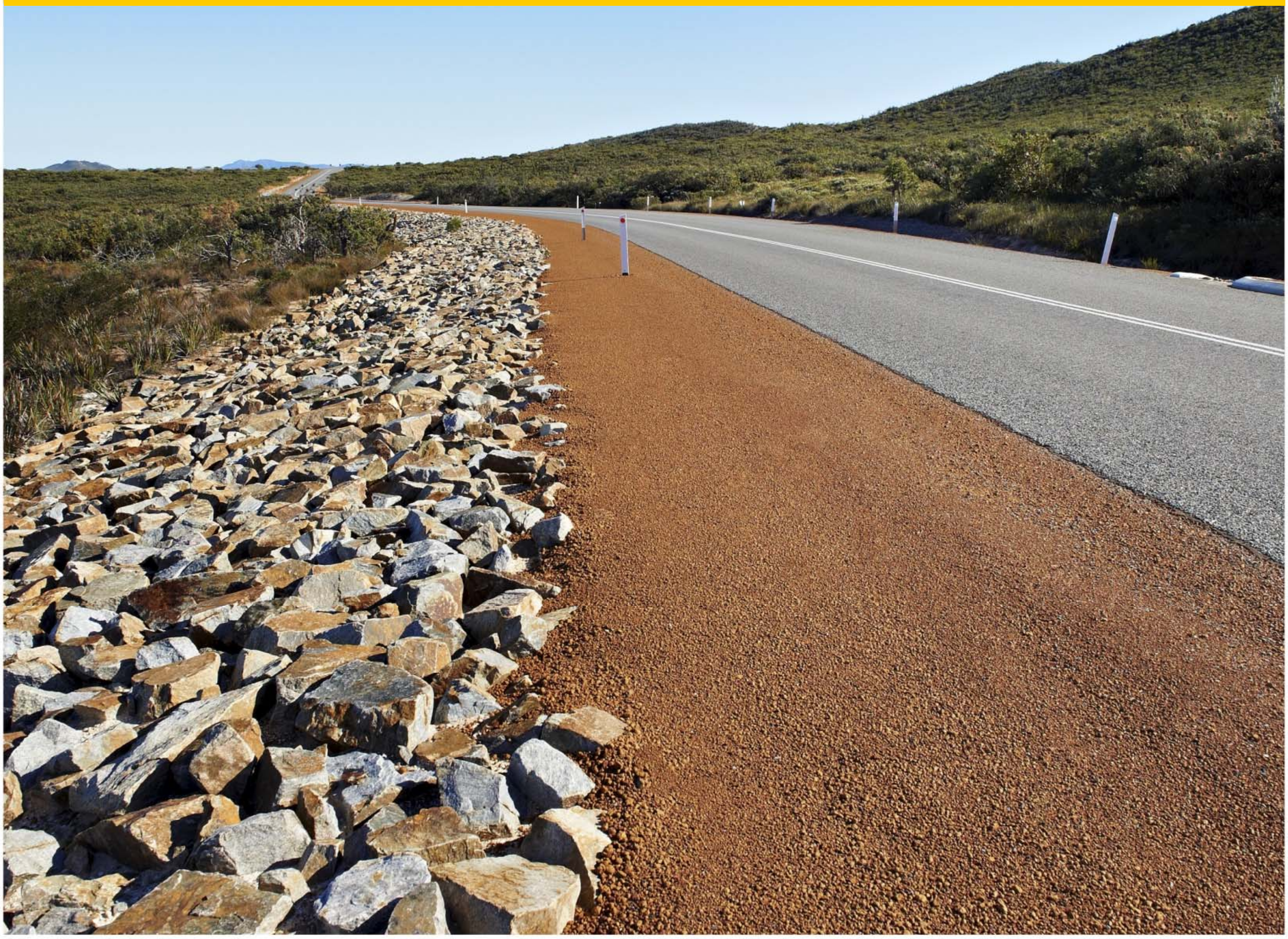
WAPARC

Western Australian Pavement Asset Research Centre

Enhanced Use of Construction and Demolition Waste as Road Pavement Materials: Scoping Study

2012/06



CONTRACT REPORT

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Enhanced Use of Construction and Demolition Waste as Road Pavement Materials: Scoping Study

Project No: 006992

by Bob Andrews

for Western Australia Pavements and Assets Research Centre

November 2013

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SUMMARY

This scoping study of the wider use of pavement materials sourced from construction and demolition (C&D) waste was commissioned by the Western Australian Pavement Asset Research Centre (WAPARC) in association with the Western Australia Waste Authority and industry partners All Earth P/L and Capital Recycling Pty Ltd.

The C&D waste considered in this report refers to inert wastes comprising recovered concrete, asphalt, bricks, sand, soil, glass, clean fill and rubble. Other common inert wastes such as plastics, plasterboard, timber and tyres are not considered.

The study was initiated in recognition that, compared to most other mainland States, the recycling of C&D waste is very low in WA. The aim was to identify actions that would enhance wider adoption of recycled materials in pavements (e.g. roads, car parks, industrial pavements, footpaths and shared paths).

Nationally the use of recycled materials is very mature in NSW, Victoria and South Australia and developing status in Queensland and Western Australia. Whilst large volumes of recycled materials are manufactured, they form a small fraction of the total consumption of civil infrastructure materials.

This report identifies several possible strategies for improved development and acceptance of recycled materials in the construction industry. It is important that any developments be undertaken through a consultative process involving road authorities (State and Local), C&D waste recyclers, the demolition industry, design consultants, the construction industry waste authorities and landfill operators.

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ABBREVIATIONS and ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ALT-MAT	European Alternative Materials Project
APC	Australian Packaging Covenant
Austroads	Association of Australian and New Zealand road transport and traffic authorities
CBR	Californian Bearing Ratio
CC&AA	Cement, Concrete and Aggregates Australia
C&D	Construction and Demolition
DECCW	Department of Environment Climate Change and Water (New South Wales)
DEWHA	Department of Environment, Water, Heritage and the Arts (Australia - Federal)
DPTI	Department of Planning, Transport and Infrastructure (South Australia)
EN 13242	European Standard on Aggregates for Unbound and Hydraulically Bound Materials for Use in Civil Engineering Work and Road Construction
ESA	Equivalent Standard Axle
FHWA	Federal Highway Administration (United States of America)
GhG	Greenhouse gas
IPWEA	Institute of Public Works Engineering Australia
LNEC	National Laboratory for Civil Engineering (Portugal)
MnDOT	Minnesota Department of Transportation (United States of America)
MRWA	Main Roads Western Australia
NATA	National Association of Testing Authorities (Australia)
NEPM	National Environmental Protection Measures (Australia)
PCC	Portland Cement Concrete
POEO Act	Protection of the Environment Operations Act 2005 (New South Wales)
Qld TMR	Queensland Department of Transport and Main Roads
RAP	Recycled asphalt pavement
RCA	Recycled crushed aggregate
RCG	Recycled crushed glass
RDC	Recycled demolition concrete
RMS	Roads and Maritime Services (New South Wales)
RTA Txxx	Roads and Traffic Authority (New South Wales) Test procedure ‘xxx’
SASA	Sustainable Aggregates South Australia
UCS	Unconfined compressive strength
USEPA SW	United States Environmental Protection Agency – Solid Waste test methods
WAPARC	Western Australian Pavement Asset Research Centre
WMAA	Waste Management Association of Australia
WSA PS	Water Services of Australia Product Specification

1 INTRODUCTION

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The methodology detailed in the contract was as follows:

1. Collate available data from the WA Waste Authority/industry on the quantities of various materials being sent to landfill in the Perth metropolitan area and the likely percentages/volumes of materials suitable for road construction.
2. In consultation with the WA Waste Authority and industry representatives agree a short-list of several key products that have economic recycling potential, including consideration of blending with traditional road-making materials.
3. Review State, national and international use of these key products. Particular emphasis should be given to specification clauses and design guidelines and in-service performance.
4. Summarise the technical, financial, OH&S and environmental issues inhibiting the increased use of these materials in road works, including a comparison of the costs of these key products with traditional road-making materials (if possible include a consideration of environmental impacts).
5. Scope the R&D required to develop mix design, structural design and specifications for supply and placement of these key products.

Whilst this project focusses on C&D waste, a previous study undertaken by ARRB for the Western Australian Local Government Association (Leek & Huband 2010) discussed all aspects of recycling opportunities associated with road infrastructure (e.g. C&D waste, rubber tyres and used oils) including recommendations for policy development.

2 WESTERN AUSTRALIAN C&D RECYCLING

2.1 WA Waste Strategy

The WA Government Waste Strategy, released in March 2012 (Waste Authority 2012), sets resource recovery targets for the C&D sector as shown in Table 2.1.

