Specifications for Recycled Crushed Glass as an Engineering Material

for The Packaging Stewardship Forum of the Australian Food and Grocery Council

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SUMMARY

The Packaging Stewardship Forum (PSF) of the Australian Food and Grocery Council commissioned ARRB Group to develop specifications for the manufacture and supply of recycled crushed glass (RCG) in various infrastructure applications for products with a maximum nominal size of 5 mm which is the common size commercially manufactured in Australia.

A review of international specifications for recycled crushed glass was undertaken together with a summary of typical blend volumes applicable to particular applications.

As a result specifications have been developed for the Australian market by reviewing current particle size distribution of Australian manufactured recycled crushed glass and other attributes associated with intended use.

Environmental contaminant testing has also been included in the Specification. The requirements will vary State by State, but the specification is based upon the most recent publication of the New South Wales Department of Environment Climate Change and Water (DECCW NSW) in relation to type and frequency of testing.

These specifications have been developed for use by local and state authorities and others responsible for the procurement of materials and the construction of paving and roads.

They provide a common standard for use in Australia based on international best practice and local conditions.

The project has been peer reviewed by the geotechnical division of engineering consultants GHD to verify the accuracy of the data and the references within the report.

Background to the Packaging Stewardship Forum (PSF)

The PSF facilitates an industry product stewardship program on behalf of its members, Australia's major beverage manufacturers and their packaging suppliers: Amcor, Bundaberg Brewed Drinks; Coca-Cola Amatil; Fosters; Golden Circle; Lion Nathan; Owens-Illinois; Schweppes and Visy. The PSF allocates industry funding to support the development of applications which use recycled glass and has funded the development of specifications to encourage standardised use.

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

The use of recycled crushed glass (RCG) as an engineering material in Australian infrastructure is an emerging commercial development. However, only about 39% of glass containers (bottles and jars) are currently recycled in Australia with a national goal to increase this to 55% by 2010 (2009 National Packaging Covenant Annual Report).

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 manufacture of fine aggregate products with significant research and commercial implementation 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 (it does not wear out and can be recycled over and over again without any reduction in quality), it has no place in landfill at all (KESAB 2008).
- In most cases recycled glass substitutes a virgin quarried material. There are benefits associated with avoiding the environmental impacts of quarrying and processing the raw material (British Glass Manufacturers' Confederation).

In addition, GHD (2008) provided a business case study to the PSF on opportunities for inclusion of RCG in infrastructure, detailing a strategy for its implementation.

The PSF contracted ARRB Group to develop specifications for the manufacture and supply of recycled crushed glass (RCG) for use in various infrastructure applications. This project is confined to products a maximum nominal size of 5 mm representing the common size commercially manufactured in Australia for the engineering materials market.

2 PROJECT SCOPE

The scope of this project has been defined against the following activities:

a) national and international literature search and review of existing specifications and product applications

b) correspondence with the Australian manufacturers of RCG products

c) consideration of current specifications associated with traditional sourced materials

d) correspondence with appropriate stakeholders such as the crushed rock and construction and demolition (C&D) recycling counterparts, asphalt and concrete manufacturers

e) sampling and testing of current commercial crushed recycled glass

f) consideration of environmental legislation

g) recommended draft specification for manufacture of recycled crushed glass to be associated with targeted applications.

3 TARGET APPLICATIONS

Internationally, RCG has recognised infrastructure applications in:

1. basecourse and subbase layers on sealed roads
2. unsealed road wearing courses
3. fine aggregate for concrete and asphalt production
4. fine aggregate for bituminous slurry emulsions
5. bedding and backfilling material for underground pipes/cables and services
6. bedding material for block paved pavements and footpaths.

Each of these applications has a product specification counterpart based upon traditional material sources (i.e. sand or fine aggregate) and the inclusion of RCG should be such that these overall requirements are not changed. The specifications developed in this project identify the 100% RCG as an alternative aggregate material for use in its own right (see Section 5) or suitable for blending with a parent natural aggregate to meet the required final product specification (see Section 6).

4 CURRENT MANUFACTURE OF RCG IN AUSTRALIA

Five of the six Australian manufacturers of RCG were requested to provide samples of current production RCG aggregate. Samples received were subsequently tested for particle size distribution in the laboratory to identify potential uses and to assist in specification development.

Manufacturers involved were:

- Glass Granulates Pty Ltd – Quarry materials in addition to recycled materials
- Recycled Glass Solutions – Other products and not currently in the aggregate market
- Alex Fraser Recycling Industries – Recycled construction and demolition products
- Colmax Glass – Other products and not currently in the aggregate market
- Hazell Bros – Recycled construction and demolition products

Recognition of the Fulton Hogan plant in West Australia was received during the course of the project. However, a sample from the plant could not be provided within the project timeframe.

All manufacturers use the same basic manufacturing processes for RCG as shown in Figure 1:

- Sorting: to select suitable glass sources for fine glass cullet (e.g. crushed food and drink glass containers, drinking glasses and window glass) and eliminate undesirable glass sources (e.g. glass from hazardous waste containers, reinforced and laminated glass, light bulbs, fluorescent tubes and cathode ray tubes) from the collected wastes.
- Cleaning: required to reduce odours or eliminate sugars.
- Crushing and screening: to produce RCG of different nominal sizes and desired gradation for various applications other than those considered in this report.
- Mixing and blending: to produce a desired final product incorporating a parent material such as a natural material.

Source: C. Leek, City of Canning WA

Figure 1: Recycled crushed glass - source material and final RCG product

Table 1 shows typical properties of manufactured RCG used as pipe embedment and fine aggregate in asphalt and concrete (no details of manufacturing tolerances or specific mix design proportions are cited) provided by Glass Granulates Pty Ltd (GG P/L) (www.benedict.com.au) and Hazell Bros (www.hazellbros.com.au). In practice, commercial fine glass cullet would have significant grading variations, depending on the quality of material sources sorted and manufacturing processes selected.

Table 1: Typical properties of commercial manufactured RCG

Test method	Test	Hazell	GG P/L
AS 1141.11 Particle Size Analysis	% by mass passing AS sieve		
	4.750 mm	100	100
	2.360 mm	85	77.1
	1.180 mm	49	44.4
	0.600 mm	31	26.5
	0.425 mm	25	20.0
	0.300 mm	20	14.6
	0.150 mm	12	8.2
	0.075 mm	8	4.6
RTA 262 Moisture Content		3	1.8
AS 1141.5 Particle Density (e.g. for concrete aggregates)	Apparent		2.46 t/m³
	Dry		2.43 t/m³
	SSD	2..44 t/m³	2.44 t/m³
	Water absorption		0.4%
AS 1289 5.1.1 Compaction (e.g. for pipe bedding materials)	Max dry density Minimum dry density (loose)	1.77 t/m³ 1.37 t/m³	1.77 t/m³ 1.37 t/m³
RTA276 Foreign materials	Type 1 (metals and rock) Type 2 (wood, clay, friables) Type 3 (rubber, plastic, paper , etc)		0 0 0.2
International Slurry Surfacing Assoc No.145	Methylene blue absorption		1.0 mg/g

5 GENERIC SPECIFICATIONS FOR NATURAL AND CRUSHED FINE AGGREGATE

Natural occurring and crushed fine aggregate with a maximum nominal size of 5 mm have been used as traditional material sources for many target applications for RCG as identified in Section 3. Although recycled glass aggregate is a relatively new construction aggregate material, it is known to be durable, strong, and easy to place and compact. Subsequently, 100% glass aggregate has been accepted as alternative fine aggregate in many application products. Some typical application product specifications are given below.

