network. The guide is broken down into the types of materials that could be used in different road layers and related specifications the allow for the use of these materials. Sustainable alternatives for construction methods and road maintenance are also explored.

Sustainability and Recycling at Main Roads Western Australia

Within a Main Roads context, Sustainability is defined as a commitment to 'creating lasting benefits through an integrated consideration of social, environmental and economic aspects in all that we do'. This is an interpretation of the Western Australian State Sustainability Strategy 2003, which defines Sustainability as "meeting the needs of the current and future generations through an integration of environmental protection, social advancement, and economic prosperity." The Main Roads Sustainability Policy outlines six key aspects that guide us to deliver a sustainable road network. These include:

- Sustainable Transport
- Climate Change
- Environmental Footprint
- Behaviour
- Governance and Performance
- Funding and Financing

A large aspect of achieving sustainable outcomes comes from the materials we use in road construction and maintenance. This Reference Guide summarises the opportunities for recycled construction and sustainable materials to be used in Main Roads' infrastructure projects, and highlights future opportunities that may arise from studies currently being undertaken. With a large number of fast-tracked infrastructure projects, it is important for Main Roads to seek out recycled materials in many aspects of road construction, all while ensuring long-term performance and maintaining the safety of the road network.

There are a number of issues with basic raw/virgin road construction materials. These are summarised in Table 1:

Table 1 Limitations of Natural Resources

Material	Issue
Gravel	• Mining of gravel causes land degradation, biodiversity loss. • Limited good quality supply of raw gravel in WA.
Sand	• Global sand crisis due to high amount of construction and population growth. • Around 10 million tonnes of sand goes to landfill each year in WA.
Limestone	• Large amount of embodied energy. • 3.13kg of CO2-e produced from mining one tonne of limestone. • Natural limestone can degrade overtime from environmental conditions. • Limited good quality limestone ($CaCO_3$ content above 60%).
Rock/aggregate	• Rock extraction and processing has high embodied energy costs. • Significant amount of rock/aggregate required in road construction. • Limited rock sources in WA that can be extracted.

The materials outlined in this report include crushed recycled glass, crumb rubber, crushed recycled concrete and reclaimed asphalt pavement. A key aim of the use of these materials in road construction is to support the circular economy in Western Australia (WA) and where possible to support up-cycling, avoid down-cycling and keep materials circulating within the economy, reducing the need for more raw, virgin materials. A summary of all the recycled construction materials used in the 2020/2021 financial year can be found below in Figure 1.

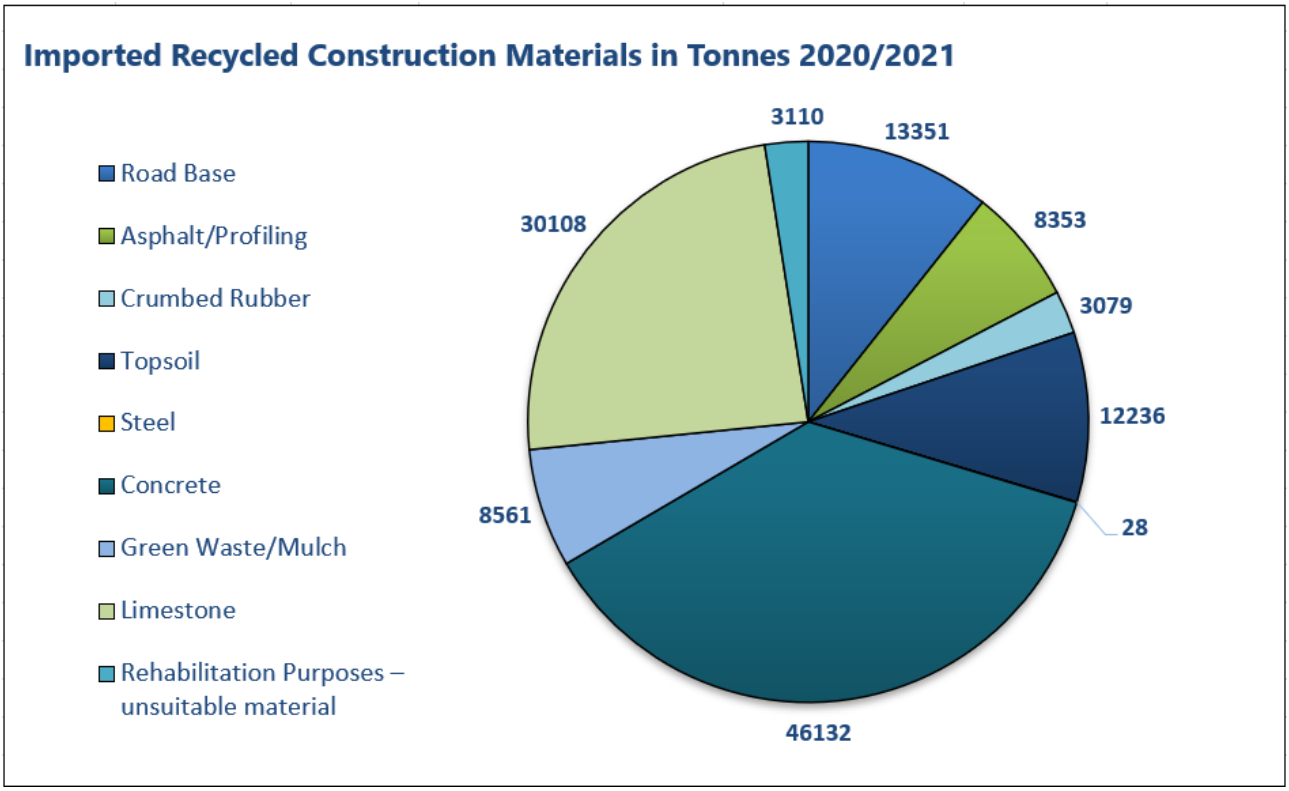

Figure 1 Recycled Materials Used on Main Roads Projects in 2020/2021

Drivers for the Circular Economy

Main Roads has a number of drivers that are guiding the use of sustainable construction materials and promoting the circular economy for road building materials. These drivers include:

- Waste Avoidance and Resource Recovery Strategy 2030 (including Roads to Reuse)
- AfPA commitment to have 50 percent of metropolitan road projects using crumb rubber
- Using crumb scrap tyre rubber for asphalt and surface sealing projects, targeting the use of over 1,200 tonnes each year
- Expanding the use of crumb scrap rubber in spray seals and asphalt
- Using recycled construction and demolition (C&D) waste, particularly crushed recycled concrete (CRC) in 2022-23 and beyond
- Increasing the amount of Reclaimed Asphalt Pavement (RAP) in asphalt mix design to be at least 20-25 percent RAP through the WA Road Research and Innovation Program (WARRIP)
- Increasing the use of Crushed Recycled Concrete on the network to over 200,000 tonnes
- Western Australia's Plan for Plastics (reducing and avoiding single use plastics)
- Council of Australian Governments (COAG) ban on the export of various waste categories,
- Western Australian Climate Change Policy, and
- Australia's Long-Term Emissions Reduction Plan.