Table 2.1: 2010-2020 Western Australian C&D waste strategy targets

Year	Estimated waste generation (tonnes)	Estimated C&D recovery (tonnes)	Estimated C&D to landfill (tonnes)
2009/10[1]	4,431,104	1,295,327	3,135,777
2014/15	4,865,088	2,919,053	1,946,035
2019/20	5,371,450	4,028,588	1,342,863

Source: Oke et al. (2009).

It can be seen from Table 2.1 that the current recovery rate of C&D waste is expected to more than double over the next two years, whilst the amount sent to landfill will reduce by more than one-third.

2.2 Data on Recycling C&D Waste

In an attempt to define what C&D materials and volumes are currently being sent to landfill that could be recycled, local consultant Bowman & Associates was engaged to liaise with the WA Department of Environment & Conservation (DEC) (2012) and industry. Of the 3 million tonnes of C&D material reported in Table 2.1 as being disposed to landfill, a breakdown of C&D component materials being landfilled (and recycled) was not available from the DEC.

DEC data on the capacity of industry to recycle C&D waste in terms of annual throughput (facility design and maximum capabilities) is shown in Table 2.2.

Table 2.2: WA industry capacity

Name	Categories	Description	Throughput Design (tpa)	Throughput Max (tpa)	Location
Farfield Foldings Pty Ltd - Capital Recycling	62	Solid Waste Depot		50,000	Welshpool
Waste Stream Management Pty Ltd	62	Solid Waste Depot		500	Kwinana Beach
Cell 6 Pty Ltd - Non Organic Disposals (Landsdale)	62	Solid Waste Depot		5,000	Darch
Eclipse Resources - Flynn Drive	61A	Solid Waste Facility		5,000	Carramar
Waste Care	62	Solid Waste Depot	>500	210,000	Bayswater
Eclipse Resources - Postans	61A	Solid Waste Facility		100,000	Postans
RSV Group Pty Ltd	62	Solid Waste Depot	5,000	5,000	Bullsbrook
Eclipse Resources - Wanneroo Road	61A	Solid Waste Facility		100,000	Neerabup
Farfield Holdings Pty Ltd - Capital Recycling Bayswater	13	Crushing of Building Material	>1,000	500,000	Bayswater
Redoak Corporation and West Bins	62	Solid Waste Depot	80,000	88,000	Malaga
Carramar Resource Industries	62	Solid Waste Depot		150,000	Neerabup
WKM Holdings	62	Solid Waste Depot	>500	65,000	Landsdale
Waste Stream Management Pty Ltd	62	Solid Waste Depot	>5,000		Welshpool
Resource Revovery Solutions Pty Ltd	62	Solid Waste Depot	>500	170,000	Pinjarra
Eco Recources Pty Ltd	62	Solid Waste Depot	>500	156,000	Naval Base
Peel Resource Recovery Pty Ltd	62	Solid Waste Depot	>500	100,000	Pinjarra
Perth Bin Hire	62	Solid Waste Depot	50,000	50,000	Bayswater
Bronzewing Investment Pty Ltd	62	Solid Waste Depot	>500	50,000	Hazelmere
Matera 3 Pty Ltd	62	Solid Waste Depot	>500	100,000	Postans
New Age recycling	62	Solid Waste Depot		75,000	Kenwick
Advance Waste Disposal	62	Solid Waste Depot	> 500	50,000	Malaga
Brajkovich Demolition and Salvage Pty Ltd	62	Solid Waste Depot	>500	100,000	Henderson
All Earth Group Pty Ltd	62	Solid Waste Depot	80,000	80,000	Maddington
TOTAL CAPACITY				**2,209,500**	

It is noted that the industry capacity for C&D recycling is lower than the Waste Strategy targets.

In terms of defining the composition and volumes of C&D materials being recycled, Pogson & Mountjoy (2013) undertook a survey of industry in WA in 2011/12. The results are shown in Table 2.3.

Table 2.3: Composition of C&D materials recycled in 2011/2012

Material	Net recycling (tonnes)
Asphalt	144,269
Bricks	54,845
Concrete	395,540
Sand, soil, clean fill, rubble	455,643
Total	**1,050,297**

Source: Pogson & Mountjoy (2013).

Bowman, in discussion with Hyder Consulting, considered that this data is still current and further surveys/consultations with industry would not change the information.

3 NATIONAL C&D RECYCLING

3.1 Manufacture and Consumption of Natural Materials

The Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA 2010) reported national statistics on annual C&D waste in relation to individual States as shown in Table 3.1 for 2006/2007.

Table 3.1: C&D waste generation and recycling for Australia (ktonne)

State/Territory	Total C&D	Disposed to landfill	Commercially recycled	Per cent recycled
NSW	6,251	2,036	4,216	67
Vic.	4,084	1,138	2,946	72
Qld	2,083	1,466	617	30
WA	**2,348**	**1,939**	**409***	**17**
SA	1,460	304	1,155	79
ACT	227	21	206	91
Tas.	14	14	unknown	–
NT	51	51	unknown	–

* excludes sand, soil, clean fill and rubble.

Source: DEWHA (2010).

In contrast, the estimated total consumption of quarried materials in Australia for all infrastructure development in 2001 is shown in Table 3.2.

Table 3.2: Quantity of aggregates used as construction materials in Australia (tonnes)

Quantity of production (tonnes)	NSW	Vic.	Qld	WA	SA	Tas.	NT	Total
Crushed and broken stone	16,255,785	14,864,673	21,929,555	**10,000,000**	9,146,531	3,097,231	362,414	75,656,189
Gravel	3,644,030	3,556,261	1,354,923	**800,000**	51,636	41,438	162,959	9,611,247
Sand	8,768,948	5,902,973	5,466,930	**2,500,000**	2,091,294	315,650	165,766	25,211,561
Total quantity	28,668,763	24,323,907	28,751,408	**13,300,000**	11,289,461	3,454,319	691,139	110,478,997
C&D sourced	4,216,000	2,946,000	617,000	**409,000**	1,155,000	206,000	_	_
% of crushed stone volume	26.0	20.0	2.8	**4.1**	12.6	6.6	_	_

Note: Other forms of recycling existing pavements such as in situ stabilisation are not included here.

Source: DEWHA (2010).

4 SPECIFICATIONS

4.1 Overview of National Specifications

Specifications for pavement materials sourced from recycled C&D waste (principally crushed concrete) are generally confined to unbound granular and uniformly-graded materials. Other applications recognised include earthworks, drainage and pipe bedding as detailed in the Institute of Public Works Engineering Australia specifications (IPWEA 2010). Specifications for recycled aggregates associated with inclusion into asphalt and concrete mixes are not discussed in this report.

Receiving and processing C&D waste is controlled by legislation in each State through licensing, in addition to relevant guidelines to limit contaminants (e.g. poisons, heavy metals, hydrocarbons and asbestos).

Product specifications are generally based on the traditional quarried material counterparts in terms of grading, plasticity and stone hardness. Specifications also address limitations on supplementary materials to recycled concrete as the prime component (principally brick, glass and asphalt) in addition to the control of deleterious materials such as metal, timber, plastic, plaster, clay, etc.

Other stand-alone products that could be manufactured from recycled C&D are aggregates for drainage and minor erosion protection as well as sand products for applications such as trench fill and pipe bedding.

The relevant Australian specifications and legislation relating to contaminant management are listed in Table 4.1.

Table 4.1: Guidelines and specifications for pavement materials sourced from recycled C&D waste

State	Document
NSW	Management of asbestos in recycled construction and demolition waste (WorkCover NSW 2010) Position paper on soil and aggregate (WorkCover NSW undated) NSW RMS Specification 3051: Granular Base and Sub-base Materials for Surfaced Road Pavements (RMS 2011)
Victoria	Recycling construction and demolition material (WorkSafe Victoria 2007) VicRoads Section 820: Crushed concrete for pavement sub-base and light duty base (VicRoads 2009)
WA	**Guidelines for managing asbestos at construction and demolition waste recycling facilities (DEC 2012)** **MRWA Specification 501: Pavements (MRWA 2012)**
SA	Standard for the production and use of waste-derived fill (EPA SA 2010) DPTI Master Road Specification Part 215: Supply of Pavement Materials (DPTI SA 2011)
QLD	Queensland Government Main Roads Specification MRS35: Recycled Materials for Pavements (Qld TMR 2012)
IPWEA	IPWEA Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage (IPWEA 2010)

4.1.1 Engineering Parameters

As discussed above, specifications have been based upon parameters associated with quarried material equivalents. These are now broadly discussed.

