Practitioners Guideline: Design and Construction using crushed recycled concrete on Local Government roads in WA

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1.0

About LG TRRIP

The Local Government Roads and Research and Innovation Program (LG TRRIP) is an initiative between Main Roads Western Australia and the Western Australian Local Government Association.

LG TRRIP has a strategic commitment to the delivery of collaborative research and development that positively contributes to the design, construction and maintenance of safe, sustainable transport infrastructure in Western Australia.

Acknowledgements

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Contents

1 Introduction

1.1 Overview

Construction and Demolition (C&D) material makes up approximately half of total waste generated in Western Australia and therefore represents considerable opportunity for recovery. The Roads to Reuse (RtR) program supports the supply of recycled C&D products to market that meet a product specification designed to protect human health and the environment. Crushed Recycled Concrete (CRC) is sourced from C&D material that primarily comprises concrete, but may also contain sand, brick, tile, asphalt and glass. To enable successful use of CRC products in infrastructure projects, it is valuable to have an understanding of the unique qualities of these materials and how engineering properties can vary depending on the material's source.

CRC, in most cases, can be used as a direct replacement for granular sub-base layers with no changes to the pavement profile. It is typically only where CRC is used as a basecourse material that additional treatments need consideration.

The *Practitioners Guideline: Design and Construction Guideline for the use of Crushed Recycled Concrete on Local Government Roads in WA* (this guideline) provides a catalogue of pavement profiles for sub-base and basecourse applications based on design traffic and subgrade CBR scenarios.

While typically low consequence, shrinkage (block) cracking and surface defects arising from the presence of expansive materials may warrant further consideration, depending on the required level of pavement performance. Treatments to manage the risks associated with CRC may be required in some cases, and guidance is provided to assist practitioners in deciding when treatments may be required and selecting an appropriate treatment.

This guideline supports practitioners proposing to use CRC by providing advice on material properties, case studies of existing CRC pavements, considerations when planning the use of CRC, CRC pavement designs, options to mitigate the unique risks associated with CRC, construction advice and expected CRC pavement maintenance requirements.

This guideline does not contain significant background or supporting information. The accompanying technical report should be referred to for further information.

1.1.1 Acronyms and Key Terms

Definition of the acronyms and key terms presented in this report are provided in Table 1 and Table 2 respectively.

Table 1: Acronyms

Acronym	Definition
C&D	Construction and Demolition
C170	Class 170 (bitumen)
CBR	California Bearing Ratio
CRC	Crushed Recycled Concrete
DWER	Department of Water and Environmental Regulation
ESA(s)	Equivalent Standard Axle(s)
GRS	Geotextile Reinforced Seal
IPWEA	I Institute of Public Works Engineering Australia
LG(s)	Local Government(s)
LG TRRIP	Local Government Transport and Roads Research and Innovation Program

MRWA	Main Roads Western Australia
NATA	National Association of Testing Authorities
NTRO	National Transport Research Organisation
PDWSA(s)	Public Drinking Water Source Area(s)
pH	Potential of Hydrogen
PTA	Public Transport Authority (of Western Australia)
RtR	Roads to Reuse
SAMI(s)	Strain Alleviating Membrane Interlayer(s)
WA	Western Australia
WALGA	Western Australian Local Government Association

Table 2: Key Terms

Key Term	Definition
Asphalt Geogrid	Asphalt Geogrid A reinforcing geogrid specifically designed for use within or immediately below asphalt layers.
Block Cracking	Cracking typically associated with shrinkage of a cementitious material, generally occurs as a "block" pattern with cracks spaced several metres apart. Also known as shrinkage cracking.
Bonded	In the context presented in this report, bonded pavement layers refers to layers which have been constructed separately, but have sufficient strength at the layer interface such as they act as a combined homogenous layer.
Bound	With regard to pavements, a material which has the ability to develop tensile strength, typically through modification with cement or bitumen. Austroads (2017) defines a bound pavement material as having a 28-day UCS >2.0 MPa.
Class 170 (C170) Bitumen	Unmodified bitumen typically used for sprayed sealing and in the manufacture of asphalt.
Contaminant	In the context of this report, refers to items that may be present within CRC and could cause harm to human health or the environment. Typically refers to asbestos and heavy metals.
Crack Mitigation Layer	A layer placed below the wearing surface to intercept and reduce the risk of block cracking occurring in underlying bound layers reflecting through the wearing surface.
Crushed Recycled Concrete	Material sourced from construction and demolition material primarily comprising crushed concrete. For the purpose of this report, CRC includes material that will be subject to rehydration of residual cement in the product, with behaviour in the long term similar to lightly bound, bound or modified materials as defined by Austroads (2017).
Crushed Rock Base	A basecourse-quality unbound granular pavement construction material sourced from high strength crushed rock.
Fatigue Cracking	Cracking in a bound layer (typically asphalt or a cementitious layer) induced by the repeated action of traffic. Typically evidenced by crocodile cracking, but may present as tightly spaced block-shaped (square) cracks typically confined to the wheel path when occurring in a bound pavement layer.
Foreign Material	Material which does not form part of the CRC source material (i.e. concrete) such as solid metals, aggregates, asphalt, paper, glass, organics etc.
Geotextile Reinforced Seal	A sprayed seal which contains a layer of geotextile.
Impurity	In the context of this report, refers to foreign material that may affect the performance of CRC when used in a pavement. Typically refers to metallic aluminium and gypsum.
Reflection Cracking	The occurrence of cracking in a wearing surface (usually asphalt) induced by cracking which commenced in an underlying layer. Typically relates to block cracking in an underlying cementitious layer presenting at the surface of the asphalt.
S20E	A polymer modified bitumen used for sprayed sealing.
S45R	A rubber modified bitumen used for sprayed sealing.
Shrinkage Cracking	Block Cracking.
Strain Alleviating Membrane Interlayer	A sprayed seal using a modified bitumen (such as S20E or S45R) intended for use below an asphalt wearing course. Not intended to be trafficked until construction of the overlying asphalt is complete.
Unbonded	In the context presented in this report, unbonded pavement layers refers to layers which have been constructed separately, but have insufficient strength at the layer interface to act as a combined homogenous layer.
Unbound	A granular pavement material that does not develop significant tensile strength. Strength of unbound materials predominantly occurs through interparticle friction.

Unconfined Compressive Strength	The maximum axial compressive stress that a sample can withstand under zero confining stress.

1.2 Background

This Guideline has been prepared under LG TRRIP, which is a program undertaking innovative research targeted for Local Governments in WA. The objective of the program is to achieve better implementation of innovative practice by improving the specialist capability of LG through a collaborative program of projects which deliver advanced technology, cost effective and practical solutions.

LG TRRIP is managed by WALGA and MRWA with the assistance of NTRO. A considerable amount of suitable construction materials have historically been sent to landfill, with C&D material in particular making up approximately half of total waste generated in WA. There is opportunity to recover this material for use in construction, with potential benefits including a reduction in reliance on virgin materials, reduced landfill requirements and lower emissions associated with waste transport. The RtR program has been developed to ensure that recycled C&D products meet a product specification designed to protect human health and the environment.

CRC is a valuable C&D material, and a resource that is suitable for use in construction of pavements. This guideline and associated technical report have been prepared to facilitate wider use of CRC in local roads for LG pavements, and to help asset owners understand how CRC pavements may perform. This will help LGs make informed decisions on the suitability of CRC for use on their road network.

1.3 Definition of CRC

CRC is sourced from C&D material that primarily comprises concrete, but may also contain sand, brick, tile, asphalt and glass. It is typically a high strength pavement construction material and has self-cementing properties, with an increase in stiffness over time as residual cement present in the material rehydrates. CRC can behave as a “lightly bound” pavement material in the longer term as this rehydration occurs (MRWA, 2022).

1.4 Advantages of using CRC

CRC has a number of advantages over traditional pavement construction materials, including:

- CRC has significant sustainability benefits compared with virgin materials and reduces our reliance on quarried pavement construction materials.
- CRC is typically widely available within metropolitan areas (and some regional areas), with a number of suppliers located within the vicinity of the Perth metropolitan area.
- The rigorous pre-acceptance and material processing controls, as well as batch testing requirements for CRC sourced from RtR accredited suppliers, results in a very low risk of contamination, with no reported asbestos exceedances at the time of writing since the current testing program commenced in financial year 2019/20.
- As a manufactured (crushed and screened) material, CRC can be produced to a relatively tight specification requirement, reducing variability in performance.
- CRC has demonstrated good performance in pavement applications. The technical report contains further information on CRC performance.
- CRC is typically cost competitive with comparable materials.
- CRC is easy to place, moisture condition and compact.
- CRC can be trafficked unsealed for short periods with minimal risk of damage, potentially facilitating construction.

1.5 Structure

The following documents have been prepared:

- Practitioners Guideline (this guideline).
- Technical Report.

The content and relationship between each of these documents is summarised in Table 3.

Table 3: Structure of the documents

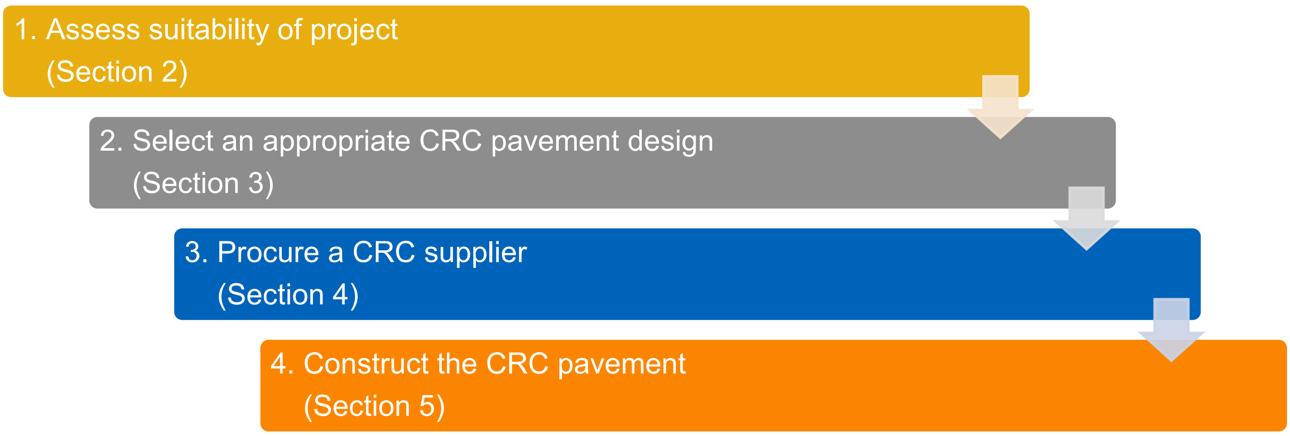
Document	Content
Practitioners Guideline	The Practitioners Guideline is presented in a user-friendly format and provides key information needed for LG road managers practitioners to manage projects incorporating CRC.
Technical Report	The Technical Report containing the background research and supporting technical information for the Practitioners Guideline.

1.6 How to use this Guideline

This guideline contains information to assist practitioners in the selection, design and construction of projects suitable for CRC. It generally does not contain supporting information for the advice presented. The technical report should be referred to for additional background information.

The general process for using this guideline is presented in Figure 1.

Figure 1: Process for using this guideline



1.7 Roads to Reuse Program

The Western Australian Government has developed the RtR Product Specification which includes sampling, testing and auditing requirements and the requirement to produce a material acceptance and sampling plan to ensure that materials produced meet specifications designed to protect human health and the environment. These include requirements such as:

- Pre-acceptance and operational controls, such as identifying source material and contamination risks associated with the material's source, inspections, and non-acceptance or removal of non-permitted materials.
- Product sampling, testing and analysis.
- Auditing.
- Record keeping.

Depending on the source of the material and the previous use(s) of the source site, non-accredited C&D materials may include contaminants such as pesticides, asbestos, and heavy metals. The high alkalinity (pH) of CRC has a propensity to leach potential contaminants such as heavy metals into surrounding soil and drainage.

Acquiring CRC from a RtR accredited supplier provides assurance that the material has been produced to a certified standard that ensures risks associated with the material use have been assessed and managed. It is recommended that only RtR accredited materials, sourced from a RtR accredited supplier, be used. A current list of accredited RtR suppliers is available on the Waste Authority WA website (Roads to Reuse | Waste Authority WA).

1.8 Limitations

This guideline is limited to the use of CRC in typical local government pavement applications with generally low to medium traffic volumes (less than about 10^7 ESAs). This guideline may not be appropriate for roads with very high traffic volumes, high proportions of heavy vehicles, or unique loading conditions such as industrial pavements (i.e. non-road legal axle configurations or loads). However, this does not necessarily imply that CRC would not be suitable in these cases.