5.1.1 Specifications for fine aggregates in concrete and asphalt

There are many specifications for naturally sourced fine aggregates for use in concrete and asphalt which usually include a source quality statement such as:

Fine aggregate used in concrete and asphalt must be clean, hard, strong, durable, uncoated grains resulting from the natural or artificial disintegration of rock or other inert materials with similar characteristics, or a combination thereof.

In addition, particle size distributions for natural or crushed sources are provided as illustrated in Table 2.

Table 2: Grading specifications for natural and crushed fine aggregate

	Natural sand	Crushed fine aggregate
Particle size distribution	Percent finer	Percent finer
4.75 mm	95 - 100	95 - 100
2.36 mm	60 - 100	76 - 98
1.18 mm	40 - 80	56 - 85
0.600 mm	20 - 60	38 - 65
0.300 mm	10 - 40	15 - 35
0.150 mm	0 - 15	2 - 10
0.075 mm	0 - 6	0 - 2

Source: DTEI (SA) (2009) Master Road Specification Part 215

RCG fine aggregate can be used in concrete and asphalt. Once reduced to the desired size, the glass fine aggregate can be blended with the natural aggregate to obtain a uniform glass/natural aggregate mix as given in Table 2 prior to mixing with the other components in concrete and asphalt.

It should be noted that acceptable gradations for the RCG/natural aggregate mix within the asphalt will be determined by the proportion of RCG aggregate in the mix. The proportion of the components can follow the Marshall Mix Design Method for conventional asphalt, as specified by the Asphalt Institute. However, mixes containing 20% or less by mass of glass are recommended in order to meet the other engineering properties associated with stability, flow, percent air voids, and percent voids in mineral aggregate.

Experience suggests that stripping may not be a problem when using 5mm glass aggregate; however, in association with the asphalt mix design it is recommended that the Austroads test method: AG:PT/T232 – *Stripping potential of asphalt – Tensile strength ratio* be incorporated into the design.

An adverse result of using glass cullet in Portland cement concrete (PCC) is the alkali-silica reaction (ASR). In addition, when mixed in PCC, sugar contamination in the glass cullet can cause an unpredictable increase in setting time and a decrease in the ultimate strength. A test for sugar has been included in the draft specification in Table 9.

More details of desirable characteristics of natural and crushed aggregates used in road construction, particularly for concrete and asphalt can be found in the Austroads *Guide to Pavement Technology Part 4J: Aggregate and Source Rock* (Austroads 2008a), *Part 4B - Asphalt* (Austroads 2009a) and *Part 4C - Materials for Concrete Road Pavements* (Austroads 2009b).

5.1.2 Specifications of laying-course materials for concrete block paving

Laying-course materials have been used in concrete block paving world-wide. The laying-course material should be naturally occurring sand or crushed sand which may be washed or unwashed. This granular material should be such that 90% passes the 5 mm AS sieve. It should contain no more than 3% by mass of clay and silt and the materials should be free from deleterious salts or contaminants. The grading of economically available material may vary from locality to locality, but the following bedding-sand grading recommended by Shackel (1980) has been found to give satisfactory results.

Table 3: Bedding sand specification for concrete block paving

Particle size distribution	Percent finer
4.75 mm	95 - 100
2.36 mm	80 - 100
1.18 mm	50 - 95
0.600 mm	25 - 60
0.300 mm	10 - 30
0.150 mm	5 - 15
0.075 mm	0 - 10

Source: Shackel (1980)

5.1.3 Specifications of sands for bedding and backfill

Specifications for sands and fine aggregates used for bedding and backfill will depend on the type of infrastructure installed. For example, a cable bedding material must be clean sand free of rocks, clay lumps, tree roots, building rubble, metal, sharp objects, organic solvents or other deleterious material that is likely to damage cables and must comply with the particle size distribution requirements shown in Table 4. For maintenance purposes (e.g. ease in removing and upgrading the cables) a minimum sand equivalent value should be specified. Cleaner aggregates will have higher sand equivalent values.

Table 4: Particle size distribution requirements for cable bedding and backfill

Particle Size Distribution	Pipe bedding and backfill[1]	Cable bedding and backfill[2]
	Percent finer	Percent finer
9.5 mm	100	-
4.75 mm		100
2.36 mm	25 - 100	95-100
0.425 mm	0 - 60	
0.075 mm	0 -10	0-5

[1] – Source: Western Power (2001)
[2] – Source: Northmidlands (2003)

The differences in grading requirements for the above applications are illustrated in Figure 2. Fine glass cullet, once reduced to the desired grading size, can be used as an alternative fine aggregate in the above applications. It should be noted that for each application, and in addition to the requirements regarding the cullet content, cullet gradation and debris level, a level of

compaction must be specified. The compaction specification should be generated based on criteria that are related to the engineering behaviour of the in-place material.

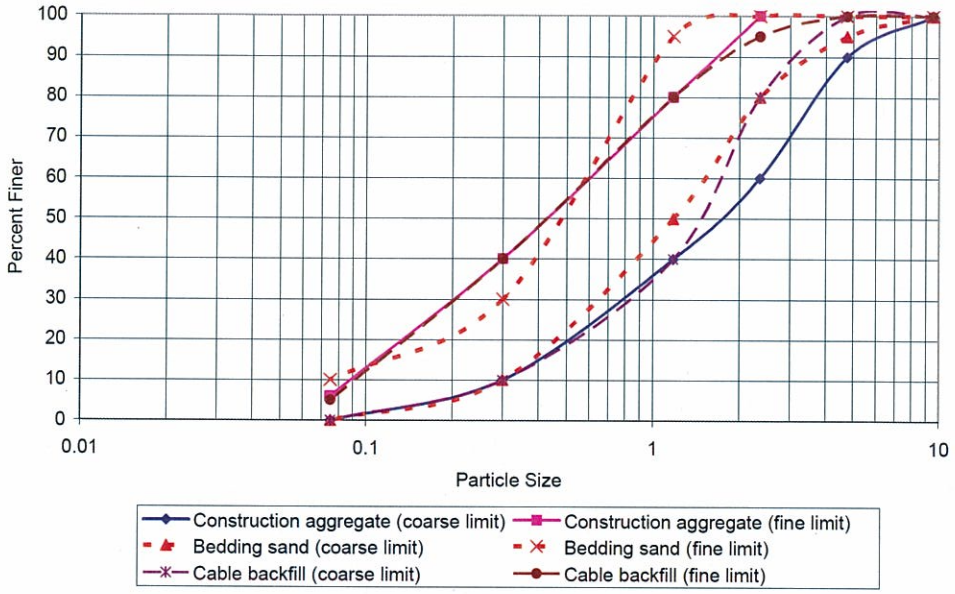


Figure 2: Specifications for natural and crushed fine aggregate in various applications

6 SPECIFICATIONS FOR RECYCLED CRUSHED GLASS ADDITIVE IN UNBOUND AGGREGATE – SURVEY

There are several specifications for RCG additive in unbound aggregate adopted by road authorities all over the world. Some typical application product specifications are presented below.