Further Information

Further information regarding specifications for Main Roads alternative materials can be found in the Main Roads Contractor Monthly Reporting Form Reference Guide.

ISC Resource Efficiency and Recycled Materials

Main Roads has an ongoing commitment with the Infrastructure Sustainability Council (ISC) to deliver sustainable road projects. Every Main Roads project valued over $100 million is registered with ISC to receive a Planning, Design and As Built IS rating. Projects valued between $20 million to $100 million are not required to undergo formal IS verification; however these projects complete an internal sustainability assessment to ensure sustainable initiatives are implemented where possible.

ISC rewards the development and implementation of Resource Efficiency Strategies, and associated Resource Efficiency Action Plans. The aim of the criteria is to recognise the importance of resource efficiency during the planning, design, and construction phases of a major road project. It is important for each Main Roads project to have its own specific Resource Efficiency Strategy, which should include adopting the principles of industrial ecology and maximising the use of recycled construction products. To do this, projects align resource efficiency with the following waste hierarchy:

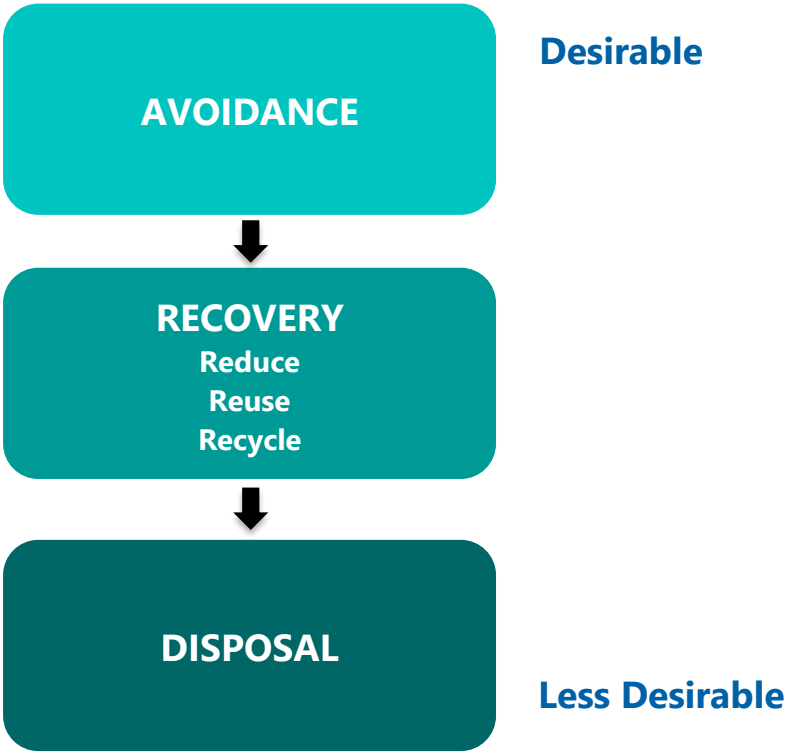

Figure 2 Waste Hierarchy

Road Infrastructure Components

The following figure was supplied by Austroads and provides a schematic look at road infrastructure components. This diagram showcases the different elements within the road reserve environment outlined in this document.