2 Planning for the use of CRC

2.1 General

CRC is suitable for a wide variety of pavement types and locations. When used as a sub-base, it can be used as a direct substitute for other materials without adjustments to the pavement design.

2.2 Why use CRC?

Using CRC for pavement construction reduces our reliance on quarried materials and results in a reduction in associated emissions. It also diverts suitable materials away from landfill.

CRC which complies with a suitable specification, such as IPWEA/WALGA (2016) is a high-quality material and can be produced to tight specification requirements. This is a similar process to crushed and screened quarried aggregates, and ensures consistent performance. It is also easy to moisture condition, place and compact.

A CRC pavement can withstand a reasonable volume of public traffic during construction, making it an ideal material for projects that need to be opened to traffic at the end of shifts.

There is a very low risk of contamination if a RtR accredited supplier is used. At the time of writing, no exceedances for asbestos in any sample had occurred since the commencement of the current program in 2019/20.

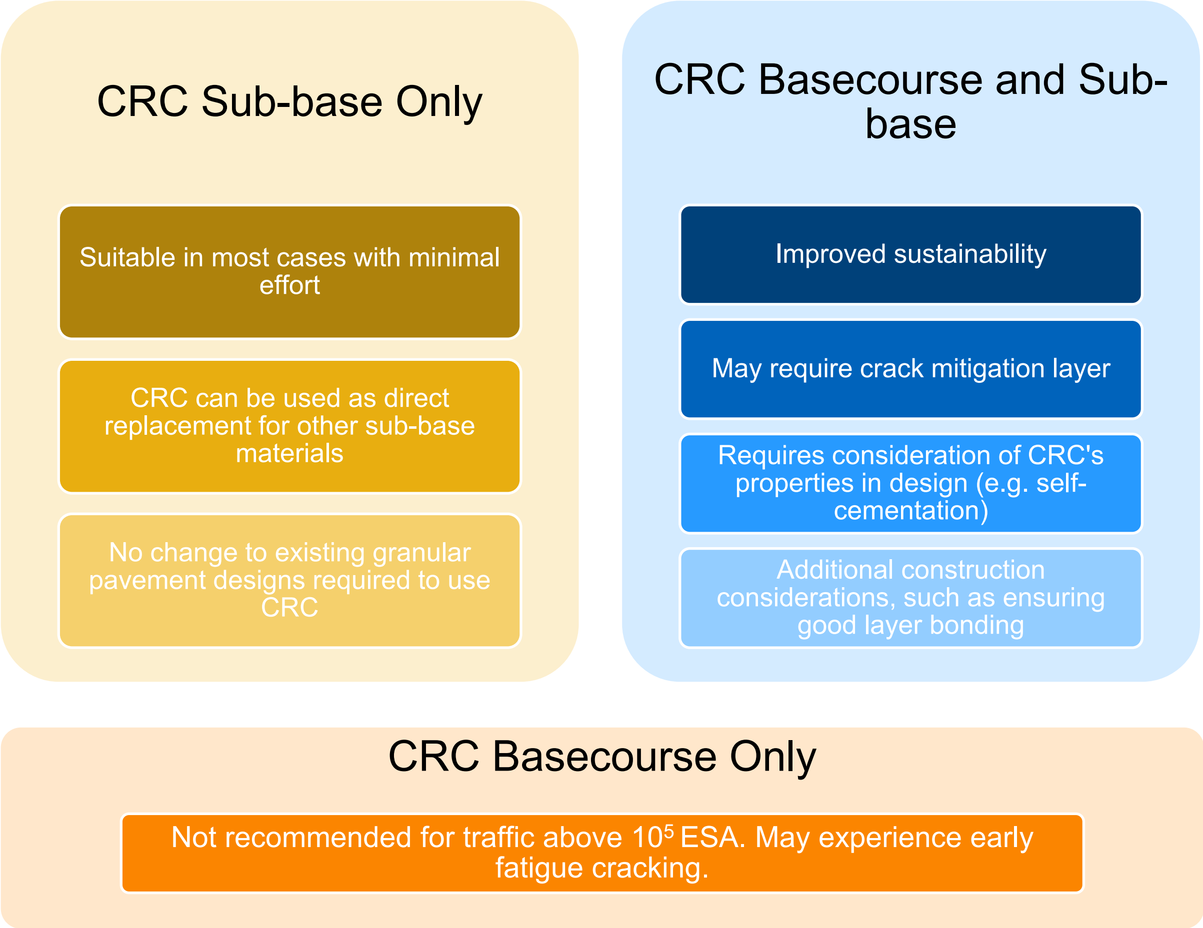
CRC is also cost competitive with comparable pavement construction materials, although this will depend on relative haulage distances.

2.3 Selecting a Pavement Profile

CRC may be used as either sub-base, or as both the basecourse and sub-base. CRC is not recommended for use in the basecourse layer without a CRC sub-base, as it may not achieve the required pavement life due to the increased risk of fatigue of the CRC layer.

Where practitioners have limited experience using recycled materials or want a direct replacement for existing pavement materials, using CRC in the sub-base only is recommended. Figure 2.1 provides information to assist practitioners in selecting appropriate pavement layers for CRC. If there is any uncertainty regarding which pavement layers should incorporate CRC, it is noted that in most instances the use of CRC as a sub-base layer is a very low risk option.

Figure 2: Selection of CRC pavement layers[1]



3 CRC Pavement Designs

The CRC pavement designs presented in this guideline assume that the IPWEA/WALGA Specification for the Supply of Recycled Road Base (IPWEA/WALGA, 2016) will be used for specification of CRC.

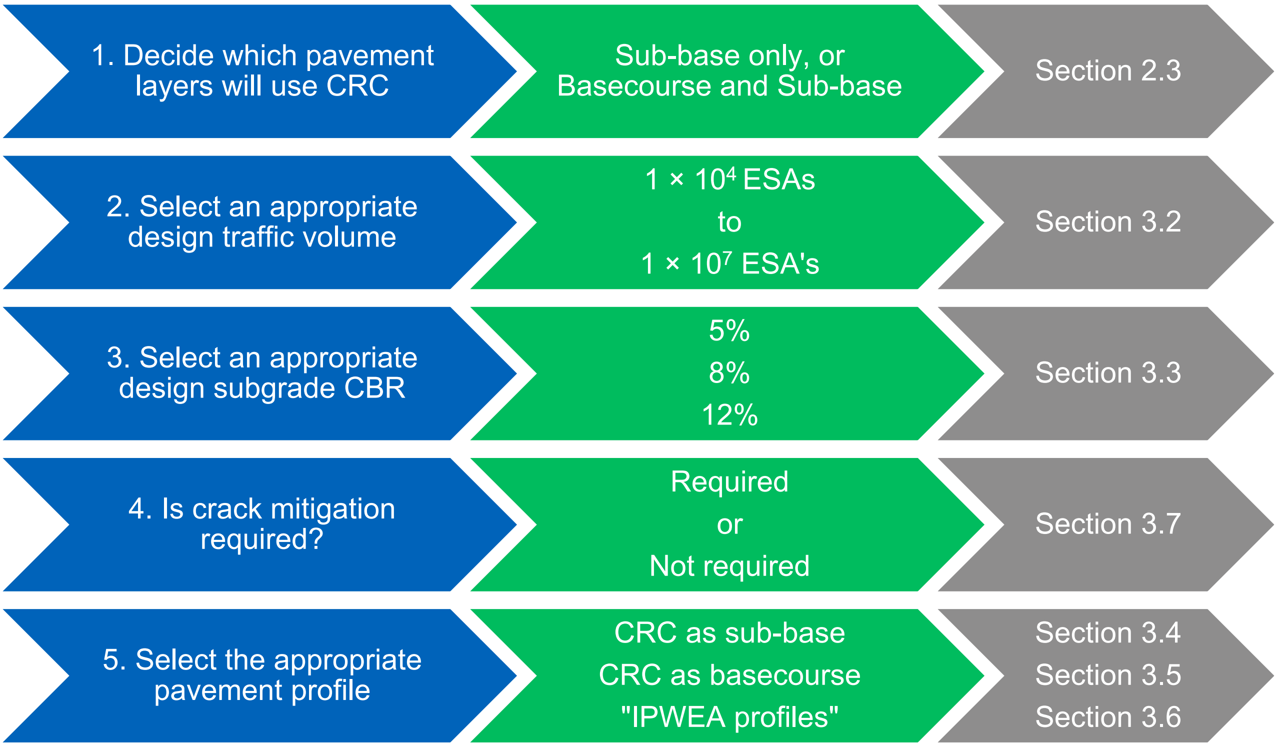
The pavement designs included in this guideline, without supporting information, are also provided in Appendix A in a printer-friendly format.

It must be noted that the minimum pavement thicknesses provided in this guideline are relatively thin (150 mm). As with any pavement, practitioners must ensure that construction is to a high quality and achieves the appropriate specification requirements to optimise the life of the pavement.

3.1 CRC Pavement Design Process

An overview of the design process is presented below.

Figure 3: CRC pavement design process



3.2 Design Traffic Volumes

Design traffic volumes ranging from 1×10^4 ESAs to 1×10^7 ESAs have been adopted for the pavement designs presented in this guideline. The designs assume a 40-year pavement design life.

Practitioners should consider expected construction vehicle traffic when selecting a CRC pavement design. For example, residential subdivisions typically have high volumes of truck movements within the first few years.

CRC may be suitable for pavements with design traffic volumes above 1×10^7 ESAs, particularly as subbase; however, it is recommended that project-specific pavement designs be conducted.

Practitioners are reminded that the importance of uniform and conforming pavement construction materials increases with design traffic loading. CRC (or any other pavement material) should only be specified for high traffic conditions where there is confidence in the quality of the material source.

3.3 Subgrade Design CBR

Pavement designs have been conducted for selected subgrade design CBRs. A guide to the CBR values adopted for various subgrade materials is presented below:

- CBR 5% – typically clayey subgrades such as Guildford Formation clays in the Perth region.
- CBR 8% – typically sandy/clayey subgrades such as some Guildford Formation clayey sands in the Perth region, and some clayey sands encountered in the Wheatbelt.
- CBR 12% – typically sandy and gravelly soils such as sand derived from Tamala Limestone (“brickies sand”) or Bassendean Sand.

It must be noted that the designs only consider subgrade strength, and other factors, such as shrink-swell movements or poor drainage conditions, may require an increase to the pavement thickness or the inclusion of a select subgrade layer. The requirement for these layers will be dependent on site-specific conditions and is beyond the scope of this guideline.

3.4 CRC as Sub-base

Pavements incorporating CRC are expected to perform comparably to pavements constructed from other materials when CRC is used in the sub-base layer only.

Practitioners are strongly encouraged to adopt CRC sub-base on their projects.

3.4.1 Direct Replacement

Where CRC is used as sub-base only and overlain by a granular basecourse layer, it is acceptable to use it as a direct replacement for other sub-base materials. LGs may adopt their typical pavement profiles and replace their typical sub-base materials with CRC. No further design is considered necessary in this instance.

Alternatively, the following designs may be used.

3.4.2 Pavement Designs

Guidance on the various pavement layers for CRC used as sub-base only is provided in Table 4. Crack mitigation is optional but should be considered based on the risk tolerance for block cracking for each project.

Table 4: CRC Pavement design profiles – CRC as Sub-base

Pavement Layer	Thickness (mm)
Wearing Course	Type and thickness to be selected by LG
Crack Mitigation (optional)	Refer to section 3.7
Unbound Granular Basecourse	Refer Table 5
CRC Sub-base	Refer Table 6

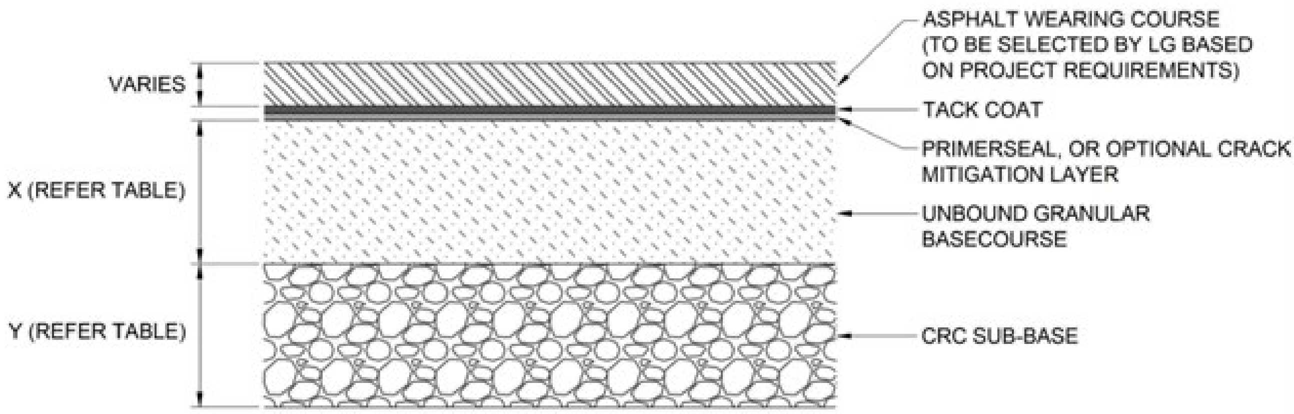
The minimum unbound granular basecourse and CRC sub-base thickness requirements are summarised in Table 5.