6.1 Specifications of RCG additive in basecourse material by New Zealand Transport Agency (formerly Transit New Zealand)

The general specification for basecourse pavement materials TNZ M/4 contains a section pertaining to RCG as a sand-sized material with up to 65% of particle sizes coarser than 2.36 mm and up to 30% of particle sizes coarser than 4.75 mm (NZTA 2006). The specification permits up to 5% addition of glass to be blended into granular pavement materials but makes no reference to the use of the RCG as aggregate in concrete or asphalt.

This specification is reproduced in Figure 3.

TNZ M/4: 2

AGGREGATE / RECLAIMED GLASS BLENDED BASECOURSE

DEFINITION

Overseas experience suggests that appropriately processed reclaimed glass is well suited for use as a basecourse aggregate. Adding glass to aggregate, in suitable proportions, provides a number of environmental benefits without compromising the mechanical properties of the aggregate.

This extension of the M/4 specification allows up to 5% reclaimed glass (by mass) to be blended with natural or recycled aggregate for road base construction. The aggregate / reclaimed glass (cullet) blend must comply with the requirements of the M/4 specification except for the variations and additions provided in this table.

Up to 5% reclaimed glass can also be added to subbase aggregate in accordance with the relevant requirements of the M/4 specification.

Proportions of cullet in excess of 5% may be used at the discretion of the Transit New Zealand Engineering Policy Manager, provided that the requirements of the M/22 specification have been satisfied. Such applications are likely to be restricted to relatively low traffic volume projects and the material may be subject to higher standards with respect to contamination limits.

CULLET PROPERTIES

Reclaimed Glass Source	The cullet can originate from a number of glass products, viz: waste food and beverage containers, drinking glasses, window glass, or plain ceramic or china dinnerware. Reclaimed glass from hazardous waste containers, light bulbs, vehicle windscreens, fluorescent tubes or cathode ray tubes shall not be used.
Grading	The cullet shall be crushed to achieve the following gradation: (NZS 4407:1991 Test 3.8.1)

Sieve	Percent Passing
9.5 mm	100
4.75 mm	70 – 100
2.36 mm	35 – 88
1.18 mm	15 – 45
0.30 mm	4 – 12
0.075 mm	0 - 5

The plus 4.75 mm component of the cullet must not contain more than 1% of flat or elongated particles, i.e. particles with a maximum to minimum dimension ratio greater than 5:1. The ASTM D 4791 test is appropriate (except that the test sample shall be taken as the material retained on the 4.75 mm sieve).

Contamination Limit	Debris, such as paper, foil, plastic, metal, cork, food residue, organic matter, etc can have a significant influence on the performance of the aggregate / glass material. The cullet shall not contain more than 5% debris, as determined using the procedure described in RTA Test Method T267 (where "reclaimed glass" is substituted for "recycled concrete").
Cleanliness	The cullet shall be washed to ensure that undesirable odours are eliminated.

PRODUCTION

Concentrations of reclaimed glass within the aggregate could have a detrimental influence on the performance of the material in a basecourse layer. Therefore, the aggregate and reclaimed glass shall be mixed thoroughly to ensure that there is an even distribution of glass throughout the basecourse stockpile.

CULLET QUALITY ASSURANCE TEST FREQUENCY

Tests for compliance with grading, particle shape and contamination shall be carried out at a frequency of two tests (each) per cullet stockpile.

ADDITIONAL PRODUCTION TESTING	As per TNZ M4	
TRAFFIC LOADING LIMIT		

Figure 3: Transit New Zealand TNZ M/4 specification

6.2 Specifications of RCG additive in unbound aggregate in United States

The United States has the greatest number of specifications allowing the use of glass in unbound aggregate and a summary of various State practices prepared by the Clean Washington Center (www.cwc.org) is reproduced below:

6.2.1 The Washington State Department of Transportation (WSDOT)

The WSDOT permits the use of recycled glass as an additive at up to 15% for unbound aggregate used for 17 specific applications, including a number of fill and ballast uses. No more than 10% of the glass should be retained on a 6.4 mm sieve.

WSDOT also provides specifications for construction aggregates composed entirely of cullet. These aggregates may be used for wall backfill, rigid and flexible pipe bedding, drainage backfill, drainage blanket, and gravel borrow. The cullet must be smaller than 19 mm (¾ inch) and should contain no more than 5% by mass of material finer than a 0.075 mm sieve. The maximum debris content, including all non-glass constituents, is 10% as identified by visual methods.

6.2.2 The Oregon Department of Transportation (ODT)

The ODT has issued special provisions with bid specifications allowing the use of up to 100% recycled glass in a number of applications: drainage blanket, utility bedding and backfill, and subsurface drains. One hundred percent of the glass must pass a 12.7 mm sieve, with a maximum of 5% by mass finer than No. 200 sieve (0.075 mm). Maximum debris content is 5% or 10% as specified per application, determined by visual classification.

6.2.3 The California Department of Transportation (CalTrans)

CalTrans has accepted cullet for Classes 1, 2, 3 and 4 bases and Classes 2 and 3 subbase road aggregate for the support of flexible and rigid pavements. These aggregates can consist entirely of cullet, or a mixture of cullet and other reclaimed materials, such as asphalt concrete, cement concrete, lean concrete base and cement treated base. The different classes of base and subbase aggregate are distinguished by gradations. The size of the cullet must follow the size criteria specified for those aggregate applications by CalTrans. Material used in these base and subbase aggregates must be free of organic material and other deleterious substances. Surfacing material must be placed over all aggregate bases and subbases containing glass cullet.

6.2.4 The State of Connecticut

The State of Connecticut specifies that aggregate used for roadway embankments may contain up to 25% by mass of cullet smaller than 25 mm (1 inch). Aggregate containing cullet cannot be placed within 1.5 m (5 feet) from the face of any slope.

6.2.5 The New York State Department of Transportation

This Department allows aggregate for embankments to contain up to 30% by volume of glass cullet. In addition, roadway subbase material may contain up to 30% by mass of glass cullet. Cullet used for these applications must be smaller than 9.5 mm (⅜ inch), and should contain no more than 5% by volume of ceramics and non-glass materials, based on visual inspection. Waste glass cannot be placed in contact with any synthetic liners, geogrids or geotextile material.