- Grading: based on the maximum density principle with maximum size ranging from 20 mm up to 40 mm. It should be noted that most concrete does not contain aggregate of size greater than 20 mm. Therefore, in recycled products, aggregate size above 20 mm is made up of stone and mortar; this can be associated with a higher potential for aggregate breakdown.
- Plasticity: generally defined by Liquid Limit and Plasticity Index. Recycled materials have a higher Liquid Limit than most quarried materials due to the porosity of the mortar. Therefore, higher Liquid Limits are generally specified. Plasticity Index remains unchanged from quarried materials for the various product qualities.
- Stone hardness (which relates to aggregate breakdown of granular materials): specified in a number of ways, e.g. Los Angeles Abrasion, 10% fines, wet/dry strength variation.
- Strength (which is indirectly related to performance): specified in terms of CBR and Unconfined Compressive Strength (UCS) (to ensure that the material does not inherit bound material characteristics) and, in one case (South Australia), in terms of shear strength (cohesion and friction angle to protect against shoving failure) and repeated loading (characteristic resilient modulus and permanent deformation to adopt engineering properties associated with mechanistic design).

4.1.2 Supplementary Materials Composition

With demolition concrete as the main component, limitations are placed on supplementary materials such as brick, asphalt and glass. Whilst the proportions differ between States, there is no published data on supplementary materials limits and the reasoning behind the selection is not apparent other than to limit 'contamination' of the crushed concrete.

The limitation on brick content is generally associated with maintaining adequate stone hardness and durability. However, its benefits are that it adds plasticity and fines to the product to enhance compaction and density.

The limitation on glass is based on the need to avoid broken glass (elongated particles) which, in small quantities, is not detrimental to product performance.

The limitation on asphalt is based on controlling the overall bitumen content of the product in terms of loss of shear strength with increasing temperature. In addition, when recycled materials are stabilised with cementitious binders, loss of cementitious bonding of bitumen coated aggregate is a concern.

There is no standard approach to the quantity of supplementary materials permitted. Typically all products allow 100% recycled concrete content, but maximum limits for brick range from 5% to 20%, asphalt 5% to 20% (some limit bitumen content to 2%), and glass less than 5% exclusively.

4.1.3 Contaminants

(a) Asbestos: Whilst all states have Guidelines in place for management of asbestos to ensure that it is not present in recycled pavement material products, most States have a regulatory process to manage materials that contain asbestos. In WA, the Guideline was issued in 2012 (DEC 2012).

(b) Poisons, heavy metals and hydrocarbons:

Throughout Australia there is no common legislation or regulation of limits on chemicals and contaminants in recycled materials.

As an example, the Department of Environment Climate Change and Water NSW regulations pertaining to product exemption from the Environment Act and contaminant control for recovered aggregate and recycled crushed glass (refer to Appendix A) are now briefly described.

Routine sampling for environmental compliance shall be undertaken in accordance with composite sampling, i.e. a composite sample is defined as a sample comprising five discrete sub-sample increments at the following frequencies:

a) Characterisation sampling: composite sampling shall be undertaken once every two years comprising 20 composite samples representing individual batch (or lot) truckload or certified stockpile.

b) Routine manufacture sampling: Five composite samples per 4,000 tonnes or five composite samples per three months are required.

Contaminant testing, sampling and maximum limits are listed in Table 4.2.

Table 4.2: Contaminant limits in NSW

Chemical attribute	Max average concentration	
(Test procedure)	Characterisation sampling	Routine sampling
	Mg/kg "dry mass"	
Mercury (USEPA SW – 846 – 7471B)	0.5	not required
Cadmium (USEPA SW – 846 – 6010C)	0.5	0.5
Lead (USEPA SW – 846 – 6010C)	50	50
Arsenic (USEPA SW – 846 – 6010C)	10	not required
Chromium (total) (USEPA SW – 846 – 6010C)	20	not required
Copper (USEPA SW – 846 – 6010C)	40	not required
Molybdenum (USEPA SW – 846 – 6010C)	5	not required
Nickel (USEPA SW – 846 – 6010C)	10	not required
Zinc (USEPA SW – 846 – 6010C)	100	100
Total organic carbon (NEPM 1999 Method 105)	1.0%	1.0%
Electrical conductivity (NEPM 1999 Method 104)	1 dS/m	1 dS/m
Metals (RTA NSW T276)	0.25%	0.25%

Source: NEPM: National Environmental Protection Measure

In a similar vein, in South Australia, the Environmental Protection Authority has produced a standard for the production and use of waste derived fill (EPA SA 2010).

4.1.4 Deleterious (Foreign) Materials

The classification of deleterious materials, including metal, plastic timber and clayey and friable materials, does not vary significantly between States. A typical specification is shown in Table 4.3 (DPTI SA 2011).

Table 4.3: Deleterious materials (DPTI SA 2011)

Classification	Foreign material	Tolerable limit
Inert	Metal. glass, ceramic, and slag	3%
Friable	Plaster, clay lumps,	1%
Plastics & rubber	Rubber, plastic, paper, cloth, paint, wood, organics	0.2%

Source: DPTI SA (2011).

4.1.5 Glass Cullet

Recycling glass by crushing and screening to produce glass cullet is generally a separate industry to general C&D recycling and, whilst not a C&D waste, the use of cullet as an engineering material in Australian infrastructure is an emerging commercial development.

Approximately 39% of glass containers (bottles and jars) is currently recycled in Australia, with a national goal to increase this to 55% by 2010 (Australian Packaging Covenant 2010). There is no published information on current levels of recycling and updated targets.

The impetus to recycle glass as an engineering material is both commercially and environmentally based, viz.

- Internationally, recycled crushed glass is a recognised resource recovery source for the manufacture of fine aggregate products. Significant research and commercial implementation is being undertaken.
- Glass recycling removes a significant quantity of material from the waste stream that would otherwise go to landfill. As glass is 100% recyclable, i.e. it does not wear out and can be recycled over and over again without any reduction in quality, it has no place in landfill.

Recycled crushed glass (RCG) is crushed according to the Water Services Association specification WSA PS – 368 (WSA 2013). It is now commercially produced for use as pipe and cable bedding.

The use of cullet as a replacement for fine aggregate in asphalt is a debateable application but some trials are being undertaken in the asphalt industry to include 5% RCG as replacement of conventional fine aggregates in asphalt.

It should be noted that ARRB developed national specifications for recycled glass, including a review of national and international specifications (Andrews 2010).

4.2 Overview of International Specifications

There is a considerable history of recycling construction waste in Europe. For example, from 1945 to 2000, about 600 million m^3 of masonry debris was used in the rebuilding of Germany after World War II. In Finland in 1998, approximately 350,000 tonnes of recycled crushed aggregate was used in the construction of bases and sub-bases for roads.

The European Alternative Materials (ALT-MAT) project was established in Europe in 1998 to encourage the use of alternative materials in road construction and develop methods for the evaluation for these materials. In an attempt to close the gap between the laboratory evaluation of materials and field experience, data was obtained from nine research organisations in seven countries.

4.2.1 European Specifications

Several European countries have accepted recycled concrete aggregate (RCA) for use in the construction of base and sub-base layers in road construction (e.g. Finland, Sweden, Denmark, Netherlands, and Portugal). Most of the specifications have been based on experience gained from the construction of field trials and case studies. The following brief review of some of the specifications in Europe and the USA is based on the research undertaken by Cameron and Gabr (2011). The information is limited due to the lack of access to English translations of relevant documentation. Furthermore freeze-thaw-related specifications are not discussed.

Finland

Finland has used RCA since 1994 under the trade name Betoroc-crushed. Betoroc-crushed is classified into four grades based on the raw materials and technical properties for base and subbase layers. The specific applications of the different grades are not clear. The Plate Load Test or the Falling Weight Deflectometer (FWD) was used to determine the design bearing capacity of RCA, which is actually reported as stiffness. The key properties of the RCA materials are summarised in Table 4.4.

Table 4.4: Summary of Finland Specification for RCA materials

Property	I	II	III	IV	In general
Grain size (mm)	0-50	0-50	0-50	Varies	-
Optimum moisture content (%)	8-10	8-12	-	-	8-12
Maximum dry density (kN/m^3)	18-20	17.5-20.5	-	-	-
Specific gravity	-	-	-	-	2.55-2.65
UCS at 7 days (MPa)	1.2-1.3	0.3-1.1	-	-	-
UCS at 28 days (MPa)	2.0-2.1	0.6-1.3	-	-	-
CBR	-	-	-	-	90-140
Design modulus (MPa)	700	500	280	200	-
Los Angeles Abrasion (%)	23	28	-	-	-
Friction angle (ϕ) °	-	-	-	-	40
Permeability m/s	(1-7) x 10^{-5}	-	-	-	-
pH	12.7-12.9	-	-	-	≥ 11
Capillarity (m)	0.25	0.2	-	-	-
Contamination limits					
Bricks content (%) (max)	0	10	10	30	-
Other materials such as wood, plastics, etc. (%) (max)	0.5	1.0	1.0	1	-

Sweden

In a translated technical report (Håkan, 2004), the RCA materials are classified into four classes according to their material properties. Class 1 or 2 can be used as either base or sub-base in pedestrian and bicycle lanes. Class 3 can be used as capping layers and Class 4 as fill material.

