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Packaging Stewardship Forum, Australian Food and Grocery Council

The use of Crushed Glass as both
an Aggregate Substitute in Road
Base and in Asphalt in Australia

Business Case

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Executive Summary

Increasingly, on a global scale, nations are making advances in the use of recycled materials in road construction. The use of recycled aggregates instead of virgin materials is helping ease the burden on the rapidly dwindling landfill capacity. Additionally, economic interest has been created due to increased landfill and transport costs. Authorities are now beginning to realise the value of materials traditionally considered waste.

International research and on-road trials have demonstrated that crushed glass can be successfully used as an aggregate in asphalt and roadbase. The acceptance and use of the crushed glass product in road construction in Australia is also gaining momentum.

Currently the State Road Authorities (SRAs) in Australia do not accept crushed glass as an aggregate within their specifications. It is, however, accepted as a foreign material. The current percentages of crushed glass accepted by SRAs in the road layers on a state-by-state basis, is provided in Table 1.

Table 1 Indicative percentages of glass permitted in Australian road construction

State/Territory	Asphalt	Base	Sub-base	Sub-grade
ACT	0%	3%	3%	25%
NSW	Limited	3-5%	5%	5%
NT	0%	0%	0%	0%
Qld	0%	0%	0%	0%
SA	0%	0%	0%	0%
Tas	0%	0%	0%	0%
Vic	0%	2-5%	2-5%	2-5%
WA	0%	5%	15%	-

Existing specifications do not, however, preclude crushed glass from being used as an aggregate. For there to be acceptance of crushed glass as an aggregate, it must be demonstrated that an asphalt or roadbase mix can meet the required properties and performance measures. These results, together with successful field trials and corporate procurement and sustainability policies, will provide a strong argument for acceptance by the SRAs.

The major barriers to the acceptance of crushed glass include:



- » The majority of personnel engaged in this study within SRAs were unaware of the potential for crushed glass to be used as an aggregate;
- » Many of those who were aware of this opportunity had incorrect perceptions as to, or in relation to, the physical properties, characteristics and safety and handling issues of crushed glass;
- » A limited amount of research and testing has been conducted in Australia to define the specific environmental considerations which may impact on specifications;
- » The research and testing that has been completed has largely been completed by private companies and has therefore not been released for public consumption;
- » Glass crushing infrastructure and facilities for glass fines are limited; and
- » There is limited understanding of the potential market size.

Opportunities exist to promote the use of crushed glass in road construction in the form of awareness campaigns, research and testing and field trials. In addition to targeting SRAs, Local Government Authorities, and sustainability, waste management and procurement advocates should be targeted to optimise awareness and momentum for the acceptance of the crushed glass product for use in road construction. Given these opportunities and the barriers discussed previously, the following actions are recommended:

1. Establishment of an interest group incorporating stakeholders from industry, LGAs and associations (ARRB, APPA, IPWEA) to confirm the status of existing testing and research, and develop scope and requirements for further testing to aid in gaining acceptance of the crushed glass product.
2. Source funding for and engage ARRB to complete testing, publishing the results, possibly including State Departments and resulting in a GreenSpec, or similar.
3. Launch an awareness campaign targeting key personnel, such as environmental policy makers and asphalt engineers within LGAs and SRAs. The contributors listed in Appendix B of this report could also be included.
4. Support and encourage the establishment of appropriate glass crushing infrastructure in regions that have adequate market size and local champions.
5. Lobby the AAPA and SRAs to include crushed glass as a recognised aggregate in road construction in their relevant specifications.

1. Introduction & Overview

More and more nations are turning their attention to the possibility of using recycled materials in road construction. The use of secondary (recycled) aggregates instead of primary (virgin) materials is helping to ease the burden on the rapidly dwindling landfill capacity. Additionally, economic interest has been created due to more expensive landfill fees and a more holistic view of transport costs. Authorities are also acknowledging their responsibility to not simply dispose of valuable materials, traditionally considered waste, in a world where natural resources are becoming depleted.

In Australia we can increase our awareness of, and willingness to take action on these issues. One opportunity to demonstrate this is to successfully follow the course of global leaders, the USA, Europe, New Zealand and Taiwan, in incorporating crushed glass into asphalt and roadbase.