6.2.6 *The New Hampshire Department of Transportation (NHDOT)*

NHDOT allows glass cullet to replace 5% by mass of the dry aggregate used for roadway basecourse material. The material used to produce this cullet should consist primarily of recycled food and beverage glass containers. Small amounts of ceramics and plate glass are also permitted, although glass containing hazardous or toxic materials is not allowed. The cullet must be smaller than 12.7 mm (½ inch) in size, and not more than 1.5% of the material smaller than a 4.75 mm sieve should be smaller than a 0.075 mm sieve. NHDOT requires that all basecourse be tested for compliance with this gradation prior to placement. Post-placement visual inspection of the basecourse is also required. Basecourse containing cullet must be capped with non-cullet aggregate before the public is allowed to drive over the material.

6.2.7 *AASHTO*

In December 2000, the American Association of State Highway and Transportation Officials (AASHTO) adopted a new national specification, M 318-01 *Glass cullet use for soil aggregate base course* (AASHTO 2000) for recycling glass in soil aggregate basecourses. Up to 20% glass cullet is routinely allowed to be mixed with aggregate basecourse. However, the glass cullet is required to be at least 95% container/beverage glass to limit the use of other glass-like ceramics. There is a requirement to check that the resilient modulus from repeated load triaxial (RLT) testing and California Bearing Ratio (CBR) is not affected/reduced due to the addition of glass. The engineer may also allow higher percentages of glass cullet provided the CBR and resilient modulus does not reduce. For safety requirements AASHTO requires 99% of the glass cullet to pass the 4.75 mm sieve.

6.2.8 *Massachusetts DOT*

The Massachusetts DOT (2001) specification (Figure 4) is associated with a general pavement material specification M2. The specification for RCG is shown below where it will be noted that the particle size distribution is identical to the TNZ specification.

M2.01.8 Processed Glass Aggregate (PGA)

Processed Glass Aggregate (PGA) shall be manufactured from an approved supplier of crushed cullet. The material shall consist of recycled glass food and beverage containers, free of debris such as paper, metals, fabrics, toxins, clay loam or other materials that would be associated with the glass recycling process. A maximum of 5% mass of the material may be produced from china dishes, ceramics, plate glass or other glass products. The material will have a nominal aggregate size of 10 millimetres and meet the following gradation requirements:

Sieve Designation	Percent by Mass Passing Square Mesh Sieve
9.5mm	100
4.75mm	70 – 100
2.36mm	35 – 88
1.18mm	15 – 40
0.300mm	4 – 12
0.075mm	0 - 5

The percentage wear as determined by the Los Angeles Abrasion test Class C or D will be a maximum of 40%

Figure 4: Massachusetts DOT specification

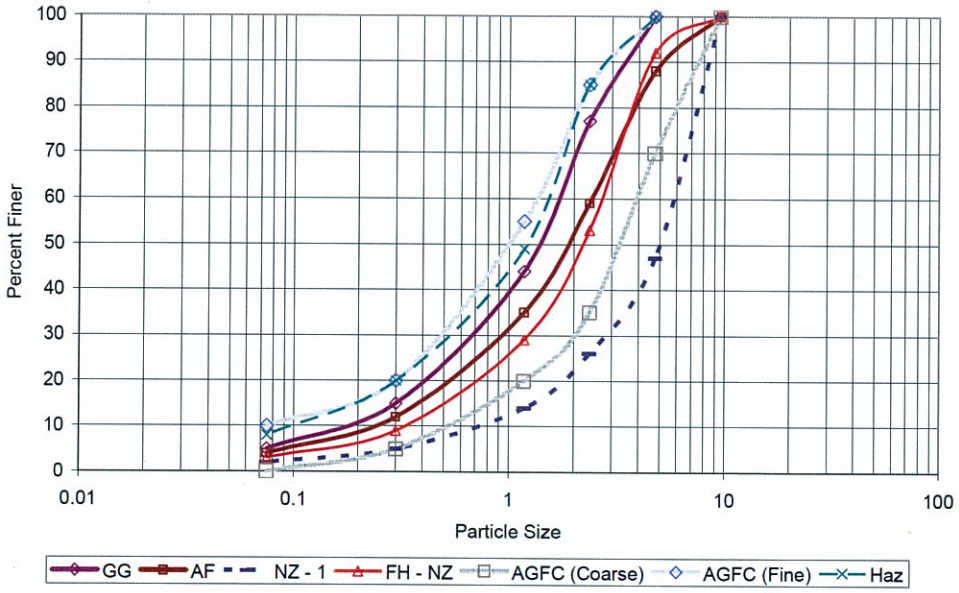
The use of this specification is for blending with natural aggregates but allowing a maximum of 10% glass cullet for all applications.

7 DEVELOPMENT OF NATIONAL SPECIFICATIONS FOR RECYCLED CRUSHED GLASS ADDITIVE IN UNBOUND AGGREGATE

This section identifies grading requirements for fine glass cullet that can be blended with the natural aggregate to obtain a uniform glass/natural aggregate mix for use in specific applications. It also shows a blending calculation method to determine the proportion of glass aggregate in a mix design, in terms of grading requirements.

7.1 Target grading of RCG manufactured products

The target grading for RCG manufactured products can be realistically set based on the available commercial fine glass cutlets produced by various producers in Australia and New Zealand as given in Figure 5.



GG	Glass Granulates (website)
AF	Alex Fraser (Melbourne) submitted sample
NZ – 1	Arnold et al. (2008) correspondence (not representative of current commercial production)
FH – NZ	Fulton Hogan (NZ) provided by Mike Williams (Glass Granulates P/L)
Haz	Hazell Bros – Peter Bennett
AFGC Coarse & Fine	Recommended fine and coarse limits to Australian Food & Grocery Council

Figure 5: Particle size distribution of various Australian and New Zealand suppliers

Requests for production samples to be tested to determine particle size distribution were sent to the five Australian manufacturers from which only one sample from Alex Fraser P/L was received.

In addition, Glass Granulates P/L has a typical testing result on its website; similarly, a fact sheet provided by Hazell Bros P/L and a typical current production of RCG from Fulton Hogan (NZ) was received.

Arnold et al (2008) report on the performance of New Zealand basecourse aggregate with the inclusion of RCG. In this case the RCG grading was found to be on the coarser side of the envelope, when compared with other suppliers and it was concluded that it does not represent current manufacture practices, which are better represented by sample FH-NZ) in Figure 5.

It should be noted that RCG with a maximum nominal size of 10 mm has been permitted for blending with natural aggregates in NZ and USA. However, for safety reasons as identified by AASHTO (2001) and various road authorities, the RCG products investigated under this project are limited to those products with a maximum nominal size of 5 mm. Whilst AASHTO requires 99% of the glass cullet to pass the 4.75 mm sieve, this limit can be relaxed to 85% limit to allow all available commercial RCG products in Australia to be utilised.

7.2 Blending Calculations

The mix design, in terms of grading, when blending two or more source materials, can be determined using simple proportion calculations of the constituent materials passing the respective sieves viz:

$$(A\% \times A_{pass})/100 + (B\% \times B_{pass})/100$$

where $A\%$ = percentage of material A being added

A_{pass} = percentage of material A passing allocated sieve

$B\%$ = percentage of material B being added

B_{pass} = percentage of material B passing allocated sieve.