The quality of each class was based on the properties of the concrete prior to being crushed for compressive strength or for the durability test, Micro-Deval. A summary of some key properties of RCA materials is presented in Table 4.5. It should be noted that the base rock in Sweden is often granite.

Table 4.5: Summary of Swedish Specification for RCA materials

	I	II	III	IV
Concrete quality				
Compressive strength of drill cores (MPa) (min)	30	20	10	
Micro-Deval max.	25	35	50	
RCA property				
Modulus (MPa)	450	450	250	150
Optimum moisture content (%)	6	6	10	12
Maximum dry density (kN/m^3)	18	18	16	15
Porosity	0.32	0.32	0.40	0.43
Water saturation ratio	0.34	0.34	0.40	0.42
Contamination limits				
Concrete content % (min)	100	95	80	50
High density brick > 1.6 Mg/m^3 (%) (max)	0	5	20	50
Low density concrete < 1.6 Mg/m^3 % (max)	0	1.0	5	50
Other materials such as wood, plastics, etc.( )% (max)	0	0.5	2	10

Source: Håkan (2004).

Denmark

In 2002, the Danish Road Institute established national specifications for using RCA as a road base. Three classes were created (A, B and C), which were based on the back-calculated modulus, the durability determined by Los Angeles Abrasion testing and the purity of the material (see Table 4.6). Class A and B can be used as base in all types of roads; however, Class C has limited use (Pihl, Milvang-Jensen & Berg 2003).

Table 4.6: Summary of Danish specification for RCA materials

Engineering property	A	B	C
Modulus (MPa)	400	300	200
Los Angeles Abrasion (%) (max)	35	40	-
Contamination limits			
Concrete content (%) (min)	98	95	80
Asphalt (%) (max)	2	2	2
Low density concrete (%) (max)	2	5	20
Glass, china, hard plastic, iron and other hard material (%) (max)	2	5	20
Wood, soft plastics, paper, ash and insulating material (%) (max)	5	1	2
Light insulating material such as polyurethane (%) (max)	0.02	0.02	0.02

Source: Pihl et al. (2003).

The Netherlands

Molenaar (2010) referred to a summary of specifications for RCA as basecourse in the Netherlands in his lectures at Delft University. The specification was based on the gradation and the purity of the material. A summary of some key properties of 20 mm RCA according to the Dutch specifications is presented in Table 4.7.

Table 4.7: Summary of Dutch specification for 20 mm RCA materials

Particle size distribution	**Base (0-20)**
Sieve size	Mass percentage (%)
C 31.5	0
C 22.4	0-10
C 16	-
C 8	15-45
C 4	-
2 mm	45-70
63 µm	92-100
CBR after preparing % (min)	50
Crushing factor	0.65
Contamination Limits	
Concrete content (%) (min)	80
Asphalt % (max)	5
Other broken crushed stone, dry density > 2.1 t/m^3 (%) (max)	10
Other broken crushed stone, dry density > 1.6 t/m^3 such as light concrete, glass, slag, etc. (%) (max)	10
Organic materials such as wood, rope, paper, etc. (%) (max)	0.1
Gypsum, metals and plastics (%) (max)	1.0

Source: Molenaar (2010)

Portugal

In 2006, the Portuguese National Laboratory for Civil Engineering (LNEC) developed specifications for using RCA in base and sub-base pavement layers. Recycled products are classed into either B or C according to the product composition.

Thereafter the product specification is designed to fit the end use, i.e. traffic defined by Daily Average Traffic (DAT). The RCA materials are categorised into AGER 1, 2 and 3. Category 3 is for relatively heavy traffic (DAT = 300) and for this category only Class B material is deemed satisfactory. Accordingly, durability requirements may be more stringent. The Portuguese classification of RCA is presented in Table 4.8 whilst a summary of some properties of RCA materials are presented in Table 4.9.

France

Cameron and Gabr (2010) included in their report a summary of information obtained from an internal report prepared by the Direction Regionale de l'Equipment d'Ile-de-France in 2003. About 3,000,000 tonnes of recycled materials are produced each year. The recycled materials are categorised into five classes according to particle size and durability as indicated in Table 4.10. GR0 and GR1 can be used as fill in embankments but the use of GR0 as a capping layer is not recommended. GR2, GR3 and GR4 can be used as base material in road construction depending on the traffic classes – either in raw form or after treatment with hydraulic binder.

Table 4.8: Portuguese Classification of RCA

Class	Constituents according to EN 13242				
	$R_C+R_U+R_G$	R_B	R_A	FL_S+FL_{NS}	X
B	≥ 90%	≤ 10%	≤ 5%	≤ 1%	≤ 0.2%
C	≥ 50%	≤ 50%	≤ 30%	≤ 1%	≤ 0.2%

where

- R_C = Concrete products, concrete and mortar
- R_U = Unbound aggregates, natural stone, aggregates treated with hydraulic binders
- R_G = Glass
- R_B = Masonry units of clay materials (brick, tiles, etc.) masonry units of calcium silicates
- R_A = Bituminous materials
- FL_S = Floating stone material
- FL_{NS} = Stony material does not float
- X = undesirable materials, e.g. cohesive materials (i.e. clay soils), plastics, rubber, and metals (ferrous and non-ferrous).

Table 4.9: Summary of some properties of RCA materials

Category	AGER1		AGER2		AGER3
Class	B	C	B	C	B
Description	0/31.5	0/31.5	0/31.5	0/31.5	0/31.5
Los Angeles Abrasion (%) (max)	45	45	40	40	40
Micro-Deval (max)	45	45	35	35	35
Los Angeles + Micro-Deval (max)	80	80	65	65	65
DAT for base (max)	150	NR	150	150	300
DAT for sub-base (max)	150	50	300	150	300

Notes: NR = Not recommended.

Table 4.10: Summary of some properties of recycled materials

Category	GR0	GR1	GR2	GR3	GR4
Size 0/D (mm)	NC	0/80	0/31.5	0/20	0/20
Los Angeles Abrasion (%) (max)	NA	45	45	40	35
Micro-Deval (max)	NA	45	45	35	30
Los Angeles + Micro-Deval (max)	NA	NA	80	65	55
DAT for base without treatment (max)	NA	NA	50	85	150
DAT for base with treatment (max)	NA	NA	50	50-150	150-300

Notes: NC = Not calibrated. NA = Not applicable.

4.2.2 American Specifications

Over 130 million tonnes of C&D waste are generated in the USA each year, with concrete being the most common material recycled. However, the USA did not have a national specification for the use of RCA until 2004 when the Federal Highway Administration (FHWA) published a report on the suitability of using RCA and its benefits (US Army Corps of Engineers 2004).

Minnesota

The Minnesota Department of Transportation (MnDOT) has used RCA as coarse aggregate in Portland Cement Concrete (PCC) since 1970. A summary of the MnDOT specification is presented in Table 4.11. Currently, Minnesota uses RCA in high-volume freeways as dense graded base layer. The MnDOT specification states that RCA can be used as granular material, stabilised material in subgrade, and as aggregate for wearing surfaces and basecourses. It may also be blended with virgin aggregate. The specifications are based simply on gradation and Los Angeles characteristics. However, it is also stated that RCA shall not contain any impurities such as wood, rubber, plants and reinforcing steel.

Table 4.11: Summary of MnDOT specification for RCA

Particle size distribution & durability Sieve size (mm)	**Class 7** Passing percentage (%)
50	100
37.5	95-100
25	65-95
19	45-85
9.5	35-70
4.75	15-45
2.00	10-30
0.425	5-25
0.075	< 12
Los Angeles Abrasion % (max)	40

American Association of State Highway and Transportation Officials

American Association of State Highway and Transportation Officials (AASHTO 2002) established a standard specification, M319-02, for the application of RCA as unbound granular base material. This specification covers the requirements for some physical properties of RCA and the limits of deleterious substances as shown in Table 4.12.

Table 4.12: Summary of some properties of the M319 specification for RCA

Engineering property	**Base**
Liquid Limit (%) (max)	30
Plasticity Index (%) (max)	4
Sand equivalent value (%) (min)	25
Los Angeles Abrasion (%) (max)	50
Contamination limits	
Bituminous concrete content (%) (max)	5
Brick content (%) (max)	5
Hazardous materials or solid waste (%)	0
Wood, metal, plaster and gypsum (%)	0

Source: AASHTO (2002).