Table 5: Minimum unbound granular basecourse and CRC sub-base thicknesses

Subgrade Design CBR (%)	Design Traffic (ESAs) and Minimum Basecourse / Sub-base Thickness (mm)(1)						
	1×10^4	3×10^4	1×10^5	3×10^5	1×10^6	3×10^6	1×10^7
5	100 / 100	100 / 140	100 / 195	115 / 225	135 / 260	150 / 290	170 / 325
8	100 / 75	100 / 85	100 / 125	115 / 145	135 / 165	150 / 185	170 / 205
12	75 / 75	75 / 75	100 / 75	115 / 85	135 / 85	150 / 110	170 / 120

1. Values presented as "Basecourse / Sub-base". I.e. 100 / 75 = 100 mm basecourse and 75 mm CRC sub-base

Figure 4: Design profile – CRC as sub-base



SUBGRADE DESIGN CBR	TRAFFIC VOLUME (ESAs) / X/Y (mm)						
	1×10^4	3×10^4	1×10^5	3×10^5	1×10^6	3×10^6	1×10^7
5%	100 / 100	100 / 140	100 / 195	115 / 225	135 / 260	150 / 290	170 / 325
8%	100 / 75	100 / 85	100 / 125	115 / 145	135 / 165	150 / 185	170 / 205
12%	75 / 75	75 / 75	100 / 75	115 / 85	135 / 95	150 / 110	170 / 120

Note: ESAs - Equivalent standard axles

CRC AS SUB-BASE

Source: WSP

3.5 CRC as Basecourse and Sub-base

Guidance on the various pavement layers for CRC used as basecourse and sub-base are provided in Table 6. It must be noted that for this option there are no separate basecourse and sub-base layers; rather, the pavement is one homogenous layer of CRC that may be constructed in multiple layers depending on the pavement thickness. Bonding between each constructed layer is critical to optimising the life of the pavement (refer Section 5.4).

Fatigue of the CRC layer has not been considered for traffic volumes of 3×10^5 ESAs or below. In the author's experience, fatigue of CRC causing a significant reduction in pavement life is unlikely to occur at these relatively low traffic volumes. However, practitioners should note that thin CRC pavement layers may be more susceptible to fatigue if excessive traffic loading occurs.

Table 6: CRC Pavement design profiles – CRC as Basecourse and Sub-base

Pavement Layer	Thickness (mm)
Asphalt Wearing Course	Type and thickness to be selected by LG
Crack Mitigation (recommended)	Refer Section 3.7
CRC Basecourse and Sub-base	Refer Table 7

The minimum combined CRC basecourse and sub-base thickness requirements are summarised in Table 7. Individual CRC layers should typically be placed between 75 mm and 250 mm compacted thickness and be well bonded as outlined in Section 5.4. Adjustments to these layer thickness requirements may be made by LGs to facilitate construction where the specification requirements can be achieved.

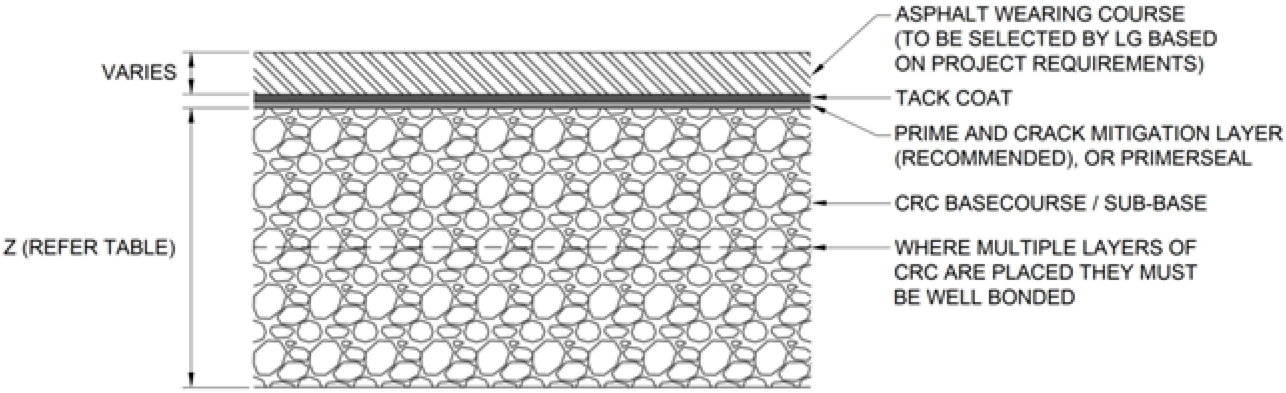
Table 7: Minimum CRC sub-base and basecourse combined layer thickness requirements

Subgrade Design CBR (%)	Design Traffic (ESAs) and Minimum Basecourse / Sub-base Thickness (mm)[1]						
	1×10^4	3×10^4	1×10^5	3×10^5	1×10^6	3×10^6	1×10^7
5	200	240	295	340	355	375	405
8	175	185	225	260	320	340	370
12	150	150	175	200	285	305	330

1. Fatigue of CRC layer not considered for design traffic volumes of 3×10^5 ESAs or less.

For pavements with traffic less than 3×10^5 ESAs, the CRC can be constructed in a single layer.A design profile for CRC as basecourse and sub-base is included in Figure 5. Where the required level of compaction can be achieved for the full thickness of the pavement, construction of the basecourse and subbase as one combined layer may be considered, as this eliminates the potential for a poor bond to occur at the sub-base/basecourse interface.

Figure 5 Design profile – CRC as basecourse and sub-base



SUBGRADE DESIGN CBR	TRAFFIC VOLUME (ESAs) / Z (mm)						
	1 x 10^4	3 x 10^4	1 x 10^5	3 x 10^5	1 x 10^6	3 x 10^6	1 x 10^7
5%	200	240	295	340	355	375	405
8%	175	185	225	260	320	340	370
12%	150	150	175	200	285	305	330

Note: ESAs - Equivalent standard axles

CRC AS BASECOURSE AND SUB-BASE

Source: WSP

3.6 IPWEA Local Government Guidelines for Subdivisional Development Pavement Profiles

IPWEA (2016) provides various pavement profiles for urban pavements. While the CRC designs presented in Sections 3.4 and 3.5 are generally recommended, where LGs would typically adopt an IPWEA (2016) pavement profile, CRC may be used as direct replacement for the sub-base layers.

3.7 Crack Mitigation

Crack mitigation is typically not required where CRC is used as a sub-base only, as the presence of the overlying unbound granular basecourse provides some resistance to reflection of block cracking in the CRC layer through the wearing course. However, practitioners can elect to include additional crack mitigation measures depending on the risk tolerance of their specific project.

The intent of crack mitigation is to reduce the risk and severity of cracks occurring in the CRC pavement from affecting the wearing course. It may comprise a layer included specifically for this purpose (typically a type of sprayed seal such as a SAMI) or adjustments to the properties of the asphalt wearing course. Practitioners should note that, depending on the treatment adopted, these treatments may only delay the onset of reflection cracking.

Where reflection cracking needs to be managed, several options may be considered. The benefits and risks associated with each option are discussed further in the technical report.

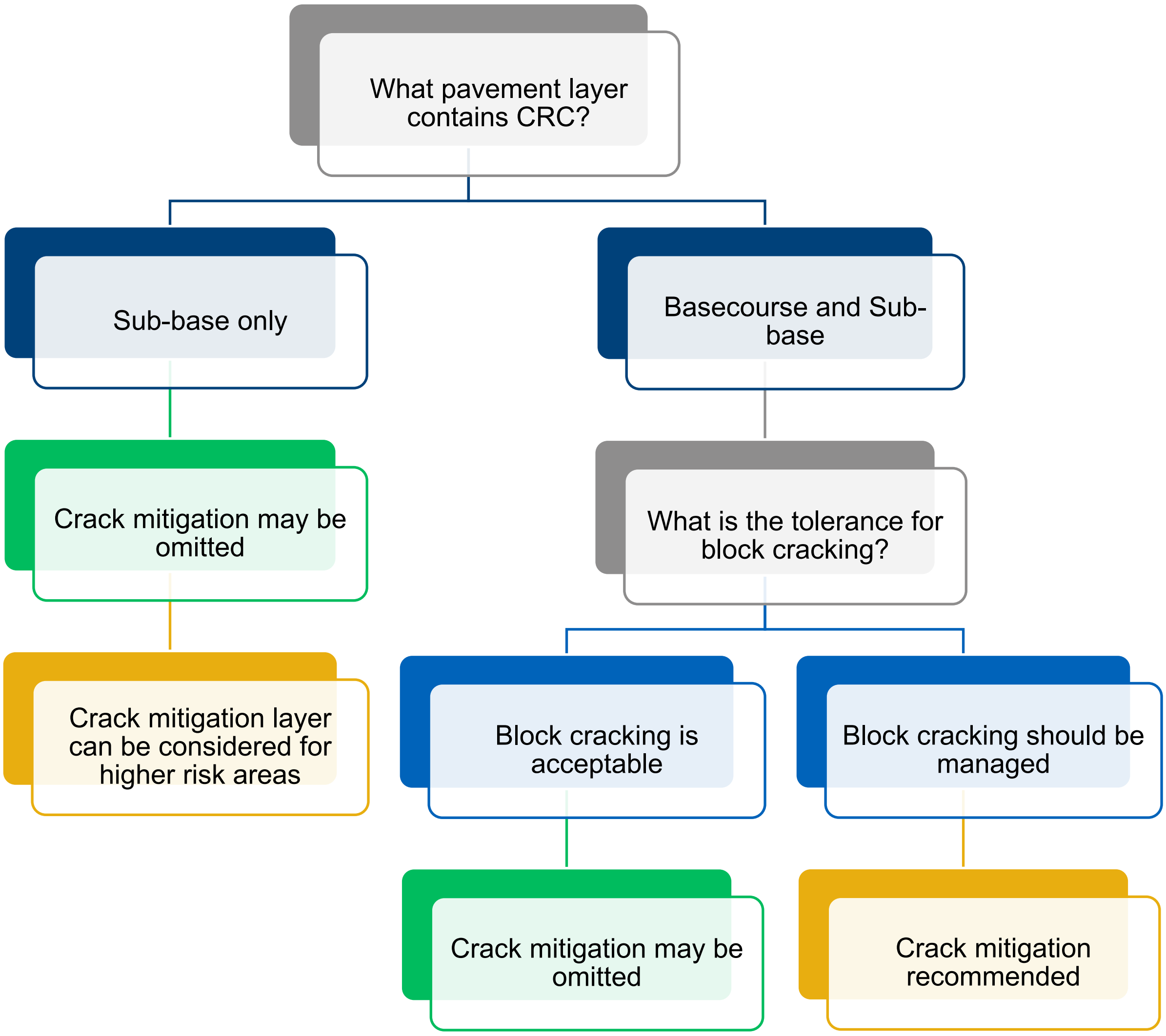
3.7.1 Requirement for Crack Mitigation

Options for crack mitigation may include:

- A thickness of unbound granular basecourse above the CRC layer (i.e. using CRC as the sub-base only, Section 3.4).
- A separate crack mitigation layer below the wearing course (Section 3.7.2).
- Alternative crack mitigation options, typically comprising modification of the asphalt wearing course (Section 3.8).

It is noted that in some areas, such as car parks, block cracking is more likely to be tolerated, and omission of the crack mitigation layer could be considered.

Figure 6: Crack mitigation flow chart



3.7.2 Crack Mitigation Layer Options

Options for the block cracking mitigation layer are provided in Table 8. For most situations a SAMI should be suitable. Note that these treatments are not guaranteed to eliminate the risk of block cracking but will delay the onset and severity of cracking.

It is noted that typically, LG pavements would have a 7 mm primerseal applied. The cost difference between this standard approach and a SAMI may not increase the overall cost of the pavement significantly.

Alternative treatments to manage cracking may also be suitable. These are discussed in Section 3.8 and Section 7.2.