Figure 1 Crushed Glass



1.1 Australian Roads

Roads make up a large proportion of the transport infrastructure in Australia. The responsibility for roads within each state and territory is divided between the State/Territory Road Authorities (SRAs) and the multiple Local Government Authorities (LGAs). The approximate kilometrage of roads in each state and territory is provided in Table 2. This road network requires significant maintenance, renewal and extension, accounting for a considerable proportion of the approximate 9 million tonnes of asphalt produced in Australia annually.¹

Table 2 Kilometres of Australian Roads (approximate)

No.	State/Territory	SRA managed roads (km)	LGA managed roads (km)	Total (km)
1	Australian Capital Territory	5,625*		5,625
2	New South Wales	20,858	163,224	184,082
3	Northern Territory	1,270	22,731	24,001
4	Queensland	33,535	143,465	177,000
5	South Australia	22,498	72,502	95,000
6	Tasmania	3,650	20,350	24,000

¹ AAPA (2008) John Lambert, CEO – in conversation with



No.	State/Territory	SRA managed roads (km)	LGA managed roads (km)	Total (km)
7	Victoria	22,340	178,000	200,340
8	Western Australia	17,800	159,900	177,700
TOTAL (Australia)		127,576	760,172	887,748

*lane kilometres

The large size of the road industry provides great opportunity for improvements and innovations in road design and technology. Review and development of materials, including aggregates, is one component of this.

1.2 Recycled Material in Roads

Recycled materials currently utilised in road construction include waste rock, reclaimed concrete, Reclaimed Asphalt Pavement (RAP), reclaimed sealing aggregate, crushed bricks, coal fly ash, smelter slag, spent foundry sands, scrap tyres, waste motor oil, waste plastic and, increasingly, glass.²

Recycled materials used in road construction fall into one or more of the following categories:

- » Mineral filler;
- » Aggregates for bituminous seals, asphalt mixtures for pavement construction, basecourse stabilisers; and
- » Bitumen additives and modifiers.³

The Federal Highway Authority in the USA has a list of 18 guidelines for recycled materials, including 'Waste Glass' (M-318-01). These uses are summarised in Table 3 below, to demonstrate the scope and range for the inclusion of recycled materials in road construction, particularly, glass.

² AASHTO (2008) *Chapter 5, Pavement, Materials and Recycling, Centre for Environmental Excellence by AASHTO*, http://environment.transportation.org/environmental_issues/construct_maint_prac/compendium/manual/5_5.aspx

³ Herrington, P. Kvatch, I. & O'Halloran, K. (2006) "Assessing the environmental effects of new and recycled materials in road construction, Proposed Guidelines", *Land Transport New Zealand Research Report No. 306*



Table 3 Recycled Materials Applications – FHWA⁴

Application/Use	Material
Asphalt aggregate	Blast Furnace Slag
	Coal Bottom Ash
	Coal Boiler Slag
	Foundry Sand
	Mineral Processing Wastes
	Municipal Solid Waste Combustor Ash
	Nonferrous Slags
	Reclaimed Asphalt Pavement
	Roofing Shingle Scrap
	Scrap Tyres
	Steel Slag
	Waste Glass
Bitumen Aggregate (Seal Coat or Surface Treatment)	Blast Furnace Slag
	Coal Boiler Slag
	Steel Slag
Asphalt – Mineral Filler	Baghouse Dust
	Sludge Ash
	Cement Kiln Dust
	Lime Kiln Dust
	Coal Fly Ash
Asphalt – Bitumen Modifier	Roofing Shingle Scrap
	Scrap Tyres
Portland Cement Concrete – Aggregate	Reclaimed Concrete
Portland Cement Concrete – Supplementary Cementitious Materials	Coal Fly Ash
	Blast Furnace Slag

⁴ Federal Highway Administration (2006), “User Guidelines for Waste and Byproduct Materials in Pavement Construction”, www.fhrc.gov/hnr20/recycle/waste/index.htm



Application/Use	Material
Granular Base	Blast Furnace Slag
	Coal Boiler Slag
	Mineral Processing Wastes
	Municipal Solid Waste Combustor Ash
	Nonferrous Slags
	Reclaimed Asphalt Pavement
	Reclaimed Concrete
	Steel Slag
	Waste Glass
Embankment or Fill	Coal Fly Ash
	Mineral Processing Wastes
	Nonferrous Slags
	Reclaimed Asphalt Pavement
	Reclaimed Concrete
Stabilised Base – Aggregate	Scrap Tyres
	Coal Bottom Ash
Stabilised Base – Cementitious Materials (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Coal Boiler Slag
	Coal Fly Ash
	Cement Kiln Dust
	Lime Kiln Dust
Flowable Fill – Aggregate	Sulfate Wastes
	Coal Fly Ash
	Foundry Sand
Flowable Fill – Cementitious Material (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Quarry Fines
	Coal Fly Ash
	Cement Kiln Dust
	Lime Kiln Dust