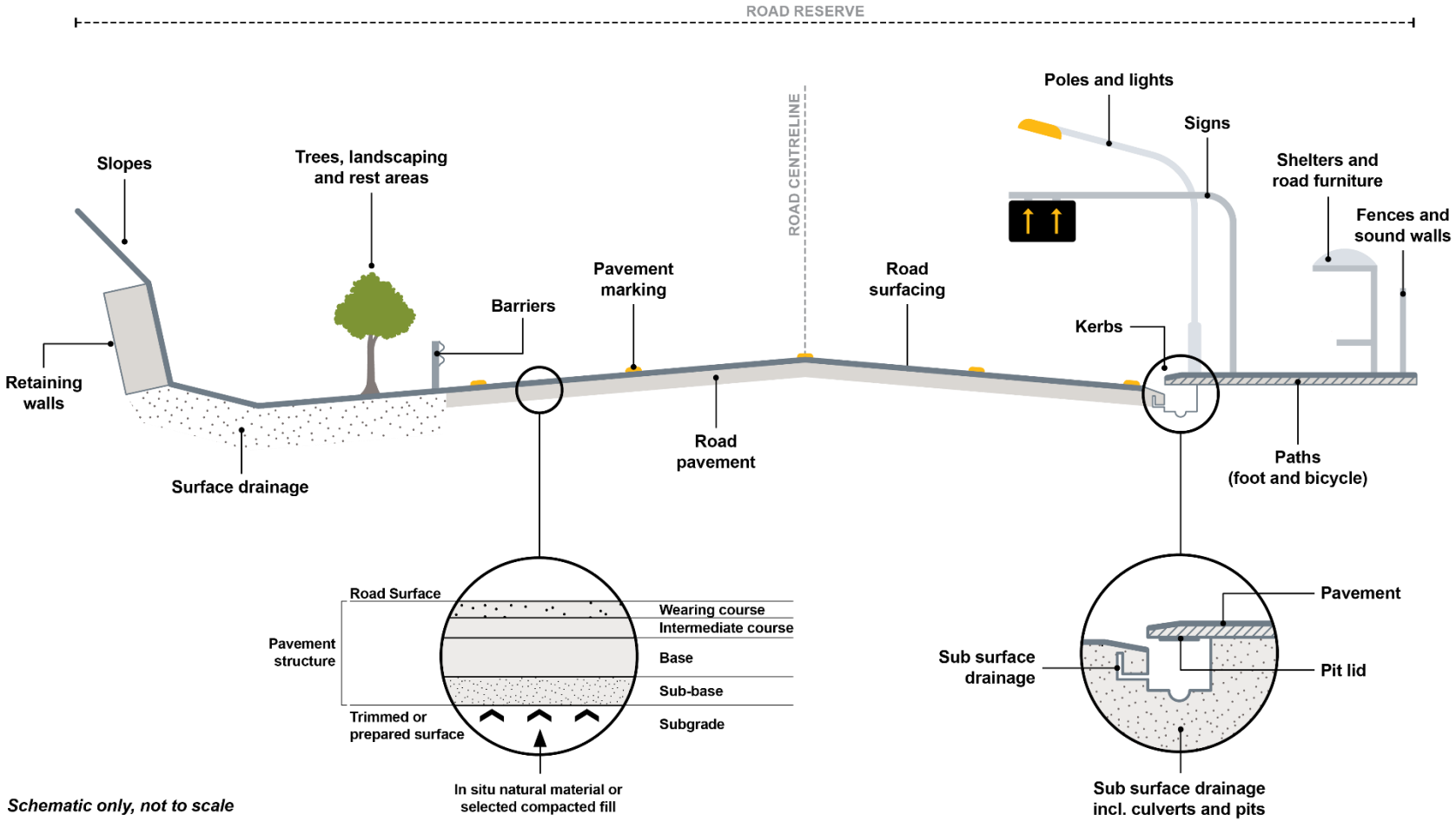

Figure 3 Schematic diagram of a road reserve (source: Austroads 2021)

Embankment/Subgrade Materials

Crushed Recycled Glass
Key Specification: 302.10.1
Used in:

- Fill
- Temporary tracks in heavy clay to reduce bogging of equipment
- Bedding Sand
- Drainage
- Retaining Walls

Key Properties	Optimum Use of Material	Alternative Use in Roads
• **Inert** • **Robust** • **Reusable** • **High embodied energy content**	• Refill and reuse repeatedly • Reuse cullet into new glass	• Recycle into drainage layer • Recycle into sand

The use of any glass cullet in road construction must meet the requirements outlined in Main Roads Specification 302 *Earthworks* (302.10.1). Main Roads specifications permit the use of glass cullet in fill material. The preference is for glass to be reused as it contains significant embedded energy and does not degrade over time. Where reuse is not possible, Main Roads recommend recycling glass to produce other new glass products. This is currently not feasible in WA due to the absence of local glass reprocessing facilities. Main Roads accepts that the use of recycled glass in roadbuilding is a low-value application (down-cycling) of the material, but is part of an interim solution to reduce waste glass sent to landfill.

Research and development is underway to enhance the economic sustainability of using crushed recycled glass and glass cullet, with the aim to reduce costs associated with milling the glass to a consistent grading and washing to remove contaminants (e.g. paper, adhesive, organic matter). However, using recycled glass has environmental benefits, including conserving virgin materials and reducing environmental disturbance.

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

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

- A reduction in virgin materials used,
- Reduced amounts of land cleared to store virgin material stockpiles,

- Show leadership and set a standard for future Main Roads projects,
- Assisted in transforming the WA market of recycled glass products.

Recycled Sand
Key Specification: MRWA Specification 302
Used in:

- Embankment / subgrade

As outlined in MRWA Specification 302, recycled sand must be material sourced from recovered construction and demolition waste, and shall be free of contaminated soils and other deleterious materials. Recycled sand can be used in the embankment / subgrade layer of the road as a substitute for traditional construction sand, gravel, clay and silt. In 2021 the Director General of the Transport Portfolio WA committed to explore the opportunities of increasing the use of recycled sand in road construction. A recycled sand specification is currently being prepared by the Department of Water and Environmental Regulation (DWER) in collaboration with Main Roads and the Waste Authority.

All recycled sand used in Main Roads projects must come from Roads to Reuse approved suppliers to avoid risks associated with the material, including warranty implications with the materials, metal corrosives in the sand, and perceived risks associated with using this material.

Over 35,000 tonnes of recycled sand from a Roads to Reuse approved supplier on Main Roads projects as of June 2022. Feedback from the Contractor has included that using recycled sand is cost effective, however the use of the product needs to align with the project schedule. There are a number of factors which also need to be considered when using the product including the availability of the material, and the availability of trucks to cart the material. Contact Main Roads Materials Engineering Branch for further information regarding the use of recycled sand.

Subbase Materials

Alcoa Red Sand

Used in:

- Subbase layer

Main Roads have been liaising with Alcoa to evaluate the supply and construction processes associated with the use of red sand residue in road construction. Previous research has gone in to discovering the possibility for using the residue red sand as a subbase material in roads, which is a by-product from the production of aluminium from bauxite.

In 2009, a 500-metre-long section of Greenlands Road in Pinjarra was constructed using residue sand from Alcoa's Wagerup site as a subbase material. Approximately 2,000m^3 of material was used to construct a section of subbase on the road. An initial lab trial of the material found that red sand could potentially be used as a subbase material instead of limestone where a at least 100mm of gravel basecourse is applied. The results of the Greenlands Road trial found that although limestone is a stronger subbase material, red sand also met specific pavement requirements including deflection, roughness and rutting. Falling-weight deflectometer tests were taken every five metres on the red sand subbase trial section to determine the performance strength of the road and compare it to the limestone subbase section.

Monitoring of pavement performance has also been undertaken using a Traffic Speed Deflectometer, indicating that the trial section is consistent with conventional pavement, based on the deflection, roughness and rutting data. The road remains in good, drivable condition today (12-years post-trial).

Main Roads continue to test the suitability of the red sand as a subbase material for future road projects. A key factor outside of the behaviour of the material is the proximity of the Alcoa Refinery in Kwinana to future project sites. The economic sustainability of carting the sand to site must be viable to use the material in a project, like that in the Greenlands Road trial.

Excess Site-won Fill

Used in:

- Subbase layer
- Embankment fill

Western Australia passed legislation in April 2018 allowing the use of excess site-won or uncontaminated fill in road construction without having to pay a waste levy[1]. The aim of this legislation was to increase the recycling of materials in construction projects and significantly reduce the amount of material that was headed to landfill. DWER determine whether recycled fill is contaminated through the *Landfill Waste Classification and Waste Definitions* document. The guidance was amended in 2019 when this legislation was passed.