A worked example is shown below, in which 30% RCG manufactured by Alex Fraser – Melbourne is blended with 70% of a typical Class 2 crushed rock (with a grading similar to the coarse limit of the CR specification). Figure 6 shows the particle size distribution of the parent materials and Figure 7 the calculated particle distribution of the 70:30 blended materials. Referring to Figure 6, the grading of the RCG/coarse CR blend is within the Class 2 CR grading limits.

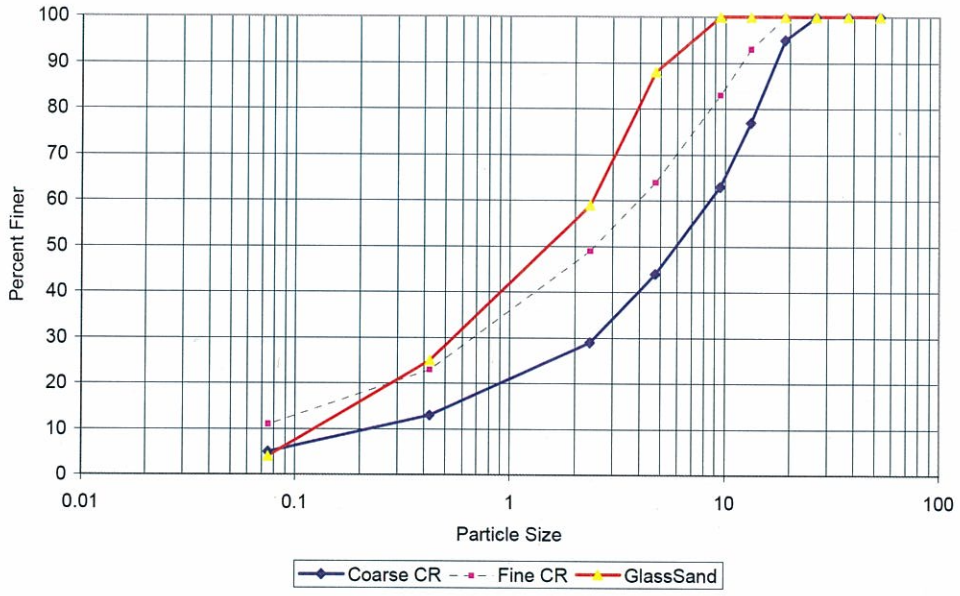


Figure 6: Particle size distributions for the parent coarse crushed rock and RCG

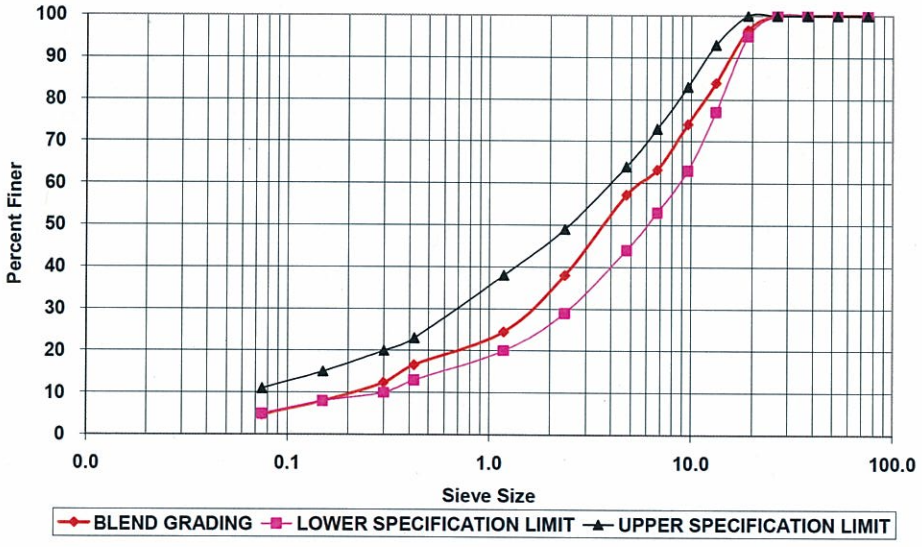


Figure 7: Grading of 'crushed rock 70% + RCG 30%' blend and basecourse specification limits

This example analysis has been undertaken using a simple spreadsheet that can be made available on request. The spreadsheet can be used to calculate the PSD that can be expected when various proportions of RCG and parent material are blended viz:

(a) The parent material is a natural crushed material where the RCG blend is to be used as a pavement material (sealed or unsealed road) as in the above example.

(b) The parent material is a natural or crushed sand which when blended with RCG is to be used as fine aggregate in concrete, asphalt and slurry surfacings.

7.3 Maximum Percentage RCG Additives in Unbound Aggregate for Sealed and Unsealed Roads

The specification of unbound aggregate in basecourse and wearing course for sealed and unsealed roads is provided in Austroads *Guide to Pavement Technology Part 4A – Granular Base and Sub Base Materials* (2008b) and *Part 6: Unsealed Pavements* (2009c). Table 6 also shows the target particle size distribution to be considered when blending RCG with a parent pit material for unsealed roads.

Currently, RCG has not been broadly accepted as an aggregate in Australia. The RTA and VicRoads allow up to 5% RCG, as a foreign material, to be added to recycled building materials, e.g. VicRoads specification for recycled crushed concrete (VicRoads 2007). However, VicRoads specifications for unbound aggregates (VicRoads 2006) provides for the submission of other aggregate mixes as long as they meet all requirements for natural aggregate as specified by VicRoads for the application concerned. A glass/natural aggregate mix for a specific application requires further laboratory studies and field trials to demonstrate other requirements associated with workability, stability and other engineering behaviour of the in-place material. Alex Fraser (Vic) has reported that an asphalt mix containing up to 20% RCG has been given conditional approval by VicRoads. Vuong et al (2010c) have also reported that up to 30% RCG has been used in crushed rock base and subbase beneath municipal footpaths and shared paths.

The City of Canning WA (2009) mandates a minimum of 5% RCG in asphalt with the opportunity for higher inclusions based upon further testing viz:

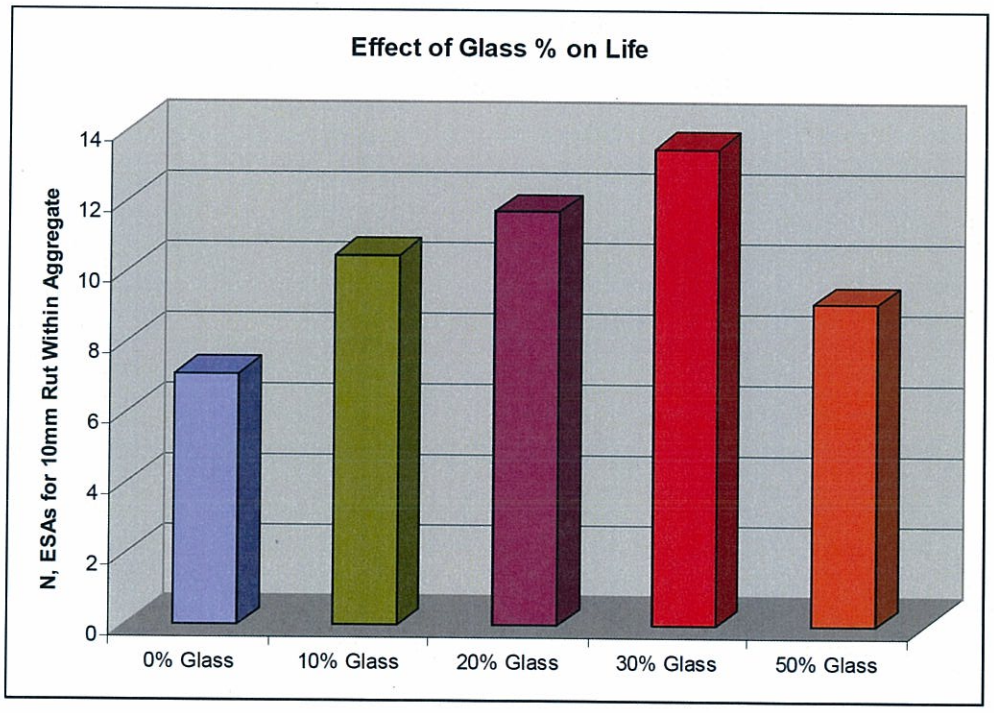
> "**2.1.4 Use of Recycled Materials**
>
> A minimum of 10% by mass of RAP shall be included in all dense grade mix used within the City, and increased proportions may be requested in certain cases.
>
> A minimum of 5% by mass of recycled crushed glass of maximum size of 5 mm shall be included in all dense grade mixes used within the City, but increased proportions of up to 15% will be trialled during the tender period, and the Contractor shall ensure a supply of crushed glass to meet this requirement.
>
> All glass used for the purpose of this tender shall be clean, with a maximum of 2% by mass of foreign matter allowed in the crushed glass supply.
>
> The Contractor will agree to conduct trials of recycled glass in Stone Mastic Asphalt."

This report specifically draws attention to the Institute of Public Works Engineering Australia (IPWEA) specification for recycled materials and the recommendations therein for blends of specific constituent sources as shown in Table 5 (IPWEA 2010). The US (Washington State DOT) permitted blend proportions of RCG in relation to individual product specifications pertaining to application are also included in Table 5 for comparison with the IPWEA specifications.

Table 5: Blend proportions of RCG

Application	Percent RCG Permitted	
	US	IPWEA NSW
Aggregate for concrete and asphalt	0%	Not addressed
Ballast, granular pavement layers,	15%	10%
Backfill for foundations, walls, pipe bedding	15%	50%
Backfill for drainage, filters, trenches	100%	100%

It should be noted that the blending does not necessarily include other requirements associated with workability/constructability, stability and other engineering behaviour of the in-place material. Various laboratory studies on performance of RCG additive in unbound aggregates for sealed roads (Arnold et al 2008) using the repeated load testing apparatus indicated that adding RCG of up to 30% by mass to parent base and subbase crushed rocks had the potential to double the Traffic loading (ESA's) to achieve a 10 mm rut depth (Figure 8).



Source Arnold et al 2008

Figure 8: Effect of RCG inclusion with crushed rock aggregate

SUT (2010) also reported that adding a high percentage of RCG (> 30% by mass) to a parent base crushed rock would produce a blending gradation closer to or exceeding the VicRoads upper (fine) limit for subbase and hence, a lower maximum dry density and lower soaked CBR values.

Recent laboratory and field trials of 5 mm nominal size RCG additive in basecourse materials in sealed roads (Vuong et al 2010a, Vuong et al 2010b) indicated that adding the RCG in quantities

of up to 20% by mass in a parent unbound aggregate would have little impacts on workability and other engineering behaviour of the in-place material, provided that the grading of the glass/natural aggregate mix meets the specification grading.

Therefore, the maximum recommended blend for RCG in unbound aggregates, for sealed and unsealed roads, is 15% for heavy-duty granular base, and 30% for pavement subbase and light duty base of the total product. It should be noted that for each application and in addition to the requirements regarding the blending gradation, a dry density ratio pertinent to the maximum dry density of the material containing RCG must be specified. The compaction specification should be generated based on criteria that are related to the engineering behaviour of the in-place material.

Table 6: Grading specifications for unbound aggregate in unsealed roads

Sieve size (mm)	Per cent passing for all maximum sizes
55	100
37.5	95-100
26.5	90-100
19	80-100
2.36	35-65
0.425	15-50
0.075	10-40
Plasticity	Less than 500 mm annual rainfall – max. 20 More than 500 mm annual rainfall – max. 12 OR Massed Plasticity Index (PI x % passing 0.425 mm) Max. 500 for low rainfall Max. 250 for > high rainfall
4 day soaked CBR	Minimum 40%

8 ENVIRONMENT AND LEGISLATURE

General legislation throughout Australia identifies recycled materials as waste for which exemptions or approvals are sought through a licence in order to manufacture and distribute them into the market.

In terms of contaminants, limits are placed on heavy metals, poisons and foreign materials by the NSW Department of Environment Climate Change and Water (DECCW NSW) and for which a testing frequency regime is required.

It is beyond the scope of this report to detail the various legislations in Australia and for the purpose of developing a generic specification for RCG, exemptions or approvals will be required to be sought by individual manufacturers to meet the respective requirements within the particular state or territory.

A survey of construction and demolition recyclers was undertaken to identify the environmental legislation under which they operate. Table 7 indicates the response received..

Table 7: State legislation regarding recycling

STATE	LEGISLATION REFERENCE
NSW	'Resource Recovery Exemptions' under clause 51 and 51A of the Protection of the Environment Operations (Waste) Regulation 2005
SA	Standard for the Production and Use of Waste Derived Fill – ISBN 978-1-921495-07-6 January 2010
WA	Waste Avoidance and Resource Recovery Act 2007 Section 5

The exemption for recovered glass sand in New South Wales legislation is provided in Appendix A.

9 RECOMMENDED SPECIFICATIONS FOR RCG

The following specifications detail the intrinsic and state legislative requirements for recycling predominantly beverage glass by washing, crushing and screening (where necessary) to produce sand-sized graded material. They include RCG with a maximum nominal size of 5 mm for blending with other materials to produce other products and the use of the RCG in its own right as a fine aggregate.

9.1 RCG Specification 1: for blending with natural unbound aggregate in various infrastructure applications

This specification for recycled crushed glass is applicable for blending with natural occurring sands and crushed fine aggregates prior to mixing with other coarser components to form a RCG/natural aggregate mix for use as granular basecourse and subbase in sealed roads, wearing course in unsealed roads, bedding/backfill material for pipe/cable and block paving bedding sand.

9.1.1 Source Materials

The material shall consist of recycled glass food and beverage containers, drinking glasses, window (or flat) glass and plain ceramic. Glass from hazardous waste containers, reinforced and laminated glass, light bulbs, fluorescent tubes and cathode ray tubes shall not be included.

The source shall be free of debris such as paper and cardboard, plastic, fabrics and toxins.

The material shall be washed post crushing to remove odours, traces of original contents, soil, sugars and labels, etc.