1.3 About Crushed Glass

Glass material is non-metallic and inorganic; it can neither be incinerated nor decomposed and can be recycled without loss of product quality.⁵ In the USA, glass makes up around 7% (12 million tonnes) of total weight of municipal solid waste, with only 20% of this glass being recycled. These rates of recycling are similar amongst many developed nations.

Figure 2 Crushed Glass – A Snapshot

Origin:

Glass is formed by supercooling a molten mixture of sand (silicon dioxide), soda ash (sodium carbonate), and/or limestone, to form a rigid physical state. Glass aggregate is a product of recycled mixed glass from manufacturing and post-consumer waste.

Physical Properties:

Glass aggregate, also known as glass cullet, is 100 percent crushed material that is generally angular, flat and elongated in shape. This fragmented material comes in colour or colourless forms. The size varies depending on the chemical composition and method of production.

Engineering Value:

When glass is properly crushed, this material exhibits a coefficient of permeability similar to coarse sand. Also, the high angularity of this material, compared to rounded sand, may enhance the stability of asphalt mixes. In general, glass is known for its heat retention properties, which can help decrease the depth of frost penetration.

Federal Highway Administration (2002) *Utilization of Recycled Materials in Illinois Highway Construction: Glass Aggregate*, <http://www.fhwa.dot.gov/pavement/recycling/recymat.cfm>

It is recognised that there are many other uses for crushed glass as a resource worldwide, including:

- » Aggregate in road base and sub-base;
- » Aggregate in asphalt, including “Glassphalt”;
- » Aggregate in tiles;
- » Aggregate in decorative concrete for architectural facades;
- » Alternative to mulch;
- » Filtration material;
- » Alternative to sand in golf courses;
- » Alternative to fill material; and
- » Aggregate in concrete / cement.

⁵ Wu, S, Y., Yong, W. & Xue, Y. (2005) “Preparation and Properties of Glass-asphalt Concrete”, Gjenbruksprosjektet 2002 - 2005 – BCRA workshop: Papers and presentations, <http://www.gjenbruksprosjektet.net/article/articleview/275/1/148/>

1.4 Definitions & Abbreviations

Around the world and between states and territories in Australia, there are significantly different terminologies for asphalt mixes, application processes and road layers. As an example “asphalt” as used in the USA is called “bitumen” in Australia and United Kingdom. “Asphalt” as used in Australia is called Bituminous Concrete or Asphaltic Concrete overseas. As a result, there is frequent misunderstanding among and between parties.

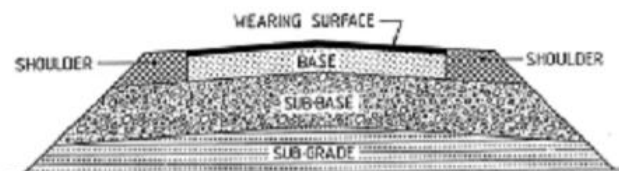
Within this Business Case, Australian terminologies have been used. Types and classes of crushed rock, road layers and traffic where referred to under state/territory headings, have been standardised as indicated in Table 4.

Table 4 Road Layer Terminology

Layer No.	Term used	Also Known As
1	Wearing Course	Wearing surface Surface course Surfacing Road Asphalt surfacing
2	Base-course	Roadbase Base
3	Sub-base	Capping
4	Sub-grade	Foundation Select material layer

For reference, the basic structure of a road is provided in Figure 3.

Figure 3 Terminology for the Structure of a Road



A full list of definitions and abbreviations as used in this Business Case are provided in Appendix A.



2. Literature Review

The readily available literature on the use of crushed glass as an aggregate is extremely sparse. The focus of this Literature Review is the use of crushed glass as an aggregate in asphalt, sub-base and roadbase.

2.1 The History of Crushed Glass in the USA

Crushed glass has been used in road-base in the USA intermittently since the 1960s. Research has increased over the last decade, especially with the success New York City has experienced in improving their glass recycling rates by providing specifications for the use of crushed glass in road construction.