At a Main Roads project level, the Reid Highway Dual Carriageway used excess site-won fill from the Matagarup Bridge Project. It was needed for the construction of the westbound carriageway and the Arthur Street Bridge. This opportunity to re-use the material was identified during the

[1] Source https://www.mediastatements.wa.gov.au/Pages/McGowan/2018/04/Regulatory-changes-to-benefit-industry-and-the-environment.aspx.

tender stage of the Reid Highway Project. The material was fill containing an outer layer of rock armour and inner compacted hardstand.

The contract for this Project outlined specifications to ensure the material was successfully implemented. This included the potential need to further crush or blend the material in order to meet both Australian and Main Roads standards.

The material was excavated from the Matagarup Bridge site within a hardstand area established within the Optus Stadium precinct. This hardstand area was built for the Project to assemble key Bridge components and to enable construction material to operate under the Bridge. Approximately 100,000m^3 of the material was transported to the Reid Highway Project site for use.

After being awarded the Reid Highway contract, the Contractor tested the stockpile of this extracted material immediately and confirmed that it was suitable to be used on the Project. The Contractor found that the larger rock in the stockpile could be used in the first layer of embankment in wetter areas. This allowed the material to 'bridge' the areas of high-water table, meaning subsequent layers could be built above this on the dryer earth.

Through using this material in the lower layers of embankment and in the Arthur Street Bridge embankment, all of the 100,000m^3 stockpile was used on the Reid Highway Dual Carriageway. The benefits associated with re-using this material included delivering significant cost savings, preserving virgin resources and reducing the amount of waste sent to landfill.

Crushed Recycled Concrete
Key Specification: 501.92
Used in:

- Subbase under full depth asphalt
- Basecourse under low traffic local roads

Key Properties	Optimum Use	Alternative Uses in Road
• **Re-cements**	• Reuse in new concrete	• Recycle into road base • Recycle into drainage backfill

Crushed Recycled Concrete (CRC) is a roadbuilding product derived from construction and demolition waste consisting primarily of concrete, but also containing sand, brick, tile, asphalt and glass. Extensive research and long-term trials have demonstrated the material is suitable for use as subbase under full-depth asphalt (FDA) pavements on the Main Roads network. CRC is a high strength and durable product with self-cementing properties, meaning the stiffness of the product increases over time. Crushed limestone is traditionally used in subbase applications beneath FDA. Over time, CRC increases in strength and stiffness due to reactivation of the dehydrated cement content, and behaves similar to lightly bound materials. The level of re-cementation varies significantly, depending on the cement content and age of the source material.

In 2019/2020, Main Roads undertook the pilot trial of Roads to Reuse specified CRC, using over 25,000 tonnes of the material as subbase under FDA pavements. The trial was undertaken on the

Kwinana Freeway Widening between Russell Road and South Street. The majority of this CRC material was sourced from the demolition of Subiaco Oval, demonstrating the circular economy in Perth. This pilot program was a success, as all the material was compliant. This initiative was delivered under the Roads to Reuse (RtR) pilot program with the Department of Waste and Environmental Regulation and the Waste Authority. This RtR program controls environmental and Occupational Health and Safety risks (e.g. hazardous materials and leachate) associated with CRC.

Main Roads has set a target to use 100,000-200,000 tonnes of CRC per annum from 2021/22 onwards and reinstated the Main Roads Subbase CRC Specification (Specification 501). There are now five RtR approved suppliers of CRC in the Perth Metropolitan Area. Independent audit testing overseen by the Waste Authority (for compliance with contamination criteria) continues to demonstrate that the RtR approved suppliers have robust systems in place to safely manage asbestos and other potentially hazardous contaminants, and ongoing independent audit testing is essential to its success.

Since 2019, over 117,000 tonnes of CRC has been used on Main Roads projects, including Kwinana Freeway Northbound Widening, Armadale Road to North Lake Road Bridge, Murdoch Drive Connection, Tonkin Gap and Associated Works, Karel Avenue Upgrade, Leach Highway and Welshpool Road Interchange, and High Street Upgrade.

Construction contractors that have undertaken work for Main Roads have provided positive feedback regarding the use of CRC, including:

- CRC is workable
- CRC produces a tight surface finish
- CRC provides a stiffness benefit in design, resulting in approximately a 10mm reduction in FDA pavement thickness.

There are a number of additional benefits of CRC use, including:

- Reduced demand for virgin materials
- Reduced amount of construction and demolition waste sent to landfill
- A durable and high strength finish to the road
- The material has self-cementing properties
- The production of a strong sub-base under FDA, creating a stiff underlying layer helping extend the pavement life
- Less water required for compaction compared to limestone
- Less mixing is required
- The product is a more consistent material and works similar to conventional granular materials
- The product can withstand moderate traffic from construction traffic without further material breakdown. Conventional materials are more likely to breakdown under the same traffic volume.

There are technical risks that need to be considered on road projects that are looking into the use of CRC. These risks and how Main Roads mitigate them are found in Table 3.

Table 2 Risks Associated with Crushed Recycled Concrete

Risk	Cause	MRWA Mitigation Measures
Cracking	Reactivation of cement	Use as sub-base under Full Depth Asphalt. Do not use as basecourse under heavy traffic. Apply geofabric seal if used as basecourse.
Popping	Expansive contaminants (e.g. aluminium, gypsum)	None identified (steel is removed) - remove and replace if occurs
Hazardous Contaminants	Asbestos and other hazardous materials not removed in demolition	Refer to Roads to Reuse Specification and Guidelines Robust management systems Supplier end product testing DWER independent audit testing
pH	Reactivation of cement	Do not use near wetlands or groundwater sources

There is a minor risk when using CRC in close proximity to water bodies. The alkalinity level of CRC may leach contaminants into water bodies. The greatest risk of leaching during construction is likely to occur from precipitation and dust control measures required on site. The Contractor is responsible for considering and monitoring the risk of leaching. Additionally, Main Roads requires that CRC is not used in applications that are potentially subject to moisture ingress.

The risk of leaching from CRC under road pavement once laid is low. Due to this, DWER relaxed the setback requirement for using CRC near wetlands, changing it from 'not within 100m' to 'implement site specific controls to minimise run off into sensitive environmental receptors".

Case Study: CRC Use on Armadale Road North Lake Road Bridge Project
CRC was used on the Armadale Road North Lake Road Bridge (ARNLRB) Project, laid under the intersection of North Lake Road, and under the new Public Transport Authority carpark. The Project used approximately 29,000 tonnes of CRC from a Roads to Reuse approved supplier.