4.3 Comparison of Specifications

It will be noted in comparing the various specifications that a variety of limits are placed upon supplementary materials such as brick, asphalt and asphaltic materials as well as foreign materials. However, data on quantities of the materials being disposed to landfill in Australia could not be obtained other than the overall statistics shown in Table 2.1 (current estimate of 3 million tonnes of C&D to landfill) and Table 2.3 (recycling volumes of C&D waste 2011/12).

Overseas specifications also vary in permissible content, though the zero allowances associated with the use of timber, plastic etc. in some jurisdictions is worthy of note. However, it is not practicable to achieve zero tolerances in Australian recycling operations.

In terms of technical parameters, the Micro-Deval abrasion test, sand equivalent test, crushing tests, resilient modulus and intrinsic properties such as porosity and percentage of broken or dense materials are parameters which do not generally appear in Australian specifications.

5 SELECTION OF RECYCLED MATERIALS

Traditionally pavement material specifications in contract documents are limited to technical considerations. However, there are additional considerations and opportunities associated with environmental and financial factors when recycled materials are used.

5.1 Environmental Considerations

Recycling and reuse of recycled aggregates brings substantial environmental gains (RMCG 2008) in terms of:

- reduced resource consumption – substitution of new products by recycled products results in the conservation of primary aggregates for future generations
- diversion of waste materials from landfill – reduced biodiversity, amenity and transport emissions costs
- reduced quarrying – reduced amenity and biodiversity costs
- reduced greenhouse gas (GhG) emissions – recycled aggregates are associated with lower embodied energy in addition to reduced transport emissions: recycled materials are reused in close proximity to the site of reprocessing.

In addition, transporting aggregate to site is not only a financial consideration in terms of tonne/kilometre costs but also the emissions generated by their transport. Therefore source location in relation to project location can be an environmental consideration.

In consideration of GhG emissions associated with product manufacture and transportation to site, a calculation spreadsheet tool was developed by Sustainable Aggregates South Australia (RMCG 2010). The user-friendly spreadsheet tool calculates the emissions and financial implications of materials choices (recycled and primary aggregates) on a project basis.

The spreadsheet tool uses emission factors based on both primary research and published values. The tool calculates values of energy use and CO_2 emissions produced from a range of activities, including:

- winning, handling, crushing, screening and blending of primary aggregates (quarrying)
- crushing, screening and blending of recycled aggregates (recycling)
- transport of materials between points of origin and delivery to construction site.

The objective of the spreadsheet tool is to enable an estimate of the CO_2 savings arising from substituting primary or quarry aggregates for recycled aggregates into a construction job (in terms of embodied energy and direct energy usage in transport of materials). The spreadsheet takes account of both:

- differences in material density and freight distance between a construction job and the recycling facility, i.e. reduced transport emissions
- differences in embodied energy of recycled and new quarry aggregates, i.e. reduced embodied emissions.

The tool also provides an opportunity for the user to broadly determine any financial cost differences between jobs with different materials choices. This will vary from job to job depending on the proximity of the material source to the project site and the actual cost of the materials.

5.2 Financial Considerations

The 'ex-bin' price and associated delivery costs of pavement materials are always a consideration in tenders and contracts. Other considerations include compacted material density (for recycled materials the density is 2.0 tonne/m^3). Hard rock sources in the Perth area have higher densities and therefore a comparatively lower volume of material per tonne, which requires a larger number of truckloads to transport the material.

In addition to transport costs ($/tonne/kilometre), which favour sources in close proximity to the project, the indirect cost of road wear on the transport route is generally not considered.

Where recycled aggregate is used as part-replacement for virgin aggregate in concrete and asphalt the value becomes greater, not only in terms of higher 'ex-bin' prices of these products but also due to the higher quality stone requirements compared to granular pavement materials. This implies that the best material must be extracted from the quarry to produce aggregate. In some States this has led to high quality rock sources being depleted and alternate (more distant) sources having to be found.

The aim of an Austroads project being conducted in 2013/14 aims to determine the economic costs associated with the decreasing availability of traditional road-building materials and the extent to which future availability of pavement materials will impact on road maintenance and construction activities.

The Austroads project has been established in consideration of the need to investigate the economics associated with both the continued use of traditional pavement materials and also the adoption of alternative strategies involving the use of recycled materials. The project outcomes aim to assist road agencies to make more informed decisions regarding the management of pavement materials and maintenance and rehabilitation strategies.

All traditional pavement materials (high quality and natural aggregates, asphalt, concrete, etc.) are being considered, whilst recycling options being addressed include in situ recycling, recycled asphalt pavements (RAP), and C&D waste.

6 SUGGESTED STRATEGY FOR ENHANCING THE USE OF RECYCLED MATERIALS IN WA

6.1 Introduction

In identifying key high-volume materials that have potential for use in road construction, no new materials were identified other than the traditional C&D waste composites of concrete, asphalt, brick, ceramics and rubble.

The use of recycled materials in unbound granular materials is the most common application of C&D derived products. However, there is a general lack of acceptance of recycled materials due primarily to a lack of experience and knowledge of the products and their performance.

In 2008, ARRB undertook a survey of stakeholders to identify issues associated with acceptance of recycled materials. The results are shown in Table 6.1 (Leek & Huband 2010). It was apparent that there was full support for uses as aggregate replacement in concrete and asphalt as well as bedding material in service trenches; however, there was some opposition to their use as granular basecourse and sub-base materials.

Table 6.1: Result of WA survey of recycled materials acceptance issues

Inhibitors	Actions
It is easier to continue doing the same thing over and over again than to adapt to change and introduce new methods	Identify champions to undertake more demonstration projects in receptive Local Governments
A lack of confidence; recycled products are often viewed as second hand and second class	Undertaking detailed testing and dissemination of test results
A perception that, by using a non-standard product, there is a higher level of risk in terms of pavement performance.	Disseminate consistency reports by independent laboratories undertaken as a SWIS grant project
A lack of hard data and prior examples of local use of recycled products	Run workshops to disseminate examples of successful use of recycled products
A lack of availability of recycled products	Increase landfill levy to encourage greater diversion of recycled products
An historical carryover of the poor quality control of early recycled products	Develop and disseminate specifications for use of recycled products including: ▪ crushed glass in roadbase and asphalt ▪ recycled roadbase made from demolition materials ▪ crumb rubber asphalt ▪ non-structural concrete Ensure that quality control methods used by recyclers are well known, documented and disseminated
Concern about contaminants including heavy metals, poisons and asbestos	Develop appropriate quality management systems and source separation
Little understanding of the total environmental footprint of products	Undertake further studies to quantify environmental footprint of various products and disseminate at workshops
Lack of appreciation of the value of demolition and waste materials, a widespread community view that waste = worthless	Ensure comprehensive public and industry education on the value of recycled products

Inhibitors	Actions
Cheap supply of raw materials makes recycling unprofitable	Introduction of a resource tax to reflect true costs of producing new materials Introduce true triple bottom line accounting to cost environmental and social costs including greenhouse gas emissions
Vertical integration of concrete plants and aggregate quarries.	Insert 'preference to recycled product' clauses into specifications. Analyse tenders on total environmental cost basis
Lack of incentives to use recycled materials	Education campaign to explain other less tangible benefits of using recycled materials Subsidise recycled materials from landfill levy
Recycled materials require different approach to usual methods	Undertake trials and educate crews about environmental and structural benefits

Source: Leek & Huband (2010)

The current MRWA specification has been temporarily withdrawn due to an issue with managing asbestos risks. The specification does not permit the use of recycled crushed concrete in basecourse layers due to concerns over post-construction cementation leading to bound material characteristics as opposed to unbound granular characteristics and consequential cracking as demonstrated in trial sections established by the City of Canning on Welshpool Road (Leek 2009).

6.2 Formation of a Consultative Group

Within the framework of WAPARC and the WMAA C&D WA Working Group, it is recommended that the formation of a stakeholder subgroup be considered along the lines of Sustainable Aggregates SA with the purpose of contributing to the realisation of the WA Waste Strategy by:

- providing a cooperative and consultative link between the resource recovery & recycling industry and its stakeholders in WA
- recognising high benchmark standards of manufacture and product certification branding within the industry through a MRWA prequalification process
- promoting the factual technical capabilities of recycled products and environmental benefits through information documentation, technical publications and stakeholder/customer information forums
- establishing an applied research and development program through industry-stakeholder consultation focusing on market development and new product initiatives
- providing an information reference and retrieval portal (e.g. a website) to disseminate technical developments in the recycling field nationally and internationally
- providing a link and awareness of other research programs (e.g. the Austroads economic study) and product developments (e.g. Fairfield Council bituminous-stabilised material trials) to adopt or adapt and avoid repetition of research effort.

In forming a group the (non-commercial) interests of representations from waste regulators (Department of Environment Regulation), Industry (recycling and demolition), expert advisors and researchers, construction and consulting (e.g. IPWEA, Consult Australia, Civil Contractors Association) as well as government (Local and State) should be considered.