The use of pulverized glass cullet as an additive in roadway construction must meet a series of established criteria to ensure structural integrity and safety. The most comprehensive specification for glass cullet as an aggregate roadbase, was published in 2001 (M-318-01) by the Federal Highway Authority (FHWA).⁶

The Recycled Materials Resource Center (RMRC), Project 13/14, is currently completing further research on the development of specifications for recycled materials in transportation applications. This is a USA federal-university partnership. Congress has supported development of the RMRC at the University of New Hampshire to perform research and outreach to reduce barriers to recycling in a highway environment.

2.1.1 Lessons Learnt

The high proportion of glass cullet, up to 40%, permitted by Washington DOT for inclusion in asphalt in the 1960s, resulted in rutting of the pavement and stripping. Following this, Washington DOT has discontinued the use of glass aggregate in bituminous concrete pavements, despite tighter specifications leading to the successful use of crushed glass as an aggregate in other states.⁷

Crushed glass in asphalt was first used in New York's "emerald city" paving in 1990.⁸ At the time paving contained up to 40% glass. Presently, crushed glass is permitted to a maximum of 5% of the total aggregate weight by New York State Department of Transport (NYSDOT) specifications.⁹

A major limiting factor for the wide uptake of glass for use in asphalt or stabilised sub-base, is the concern that surrounds the adhesive bond between glass and the bitumen.

⁶ AASHTO (2008) *op. cit.*

⁷ Federal Highway Administration (2002) *op. cit.*

⁸ Goldman, A. L. (1987) "Glasphalt' To Sparkle On Streets", *New York Times* (1857 – Current file); Jul 6, 1987, Proquest Historical Newspapers The New York Times pg.34

⁹ NYS Executive Department (2004), *Group Specification, Bituminous Concrete – Hot Mix Asphalt*, Issued 08/10/04, Spec. No. 891, pg 5



2.2 Usage

Table 5 is an extract from the Texas Department of Transportation (TxDOT) TTI Study 0-1331 *Use of Glass Cullet in Roadway Construction*, for appropriate non-pavement applications indicating the recommended glass cullet percentages.

Table 5 Non-Surface Applications for Glass Cullet¹⁰

No.	Application	Percentage of Glass Cullet
1	Embankments	< 20% by weight of total mix
2	Flexible base (Type D)	< 20% by weight of total mix
3	Asphalt Anti-stripping agents	When cullet is used as an aggregate in asphalt-stabilised bases, lime and some liquid anti-stripping agents may not perform adequately.
4	Bitumen Stabilised Base	< 5% of the total mass of the aggregate
5	Excavation and backfill for structures	Utility bedding material may comprise up to 100% Backfill that will support any portion of roadbed or embankment < 20% Backfill that does not support any portion of the roadbed or embankment may include up to 100%
6	Retaining wall	Structural backfill < 20% Non structural backfill up to 100%
7	Pipe underdrains	Up to 100%
8	Open-graded Basecourses	< 5% of the total mass of aggregate

2.2.1 Crushed Glass as an Aggregate in Road-Base & Sub-Base

The American Association of State Highway and Transportation Officials (AASHTO) have developed the following specifications for the use of crushed glass in upper pavement layers:

- » Glass cullet should be crushed and screened if necessary so that 100 percent of the glass cullet material passes the 9.5 mm sieve.
- » The supplier should be permitted to use up to 20 percent by mass of glass cullet in composite glass cullet/soil-aggregate mixtures.
- » If the engineer wishes to use a combination of materials that exceeds the glass percentage limit indicated above, then reference should be made to the evaluation

¹⁰ Texas Department of Transportation (2008) *Use of Glass Cullet in Roadway Construction*, http://www.dot.state.tx.us/services/general_services/recycling/glass_cullet.htm



methods described in the AASHTO specification, Glass Cullet Use for Soil-Aggregate Basecourse, AASHTO Designation: M 318-01.¹¹

As shown in Table 5 above, where there is no binder in the sub-base and roadbase, up to 20% of cullet is allowed but for bitumen stabilised bases, a more conservative figure of 5% is allowed due to asphalt/cullet bonding concerns.