Grader crews mixed, compacted and trimmed the CRC, similarly to traditional pavement materials with similar daily production rates. The CRC pavement was designed to be 300mm thick, and was laid in two 150mm layers.

From using the product this way, the following observations were noted:

- CRC is a generally consistent product, however given it is not from traditional quarried materials, there can be inconsistencies in the material and the consistency of the waste making up the CRC has a significant impact on the material.
- During wetter months, the CRC held more moisture and did not dry as quickly as traditional quarried materials. This is due to the type of waste products dominating that particular mix of CRC, e.g. if it is not drying as quickly the material may have more clay based materials.

- CRC has been deemed low risk to use in carparks in liaison with Main Roads Material Engineering Branch, therefore it was perfect for use on this Project.

Figure 5 CRC on the Armadale Road North Lake Road Bridge Project

Figure 4 Trimmed and compacted CRC on the Armadale Road North Lake Road Bridge Project

Basecourse Materials

Paver-laid Basecourse
Used in:

- Basecourse

Laying basecourse with pavers is an alternative method to using graders. Paver-laid construction methods can be considered a more sustainable alternative to grader-laid methods, and were used on the northern section of NorthLink WA (Tonkin Highway between Ellenbrook and Muchea). Unbound crushed rock basecourse was paver-laid over a Road Train Assembly Area (RTAA) and later a ten kilometre section of the main Tonkin Highway carriageway. Nearly 80,000t of unbound crushed rock was laid using pavers.

Main Roads engaged the Contractor delivering the Project (prior to the use of the material on Tonkin Highway) to trial the construction method. Findings from this trial did not identify any adverse impacts to the road, allowing Main Roads to approve the use of this method on Tonkin Highway.

The team on NorthLink WA found there were a number of benefits associated with using paver laid basecourse, including:

- A reduction in water used in construction (NorthLink saved 1.8 million litres)
- A reduction in fuel consumption during construction (NorthLink saved 17,000L of diesel)
- The carbon emissions from using pavers is less than using graders (NorthLink saved 50 tonnes of CO_2 using pavers)

Future Main Roads projects currently in development are considering the use of paver-laid basecourse. Testing and investigations continue on the Tonkin Highway carriageway to understand the medium and long term performance of paver-laid basecourse for upcoming projects. For more information on the use of paver-laid basecourse please contact the Materials Engineering Branch at Main Roads.

Asphalt

Reclaimed Asphalt Pavement (RAP)
Key Specification: 510.32
Used in:

- Structural layers of asphalt pavement

Key Properties	Optimum Use	Alternative Uses in Roads
• **Asphalt with oxidised binder**	• Reuse in new asphalt	• Recycle as hardstand/shoulder

Reclaimed Asphalt Pavement (RAP) is the material reclaimed from an asphalt wearing or intermediate course by re-processing, crushing and/or screening recycling asphalt into new asphalt. There are strict specification requirements surrounding the use of RAP. Main Roads specifications allow up to ten percent asphalt reclaimed from existing pavements (RAP) to be incorporated into the structural layers of full-depth asphalt (FDA) pavements without additional mix design requirements.

FDA pavements on the Main Roads network typically have greater than 250mm total asphalt thickness. It is important to note that the specifications for the use of RAP outline that the material is not permitted in the production of wearing course (surfacing) asphalt for the Main Roads network. This is due to the potentially negative impact on cracking and skid resistance.

Main Roads used 42,000 tonnes of RAP in 2019/2020. In the NorthLink 2 (central section) Project, RAP made up approximately ten percent of the mass of the structural pavement layers. A trial on the NorthLink 3 Project (northern section) of higher RAP content asphalt mixes was undertaken where the amount of RAP used in the lower structural layers increased from ten percent to 25 percent. Some 30,000 tonnes of high RAP content asphalt was placed during this trial.

There are a number of local suppliers in Perth that have Main Roads approved mixes with 20-25 percent RAP content, and asphalt suppliers in Perth have existing RAP stockpiles that they use. Contact Main Roads for further information on these suppliers.

It is anticipated that a mix with approximately 22 percent RAP will deliver positive design outcomes, be manageable with respect to mix design, and maintain a balance between the supply and use of RAP. It is important to note that 'Level 2' RAP (11-25 percent) can only be applied to 20mm asphalt intermediate course for full depth asphalt.

EME2
Key Specifications: Main Roads have adopted interim specifications limits that are in line with the national specification framework.
Used in:

- Structural layers of asphalt pavement

EME2 stands for Enrobés à Module Elevé (translates to High Modulus Asphalt) class 2 asphalt mixtures. This asphalt technology was developed in France where it was used under roads with heavy traffic, including airports. As outlined on the WARRIP website, "EME2 technology offers the prospect of reduced asphalt thickness for heavy duty pavements" (WARRIP, 2022). EME2 can be

used as a replacement for full depth asphalt by replacing the intermediate layers. Main Roads projects currently in the development phase are investigating the opportunity to use EME2 in construction. Mixes of EME2 are created using a hard penetration grade bitumen which is applied at a higher binder content compared to traditional asphalt. Benefits of using EME2 have been identified following trials undertaken in both Queensland and Perth to demonstrate the use of the material on local aggregate.

A reduction in asphalt thickness of up to 55mm can be achieved using EME2, which also significantly reduces the amount of carbon emissions from pavement construction. This 55mm reduction equals a 25-30 percent reduction in EME2 asphalt pavements compared to traditional pavement.

There are also economic sustainability benefits of EME2, given materials reduction reduces both the upfront costs associated with the material, and the long-term maintenance costs of the material, given there is a "longer time between maintenance" (WARRIP, 2022).

For further information on the use of this material, please contact the Main Roads Materials Engineering Branch.

Warm Mix Asphalt
Key Specifications: 502.34, 504.34, 510.34, 511.21, 516.14

Used in:

- Asphalt pavement

Warm mix asphalt has been used for a number of years in Western Australia. Warm mix asphalt is produced using a workability additive which results in the production of asphalt at a lower temperature, whilst remaining workable. Main Roads have stone mastic (502), wearing course (504) and intermediate course (510) asphalt specifications that allow the use of warm mix additives. Warm mix additives are mandated in the crumb rubber open grade (516) specification.