9.1.2 Blending

RCG may be blended with natural gravels, crushed gravels and natural borrow sources. The percentage of RCG that may be incorporated into the final product can be determined from analytical computation of respective constituent particle size distributions. Final blends shall be manufactured, sampled and tested to determine compliance with the relevant target product specification viz:

- granular basecourse as defined in the relevant specifications
- granular subbase as defined in the relevant specifications

- unsealed wearing course recommendations in accordance with Austroads *Pavement Technology Series Part 6: Unsealed Pavements* (Austroads 2009c) or other local specification
- engineering fill as defined in the relevant specifications
- natural or crushed sands for use as pipe or block paving bedding as defined in the relevant specifications.

9.1.3 Production Quality Control Properties

The manufactured RCG shall comply with the quality requirements as given in Table 8.

Table 8: Requirements for 5 mm RCG in RCG/natural aggregate mixes for various infrastructure applications

PRODUCTION QUALITY CONTROL			
TEST	**STANDARD**	**REQUIREMENT**	
Particle size distribution	AS1141.11	Sieve size 9.5 mm 4.75 mm 2.36 mm 1.18 mm 0.3 mm 0.075 mm	Percent finer 100 85 – 100 50 – 85 20 – 55 5 – 20 0 - 10
NOTE: Material coarser than 4.75 mm shall not have more than 1% particles with a maximum to minimum dimension of 3:1			
Contaminants (RTA NSW T276)	Asbestos Metal Plaster and friable materials Rubber, plastic, bitumen, paper, cloth, paint, wood and other vegetable matter	0 0.1% by mass 2% by mass 0.2% by mass	
Sampling	Production sampling and specification compliance testing shall be carried out in accordance with the test procedures identified at a frequency of not less than one suite of tests per 1000 tonnes. Unless sampled within the plant during manufacture, RCG product shall be stacked in holding stockpiles not exceeding 1000 tonnes until such time as compliance has been determined.		
Product stockpiles	Conforming material may be stored in certified stockpiles identified as conforming to the requirements of this specification. Certified stockpiles must be formed on firm ground that is clean, well-drained and free of all foreign material which might contaminate the material to be certified. This includes but is not limited to all forms of vegetation both dead and alive, topsoil, and material containing oils or oil deposits and remnants of previous stockpiles of dissimilar material. Only compliant material may be added to a certified stockpile.		

9.2 RCG Specification 2: for use as fine aggregate in asphalt and concrete

This specification for recycled crushed glass is applicable for use as a fine aggregate in mix designs for asphalt and concrete when blended with natural occurring sands or crushed fine aggregates.

9.2.1 Source Materials

In addition to the requirements of source materials as given in Section 9.1.1, the final RCG may require further washing to remove fine particles (i.e. finer than 0.075 mm) and/or remove traces of sugar and other impurities.

9.2.2 Blending

RCG may be blended with natural occurring sands or crushed fine aggregates suitable for asphalt and concrete production. The percentage of RCG that may be incorporated into the final product can be determined from analytical computation of respective constituent particle size distributions. Final blends shall be manufactured, sampled and tested to determine compliance with the relevant target product specification viz:

- Natural sands or crushed fine aggregates as defined by local authority specifications for fine aggregate associated with asphalt and concrete mix designs.

The maximum blend of RCG shall be a maximum of 30% by mass of the total fine aggregate.

9.2.3 Production Quality Control Properties

The sampling of RCG from stockpiles/trucks, etc. or during manufacturing process shall be undertaken in accordance with AS1141 "Methods for Sampling and Testing Aggregates".

The manufactured RCG shall comply with the quality requirements as given in Table 9.

Table 9: Requirements for 5 mm RCG in RCG/natural aggregate mixes for asphalt and concrete production

PRODUCTION QUALITY CONTROL			
TEST	**STANDARD**	**REQUIREMENT**	
Particle size distribution	AS1141.11	Sieve size 9.5 mm 4.75 mm 2.36 mm 1.18 mm 0.3 mm 0.075 mm	Percent finer 100 85 – 100 50 – 90 20 – 45 8 – 25 0 – 2
Sugar in aggregate	AS1141.53 Sugar in Aggregate OR Department of Transport & Main Roads Queensland Q224A-2008 Sugar in Aggregate (Phenol-Sulphuric Acid) OR Q224B-2008 Sugar in Aggregate (Alpha-Naphthol)		No trace
Chloride content	AS 1012.20		0.06% m/m
Organic impurities (other than sugar)	AS1141.34		0.08% m/m
NOTE: Material coarser than 4.75 mm shall not have more than 1% particles with a maximum to minimum dimension of 3:1			
Contaminants (RTA NSW T276)	Asbestos Metal Plaster and friable materials Rubber, plastic, bitumen, paper, cloth, paint, wood	0 0.25% by mass 0.25% by mass 0.3% by mass	
Sampling	Production sampling and specification compliance testing shall be carried out in accordance with the test procedures identified at a frequency of not less than one suite of tests per 1000 tonnes. Unless sampled within the plant during manufacture, RCG product shall be stacked in holding stockpiles not exceeding 4000 tonnes until such time as compliance has been determined.		
Product stockpiles	Conforming material may be stored in certified stockpiles identified as conforming to the requirements of this specification. Certified stockpiles must be formed on firm ground that is clean, well-drained and free of all foreign material which might contaminate the material to be certified. This includes but is not limited to all forms of vegetation both dead and alive, topsoil, and material containing oils or oil deposits and remnants of previous stockpiles of dissimilar material. Only compliant material may be added to a certified stockpile.		

9.3 Environmental Compliance

Throughout Australia there is no common legislation or regulation for limits on chemicals and contaminants in recycled crushed glass. Therefore, this specification has been based on the most recent general exemption produced by Department of Environment Climate Change and Water NSW (2010).

Routine sampling of RCG for environmental compliance shall be undertaken in accordance with composite sampling i.e. a composite sample is defined as a sample comprising five discreet subsample increments at the following frequency:

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 4000 tonnes or FIVE composite samples per 3 months are required.

Contaminant testing limits to be undertaken shall be those listed in Table 10.

Table 10: Contaminant limits

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 Method105)	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: DECCW NSW (2010)

10 PARTICLE SIZE DISTRIBUTION COMPLIANCE OF CURRENT PRODUCTION

With the gradation tolerances for the AGFC specifications being set around current manufacture of RCG, Figure 9 shows the compliance of the respective products.

It is noted that the product information from Hazell Bros indicates that their general production is on the fine side of the proposed specification and when manufacturing tolerances are taken into account there will be a high likelihood that the production will lie outside the PSD limits suggested..

It is recommended that upon release, the specification be trialled over a three month production period to review compliance by the various manufacturers and to adjust the specification as required.