Transit New Zealand allow up to 5% of glass cullet in pavement layers.¹²

2.2.2 Crushed Glass as an Aggregate in Asphalt

Stripping

In general, aggregates can be classified as hydrophobic or hydrophilic of which the former is acid attributed to the silicate (SiO₂) constituent, while the later is alkali due to the dominant calcium carbonate (CaCO₃). Glass is classed as hydrophobic.¹³

Glass being hydrophobic results in a low asphalt absorption capacity, causing adhesion problems, or “stripping”. This major limitation has been overcome with the addition of a lime based additive enabling the drawing out of the beneficial volume stability of glass – its resistance to cracking during dramatic variations in temperature.

NYS DOT can be singled as a leader in the use of glass cullet in asphalt, having laid more than 220,000 tonnes of ‘glassphalt’. Research has found that proportions of up to 10 – 15% can be used successfully in low traffic areas if the asphalt mix is combined with a lime additive to improve stability.¹⁴

In addition to the naturally hydrophobic state of glass, inappropriately crushed glass demonstrates long and flat particles, also contributing to stripping. The glass particles with a larger surface areas cause stripping from bitumen film, due to the propensity for bitumen, when in contact with large smooth surface areas of glass, to erode with water. This problem is resolved by crushing glass to <4.75mm as it exhibit attributes similar to sand.¹⁵

Polished Stone Value (PSV)

Large particle sizes can lead to tyre damage and reduces skid resistance. Research has found that limiting the size and proportion of the glass cullet as a fine aggregate in asphalt for use as wearing course does not increase PSV and can in fact lead to a decreased PSV, improving skid resistance.¹⁶

¹¹ Berger, J. Leow, M. Littlejohn, B. & Pettit, R. (2004) “Glass Recycling in Montana”, Montana Public Interest Research Group, <http://www.montpirg.org/reports/GLASS.pdf>

¹² Transit New Zealand (2006), *Specification for Basecourse Aggregate*, TNZ M/4: 2006, pg 15

¹³ Su, N. & Chen, J.S. (2002) “Engineering properties of asphalt concrete made with recyclable glass”, *Resources, Conservation and Recycling*, 35, Taiwan, pp 259 – 274, Wu, S et al, (2005) *op cit*.

¹⁴ Su & Chen (2002), *op. cit.* pp 259-274

¹⁵ NYS Executive Department (2004), *op. cit.*

¹⁶ Su & Chen (2002), *op. cit.* pp 259-274



New Jersey Department of Transport, 1992

New Jersey Department of Transportation (NJDOT) specifications have allowed the substitution of up to ten percent glass (by weight) for aggregate in asphalt basecourses. In 1992, the department placed two sections of asphalt wearing courses of about 0.5 kilometres (0.3 miles) each containing ten percent glass. One of the sections contained an anti-strip additive; the other did not. Results to date indicate that both of these sections are performing as well as conventional pavement.

Su & Chen, 2002

In Taiwan, Su and Chen (2002) found that permeability in asphalt increased with the amount of recycled glass used but was still less than 1.0×10^{-2} cm/s recommended by Japanese standard JIS A1218.

To counteract the lack of bonding between the glass aggregate and asphalt, Su and Chen rated a lime additive and recommend a 2% lime additive for optimal engineering and economic advantage. The degree of deformation and aging tested over 20 days was found to increase with the proportion of glass cullet during dry / wet cycling tests for stability. The stability value of the modified asphalt (with glass aggregate) was 33% stronger than regular asphalt.

The skid resistance, measured by the British portable skid-resistance test in both longitudinal and transverse directions, increased with the proportion of glass content and skid resistance increased after one year as the glass granule was progressively exposed due to surface abrasion caused by vehicle traffic.

After one year the test section with 10% recycled glass showed equivalent performance to the strip without recycled glass.¹⁷

Senadheera, Nash & Rana 2005

Whilst conventionally glass cullet is assumed to weaken material blends, Senadheera et al (2005) has shown that with the right blend with natural aggregate, glass cullet actually increases the strength of the material blend. The use of glass cullet combined with caliche (calcium carbonate) for use in granular base layer, was shown to improve the resilient modulus test, as long as the caliche-glass cullet blend is not subject to excessive loading. Hence, whilst inappropriate for high traffic areas, the advantageous strengthening properties would be beneficial on low to medium traffic roadbases and they recommend a maximum proportion of glass aggregate of 20%.¹⁸

2.3 Safety Considerations

There exists the perception and concern that the raw crushed glass product poses safety risks in the form of cuts from handling and respiratory damage from the