Currently, two products are permitted for use on the Main Roads network: Sasol Sasobit and Evotherm. These products are referred to in specification 502, 504, 510, 511, and 516. Different additives and additive dosages will have different temperature thresholds, and these thresholds are also impacted by mix type, binder type and the climate.

Projects and contractors should note that the main challenge associated with warm mix asphalt is determining what level of temperature reduction can be achieved, and this is based on the threshold of the mix.

Note that cold mix asphalt is not yet endorsed by Main Roads. Projects should liaise with the Materials Engineering Branch if they are investigating the use of this product.

Crumb Rubber
Key Specifications: 509.21, 516,
Used in:

- Sprayed seals
- Open-graded asphalt
- Gap-graded asphalt

Key Properties	Optimum Use	Alternative Use in Roads
• **Elastomeric** • **Loves bitumen**	• Reuse into new rubber products	• Recycle into bitumen/asphalt

Crumb rubber is produced from the recycling of waste light and heavy vehicle tyres.
Crumb rubber contains valuable polymers and carbon black that are combined with bitumen, asphalt mix, or sprayed seal to increase skid resistance and drainage improvements. The use of this material in road construction also helps to solve the challenge of dealing with the large number of tyres sent to waste each year. Other benefits of using crumb rubber in asphalt mixes (dependent on mix type) include longer service life, resistance to crack reflection, and greater aggregate adhesion.

Main Roads has a long history of using crumb rubber in sprayed bituminous seals, with 600-700 tonnes of scrap rubber used annually for this application. Granulated rubber is used in seals to reduce reflection cracking and improve stone retention. Crumb rubber modified (CRM) bitumen is typically used for water proofing membranes on bridge decks, limited surfacing applications and widespread resealing where cracking is known to occur. Crumb rubber has predominantly been imported from Victoria, however there are two suppliers currently being established in Perth:

- RubberGem Kwinana; producing 2000 tonnes/annum since early 2021
- 4M Waste Malaga; processing truck and passenger tyres, capacity to produce 600 tonnes/annum expected to increase to 2000 tonnes/annum

Main Roads have recently created new methods of utilising crumb rubber in asphalt mixes through WARRIP. Similar to its use in sprayed bituminous seals, CRM bitumen in asphalt produces more durable roads that are resistant to oxidation, cracking and ravelling. It also plays a key role in further reducing the large volumes of tyres sent to landfill each year.

During 2020/21, Main Roads used approximately 2,753 tonnes of crumb scrap rubber across the state-controlled road network. This is up from the 1,900 tonnes used in 2019/2020 which equivalated to 380,000 passenger car tyres. This met Main Roads' intent to double the usage of crumb rubber from 600 tonnes to 1,200 tonnes by 2021, as outlined in the Western Australia Waste Strategy 2030.

Road Structures and Furniture

Cementitious Products – Concrete
Key Specification: 820
Used in:

- Precast structural elements
- Piles
- Buried structures

Main Roads WA uses S50M (50 MPa class concrete) that is a blended cement comprising 32 percent type GP (General Purpose) cement, 60 percent Ground Granulated Blast Furnace Slag (GGBFS) and eight percent silica fume. S50M concrete is used for mass concrete placement, as it has reduced thermal expansion and a consequent reduction in cracking. This type of concrete is also implemented in environments that have been or are exposed to sulphate and chloride attack, due to its high tolerance and resistance levels, such as marine environments.

Silica Fume is a by-product of the production of silicon alloys in electric arc furnaces. It is added to concrete to prove properties such as compressive strength, bond strength and abrasion resistance. GGBFS, when in the presence of an activator such as hydrated lime, has cementitious properties. GGBFS is a fine pozzolanic material that is a by-product of iron manufacturing. The material has been previously used successfully on Lancelin Road, where a 70/30 blend of GGBFS and Quick Lime was applied at three percent by mass to the upper 100 mm of a limestone basecourse.

Recycled Tyre Rubber
Used in:

- Guideposts

Guideposts produced from waste tyre rubber are preferable over timber guideposts due to their durability, service life, and resistance to impact and termites (compared to timber posts). These posts have been used across many projects across the state network. The type of recycled rubber guidepost commonly used is comprised of a plastic sleeve on a rubber leg drilled into the ground. Rubber guideposts are able to recover to their original upright position after being hit by a motor vehicle, and are less likely to crack or split upon impact from a vehicle or extreme weather. They also positively impact the circular economy as recycled tyres get a second use.

Recycled Plastic
Used in:

- Temporary Guideposts

A number of projects are mandating the use of recycled plastic star pickets for different temporary uses. There are companies that can collect these star pickets once used and recycle them into new products. The Bunbury Outer Ring Road currently has a commitment to investigate the use of these pickets for temporary works, and once finished being used on the Project, they will be recycled back into another form of plastic.

Recycled Glass Beads
Used in:

- Road marking paint

Recycled glass is used to manufacture glass beads that are applied to road marking paint to provide better visibility at night and in wet conditions. They act as a reflector to vehicle lights in the paint. There is potential for heavy metal contaminants to be present in some recycled products. The exclusion of heavy metals in glass beads is managed through a specification for the supply of glass beads for pavement markings, allowing them to be used on WA roads.

Reconstituted Structural Blocks
Key Specification: 905.07
Used in:

- Retaining Walls

Main Roads uses limestone retaining walls for a number of projects every year. There has been research into making retaining walls out of eco-friendly recycled materials, such as crushed recycled concrete, rubble, and crushed recycled glass that may be used in these retaining walls. The combination of these recycled materials can minimise the use of concrete in footings, reducing the amount of cement used on Main Roads projects. This initiative reduces the environmental impacts associated with cement production, including carbon dioxide emissions and chemicals leaching into waterways. It is important to note that crushed recycled concrete used in retaining must meet Main Roads specification 501.92.

Eco-blocks are a reconstituted structural block made of recycled materials including crushed recycled concrete. The Kwinana Freeway Northbound Widening Project (Russell Road to Roe Highway) used over 35,000 eco-blocks in the construction of the retaining walls. Eco-blocks replaced the need to use reconstituted limestone blocks on the Project, avoiding the use of the limited limestone resource. Eco-blocks have the same texture and appearance as reconstituted limestone, and are favourable given the quality and consistency of these blocks compared to traditional limestone.