6.3 Reinstatement of Specification 501 (Recycled Materials)

In consultation with WAPARC and specialist advice, reinstatement of a specification is essential in supporting the C&D recycling industry. However, whilst the intrinsic properties of grading, plasticity and stone hardness can be addressed, identification of performance attributes and issues need to be addressed as discussed in Section 6.4.

6.4 Characterisation of WA Materials to all State Specifications

As a relatively new product in WA, it is considered necessary to benchmark the quality of manufactured products to national specifications and products in order to provide a transparent performance link between States.

The characterisation would consider the principal source products being subjected to a laboratory testing program and identifying their fit within other State specifications. This also serves as providing some transparency between recycled material specifications where consultant designs are undertaken in other States for projects in WA.

Confirmation of the specification (and modification if necessary) in terms of performance can also be undertaken by conducting strength testing such as CBR and UCS and performance-related testing such as repeated load tests for resilient modulus and rutting characterisation coupled with laboratory wheel tracking tests.

There is a need also to develop local specifications outside of the traditional 'road pavement' applications for lighter applications such as untrafficked pavements, i.e. school yards, footpaths and bikeways. In other States these are classified as lower-quality-level products, e.g. Class 3 type levels or non-spec products.

6.5 Improved Understanding of Performance Aspects for Road Applications

It is recognised that material specifications are necessarily broad and may not guarantee expected behaviour or field performance. The principal technical issues suggest formal investigations into the following issues (some of which are of national consideration and link with other work being undertaken and identified through the consultative group):

- In-service monitoring has revealed the potential for high strength gain, leading to change in characteristics from unbound to bound (or lightly-bound) behaviour. Fatigue failure of the pavement is not considered in granular pavement design. However, if it occurs it can result in an expensive maintenance regime (i.e. crack sealing to resist pumping, potholing and rutting). Whilst some research has been undertaken internationally, it is necessary to undertake investigations on local recycled materials and environments.
- Light cementation and associated plastic shrinkage cracking have been observed with some recycled materials, with the result that some specifications limit application to lower layers in the pavement. As a consequence, a barrier is placed on material suppliers bidding for contracts as limiting the recycled material to lower layers implies multiple suppliers of granular materials which is commercially impractical.

  Research following the example of Symons (1999), who reviewed the shrinkage and erodibility characteristics of recycled materials, including lightly-bound scenarios with cementitious binders, is suggested. An illustration of this type of testing is shown in

Figure 6.1, with typical maximum values of 600 to 800 microstrain being measured on material with a small quantity of brick.

Figure 6.1: Shrinkage measurement of crushed recycled concrete

Source: Symons (1999)

- Investigate the use of higher proportions of supplementary materials such as brick and rubble (mixed wastes) as well as asphalt (particularly where it cannot be more efficiently reused as aggregate replacement in asphaltic products).

  — Brick

  Azam & Cameron (2013) undertook research on the engineering properties of recycled concrete with varying proportions of brick, including repeated loading and shrinkage tests. It was observed that the addition of 20% brick reduced the shrinkage strains by around 50% thereby reducing cracking potential. The incorporation of higher brick content in current products is viewed as one opportunity but also increased brick content for lighter applications (i.e. footpath, bikeways and shared paths) could be developed. Figure 6.2 and Figure 6.3 summarise repeated load testing determinations of resilient modulus and rate of permanent deformation.

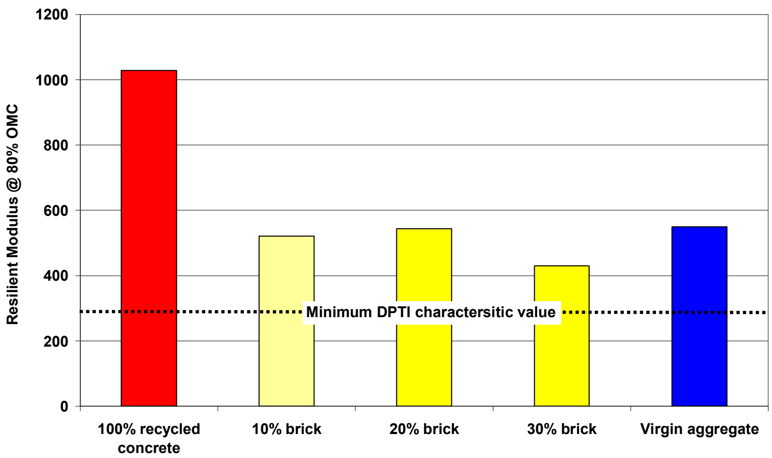

Figure 6.2: Resilient modulus and increasing brick content

Source: Azam & Cameron (2013)

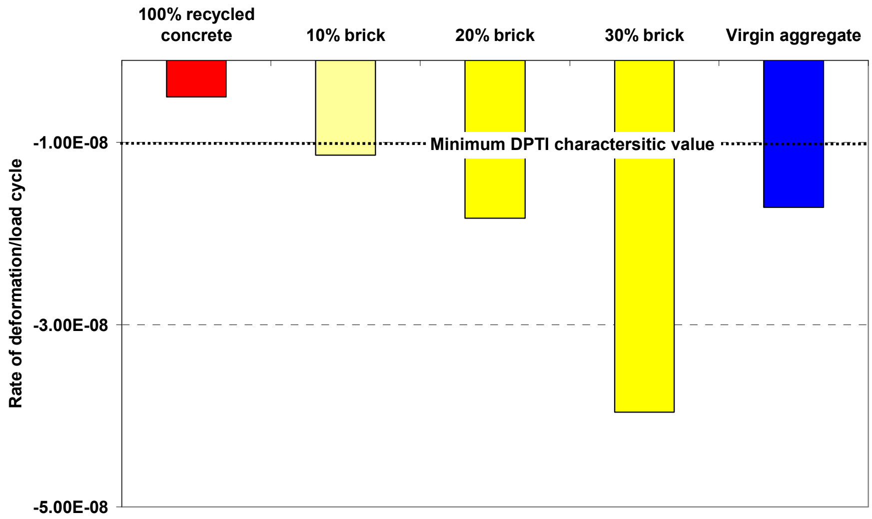

Figure 6.3: Rate of strain with increasing brick content at 80% OMC

Source: Azam & Cameron (2013)

– Glass cullet

Arnold, Werkmeister & Alabaster (2008) examined the effect of varying glass cullet content when blended with recycled aggregates using repeated load testing and the application of rut prediction models. The research suggested improved performance with increasing glass cullet content up to 30%. A summary of the data in terms of the traffic loading (ESAs) to create a predicted 10 mm rut depth in a granular pavement is illustrated in Figure 6.4.

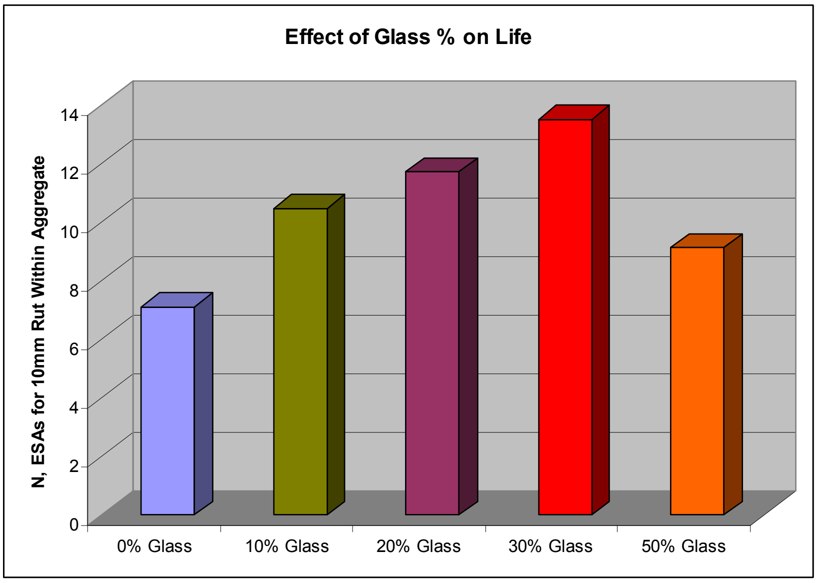

Figure 6.4: Traffic expectation for 10 mm rutting with varying glass content

Source: Arnold et.al (2008)

– Asphalt

Asphalt sourced from recycled planings (RAP) or slab asphalt which is subsequently crushed has a greater value in other applications than as an inclusion with concrete (e.g. as aggregate replacement in new asphalt or as a bituminous stabilised ‘cold mix’ product (Andrews et al. 2006). Figure 6.5 illustrates some preliminary work undertaken on the effect of varying RAP content with recycled demolition concrete (RDC) (Andrews 2010).