¹⁷ Su & Chen (2002) *op. cit.* pg 273

¹⁸ Senadheera, s., Nash, P. & Rana, A. (2005) "Characterization of the Behaviour of Granular Road Material Containing Glass Cullet", *Gjenbruksprosjektet 2002 - 2005 – BCRA workshop: Papers and presentations*, <http://www.gjenbruksprosjektet.net/article/articleview/275/1/148/>

inhalation of dust. Su and Chen (2002) found that when crushed to 4.75mm or less there exists no significant increase of personal safety risk or additional tyre wear.¹⁹

Trials and testing for the use of crushed glass as a pipe embedment material, conducted by the Department of Environment and Climate Change (NSW) (DECC), Sydney Water Corporation (SWC) and Benedict Sand and Gravel, found:

- » Glass dust is an inert nuisance dust and has no significant biological effect although it may interfere with comfort and welfare.
- » There is no evidence that glass dust causes permanent damage to the respiratory system.
- » Recycled container glass contains less than 1% crystalline. The dust generated by glass cullet is not considered hazardous and does not contribute to silicosis or cancer.
- » Particles less than 19mm represent no greater hazard of causing skin cuts than conventional crushed construction aggregates.
- » Glass particles smaller than 6mm are completely benign.
- » Because of its abrasive qualities, crushed glass can be a greater skin irritant than conventional aggregates and soils and could even cause eye damage.²⁰

Simple measures, such as damping down and use of appropriate Personal Protective Equipment (PPE), aid in controlling the hazards listed and minimising risk of exposure. Despite putting these control measures in place, SWC have continued to receive hazard notifications from employees using the product, reporting dangerous particle sizes. As a result, usage of the crushed glass product has been minimised and sampling has taken place. This sampling has, however, failed to support the claims regarding sample size. SWC continue to monitor the situation. It is possible that the raising of hazards is a cultural response and a form of resistance to accepting the new product.

Figure 4 Crushed Glass



¹⁹ Su, N. & Chen, J.S. (2002) *op. cit.*

²⁰ Department of Environment & Climate Change NSW (2007), *Trial of Recycled Glass as Pipe Embedment Material*, <http://www.environment.nsw.gov.au/warr/crushedrecycledglass.htm>, pg 8



2.4 Economic Considerations

2.4.1 Disposal Costs

Disposal costs are increasing around the world, prompting more serious attempts at recycling. Taxes to reduce landfill such as the Land Fill Tax and Levy introduced in the UK in 2002 in response to diminishing landfill capacity, is such an example. Landfill municipal waste disposal cost in Montana can cost between US\$18 and US\$40 per ton for disposal, excluding transportation costs.²¹

Tax as a policy tool is also effectively used to encourage recycling. The introduction of Landfill Tax and Aggregates Levy in 2002 in the UK was aimed at boosting the recycling rate.²² In Australian cities and towns, kerbside collection helps to guarantee a large and consistent supply of recycled glass. Though there may still be virtue in combining pay-as-you-throw programs with kerbside collection, as have proven successful in reducing waste to maximise recycling in Montana, USA.²³

2.4.2 Cost of Crushed Glass versus Virgin Products

At a cost of approximately US\$4.00/ton for glass, compared to approximately US\$20/ton for sand, glass has provided a lighter and easier medium for the contractor to handle and a higher porosity than common sand.²⁴ In Montana cullet for glass manufacture has a value that ranges from US\$3 to US\$60 per ton. Sand and gravel has a value of between US\$3 and US\$19 per ton. It is argued that even at US\$3, cullet has a significant value in large quantities, and it is to be assumed that the cost of cullet or glass fines available for use in roads would be equivalent, if not less. The authors proposed that recyclers help to cover the expenses of operating a glass pulverizer by selling the glass cullet it produces.²⁵

Whilst the cost of natural aggregates rise and virgin stocks decline, and the cost to dump waste in landfills rise, it has been proposed that natural aggregates be diverted to the construction of new roads rather than the immediate maintenance of existing roads. Glass aggregate could help fill the maintenance gap. AASHTO argues that Preventative Maintenance (PM) treatment for flexible and rigid pavements can extend a pavements service life by five to ten years, reducing maintenance or capital expenditure in the long run by reducing the amount of water infiltrating the pavements and slowing down the rate of deterioration. Savings in the USA as studied by CalTrans, amount to US\$3 to US\$20 for every US\$1 spent on maintenance if applied at the right time.²⁶ The role for crushed glass in asphalt for maintenance purposes may prove to

²¹ Burgess, K. (2008) "Slow road to acceptance", BRW, Australia, Vol. 30 Issue 15, pg 44

²² Huang, Y., Bird, R. & Heidrick, O. (2007) "A review of the use of recycled solid waster materials in asphalt pavements", *Resources Conservation & Recycling*, i52, pp 58-73.