Geopolymer Concrete
Key Specification – 820 (Concrete For Structures)
Used in:

- Bridgeworks
- Pedestrian overpasses/underpasses
- Manufacturing box culverts
- Major structural works

Geopolymer concrete is made in a similar fashion to concrete, however it consists of waste materials. Commonly, activated waste fly ash is used as the binder. Fly ash is a by-product from coal burning power stations used to generate electricity. Reusing by-products supports the circular economy. Geopolymer concrete used in Main Roads projects must consist of a mixture of fly ash, slag, sodium silicate and sodium hydroxide in solution or solid form, and extra water constituting

alkaline solution comprising of coarse aggregate and fine aggregate. Geopolymer concrete is a low-calcium product and is resistant to sulphate attack.

Main Roads have undertaken a number of feasibility studies and trials of Geopolymer concrete. These investigations found that Geopolymer concrete could be used in structural works, providing a more environmentally sustainable alternative to commonly used Ordinary Portland Cement (OPC). OPC emits approximately one tonne of carbon dioxide per one tonne of cement produced. Main Roads are also working with Curtin University to assess the performance of Geopolymer concrete in precast applications. Investigations to date have shown that it is feasible to produce high strength box culverts using Geopolymer concrete with some modification of current precast concrete practices.

Ongoing research will assess the long-term strength and durability of box culverts (used in road works and drainage) using Geopolymer concrete. The primary objectives of this research are to:

- Investigate the long-term strength of Geopolymer concrete
- Assess precast construction requirements
- Assess the durability of Geopolymer concrete in normal and aggressive environments compared to conventional concrete
- Develop a specification for box culverts.

Plastic Noise Walls

Plastic noise walls were used on a short section of Roe Highway in the Roe Highway Duplication: Tonkin Highway to Orrong Road. The plastic noise walls were used to reduce the amount of deadload on the freight rail bridge between Tonkin Highway and Orrong Road. Projects looking to use plastic noise walls should also consider the use of recycled plastic, including HDPE plastic. Investigations have commenced into the use of recycled plastic noise walls on projects currently in the planning phase.

Projects investigating the use of plastic noise walls need to consider the following:

- Plastic noise walls should not be placed in locations where they can be tampered with by the public e.g. avoiding damage and graffiti.
- Plastic noise walls should be designed to be fire resistant in all areas, especially bushfire prone areas.

By-product Materials

Mining Waste (Overburden)

Used in:

- Basecourse layer
- Embankment fill
- Basecourse on pavement overlay

Sourcing road building materials from gravel and borrow pits is becoming more challenging for all roads across the state. Main Roads is continually looking for more sustainable alternatives to these traditional road building materials. One of these materials is mining waste from different pits across WA. Each mine produces different materials that can be used in the basecourse, or as fill in the embankment layer (subbase materials) of roads.

The extraction of traditional road building materials typically requires the clearing of native vegetation, followed by a rehabilitation period once the pit has been exhausted. Using excess mining waste reduces the need to extract virgin material for road construction, while also enhancing the circular economy in WA. Mining waste (overburden) can and has been used to extend and maintain the state network across regional WA. This section is broken down into the different WA regions and the mines that have or are going to provide overburden for regional roads.

The ability for Main Roads to utilise waste materials for road construction will also benefit mine operators, as it can reduce closure costs given less material will be going into waste rock landforms. Different mine sites and their respective materials which may be used in road construction are outlined below.

Kimberley Region

Savannah Nickel Waste Rock

Waste rock from the Savannah Nickel Mine has the potential to be used in the basecourse.
The rock was trialled in 2016 on a short section of Great Northern Highway. This material was nominated in an Information for Tenders contract document, and Main Roads liaised with the mine to determine a preferred proponent in sourcing basecourse material. The trial section is now three years old and is performing well.

Pacific Niugini Nicholson's Gold Deposit

This Gold Deposit mine is located 50km west of Halls Creek on the Great Northern Highway. Initial testing of the waste rock material from this mine showed that it has potential to be used as sealing aggregate, in subbase, and in rock spalls.
This mine site is in close vicinity to the Laura River quarry and would be a suitable replacement for the deposit. It is important to note that there are heritage and environmental constraints with this quarry.

Rio Tinto Argyle Diamond Mine

Rio Tinto recently shut down their Argyle Diamond Mine in the Kimberley after 37 years in operation. Main Roads are currently liaising with the Mine Manager to collect samples and evaluate if any waste materials can be used on the road network.

Pilbara Region

Marandoo Rio Tinto Iron Ore Deposit
Main Roads collaborated with Rio Tinto to test the material within their waste rock landforms coming from the Marandoo mine site. Test results were positive and 40,000 tonnes of waste rock was carted to a hardstand area on the Paraburdoo-Tom Price Road for widening work. No further crushing or screening of the material was required, and the rock was used as embankment fill rather than basecourse, given the quantity of the material was relatively small.

FMG CID deposit
Main Roads and Fortescue Metals Group (FMG) have been collecting bucket samples and undertaking visual site inspections of the CID deposit in the Pilbara. The site is located in a favourable location and the large deposit possesses basecourse quality material. FMG are continuing investigations into what is waste and what may contain low-grade ore.

Novo Resources - Beaton's Creek
The waste material from this mine has been tested and classified as subbase quality. The site is close to Nullagine town site, and Novo Resources are using this material for their access roads.

Goldfields Region

Austral Pacific ex Paris and HHH mines
This mine site is approximately 30km east of Coolgardie Esperance Highway near Higginsville. Austral have liaised with DMIRS regarding the reuse of mining waste and have engaged Golder Associates to test and assess the suitability of this waste material. To date, the petrographic testing has come back positive.
A trial is being undertaken to assess whether crushing will generate fines with plasticity to improve the properties of the material. Austral are interested in pursuing the materials potential to supply it to projects in the Kalgoorlie-Norseman area.

Wheatbelt Region

Dalwallinu Gold Mine
The Pithara upgrade of Great Northern Highway used material from an old open-cut gold mine that is close to the Pithara town site. Material was used as rock protection and blended with local gravel to be used as a basecourse material for the upgrade in 2018-2019.

Great Southern Region

Mt. Cattlin Mine Site – Galaxy Resources, Ravensthorpe
Granite and basalt from rock and soil waste stockpiles from this mine have previously been used as rock protection on road projects. Additionally, crushed product has been used as embankment fill for bridge approaches and basecourse for pavement construction on the Phillips River Bridge project. A blend of crushed waste rock and imported laterite gravel was also used as basecourse on pavement overlay works in the region.