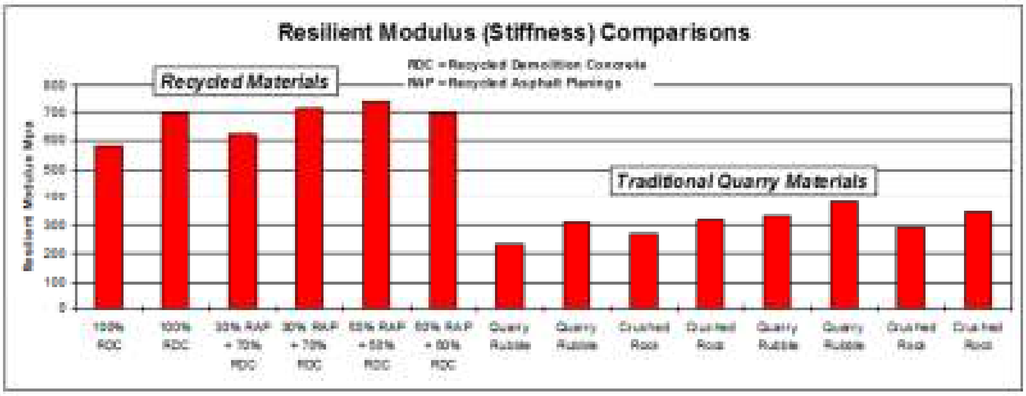

Figure 6.5: Resilient modulus of varying RAP content

Source: Andrews (2010)

– Addressing the recognition of the fact that recycled concrete products have higher abrasion characteristics (Los Angeles Abrasion Value or crushing values) leads to concerns about aggregate breakdown of the basecourse applications under traffic. Research is required along the lines of wheel tracking testing, larger-scale laboratory dynamic loading tests (or accelerated field trials).

6.6 Development of New Products

It is noted that current specifications are centred around unbound granular materials. However, other pavement materials such as modified and bound materials can provide benefits in alternate pavement configurations, viz:

- Increasing traffic volumes, particularly on urban arterials, can lead to alternate pavement configurations involving bound basecourse supporting thick asphalt layers as is the case in other mainland capital cities. Specifications for bound pavement materials particularly adopting cementitious binders need to be developed if there is a market for them. Example uses of cement-bound products using recycled materials date back over 15 years with larger projects identified including the Western Ring Road, East-Link and Albert Park Grand Prix (Alex Fraser Group Technical Information Sheet) in Melbourne and the Port River Expressway (DPTI Prexy) in Adelaide.
- High-float emulsion-stabilised materials can be used to provide a cold mix bitumen-stabilised material that can be transported and placed using conventional granular materials construction processes as well as those associated with asphalt laying and compaction. These materials also have potential application in transport and container yards and grain terminals as alternate lower-cost structural pavements or surfacings to conventional hotmix asphalt.
- The use of modified or bound materials has found application as a partial replacement for intermediate layers as well as rapid reconstruction of residential streets.

- Developmental work associated with these products has been undertaken in SA (Andrews et al. 2006) and field trials are currently being conducted by Fairfield City Council in Sydney, NSW.
- The use of crushed glass cullet for the partial replacement of crushed fine aggregate in both concrete and asphalt is currently being undertaken commercially in Perth. However, the replacement of sand and bedding sand is probably not viable for Perth owing to the volume of natural sand available as well as waste crusher dust from quarries.

6.7 Extending the Life of Natural Limestone Sources

Natural limestone sources are being commercially exploited in Perth for use in lower-quality pavement materials. On completion of extraction, the site is converted to a commercial landfill operation receiving C&D waste as a reclamation process for subsequent building development.

Whilst this can be interpreted as a recycling process, there could be commercial opportunity in extending the life of these sources by blending processed C&D products to improve the quality and application of limestone basecourses in heavier-trafficked pavements. Judicious selection of these blends for basecourse and the use of limestone in lower pavement layers could lead to more economical and wider applications for both source materials.

Should a commercial opportunity arise, then varying volumes of C&D/limestone mixtures could be researched to identify non-conformance issues in relation to current specifications. In addition, strength testing such as CBR and UCS and performance-related testing such as repeated load tests for resilient modulus and rutting characterisation, coupled with laboratory wheel tracking, are suggested.

6.8 Manufacture of Aggregates as Part-replacement in Concrete and Asphalt Mixes

The use of recycled aggregates in concrete and asphalt is described in Cement, Concrete and Aggregates Australia (2013). There are a number of aggregate specifications which have not been sourced in this document pending consultation with the end-product manufacturers and the recycled aggregate suppliers over commercial prospects.

MRWA concrete and asphalt mix specifications incorporating recycled aggregates would need to be developed based on existing specifications and use in the two industries, along with trial mixes and field trials. Should this prove to be a viable option for industry, then further surveys of national and international specifications and research on recycled aggregates is recommended.

6.9 Development of Tools and Guidelines on Environmental Considerations in Material Selection

There are difficulties associated when comparing greenhouse emission figures published in different publications. This is due to differences in the accounting methodologies used and local electricity generation factors between jurisdictions, both across Australia and worldwide.

Whilst calculation tools for GhG emissions exist, as discussed in Section 5.1, it is suggested that detailed studies of major recyclers in WA be undertaken. In addition, the development of specification clauses encouraging environmental considerations is recommended.

6.10 Enhancing Knowledge of Recycled Materials Technology

One of the main barriers associated with the acceptance of recycled pavement materials is the lack of general confidence in their performance and knowledge of their manufacture (under quality assured systems, licensing and environmental legislation). This implies that there is a necessity to provide in a non-commercial environment (i.e. through the consultative group) information forums on available products, applications, limitations and performance.

7 SUMMARY

Data was not available on absolute quantities of C&D waste going to landfill (composition and quantities) that could be diverted to recycling. However, the generic composition of C&D waste remains associated with inert wastes including concrete, asphalt, brick and rubble and, under separate industry operations, glass. No new C&D wastes were identified in the study, suggesting that increasing recycling to meet State strategies simply implies greater volumes of C&D waste being delivered to recyclers. Supporting this development requires a confident market and informed stakeholder base through information forums supported by technical research programs identifying the nature of the products and their fit-for-purpose application.

The predominant use of recycled materials is as uniformly-graded unbound granular materials in granular pavement layers. In some circumstances their application as basecourse beneath thin bituminous surfaces is not permitted or limited to roads with low traffic loading due to the risk of intrinsic properties leading to defective performance such as cracking.

Other applications such as aggregate in asphalt and concrete are well recognised, with various developments of these products with varying recycled material proportions.

Nationally the use of recycled materials is very mature in NSW, Victoria and South Australia and developing status in Queensland and Western Australia. Whilst large volumes of recycled materials are manufactured, they form a small fraction of the total consumption of civil infrastructure materials.

This report identifies several possible strategies for improved development and acceptance of recycled materials in the construction industry. It is important that any developments be undertaken through a consultative process involving road authorities (State and Local), C&D waste recyclers, the demolition industry, design consultants, the construction industry waste authorities and landfill operators.

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APPENDIX A NSW EXEMPTION DOCUMENT

Protection of the Environment Operations (Waste) Regulation 2005 – General Exemption Under Part 6, Clause 51 and 51A

The recovered glass sand exemption 2010

Name

1. This exemption is to be known as 'The recovered glass sand exemption 2010'.

Commencement

2. This exemption commences on 14 June 2010. 'The recovered glass sand exemption 2008' which commenced 20 June 2008 is revoked from 14 June 2010.

Duration

3. This exemption is valid until revoked by the Environment Protection Authority (EPA) by notice published in the Government Gazette.

Legislation

4. Under the *Protection of the Environment Operations (Waste) Regulation 2005* (the Regulation):

4.1. Clause 51 (2) authorises the EPA to grant an exemption in relation to any matter or thing including an activity or class of activities, and

4.2. Clause 51A authorises the EPA to exempt a person from any of the following provisions in relation to an activity or class of activities relating to certain waste that is to be land applied or used as a fuel:

- the provisions of sections 47 to 49 and 88 of the *Protection of the Environment Operations Act 1997* (the Act),
- the provisions of Schedule 1 to the Act, either in total or as they apply to a particular activity, and
- the provisions of Part 3 and clauses 45 and 47 of the Regulation.

Exemption

5. In this Notice of Exemption:

5.1. The responsible person listed in Column 1 of Table 1 is exempt from the provision/s listed in Column 2 of that table but only in relation to activities involving the relevant waste and only where the responsible person complies with the conditions referred to in Column 3 of the table.

However, this Notice of Exemption does not exempt the responsible person from the provisions specified in Column 2 where the relevant waste is received at premises that are, despite this exemption, required to be licensed for waste disposal (application to land) activities under the provisions of the Act.