Table 8: Crack mitigation layer options

Option	Requirements
Option 1 – SAMI (suggested in most instances)	• Prime. • S20E or S45R bitumen at 1.6 L/m² (residual bitumen at 15°C). • 10 mm sealing aggregate at 140-160 m²/m³. • Tack coat and asphalt wearing course.
Option 2 – GRS[(1)]	• Prime (optional). • C170 bitumen bond coat at 0.8 L/m² (residual bitumen at 15°C). • Minimum 130 g/m² polyester non-woven geotextile fabric. • C170 bitumen with or without 5% crumb rubber at 1.1 L/m² • 10 mm sealing aggregate at 160-180 m²/m³. • C170 bitumen with or without 5% crumb rubber at 0.6 L/m². • 5 mm sealing aggregate at 180-220 m²/m³. • Tack coat and asphalt wearing course.
Option 3 – Asphalt Geogrid[(2)]	• Prime. • C170 bitumen bond coat at 0.45-0.65 L/m². • Asphalt geogrid. • Asphalt wearing course.

1. Assumed geotextile bitumen absorption of 1.0 L/m². All application rates are indicative only. A final design must be conducted on a case-by-case basis to account for the properties of the binder, geotextile and aggregate used.
2. The requirements for the asphalt geogrid and the bond coat must be confirmed with the asphalt geogrid supplier and may need to be adjusted on a project basis. Asphalt geogrid suppliers have strict requirements for installation of their products which must be followed.

3.8 Other Crack Mitigation Options

Other options for crack mitigation that do not incorporate a separate crack mitigation layer are summarised in Table 9. The authors note that Option 4, fibre reinforced asphalt, has been used successfully on multiple LG projects with minimal effect on asphalt cost.

Note that these treatments are not guaranteed to eliminate the risk of block cracking but will delay the onset and severity of cracking.

Table 9: Crack mitigation layer options

Option	Requirements
Option 4 – Fibre reinforced asphalt	• Virgin Polyolefins and/or Virgin Aramid fibres. • Fibre length two times aggregate size.

	• A dosing rate of about 500 g/tonne may be appropriate.
Option 5 – Bottom layer SMA	• Inclusion of a layer of SMA with polymer modified binder and high bitumen content below the wearing course.
Option 6 – Alternative asphalt types	• Polymer modification of the asphalt wearing course. A15E polymer modified binder may be suitable in most instances, orC170 bitumen bond coat at 0.45-0.65 L/m^2. • SMA with polymer modified binder, or • Fine gap graded asphalt with polymer modified binder.

4 Procurement

4.1 Contractual Requirements

Practitioners should consider the following items when developing contracts for supply of CRC (in addition to typical contract requirements):

- The requirement for the supplier to maintain an RtR accreditation for the duration of the contract (where RtR accredited suppliers are being used).
- Appropriate record keeping demonstrating quality control of CRC materials including:
  - Source site of materials being purchased.
  - Characterisation of materials.
  - Records of sampling and testing results for materials purchased that can be traced to a NATA accredited laboratory.
  - Batch/stockpile number that corresponds to the above records.
- The engineering specification the material needs to be produced to.
- Testing requirements, including minimum testing frequencies. Testing to assess contamination and engineering properties will be required. RtR accredited suppliers will conduct their own contamination testing of CRC in accordance with the RtR Specification requirements; however, testing of engineering properties in accordance with the relevant specification (such as IPWEA/WALGA 2016) is also required.
- Auditing.
- Chain of Responsibility requirements.

4.2 Specification

Appropriate specification of CRC is vital to ensuring it has the required engineering properties based on the intended use. It is recommended that practitioners adopt published engineering specifications that have already been developed for CRC for use in road construction.

- The IPWEA/WALGA Specification for the Supply of Recycled Road Base (IPWEA/WALGA, 2016) includes material properties for CRC basecourse and sub-base, and is recommended for use in LG roads. **It is strongly recommended this specification be adopted.** This guideline has been developed assuming IPWEA/WALGA (2016) will be used for specification of CRC.
- MRWA Specification 501, Pavements (MRWA, 2023), may also be used for specification of CRC subbase; however, it is noted that MRWA (2023) assumes that CRC source material complies with the RtR Specification.

IPWEA/WALGA (2016) and MRWA (2023) (Annexure 501C, Crushed Recycled Concrete Subbase only) are included as Appendix B and Appendix C respectively.

Acquiring CRC from a RtR accredited supplier provides assurance that the material has been produced to a certified standard that ensures risks associated with material use have been assessed and managed. It is recommended that only RtR accredited materials, sourced from a RtR accredited supplier, be used. A current list of accredited RtR suppliers is available on the Waste Authority WA website (Roads to Reuse | Waste Authority WA).

4.3 CRC Supply

The following provides general advice to assist practitioners in assessing potential CRC suppliers:

Is the CRC supplier RTR accredited?

Using a supplier that has been accredited through the RtR program provides reduces the risk that the CRC will contain contaminants such as asbestos or heavy metals.

What is the source of the CRC feedstock?

For example, structural concrete, lower grade concrete (footpaths etc.), or concrete truck returns. CRC sourced from aged, structural concrete my have reduced risk of block cracking due to rehydration of the cement. CRC sourced from partially hydrated concrete, such as concrete truck returns, has a higher risk of developing block cracks if used in a pavement.

Will the required quantity be available in time?

Does the supplier have sufficient source material and plant capacity to produce the required volume of CRC in a suitable timeframe for the project?

What specification does the supplier manufacture their CRC to achieve?

Material supplied in accordance with IPWEA/WALGA (2016) is recommended for CRC being used for construction of LG roads.

Does the supplier have the necessary plant and equipment?

If the supplier is delivering the material to site, do they have sufficient trucks, plant (loaders etc.) and operators available at the time of the pavement works?

What is the haulage distance from the supplier to site?

Haulage can be a significant proportion of the cost of CRC, and associated emissions. Suppliers close to the site are preferred to reduce haulage distances.

What sampling and testing will be conducted by the supplier?

Sampling and testing requirements for CRC are defined in IPWEA/WALGA (2016); however, if an alternate specification is used then sampling and testing requirements will need to be included.

4.4 Variability

CRC can be a variable material with properties largely determined by the CRC source (structural concrete, kerbs/footpaths etc.) and the processing (crushing, screening, blending) undertaken. To maintain consistency within individual projects it is recommended that practitioners utilise CRC from a single source for each project. This would need to be discussed with the CRC supplier to ensure that sufficient quantity of material is available from the CRC source. If the CRC supply needs to be split on larger projects, the same source should be applied to each constructed lot.

4.5 Local Production of CRC

Some practitioners, particularly in regional areas, have indicated that they produce their own CRC from C&D material by undertaking crushing programs. Where this occurs, it is suggested that the CRC be crushed to comply with the requirements of an established specification to optimise performance of the material. However, specification requirements may need to be adjusted in some cases based on the capability of the crushing plant. For example, the particle size distribution may need to be adjusted based on the available screen aperture sizes. Where the processing cannot comply with typical specification requirements, consideration should be given to using the material deeper in the pavement profile where stresses are lower.

5 Construction of CRC Pavements

5.1 General CRC Behaviour during Construction

In general, CRC behaves similarly to other granular pavement construction materials, such as crushed rock base, and contractors familiar with granular pavement construction are unlikely to have significant issues placing, moisture conditioning and compacting CRC. The same general requirements for other granular materials also apply to CRC, such as appropriate moisture conditioning, roller selection, and the need for dryback prior to construction of overlying layers.

5.2 Layer Thickness

Where the subgrade soaked CBR is 10% or greater, has been sufficiently compacted and therefore provides adequate support, it is expected that up to a 300 mm thickness CRC pavement layer can be compacted in one lift, subject to appropriate roller mass/vibration, rolling patterns and moisture conditioning of the material.

For lower subgrade soaked CBRs, the placed layer thickness of CRC may need to be reduced to achieve the required density ratio. Alternatively, a select subgrade layer with higher soaked CBR may be used.

CRC should not be compacted in layers less than 75 mm compacted thickness, although this may need to be adjusted if material with a coarser grading than provided in IPWEA/WALGA (2016) is used.

In all cases the contractor should demonstrate that they can consistently achieve the required density for the constructed layer thicknesses adopted.

5.3 Compaction

CRC should be compacted close to optimum moisture content. Ideally the moisture content of the material should be within about 90% to 100% of optimum moisture content at the time of compaction.

In the absence of specified limits, a dry density ratio of at least 96.0% for sub-base and 98.0% for basecourse would typically be suitable (expressed as a percentage of modified maximum dry density).

5.4 Interlayer Bonding

Where CRC is used as the basecourse and sub-base layers within a pavement, a good bond between the layers needs to be achieved, otherwise the fatigue life of the CRC basecourse layer will be significantly reduced. To ensure a good bond between the layers:

- Construction of the basecourse should commence immediately following the required density testing of the sub-base. It is not necessary to wait for dryback to be achieved provided that the sub-base moisture content is close to or slightly below optimum moisture content (modified compaction).
- The sub-base should be lightly scarified.
- A light application of water should be applied to the sub-base surface immediately prior to placement of the basecourse.
- The basecourse may be placed, compacted and dried back as normal.

Where possible, construction of CRC in a single layer is the preferred method of ensuring bonding, but does require appropriate roller mass. For example, construction of a single 300 mm layer of CRC is preferred to construction of separate sub-base (150 mm) and basecourse (150 mm) layers. Depending on the layer thickness, construction trials may be required to demonstrate the specified level of compaction can be achieved.

5.5 Trimming

As CRC can recement it may become difficult to trim if left to cure for an extended period. Trimming no more than 24 hours following completion of compaction is recommended.

5.6 Dryback

When used as a basecourse, a longer dryback period is recommended. Chemical action in the hydration process will assist in obtaining dryback, but additional time should be allowed for the shrinkage from the hydration process to develop. This will reduce the risk of later shrinkage cracking.

5.7 Surface Finish and Priming

CRC may produce a tight surface finish. To facilitate penetration of a prime:

- Sweeping with a rotary broom should be undertaken. The pressure applied by the broom should be steadily increased if the required finish is not achieved. The authors note that brooms with nylon bristles have typically been suitable for this purpose. Brooms with steel in their bristles may be too harsh and damage the surface.
- The prime should be adjusted to suit the basecourse finish. An increase in the proportion of cutter and/or an adjustment in the prime application rate may be required. This will need to be assessed for each project.

5.8 Quality Control

As with other construction materials, CRC requires appropriate quality control during material supply, placement and compaction to ensure that a suitable and uniform pavement layer is constructed. Practitioners should ensure that the specification adopted for CRC supply and placement contains appropriate testing requirements for their project.

IPWEA/WALGA (2016) contains testing requirements expected to be suitable for the majority of LG pavement projects incorporating CRC.

Where alternate specifications are being used, practitioners should ensure they include requirements for both material supply (CRC properties) and construction (compaction, dryback). Specifications must include requirements for both testing frequency and the test methods to be used.

Typical quality control of the construction process is also required, including items such as surface level and shape tolerances, acceptable moisture content range during compaction, protection of areas from damage by construction plant etc.

6 Other Considerations

6.1 Selecting a Project

Before selecting a project for CRC, practitioners should address the following questions:

1. *What are the policy drivers for the use of recycled materials?* These may override other considerations.
2. *Do the RtR use conditions affect the project?* CRC may not be suitable for use in areas of high groundwater or PDWSAs (refer to Section 6.2).
3. *Is CRC economically viable?* The economics of CRC compared to alternative options will need to be considered. The location of the CRC source and haulage costs will also need to be considered.
4. *Is CRC available in sufficient quantities for this project?* CRC is typically readily available near the Perth metropolitan area, with multiple RtR accredited suppliers. However, in regional areas CRC supply may be more limited.
5. *What is the proposed road function and structure?* Using CRC as sub-base only practically eliminates the risk of block cracking and is likely suitable for most projects. If CRC is proposed as a basecourse the practitioner should review the possible risks (refer to Section 7.1). These risks could be managed by applying one of the options outlined in Section 7.
6. *What is the proposed surfacing type?* There is considerable experience with using CRC below an asphalt wearing course and CRC is generally considered suitable where the final wearing course will be asphalt. However, there is limited experience with CRC used as basecourse on pavements with a sprayed seal as the final wearing surface. CRC basecourse should be restricted to pavements with an asphalt wearing surface until performance in sprayed seal pavements can be demonstrated. CRC may also not be suitable for unsealed pavements due to the risk of leaching.
7. *What CRC specification will be used?* Various CRC specifications are available in WA. For LG projects it is recommended that the IPWEA/WALGA Specification for the Supply of Recycled Road Base (IPWEA/WALGA 2016) be adopted. However, it is likely that CRC specifications produced by MRWA and PTA will also be suitable for most projects.