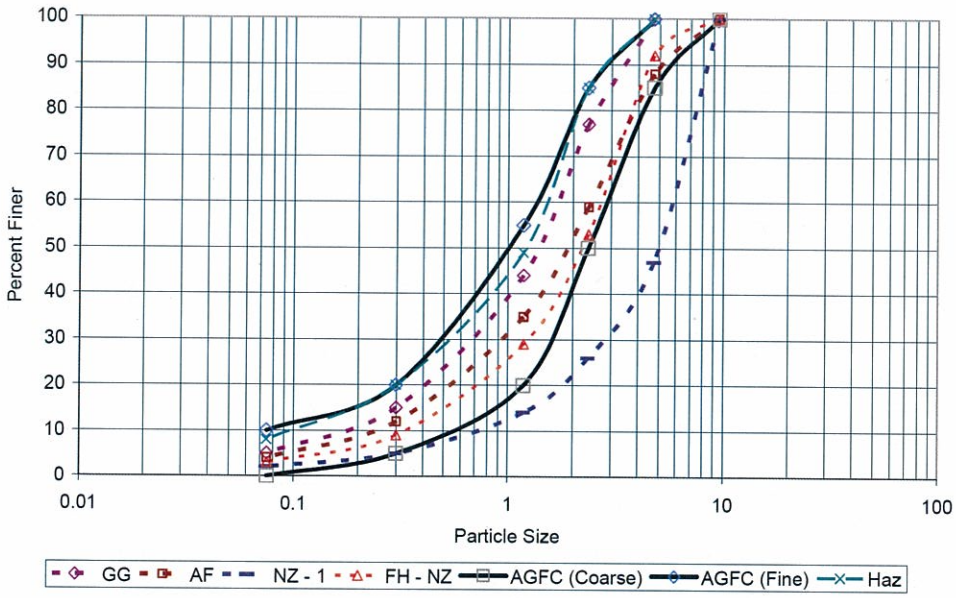


Figure 9: Compliance with particle size distribution of current RCG production

11 MATERIAL SAFETY DATA SHEETS (MSDS)

MSDS sheets for products are the responsibility of the manufacturer and may be copyright; however, typical MSDS for RCG are appended (Appendix B).

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APPENDIX A RECOVERED GLASS SAND EXEMPTION 2010 (NSW)

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.

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.

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.

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.

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 %.

APPENDIX B MATERIALS SAFETY DATA SHEETS

Libbey®

Material Safety Data Sheet

I. PRODUCT INFORMATION

Product Name:	***Cullet – Recycled Glass***
Chemical Family:	Silicon
Synopsis:	Soda Lime Glass, Crushed Glass
Formula:	Si02 + Metal Oxides (Na_2O, CaO, $A1_2O_3$)
CAS Number:	None
DOT Shipping Name:	None
DOT Shipping ID Number:	N/A
DOT Hazard Class:	N/A
EPA Hazard Class:	N/A
EPA Hazardous Waste ID Number:	None

II. CHEMICAL COMPOSITION

Libbey Glass manufactures all of its glass items from common soda lime glass. Libbey has several manufacturing factories and glass compositions may vary slightly due to the availability of raw materials. The glass composition for all manufacturing sites contains some or all of the listed chemical materials:

SiO_2	(silica dioxide)
Al_2O_3	(alumina, aluminum oxide)
Fe_2O_3	(iron oxide)
CaO	(lime, calcium oxide)
MgO	(magnesium oxide)
Na_2O	(sodium monoxide)
K_2O	potassium oxide)
SO_3	(sulfur trioxide)
TiO_2	(titanium dioxide)
SrO	(strontium oxide)
ZrO_2	(zirconium dioxide)

These formulations contain no heavy metals, namely, lead, cadmium, mercury or hexavalent chromium that are intentionally added to the glass batch.

Exposure Limits

Chemical Name	%	ACGH TLV	OSHA PEL	
Soda-Lime Glass	100	10 mg/M^3	15 mg/M^3	(Total Dust)
			5 mg/M^3	(Respirable Dust)

PRODUCT NAME: **Cullet – Recycled Glass**
Page 2 of 3 **Revised 03/24/2005**

III. PHYSICAL PROPERTIES

Boiling Point:	N/A
Melting Point:	1,350 degrees F or 732 degrees C
Vapor Pressure (mmHg):	N/A
Vapor Density (Air = 1):	N/A
Specific Gravity (Water =1):	2.5
% Volatile:	None
pH:	N/A
Solubility in Water:	Insoluble
Evaporation Rate:	N/A
Appearance & Odor:	Clear solid, variable appearance without odor

IV. REACTIVITY DATA

Stability:	Stable
Incompatibilities:	None
Hazardous Decomposition Products:	None
Conditions to Avoid:	None
Hazardous Polymerization:	Will not occur

V. FIRE AND EXPLOSION

Flash Point:	N/A
Lower Explosive Limit (LEL):	N/A
Upper Explosive Limit (UEL):	N/A
Extinguishing Media:	This material is non-combustible. Use extinguishing media appropriate for surrounding area.
Special Fire Fighting Procedures:	None
Unusual Fire and Explosion Hazards:	None

VI. HEALTH HAZARD INFORMATION

Primary Routes of Exposure:	Inhalation, when handling ground or crushed material.
Signs and Symptoms of Overexposure:	Low in toxicity. A nuisance particulate, glass does not produce significant organic disease or toxic effect. May seriously reduce visibility, irritating deposits in the eyes, ears and nasal passages.
Medical Conditions Aggravated by Exposure:	Existing cardiovascular or lung disorder.
Listing as a Carcinogen:	
NTP:	No
IARC:	No
OSHA:	No
Emergency First Aid Procedures:	
Inhalation:	Remove to fresh air. Give oxygen and/or artificial respiration as needed. Seek medical attention for treatment, observation and support as needed.
Eye Contact:	Flush eyes thoroughly with running water, including under the eyelids for at least 15-minutes. Suggest flushing with a saline or commercially prepared product to reduce irritation caused by flushing eye(s) with tap water.
Skin Contact:	Wash affected area with soap and water.

PRODUCT NAME: **CULLET – RECYCLED GLASS**
PAGE 3 of 3 **Revised 03/24/2005**

VII. CONTROL MEASURES

Basic Controls:	General ventilation recommended under normal conditions of use. Local exhaust ventilation is generally not required, may be with crushing or grinding of cullet.
Work Hygiene Practices:	Prevent inhalation of dust. Provide appropriate respiratory protection for nuisance particulate.
Personal Protective Equipment	
Respiratory Protection:	If necessary, wear appropriate respirator approved for nuisance particulate.
Eye/Face Protection:	Safety glasses recommended.
Skin Protection:	Protective gloves recommended to reduce potential for lacerations and abrasions.

VIII. ENVIRONMENTAL AND DISPOSAL INFORMATION

Reportable Quantity:	None
Spills or Leak Procedures:	Minor spills can be swept or vacuumed. Large spills, shovel or vacuum and submit for recycling.
Disposal Methods:	Recycle. Disposal permitted in regulated landfill.

IX. ADDITIONAL INFORMATION

Handling and Storage Precautions:	Protect against fugitive dusts.
Protective Measures During Maintenance:	Prevent generation of dust and subsequent Inhalation. If dusty, Wear appropriate respirator.

X. MANUFACTURER / SUPPLIER INFORMATION

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