Mid-West Gascoyne Region

Plutonic Mine
The Plutonic Mine is located east of Great Northern Highway near Kumarina. Overburden stockpiles from the mine may potentially be used as basecourse or subbase. A small quantity was used for pavement repairs in 2017 and is currently performing well. Other mines south of Kumarina along

Great Northern Highway were contacted in the 2019-2020 financial year to discuss potential rock protection and construction material for floodway upgrades in the vicinity of the Gascoyne River.

Crusher Dust

Used in:

- Embankment/subgrade
- Road Pavement

Crusher dust is a by-product produced during the process to crush rocks. It is used in road construction in the pavement layer and embankment or subgrade layer, and is generally 5mm or less in thickness (Boral, 2022). The Leach Highway and Welshpool Road Interchange have used crusher dust that is a by-product from the basecourse material laid on the Project.

This initiative has been used on a number of our previous projects, and supports a reduction in the waste going to landfill allowing more of a resource to be used.

Sustainable Stabilisation Methods

Foamed Bitumen Stabilisation

Foamed Bitumen Stabilisation (FBS) has been used over the past 30 years in WA, mainly by Local Government Authorities (LGAs). LGAs initially adopted FBS to fix local roads with bitumen that is prone to cracking. The first initiative of FBS in Perth was pioneered by the City of Canning and Downer Engineering.

The Materials Engineering Branch within Main Roads has undertaken a number of trials of FBS across the state network, including at the following locations:

- May 2009: Tonkin Highway Trial (300m of the eastbound carriageway near Perth Airport)
- February 2010: Kwinana Freeway Trial (300m of the northbound carriageway near Mundijong Bridge)
- October 2014: Thomas Road Trial (340m of the left lane westbound was bitumen emulsion stabilised, 200m of the left lane eastbound was foam bitumen stabilised)

The Kwinana Freeway trial near Mundijong Road treatment program comprised of in situ mixing of existing pavement material and thin asphalt surfacing with three to four percent foamed bitumen and 0.8 percent quick lime. The purpose of these trials was to assess the performance of this method of pavement recycling in different pavement stabilisation depths and bitumen contents.

These trials continue to perform and are maintaining well. Foamed bitumen stabilisation is being used successfully in other states, but the pavement materials are different and therefore the procedures and outcomes achieved elsewhere cannot be simply transferred to Western Australia. Although this stabilisation treatment is being used elsewhere in Australia, an Austroads method of thickness design has not been developed and consequently there is currently no method to estimate the design life of FBS pavements. There are also limitations that Main Roads faces regarding the use of FBS to rehabilitate roads in the Perth Metropolitan area, including:

- The length of time required to complete repairs before opening to road to traffic (typically around four to seven days)
- The establishment costs for FBS treatment are high and not always economically sustainable
- The costs of FBS treatment are higher than a thick asphalt inlay treatment for short sections of pavement repair

In the Wheatbelt, Main Roads have used Foam Bitumen Stabilisation, which (in regional environments) is economically sustainable and a time efficient process to stabilise the road surface. Over 6200m^2 of area has already been treated using this stabilisation method. Foam Bitumen Stabilisation completed on this area used 1.5 percent bitumen and 0.8 percent hydrated lime. Hydrated lime is commonly used as an activator to stabilise road surfaces and form a cemented finish.

Emulsion Stabilisation

Emulsion (bitumen) stabilisation is applicable to granular materials that have low cohesion and plasticity. This method is used to agglomerate the fine particles in the bitumen together, decreasing the permeability and moisture sensitivity of the granular material. The cohesive strength of the mixture increases, meaning the condition of the road surface remains in an acceptable condition for a longer period.

The Main Roads Wheatbelt Region have been undertaking extensive pavement repairs using different emulsion stabilisation methods for over three years. In the 2020/21 financial year, an area of 2300m^3 of pavement is to be treated by stabilising the basecourse.

Lime Stabilisation
Main Roads includes hydrated lime in all metropolitan and most regional asphalt mixes. It is an activator, meaning the product promotes bonding between bitumen and aggregate materials. It also assists in managing stripping in the pavement, which is caused from a loss in the bonds between the aggregate and bitumen.

Some suppliers in the Perth Metropolitan area use lime kiln dust in their asphalt mixes, however Main Roads does not currently allow suppliers to substitute hydrated lime with lime kiln dust. Main Roads is currently liaising and working with Curtin University to evaluate the use of lime kiln dust in asphalt.

Lime can also be used to stabilise clay subgrades, as lime binds to clay particles to make it less susceptible to moisture changes.

Type LH Cement
Low heat (LH) cement is similar to S50M but contains 35% GP and 65% GGBFS. LH cement is almost exclusively utilised in cement stabilisation, however it is also allowed in mass concrete applications. Contact the Main Roads Materials Engineering Branch for more information on type LH cement.

Pavement Stabilisation
Low heat cement is manufactured with lower heat generation that ordinary Portland cement. Main Roads allow for the use of type LH cement in mass concrete applications. Low heat cement has been used on the Main Roads network previously.

Other Materials

Food and Garden Organics
Used in:

- Topsoil
- Soil Conditioner
- Mulch

Food and Garden Organics (FOGO) has been identified by the Sustainability Waste Alliance (SWA) for use as soil conditioner, mulch, and topsoil. The SWA comprises of stakeholders including Main Roads WA, PTA, DWER, Bunbury Harvey Regional Council, Eastern Metropolitan Regional Council and ChemCentre among a number of others.

The SWA have recently released the Food and Garden Organics Companion Document and Product Specification. This Product Specification can be found on the SWA website, and has been developed to "sit alongside existing specifications for landscaping products in use by Government Agencies with responsibility for infrastructure development[2]." Therefore, it should be used in conjunction with AS4454 or AS4419, and not be considered as a replacement for these standards.

[2] Sourced from https://www.swainnovationhub.org/uploads/1/3/9/4/139457899/fogo_spec_and_companion_final_june_2022.pdf

The Product Specification also outlines that managing the use of FOGO on site will need to be undertaken in accordance with Main Roads relevant specifications.

There are significant environmental benefits associated with the use of FOGO. Reusing FOGO in infrastructure projects reduces the amount of food and garden waste that is sent to landfill, where it generates methane gas. Further details on the environment benefits and the risk mitigation when using FOGO can be found in the Product Specification.

FOGO is currently being investigated on a number of Main Roads projects.

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