6.2 Environmental Requirements

LGs are advised of the requirements of the Roads to Reuse Product Specification – Recycled Road Base and Recycled Drainage Rock (Waste Authority WA, 2021) (RtR Specification). Practitioners should refer to the current version of the RTR Specification available from the Waste Authority WA website as these may be subject to change. The March 2021 revision of the RtR Specification (current at the time of writing) states that:

“For the purposes of the Roads to Reuse program:

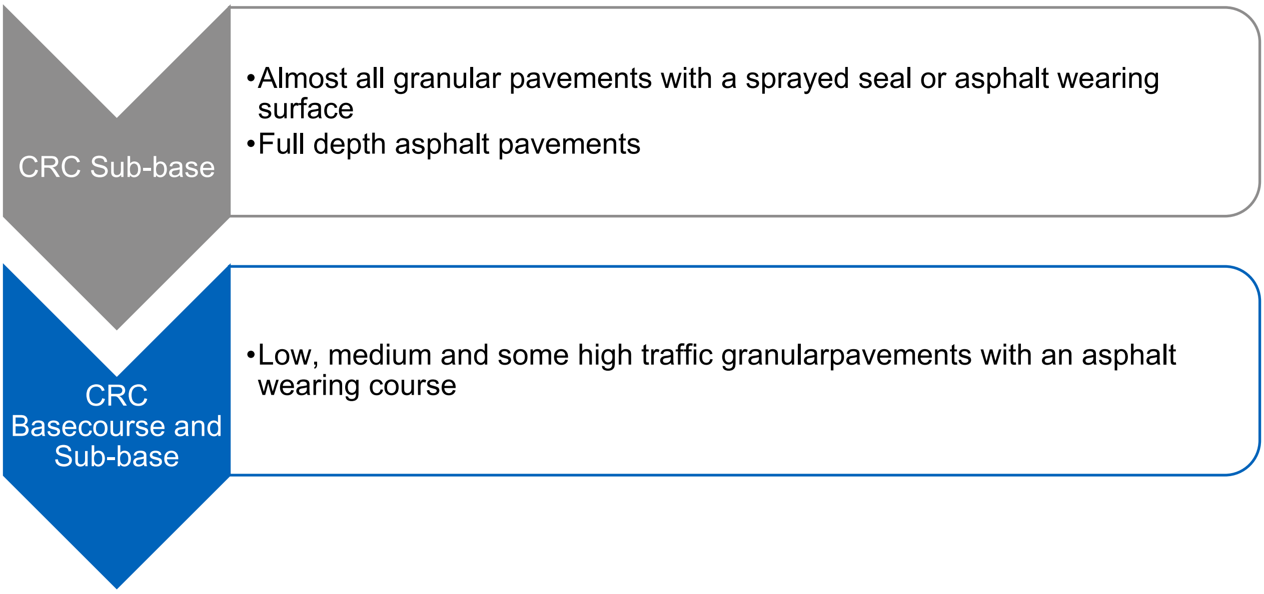
- Road base containing concrete, and with a pH greater than 9, may only be used under bituminous seal or asphalt.
- Recycled products should not be used within 0.5 m of the maximum groundwater level.
- The use of recycled road base is not to occur within the following locations within public drinking water source areas (PDWSAs):
  - Priority 1 (P1) areas
  - Wellhead protection zones
  - Reservoir protection zones.”

Further information on PDWSAs is provided in the RtR Specification.

6.3 Suitable and Unsuitable Pavement Types for CRC

Figure 7 summarises suitable pavement types for CRC.

Figure 7: Suitable pavement types for CRC



Pavement types which might require further consideration prior to the use of CRC and are beyond the scope of this guideline include:

- Pavements with CRC basecourse and a sprayed seal wearing course – Spray seal surfaced pavements are likely to be suitable for the use of CRC as sub-base; however, there is limited experience using CRC as a basecourse with a sprayed seal wearing course. Practitioners should expect block cracking to occur as a minimum.
- Unsealed roads – while CRC is typically expected to provide a suitable unsealed wearing course if trafficked, there may be increased risk of leaching if moisture ingress through the pavement occurs. The recementation of CRC may also affect maintenance, e.g. grading and resheeting is likely to be more challenging than other granular pavement materials.
- Pavements with unique or very high loading – these may be suitable for use of CRC but will need to be assessed on a case-by-case basis. Design will need to consider the loading specific to each project. The CRC pavement designs presented in this guideline assume axle loads comply with current legal limits.

7 Options to Manage Risks

7.1 What to Expect from Pavements Constructed with CRC

CRC is a workable material that provides a stiff pavement structure when used appropriately. It tends to dry back at comparable or faster speed to other materials, produces an excellent surface finish and has sustainability benefits when compared to quarried materials.

However, CRC contains residual (unhydrated) cement that can cause the material to behave similarly to a low strength concrete once compacted in a pavement. In general, this provides good support to the overlying pavement and wearing course layers. However, the variability of CRC and recementing of CRC within pavements can create unique issues that practitioners may not be aware of. These should not preclude the use of CRC in pavements but do require consideration.

It must be noted that the below sections indicate issues that may occur with the use of CRC. The risk of these issues occurring reduces significantly if CRC is used as sub-base only with an unbound granular basecourse.

- Block cracking (Section 7.2) – this is typically an aesthetic issue only and does not indicate structural issues with the pavement. Block cracking can be addressed easily through crack sealing to maintain a waterproof surface. Block cracking should not occur if CRC is used as sub-base only.
- Surface blistering (Section 7.3) – this may present a minor issue in areas of pedestrian or cyclist traffic, and a more significant issue for sports courts, but is unlikely to be a problem for traffic lanes. It can be managed through careful control of the CRC source material and removal of expansive materials. Where they occur, surface blisters can be addressed easily through patching. Surface blisters should not occur if CRC is used as sub-base only.
- Fatigue cracking (Section 7.4) – this does indicate a structural issue with the pavement but can be avoided through appropriate pavement thickness design. Fatigue cracking indicates the cemented layer is approaching the end of its life and may require remediation. Fatigue cracking should not occur if the pavement is designed appropriately or if CRC is used as sub-base only.

7.1.1 Block Cracking

Block cracking is caused by shrinkage associated with rehydration of the cement present in CRC. Block cracking is typically only a risk where CRC is used as a basecourse layer and it reflects through the overlying wearing course; although in some cases may occur where CRC is used as sub-base with a relatively thin unbound basecourse. The risk of block cracking at the pavement surface depends on:

- The properties of the CRC, typically the long-term UCS (i.e. the UCS following 90 days or longer curing). CRC with a higher UCS may have increased risk of block cracking. Shorter-term UCS results, such as 7- or 28-day, may not be sufficient to assess block cracking risk for CRC due to the typically long rehydration time.
- The cover between the top of the CRC layer and the top of the wearing surface. Increasing the cover between the top of the CRC and the top of the wearing surface reduces the risk of block cracking, for example by using CRC as sub-base and providing a cover of unbound granular basecourse.
- The presence of crack mitigation treatments, such as a SAMI. The inclusion of crack mitigation treatments can delay the appearance of block cracking at the surface and reduce its severity, but may not prevent it from occurring in the longer term.

Block cracking does not indicate structural failure of the pavement and is typically an aesthetic issue only, provided crack sealing is undertaken to prevent moisture ingress. It should be noted that many natural gravels can also block crack over time but have provided suitable long-term pavements where appropriate maintenance is conducted.

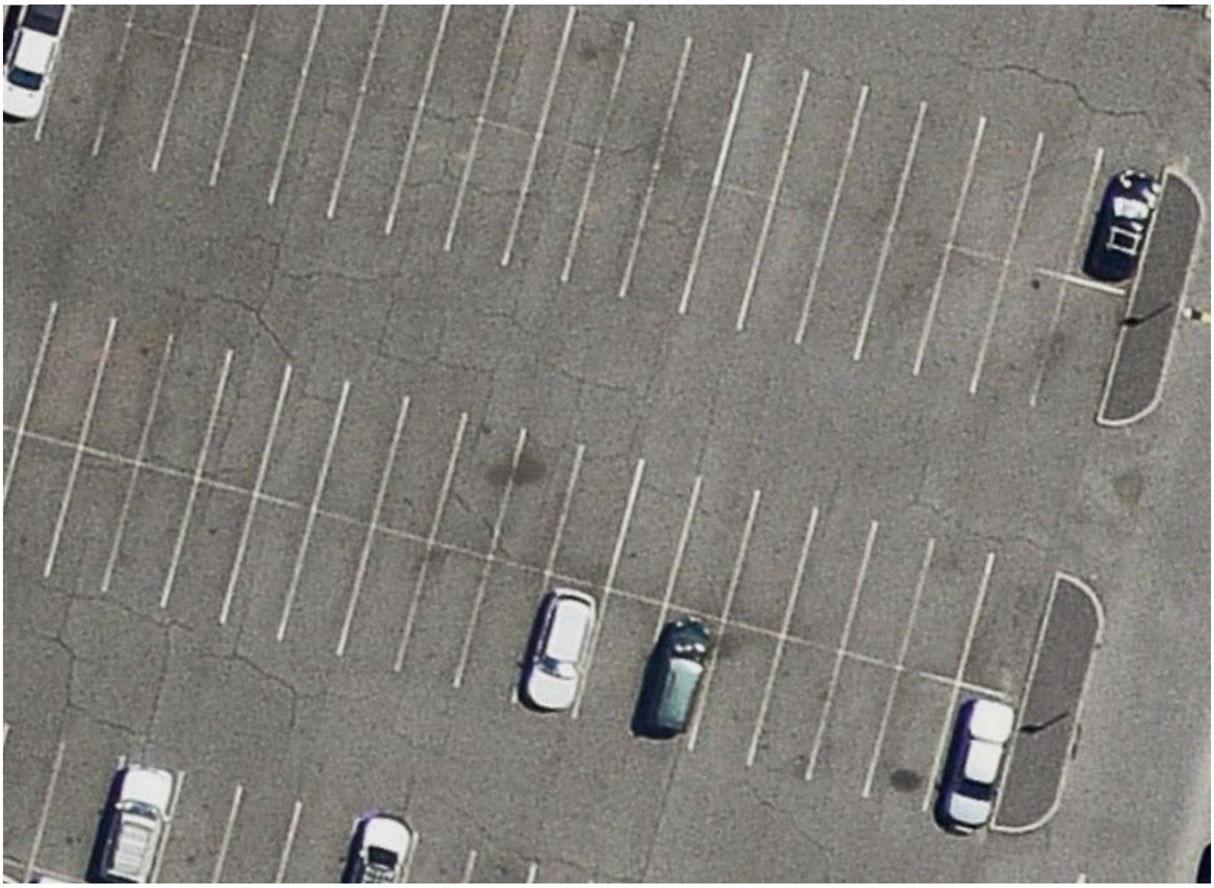
Options to mitigate or treat block cracking are provided in Section 7.2

Figure 8 shows an example of a block cracking pattern on a low traffic residential street. Figure 9 shows an example of block cracking within a public car park. Both block cracked pavements are considered suitable for use.

Figure 8: Typical block cracking on a low traffic residential street

Source: Simon Hull

Figure 9: Typical block cracking within a public car park



Source: NearMap Australia Pty Ltd

7.1.2 Surface Blistering (or “Domes” / “Popping”)

Surface blistering/domes are a localised raised area of wearing course caused by expansion of impurities in the CRC (typically metallic aluminium or gypsum). These impurities are difficult to remove once present in CRC; however, some suppliers can remove metallic aluminium if they have the appropriate equipment at their processing facility.

It is noted that in the author’s experience, surface blistering has been relatively rare occurrence.

Surface blistering is only a risk if expansive impurities are present in the CRC, and only if CRC is used close to the underside of the wearing course. Surface blistering should not occur if expansive impurities are not present in the CRC source material, or the CRC is not being used as a basecourse.

Options to mitigate or treat surface blistering are provided in Section 7.3.

Figure 10 shows examples of surface blistering.