5.2. Where a responsible person complies with the conditions of this Notice of Exemption, the activity referred to in Schedule 1 from which that person is exempt is taken to be a non-scheduled activity for the purposes of the Act.

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Table 1

Column 1	Column 2	Column 3
Responsible person	**Provisions from which the responsible person is exempt**	**Conditions to be met by the responsible person**
Processor	section 48 of the Act in respect of clause 39 of Schedule 1 to the Act	all requirements specified in section 7 and 8
Consumer	section 48 of the Act in respect of clauses 39 and 42 of Schedule 1 to the Act section 88 of the Act clause 47 of the Regulation	all requirements specified in section 7 and 9

This Notice of Exemption is a general exemption for the purposes of clause 51(3) of the Regulation.

Definitions

6. In this Notice of Exemption:

Characterisation means sampling and testing that must be conducted on the recovered glass sand for the range of chemicals and other attributes listed in Column 1 of Table 2.
Composite sample means a sample that combines 5 discrete sub-samples into a single sample for the purpose of analysis.
Consumer means a person who applies, causes, or permits the application to land of recovered glass sand within the definitions of "application to land" in accordance with the Act. The consumer may be the landholder responsible for the land to which recovered glass sand is applied. Where a person responsible for transporting the recovered glass sand to the land application site is also the party applying the recovered glass sand, this person must also meet the responsibilities of the consumer.
Once-off sampling means sampling and testing that must be conducted only once on a batch, truckload or stockpile of recovered glass sand that is not repeated, reproduced and does not form part of a continuous process.
Processor means a person who processes recovered glass into recovered glass sand for supply to a consumer.
Recovered glass means glass sourced from the collection of domestic or commercial waste. This includes glass collected from domestic commingled recycling collections. This does not include glass recovered from the sorting or processing of:

- mixed municipal waste, or
- mixed commercial and industrial waste, or
- construction and demolition waste, or
- Cathode Ray Tubes or other glass recovered from electrical equipment, or fluorescent or incandescent lights.

Recovered glass sand means recovered glass that has been processed to produce a 'sand-like' glass material with a particle size diameter generally less than 5 mm, and that contains at least 98% recovered glass.
Relevant waste means recovered glass sand that meets the requirements of Section 7.
Routine sampling means sampling and testing that must be conducted on the recovered glass sand on an ongoing and regular basis.

2

General conditions

7. This Notice of Exemption is subject to the following conditions:

7.1. The chemical concentration or other attribute of the recovered glass sand listed in Column 1 of Table 2 must not exceed any of the following:
 - 7.1.1. the absolute maximum concentration or other value listed in Column 4 of Table 2,
 - 7.1.2. for characterisation or once-off tests, the maximum average (based on the arithmetic mean) concentration or other value listed in Column 2 of Table 2, and
 - 7.1.3. for routine tests, the maximum average (based on the arithmetic mean) concentration or other value listed in Column 3 of Table 2.

7.2. The recovered glass sand can only be applied to land for the purposes of pipe bedding, drainage or for road making activities.

Processor responsibilities

8. The following conditions must be met by the processor for this exemption to apply:

8.1. Sampling must be undertaken in accordance with Australian Standard 1141 Methods for sampling and testing aggregates (or equivalent). Sampling and information on sample storage and preparation must be detailed in a written sampling plan.

8.2. Where the recovered glass sand is generated as part of a continuous process, the processor must undertake characterisation and routine sampling according to the requirements listed in Column 1 and Column 2 of Table 3.

8.3. Where the recovered glass sand is not generated as part of a continuous process, the processor may undertake once-off sampling of a batch, truckload or stockpile of recovered glass sand according to the requirements listed in Column 3 of Table 3, for the range of chemicals and other attributes listed in Column 1 of Table 2.

8.4. Where there is a change in inputs that is likely to affect the properties of the recovered glass sand, characterisation must be repeated. Characterisation samples can be used for routine testing and subsequent calculations.

8.5. Processors must keep a written record of all characterisation, routine and/or once-off test results for a period of three years.

8.6. Records of the quantity of recovered glass sand supplied to the consumer and the consumer's name and address must be kept for a period of three years.

8.7. The processor of recovered glass sand must provide a written statement of compliance to the consumer with each transaction, certifying that the recovered glass sand complies with the relevant conditions of this exemption.

8.8. The processor of recovered glass sand must make information on the latest characterisation and routine test results available to the consumer.

Consumer responsibilities

9. The following conditions must be met by the consumer for this exemption to apply:

9.1. Records of the quantity of the recovered glass sand received by the consumer and the suppliers' name and address must be kept for a period of three years.

9.2. The consumer must land apply the relevant waste within a reasonable period of time.

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Chemical and other material property requirements

10. This Notice of Exemption only applies to recovered glass sand where the chemical and other attributes listed in Column 1 of Table 2 comply with the chemical concentrations and other values listed in Column 2, Column 3 and Column 4 of Table 2, when analysed according to test methods specified in Column 5 of Table 2.

Table 2

Column 1	Column 2	Column 3	Column 4	Column 5
Chemicals and other attributes	Maximum average concentration for characterisation (mg/kg 'dry weight' unless otherwise specified)	Maximum average concentration for routine testing (mg/kg 'dry weight' unless otherwise specified)	Absolute maximum concentration (mg/kg 'dry weight' unless otherwise specified)	Test method specified within Section
1. Mercury	0.5	Not required	1	12.1
2. Cadmium	0.5	0.5	1.5	12.2
3. Lead	50	50	100	12.2
4. Arsenic	10	Not required	20	12.2
5. Chromium (total)	20	Not required	40	12.2
6. Copper	40	Not required	120	12.2
7. Molybdenum	5	Not required	10	12.2
8. Nickel	10	Not required	20	12.2
9. Zinc	100	100	300	12.2
10. Total Organic Carbon	1.0%	Not required	2.0%	12.3
11. Electrical Conductivity	1 dS/m	1 dS/m	2 dS/m	12.4
12. Metals	0.25%	0.25%	0.50%	12.5
13. Plaster, clay lumps and other friable materials	0.25%	0.25%	0.50%	12.5
14. Rubber, plastic, bitumen, paper, cloth, paint, wood and other vegetable matter	0.3%	0.3%	0.5 %	12.5

Sampling and testing requirements

11. This Notice of Exemption only applies to recovered glass sand sampled according to the requirements in Table 3.

Table 3

Column 1	Column 2	Column 3
Characterisation frequency	Routine sampling frequency	Once-off sampling frequency
20 composite samples, by taking 1 composite sample from a different batch, truckload or stockpile. This must be repeated every 2 years.	5 composite samples per 4000 tonnes or 5 composite samples per 3 months.	10 composite samples per 4000 tonnes.

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Test methods

12. All testing must be undertaken by analytical laboratories accredited by the National Association of Testing Authorities, or equivalent. All chemicals and other attributes listed in Column 1 of Table 2 must be measured in accordance with the test methods specified below:

12.1. Test methods for measuring the mercury concentration in recovered glass sand:

- 12.1.1. Particle size reduction & sample splitting may be required.
- 12.1.2. Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold vapour technique), or an equivalent analytical method with a detection limit < 20% of the stated absolute maximum concentration in Table 2, Column 3 (i.e. 0.2 mg/kg dry weight).
- 12.1.3. Report as mg/kg dry weight.

12.2. Test methods for measuring chemicals 2 - 9 in recovered glass sand:

- 12.2.1. Particle size reduction & sample splitting may be required.
- 12.2.2. Sample preparation by digesting using USEPA SW-846 Method 3051A Microwave assisted acid digestion of sediments, sludges, soils, and oils.
- 12.2.3. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of the stated absolute maximum concentration in Table 2, Column 3, (i.e. 5 mg/kg dry weight for lead).
- 12.2.4. Report as mg/kg dry weight.

12.3. Test methods for measuring the total organic carbon content in recovered glass sand:

- 12.3.1. Method 105 (Organic Carbon) and using a 2 gram sample. *In* Schedule B (3): Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure 1999 (or an equivalent analytical method).
- 12.3.2. Reporting as % total organic carbon.

12.4. Test methods for measuring the electrical conductivity in recovered glass sand:

- 12.4.1. Sample preparation by mixing 1 part recovered glass sand with 5 parts distilled water.
- 12.4.2. Analysis using Method 104 (Electrical Conductivity). *In* Schedule B (3): Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure 1999 (or an equivalent analytical method).
- 12.4.3. Report in deciSiemens per metre (dS/m).

12.5. Test method for measuring 12 – 14 in recovered glass sand:

- 12.5.1. NSW Roads & Traffic Authority Test Method T276 Foreign Materials Content of Recycled Crushed Concrete (or an equivalent method) and modified to use a 2.36mm sieve, for the materials listed in 12 - 15 of Column 1, Table 2.
- 12.5.2. Report as %.

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