Figure 10: Example of surface blistering (left and bottom – cark park, right – shared path)

Source: Colin Leek/Dale Screech

7.1.3 Fatigue Cracking

Fatigue cracking of CRC pavements results from insufficient design thickness where CRC is used as basecourse and behaving as a bound pavement. Fatigue cracking is unlikely to occur if the recommendations in this guideline are adhered to. It is only a significant risk on moderate to high traffic roads if:

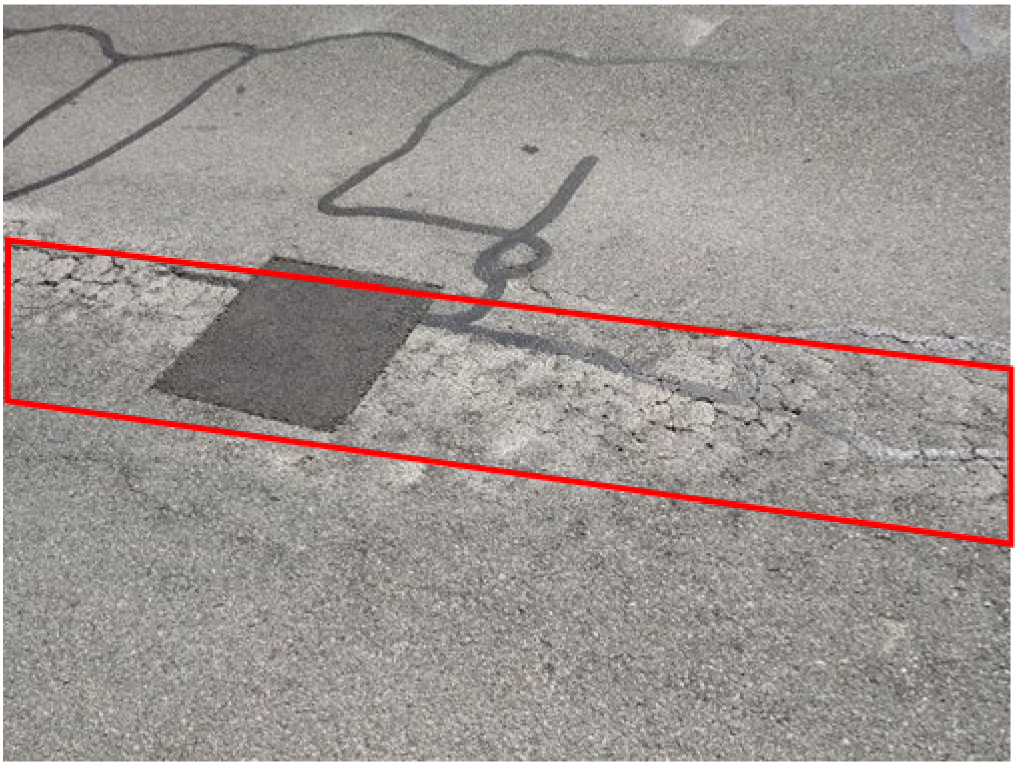
- CRC is used as a basecourse without also using it as sub-base, or

- The CRC basecourse and sub-base layers are not well bonded to form a homogenous and well-bound pavement structure.

Options to mitigate or treat fatigue cracking are provided in Section 7.4.

Figure 11 shows an example of fatigue cracking of a CRC pavement.

Figure 11: Example of fatigue cracking of a CRC pavement



Source: Colin Leek

7.2 Block (Shrinkage) Cracking

7.2.1 Control of Block Cracking through Overlying Unbound Material

The preferred and most cost-effective method of mitigating block cracking is to use CRC in the sub-base layer only and provide an unbound basecourse. Block cracking which occurs in the CRC layer should be “absorbed” through the unbound granular layer and is unlikely to reach the wearing course.

Block cracking may occur after some time, but this can be addressed during normal resurfacing treatments, possibly incorporating a crack mitigation layer.

The CRC pavement designs in Section 3.4 of this guideline include an unbound basecourse to manage block cracking.

7.2.2 Control of Block Cracking through Crack Mitigation Layers

Where a crack mitigation layer is adopted, a SAMI is generally recommended to help reduce the risk of block cracking where CRC is used as basecourse. A crack mitigation layer is not required where CRC is used as sub-base only.

Alternative crack mitigation layers such as a GRS or asphalt geogrid may be suitable. However, a GRS may be cost prohibitive and asphalt geogrids have not been used extensively to date in WA, so contractors are not familiar with installation requirements.

Options for crack mitigation layers are summarised in Section 3.7.2.

7.2.3 Control of Block Cracking through Asphalt Surfacing

If a crack mitigation layer such as a SAMI is not installed, practitioners may consider adjustments to the asphalt wearing course to reduce the risk of cracking.

The use of polymer modified bitumen within the asphalt surfacing may provide some resistance to reflective block cracking compared with an unmodified asphalt.

Asphalt types such as SMA (including bottom layer SMA) and fine gap graded asphalt with a polymer modified bitumen may also provide some resistance to reflective block cracking.

The author’s experience has shown that the addition of asphalt reinforcing fibres can resist reflective cracking. A rate of 500 g of synthetic reinforcing fibres per tonne of asphalt has been effective, and may be a more economical solution than applying a SAMI.

Alternative options for crack mitigation are provided in Section 3.8.

7.2.4 Treatment of block cracking

Where block cracking has occurred the cracks should be sealed with a polymer modified bituminous crack sealing product as is typically conducted for other cracks that occur in pavements. A waterproof surface should be maintained. If cracking is not sealed, erosion of fines and loss of surface shape can follow.

Resurfacing is typically not required for block cracking, provided that other defects are not occurring. A maintained and crack-sealed block cracked surfacing should perform acceptably for the design life of the surfacing.

7.3 Surface Blistering/Domes

7.3.1 Control of Surface Blistering

Where possible, the CRC supply should be controlled to reduce the occurrence of potentially expansive materials that can lead to surface blisters. However, removal of these materials may not always be practical, and it is unlikely they can be completely removed. Typically, these potentially expansive materials comprise:

- Metallic aluminium.
- Gypsum.

Some CRC suppliers have the ability to remove metallic aluminium through eddy current separation. Removal of metallic aluminium is recommended where it is suspected to be present in the CRC and it will be used in the basecourse layer.

Removal of expansive contaminants is not considered necessary for CRC used as a sub-base only; however, their proportions should be limited to comply with the specification being used.

7.3.2 Treatment of Surface Blistering

Where surface blistering occurs, the affected areas would typically be relatively small and isolated, unless there is a significant proportion of expansive impurities present in the CRC (in which case it may not comply with the specification). In some cases, the blisters may subside under traffic loading. Otherwise, treatment of these areas should be directed to removal and replacement of the affected material. In general, this would require:

- Saw cutting the asphalt surface.
- Removing the asphalt and affected portion of the basecourse (as a guide the upper 50 mm of basecourse as a minimum).
- Replacement of the excavated basecourse with imported basecourse or asphalt.
- Application of a prime and seal or primerseal, tack coat, and asphalt wearing course (as per the relevant design adopted).

7.4 Fatigue Cracking

7.4.1 Control of Fatigue Cracking

Controlling fatigue cracking is only possible during the design stage, or by sourcing pavement materials that are known to not be susceptible to fatigue (which generally does not include CRC). The CRC pavement options presented in this guideline have been designed considering fatigue cracking of the CRC layer for design traffic volumes above 5×10^5 ESAs. Adhering to the requirements of this guideline should be sufficient to manage the risk of fatigue cracking.

Where practitioners conduct their own CRC pavement designs, fatigue of CRC basecourse layers should be considered. If CRC is used as basecourse, CRC should also be used in the sub-base, with a good bond achieved between the layers such that the pavement behaves as a monolithic structure. Section 5.4 provides advice on achieving this requirement.

Alternatively, the sub-base and basecourse layers may be compacted in one combined layer provided that the specified level of compaction can be achieved.

Design for fatigue of the CRC layer is not required where CRC is used as sub-base only.

7.4.2 Treatment of Fatigue Cracking

Where fatigue cracking has occurred, the pavement will need to be reconstructed or stabilised in situ (foamed bitumen stabilisation has been used successfully on some projects). The reconstruction requirements for each project will be unique and are beyond the scope of this guideline.

As an interim measure for temporary treatment only, resurfacing with a crack mitigation layer in accordance with Section 3.7.2 could be undertaken. Cracking should be expected to reoccur through the surfacing in the short to medium term. The use of asphalt reinforcing grids may provide a longer-term solution than other options such as a SAMI, as the grid will allow tensile reinforcement of the asphalt layer. The asphalt reinforcement grid must be installed in accordance with the supplier’s requirements.

8 Rehabilitation using CRC

Rehabilitation of existing flexible pavements (including those not constructed from CRC) using CRC requires consideration of the requirements of each individual project, and is therefore beyond the scope of this guideline. However, general advice for practitioners considering the use of CRC for pavement rehabilitation is provided below:

- For pavements being reconstructed utilising existing granular material, overlaying with CRC and in situ stabilisation may be suitable. Small quantities of cement and/or bitumen may be included. Laboratory testing is required to assess a suitable mix design.
- CRC is also likely to be suitable as an overlay material for pavements being in situ stabilised with foamed bitumen.
- For pavements being reconstructed, CRC is generally not recommended for use as the basecourse only, due to the increased risk of fatigue of the CRC layer. If an existing pavement is being reconstructed using CRC then the designs for new pavements presented in Section 3.5 of this guideline should be adopted.

References

IPWEA (2016), Local Government Guidelines for Subdivisional Development, Edition 2.3, November 2017.

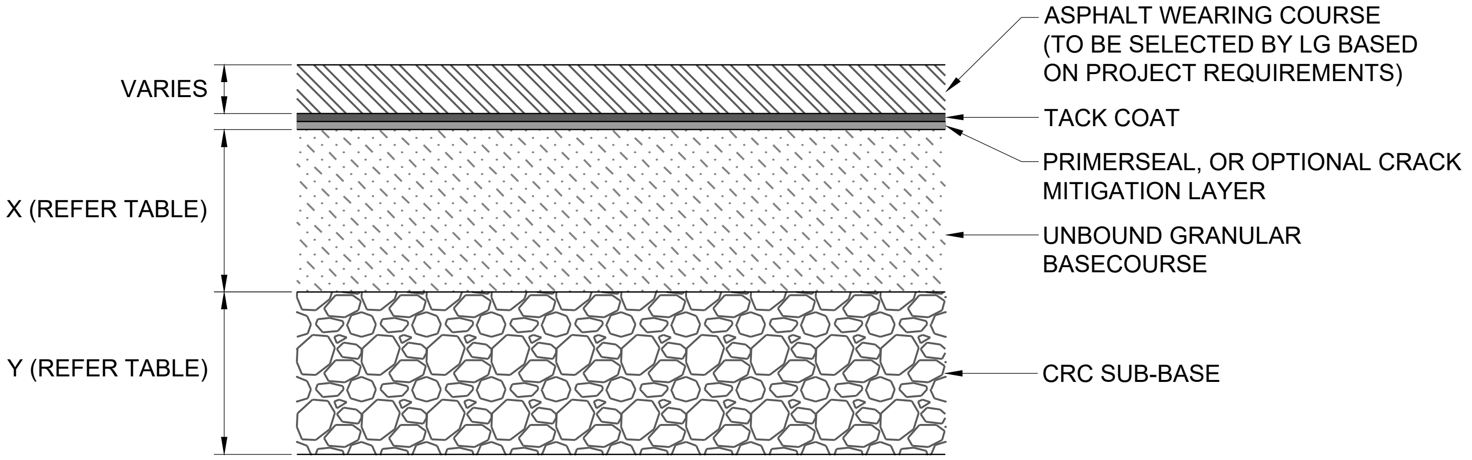
IPWEA/WALGA (2016), Specification for the Supply of Recycled Road Base, Institute of Public Works Engineers Australia, May 2016.

MRWA (2022), Recycled and Sustainable Materials at Main Roads, Reference Guide, Document No. D21#12639, November 2022

MRWA (2023), Specification 501 – Pavements, Main Roads Western Australia, 10 May 2023.

Waste Authority WA (2021), Roads to Reuse Product Specification – Recycled Road Base and Recycled Drainage Rock, Waste Authority of Western Australia, March 2021

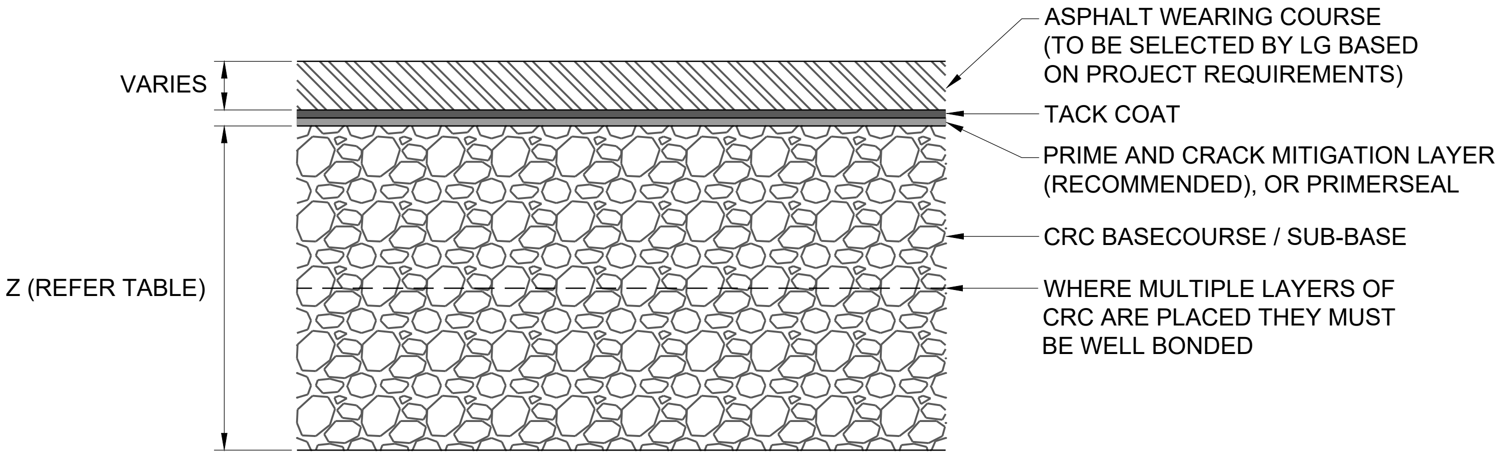
Appendix A CRC Pavement Design Profiles



SUBGRADE DESIGN CBR	TRAFFIC VOLUME (ESAs) / X/Y (mm)						
	1×10^4	3×10^4	1×10^5	3×10^5	1×10^6	3×10^6	1×10^7
5%	100 / 100	100 / 140	100 / 195	115 / 225	135 / 260	150 / 290	170 / 325
8%	100 / 75	100 / 85	100 / 125	115 / 145	135 / 165	150 / 185	170 / 205
12%	75 / 75	75 / 75	100 / 75	115 / 85	135 / 95	150 / 110	170 / 120

Note: ESAs - Equivalent standard axles

CRC AS SUB-BASE



SUBGRADE DESIGN CBR	TRAFFIC VOLUME (ESAs) / Z (mm)						
	1×10^4	3×10^4	1×10^5	3×10^5	1×10^6	3×10^6	1×10^7
5%	200	240	295	340	355	375	405
8%	175	185	225	260	320	340	370
12%	150	150	175	200	285	305	330

Note: ESAs - Equivalent standard axles

CRC AS BASECOURSE AND SUB-BASE

Appendix B IPWEA/WALGA Specification for the supply of recycled road base

IPWEA/WALGA Specification for the supply of recycled road base

Version 1

May 2016

IPWEA/WALGA Specification for the supply of recycled road base

FOREWORD

These Specifications have been developed by the Institute of Public Works Engineering Australasia Western Australia Incorporated (IPWEA WA) in conjunction with the Western Australia Local Government Association (WALGA) for the purposes of outlining the specifications for the supply of recycled road base. To the extent permitted by law, WALGA and IPWEA WA exclude all warranties as to, and responsibility for, the accuracy, completeness or suitability of the information in the Specifications or for any error or omission in the information and will not be liable for any loss or damage suffered or incurred by any persons arising from the use or reliance on the information or data contained in the Specifications. To the extent permitted by law, IPWEA WA and WALGA disclaims all liability to the user for loss, injury or damage, arising out of, or related to, the use of the material outlined in the Specifications. Prior to using the material outlined in the Specification, approval should be sought from the relevant Local Government or appropriate Road Authority.

REVISION RECORD

VERSION No.	REVISION No.	DATE	DETAILS
1	0	May 2016	Original Version.

IPWEA/WALGA SPECIFICATION

Specification for the supply of recycled road base

1 Background

Recycled crushed demolition materials are widely used in other Australian states, notably Queensland, New South Wales, Victoria and South Australia, where these materials are included in State Road Authority Specifications. However Western Australia lags other states, and Main Roads WA does not include recycled materials for base courses in Specification 501.

Recycled pavement materials based largely on recycled crushed concrete have been well researched and have been shown in many studies to be superior in structural properties when compared to virgin crushed road base. Using recycled materials has significant environmental benefits including minimising landfill and use of finite resources.

Users of this specification are advised to consider the Guidance Note at the end of the specification.

2 General

The material shall consist of a uniformly blended mixture of coarse and fine aggregate resulting from the crushing of recycled concrete and other hard materials from construction and demolition material. It may contain other materials such as clay brick and tile, sand and glass according to the limits specified in Table 2.

3 Material classes

The material classes shall be determined according to the end use of the product which will be determined by the pavement design, traffic conditions and level in the pavement. The recommended material class required for a specific application is specified in Table 1

Table 1: Material class for given application

Level in pavement	Traffic (ESA/day)			
	> 500	< 500	50-100	< 50
Base < 50 mm asphalt or spray seal	Class 1	Class 1	Class 1	Class 1
Base ≥ 50 mm asphalt	Class 1	Class 1	Class 1	Class 2
Subbase	Class 2	Class 2	Class 2	Class 2

4 Limits on source material composition

Limits on the material composition are shown in Table 2. In order to achieve the improved structural strength in base materials, a high proportion of crushed concrete is required; however some upper limit (95%) of crushed concrete is recommended for application in base materials to limit the potential for shrinkage cracking. This is an ongoing research issue and some changes in these limits may apply in future revisions.

Table 2: Limits on constituent materials based on material class

Material	Class 1	Class 2
	Maximum % by weight	
Crushed Recycled Concrete (CCRB)	95	95 as base 100 as subbase
Recycled Asphalt Pavement (RAP)	10	15
High density clay brick & tile	10	15
High density aggregates from roads etc.	25	100
Low density materials (plastic, plaster, etc.)	1	1.5
Organic Matter (Wood, etc.)	0.5	0.5 as base 1.0 as subbase
Unacceptable high density materials (metals, glass, ceramics > 4 mm)	2	3
Asbestos	As per Department of Environment Regulation: Guidelines for Managing Asbestos at Construction and Demolition Waste Recycling Facilities (latest version)	

5 Particle size distribution (PSD)

PSD shall conform to the limits of Table 4. The PSD curve shall be classified by the descriptive classification as shown in Table 3. The PSD shall be determined in accordance with MRWA test method WA 115.1

Coarse aggregate (retained 4.75 mm sieve) shall consist of clean, hard, durable, angular fragments of recycled concrete or asphalt produced by crushing sound recycled materials originally made from sound unweathered rock and shall not include materials which break up when alternately wetted and dried.

Fine aggregate (passing 4.75 mm sieve) shall consist of crushed rock fragments or a mixture of crushed recycled concrete, asphalt or brick fragments produced by crushing sound recycled materials originally made from sound unweathered rock, clays or natural sand.

Table 3: Shape variability class for PSD

Shape variability descriptor	Shape attributes of PSD curve
Low	Where the grading curve fits smoothly within the envelope, and may gradually move from the high limits to the low limits or from the lower limits to the higher limits but does not wander between extremes
Medium	Where the grading curve changes from the higher limits to the lower limits or the lower limits to the higher limits in one sieve size that is above the 2.36 sieve
High	Where the grading curve fits outside the envelope for one or two sieve sizes above the 2.36 mm sieve, or where the grading envelope changes from the lower limits to the higher limits for any sieve size 2.36 mm or less, or where the grading curve changes from the higher limits to the lower limits or the lower limits to the higher limits on more than one instance
Unacceptable	Where the grading curve falls outside the envelope for any sieve size 2.36 mm or less or for more than two sieve sizes above 2.36 mm

Table 4: Limits for particle size distribution

Material Class	Class 1	Class 2
AS sieve size (mm)	% passing by mass minimum and maximum limits	
37.5		
26.5	100 - 100	100 - 100
19.0	95 - 100	95 - 100
9.50	60 - 80	59 - 82
4.75	40 - 60	41 - 65
2.36	30 - 45	29 - 52
1.18	20 - 35	20 - 41
0.600	13 - 27	13 - 29
0.425	11 - 23	10 - 23
0.300	8 - 20	8 - 20
0.150	5 - 14	5 - 14
0.075	3 - 11	3 - 11
Ratio of 0.475:0.075	0.35 – 0.60	0.35 – 0.60
Shape variability	Low	Base: Low or medium Subbase: Low, medium or high

6 Linear shrinkage (LS)

Linear shrinkage shall be determined on the portion of material passing the 425μm sieve in accordance with MRWA test method WA 123.1 Limits for LS are given in Table 5.

Table 5: Limits for linear shrinkage

Linear shrinkage (7 day)	Class 1 & 2
Base (%)	0.2 – 1.5
Subbase (%)	0.2 – 4.0

7 Unconfined Compressive Strength (UCS)

The UCS of the material when tested in accordance with MRWA test method WA 143.1 (7 days cured and 4 hours immersed) shall conform with the requirements of Table 6.

Table 6: Limits for unconfined compressive strength

Unconfined compressive strength	Class 1 & 2
Base (kPa)	200 – 1000
Sub-base (kPa)	200 – 2000

8 Los Angeles abrasion coarse aggregate

Limits for Los Angeles abrasion are given in Table 7. Testing shall be in accordance with Main Roads WA Test Method 220.1-2012 *Los Angeles Abrasion Value*

Table 7: Limits for Los Angeles abrasion test

Los Angeles abrasion	Class 1	Class 2
Los Angeles abrasion loss (%)	<40	<42

9 California Bearing Ratio (CBR)

The CBR shall be determined in accordance with MRWA test method WA 141.1. The sample shall be soaked for four days. The minimum requirements for CBR are detailed in Table 8. (Note no curing period shall be applied for this test, and the sample shall be soaked immediately after preparation).

Table 8: Limits for CBR

California Bearing Ratio	Class 1 (98% MDD, 100% OMC)	Class 2 (98% MDD, 100% OMC)
Californian Bearing Ratio (CBR) (%)	>100	>100

10 Minimum performance requirements

These tests shall not be required where the material manufactured meets all index tests, however when a material fails to meet the index tests specified, the RLTT may be used to prove the performance of the material produced by a manufacturer, at which case the material may be accepted by the superintendent.

Performance tests including the repeat load triaxial test (RLTT) test shall be used to determine the performance parameters of:

- resilient modulus at 400 kPa normal stress and 150 kPa confining stress both at 60% OMC
- resilient modulus at 400 kPa normal stress and 150 kPa confining stress both at 80% OMC
- maximum permanent strain at end of stress stage modulus cycle (%)

Table 9: Limits for modulus, permanent strain, friction angle and cohesion

Performance test limits	Class 1	Class 2
Resilient modulus @ 400 kPa normal stress and 150 kPa confining stress		
at 60% OMC	700 - 1000	650 - 1000
at 80% OMC	>600	>550
Maximum permanent strain at end of stress stage modulus cycle (%)	3%	3.5%

The RLTT shall be undertaken in accordance with Austroads Repeated Load Triaxial Test Method – *Determination of permanent deformation and resilient modulus characteristics of unbound granular materials under drained conditions* (Vuong and Brimble 2000), **modified as below**, and shall be used to report modulus and permanent strain values. The target values are given in Table 9.

The sample shall be prepared at Optimum Moisture Content, allowed to dry back to the desired moisture content at room temperature, wrapped to allow moisture to remain at the desired content, and cured for 7 days to allow even distribution of moisture through the sample.

11 Maximum dry density (MDD) and optimum moisture content (OMC)

The MDD and OMC of the material shall be determined in addition to all other tests at Frequency A. MDD and OMC shall be determined in accordance with MRWA test method WA 133.2 *Dry density/moisture content relationship: modified compaction coarse grained soils.*

12 Test frequency and sampling methods

12.1 Sampling methods

Sampling shall be undertaken using one of three options:

- one sample per time period
- one sample per number of tonnes produced
- certified stockpile.

Where a certified stockpile is used, the stockpile shall be manufactured, tested and certified, and no more material shall be deposited to the stockpile after certification.

Where a certified stockpile is used, the number of samples shall be related to the size of the stockpile. Samples shall be collected in accordance with MRWA test method WA 200.1 part 5 except that the limits on stockpile size shall not apply.

Each sample shall be collected and tested individually. The number of samples required shall be determined as follows:

- Stockpile <1,000 m^3, 3 samples
- Stockpile 1,000 – 2,000 m^3, 6 samples
- Stockpile >2,000 m^3, 6 samples + 1 sample per 1,000 m^3.

Where sampling is undertaken during continuous batching operations and forms part of a process control, sampling shall be undertaken in accordance with MRWA test method WA 200.1 part 2.

12.2 Sampling frequency

Where sampling is undertaken during continuous batching operations and forms part of a process control, sampling shall be undertaken on either a unit of time or unit of mass basis whichever is the most frequent. Testing shall be dependent on the importance of the test and shall be at Frequency A or Frequency B or Frequency C as follows:

Frequency A

- Particle size distribution (PSD)
- Linear shrinkage (modified)
- Percentage foreign materials (modified).

These shall be at a frequency of one sample per 1000 tonne or one sample per week or change in source material.

Frequency B

- Los Angeles Abrasion
- Californian Bearing Ratio (CBR)
- Unconfined Compressive Strength.

These shall be at a frequency of one sample per 5000 tonne or one sample per month or change in source material.

Frequency C

- Repeat Load Triaxial Test

Where a material does not meet the index requirements specified above, the repeat load triaxial test may be used to prove the product performance relative to the index properties of that material, and those index properties may then form the specification for that product.

12.3 Testing authority

All testing shall be undertaken by a NATA accredited laboratory.

13 Reporting

All test results shall be kept on file and shall be distributed to the client organisation within 4 weeks of the sample date.

GUIDANCE NOTE

Guidance note for the IPWEA/WALGA Specification for the supply of recycled road base

1 General

The working of roadbase sourced from demolition materials containing significant amounts of crushed concrete varies marginally from the methods required for conventional roadbase. However the material does have a tendency to bind due to the rehydration of the cement content in the roadbase, and becomes considerably stronger than conventional roadbase very early in the dryback process. The material is referred to as Reclaimed Concrete Roadbase (RCC).

2 Layer thickness and shrinkage

RCC has residual uncured cement and this will commence rehydration and strength gain immediately on completion of the pavement, and this strength gain will continue, initially at a rapid rate, but the rate of strength gain will reduce with time, but may continue gradually for many years.

RCC will, unless containing very large amounts of non pozzolanic material, become liable to fatigue if used in thin layers. Ideally RCC should be used for the full pavement profile. Experience has shown that in thick layers, when provided with good dryback and a primer seal, minor transverse cracking in the asphalt surface may occur; however due to its great inherent strength, asphalt fatigue life will be extended considerably.

However if used as a thin base layer, under heavy traffic, fatigue of the bound layer may occur, and block cracking may be evident.

For this reason, RCC when used in lightly trafficked roads will provide an excellent subbase, but may be covered with a 100mm granular roadbase to prevent shrinkage cracking in surfacing asphalt.

3 Moisture content and density

RCC has a lower density and higher optimum moisture content than Crushed Granite Roadbase (CRB). Due to the lower density, the additional water required for compaction of RCC is greater than that for CRB, but not as much as would be suggested by the laboratory OMC. However for dust control purposes, the supplier may have already added some of this moisture, and the water requirements on site may be minimal.

4 Delivery and compaction

There are several manufacturers of RCC; some of those manufacturers produce a high quality well graded and consistent material, others may just crush and use your road to dispose of the material in an attempt to avoid the landfill levy.

Materials should only be sourced from suppliers who have an Asbestos Management Plan and have been assessed by Department of Environmental Regulation as having systems in place to meet the Reduced Sampling Criteria as described in *Guidelines for managing asbestos at construction and demolition waste recycling facilities*

The IPWEA specification for Reclaimed Concrete Roadbase has strict requirements for sampling and testing for material conformance. Users of this material should ensure that the facility that supplies the material can demonstrate consistency, and like any other construction material, random audit testing should be undertaken to ensure compliance with the specification.

On delivery of the first loads, and randomly throughout the period of supply, the material delivered to site should be laid out and visually inspected to ensure any undesirable materials are limited.

The material should be laid out in layers according to the pavement design. For residential streets where the base may be less than 250mm, one layer may be sufficient with suitable roller size and number of passes.

Over 250mm thick pavement should be constructed in two layers, the subbase layer being thicker, and the base layer not being less than 100mm. This is consistent with any other pavement material. Generally a vibratory roller on high amplitude low frequency is used for initial compaction, followed by a rubber tyre roller for finish rolling. Where structures such as high pressure gas pipelines, sensitive water mains or in cases close to existing houses, a static roller may be required, with thinner layers compacted, or a greater number of passes.

5 Finishing

Due to the potential for rehydration of the cement component, it is important to finish to final levels before dryback, as it may become harder to cut. However the time available is still considerable, and operators should be aware that the time available is more than adequate, however where with CRB, sections may be left high to account for traffic damage, this should not be undertaken with RCC.

6 Ravelling under traffic

RCC is extremely resistant to ravelling from traffic once compacted and dryback has commenced. The RCC is considerably better than CRB where turning traffic is required to use a partially completed surface. Therefore the material should be completed to design levels and not left high to allow for damage from traffic.

7 Shrinkage during dryback

During the dryback process, rehydration of the cement does result in some minor shrinkage cracking, and allowance for this phenomena should be made. It is preferable to allow the material to dryback for at least 5 days, preferably longer, before sealing although research is still underway to determine the optimum period.

8 Primer seal

Good practice for any road pavement is a well constructed primer seal. In the case of emulsion based primer seals, a two coat application is essential. A 10/5 aggregate combination with a total residual bitumen rate of 1.5l/m² is required.

9 Asphalt surfacing

Asphalt surfacing may be carried out the next day after primer sealing as normal. Where RCC is used as a base in low volume roads, consideration should be given to a Stone Mastic Asphalt instead of a Dense Grade Asphalt.

Appendix C MRWA Specification 501 – Pavements, Annexure 501C, Crushed Recycled Concrete Subbase

ANNEXURE 501C

CRUSHED RECYCLED CONCRETE SUBBASE

501C.01 GENERAL

SCOPE

1. This Annexure 501C includes:

   a) Specification Clause 501C.02 References (specifically relating to Crushed Recycled Concrete)

   b) Specification Clause 501C.03 Crushed Recycled Concrete Subbase

501C.02 REFERENCES

1. Australian Standards, and other reference documents are referred to in abbreviated form (e.g. AS 1234). For convenience, the full titles are shown below:

Australian Standards

AS 4964 Method for the Qualitative Identification of Asbestos in Bulk Samples

Other Reference Documents

DWER Asbestos Guidelines: Department of Water and Environment Regulation Guidelines for managing asbestos at construction and demolition waste recycling facilities, December 2012

Waste Authority RtR Specification: Waste Authority Roads to Reuse Product Specification for recycled roads base and recycled drainage rock, March 2021

501C.03 CRUSHED RECYCLED CONCRETE SUBBASE SUPPLIED BY THE CONTRACTOR

501C.03.01 GENERAL

1. Crushed Recycled Concrete shall only be sourced from a premises that is licensed under Part V of the Environmental Protection Act 1986 to accept, store and process construction and demolition waste, and that has been approved by the Department of Water and Environmental Regulation to supply Crushed Recycled Concrete in accordance with the Waste Authority Roads to Reuse (RtR) Specification. ***DWER Approved Supplier***

2. **Prior to delivery of Crushed Recycled Concrete to site, the Contractor shall provide the Superintendent with a copy of the Supplier's letter of approval from the Department of Water and Environmental Regulation confirming that the Supplier has management systems compliant with the Waste Authority RtR Specification. A copy of this document shall be included in as-constructed records.** ***HOLD POINT***

3. Crushed Recycled Concrete shall not be used in the following locations: ***Limitations on Usage***

   a) Any location not covered by Full Depth Asphalt pavement;

   b) Within 0.5 m of the maximum groundwater level; or

   c) Within the following locations in Public Drinking Water Source Areas:

      - Priority 1 (P1) areas;
      - Wellhead protection zones; or
      - Reservoir protection zones.

4. The Contractor shall ensure that it is aware of its responsibilities under work health and safety legislation and implement appropriate controls to protect its employees and other persons in relation to the use of recycled construction products from construction and demolition material. ***Health and Safety***

5. Crushed Recycled Concrete shall be clearly identified and referred to as Crushed Recycled Concrete in Laboratory Test Requests, Test Reports and in As-Constructed Records. ***Transparency***

6. **Prior to placement of Crushed Recycled Concrete, the Contractor shall certify to the Superintendent that the material supplied by the Contractor fully complies with the specified requirements, including in relation to health and safety and limitations on usage.** ***HOLD POINT***

501C.03.02 FOREIGN MATERIAL

1. Foreign material content shall be limited to the values shown in Table 501C. A. Testing for foreign material other than asbestos and hazardous metals is to be undertaken by visual identification of each foreign material type retained on a 4.75 mm sieve. The percentage by mass of each foreign material type shall be calculated to the nearest 0.1% as the mass of all of that material type identified compared to the total sample mass.

TABLE 501C.A: CRUSHED RECYCLED CONCRETE LIMITS OF FOREIGN MATERIAL

Material	Maximum Limit	Sampling, Monitoring and Analytical Methods
Recycled Asphalt Pavement (RAP): % by mass retained on 4.75 mm sieve	15%	Test Method WA 144.1
High Density Materials (brick and tile): % by mass retained on 4.75 mm sieve	15%	Test Method WA 144.1
Low Density Materials (plastic, plaster, etc.): % by mass retained on 4.75 mm sieve	1.5%	Test Method WA 144.1
Organic Matter (wood etc.): % by mass retained on 4.75 mm sieve	1.0%	Test Method WA 144.1
Unacceptable high density materials (inert metals, glass and ceramics): % by mass retained on 4.75 mm sieve	3.0%	Test Method WA 144.1
Bound Asbestos (as Asbestos Containing Material): % by mass retained on 7 mm sieve	0.01%	In accordance with DWER Asbestos Guidelines
Fibrous Asbestos and Asbestos Fines:	0.001%	In accordance with DWER Asbestos Guidelines
Hazardous Metals:	Refer to Waste Authority RtR Specification	In accordance with Waste Authority RtR Specification

2. All deliveries, stockpiles and unsealed sections of Crushed Recycled Concrete must be kept watered to prevent airborne dust. ***Dust Control***

3. **If any asbestos or hazardous metals are identified as exceeding the maximum permissible limits in Table 501C.A, the supply of Crushed Recycled Concrete must be immediately suspended, and not resumed until resolved and agreed with the Superintendent.** ***HOLD POINT***

501C.03.03 MATERIALS PROPERTIES

1. The material shall consist of a uniformly blended mixture of coarse and fine aggregate resulting from the crushing of recycled concrete from construction and demolition material. ***Blending***

2. Coarse aggregate (retained on 4.75 mm sieve) shall consist of hard durable angular fragments and shall not break up after wetting and drying. ***Coarse aggregates***

3. Fine aggregate (passing 4.75 mm sieve) shall consist of crushed material or crushed material and sand with similar durability properties to that of the coarse aggregate. ***Fine aggregates***

4. The particle size distribution shall be determined in accordance with WA 115.1, and shall conform to the limits shown in Table 501C.B. The grading of material passing the 37.5 mm sieve shall vary from coarse to fine in a uniform and consistent manner. The material shall not be gap graded as represented by the grading crossing from the maximum limit for one sieve size to the minimum limit for another sieve size. ***Particle Size Distribution***

TABLE 501C.B: PARTICLE SIZE DISTRIBUTION (CRUSHED RECYCLED CONCRETE SUBBASE)

AS Sieve Size (mm)	% Passing by Mass Minimum and Maximum Limits
26.5	100
19.0	95 – 100
9.50	59 – 82
4.75	41 – 65
2.36	29 – 52
1.18	20 – 41
0.600	13 – 29
0.425	10 – 23
0.300	8 – 20
0.150	5 – 14
0.075	3 – 11

5. The material shall also conform to the following limits shown in Table 501C.C when tested in accordance with the listed Test Methods: ***Other Acceptance Limits***

TABLE 501C.C: OTHER ACCEPTANCE LIMITS (CRUSHED RECYCLED CONCRETE SUBBASE)

Test	Limits	Test Method
Los Angeles Abrasion Value	42.0% Maximum	WA 220.1
Linear Shrinkage	4.0 Maximum	WA 123.1
California Bearing Ratio (CBR) (Soaked 4 days) at 94% of MDD and 100% of OMC	100% Minimum	WA 141.1
Unconfined Compressive Strength (UCS- 7 days cured and 4 hours immersed)	1.0MPa Maximum	WA 143.1

6. Crushed recycled concrete subbase material shall be pre-wet to greater than 95% of the optimum moisture content as determined from Test Method WA 133.1 or WA 133.2 as appropriate. The moisture content shall be determined in accordance with WA 110.1. ***Moisture Curing***

7. Crushed recycled concrete subbase material and water shall be thoroughly mixed using a pugmill, grader or any other alternative approved method to produce a homogeneous product suitable for placement in the final position. ***Mixing***

8. Site specific controls shall be implemented to minimise run off from exposed crushed recycled concrete to environmentally sensitive receptors during construction. ***Minimise Run off***

Perth, Western Australia