²³ Berger, et al, (2004) *op. cit.*

²⁴ AASHTO (2005), *op. cit.*

²⁵ Berger et al, (2004) *op. cit.*

²⁶ AASHTO (2005), *op. cit.* Chap 5



be a sensible argument when considering the whole of life cycle approach to pavement asset management.

2.4.3 Transportation Costs

New Zealand's glass collection rate resulted in an oversupply of glass. In 2004, 90 000 tonnes of glass was recycled. Whilst most of this glass has gone back into glass manufacture, there are significant stockpiles in towns throughout New Zealand where recycling facilities are not economically feasible and the cost of transportation to recycling plants outweighs the costs saved. This problem has been largely resolved by simply crushing the glass on site using a mobile glass crusher. Refer to Section 2.8 for further details.

2.5 Environmental Considerations

2.5.1 Depletion of Natural Resources

Worldwide, authorities are recognising that stocks of natural aggregate are diminishing. It is predicted that high specification aggregates from UK permitted extractions could be exhausted as early as 2020.²⁷

Within Australia, LGAs such as Greater Taree, are unable to adequately fund road maintenance due to the lack of local gravel resources and the cost of shipping externally sourced gravel. The acceptance of a crushed glass product and the establishment of appropriate crushing facilities could aid in alleviating the maintenance burden.

2.5.2 Landfill Capacity

United Kingdom

Landfill capacity in the UK is set to run out in the next 5 to 10 years and led to the introduction of Landfill Tax and Aggregates Levy in 2002.²⁸ The Waste Resources Action Program (WRAP, 2004) has provided the following statistics:

- » Of the 3.4 Mt of waste glass 2.4 Mt (71%) was container glass and 0.76 Mt of flat (window) glass.
- » Only 1.1 Mt (33%) of waste glass was recycled, of which 13% or 0.14 Mt was used as aggregate in various applications.
- » Of the 3.4 Mt total waste glass, 2.3 Mt (67%) of waste glass was sent to landfills.

Taiwan

In 2000 it was estimated that around 600 000 tonnes of waste glass was dumped. Since 1989, the government allocated areas where this glass can be dumped and

²⁷ Huang et al (2007), *op. cit.*

²⁸ Environmental Agency, (2008), *Recent change sin waste legislation*, http://www.environment-agency.gov.uk/business/1745440/444663/landfill/1789720/?version=1&lang=_e



buried but these were quickly exhausted, leading to the push for recycling. Currently, around 20% of glass is recycled in Taiwan.²⁹

2.5.3 Leaching

Concerns of authorities when considering the use of recycled materials as aggregate include performance and the environmental impact. Contaminants from road construction materials primarily enter the environment through the process of leaching. Where hazardous chemicals are present, leaching can have an adverse impact on the environment.

Chemical testing of crushed glass was completed as part of the DECC's *Recycled Glass as a Pipe Embedment Material* trial (2007). The study made the following conclusions:

- » Chemical and physical contaminants detected were at most background or trace levels; and
- » The presence of any aluminium metal and/or metal compounds in the glass fines is not expected to present an unacceptable human health and/or environmental impact.³⁰

Herrington et. al (2006) additionally demonstrated that the addition of crushed glass does not result in the leaching of toxic chemical residue. The risk of contamination from recycled glass only exists if the glass was a container for hazardous substances or was used for lighting purposes or vehicle windscreens.³¹

2.6 Policy and Regulations

Whilst it may be argued that market forces will increase demand, there is a risk of market failure due to inadequate dissemination of accurate and meaningful product information. To encourage up-take, it is recommended that active marketing be put in place, and further, the incentive for recycling is increased through encouragement by authorities via the introduction of legislation and financial incentives.³²

In the USA all construction projects using Federal funds need to consider recycled materials. FHWA's *Recycled Materials Policy* stresses the importance of including recycling in pavement construction, stating that:

²⁹ Su & Chen (2002) *op. cit.*

³⁰ Department of Environment & Climate Change NSW (2007), *op. cit.*

³¹ Herrington et. al (2006) *op. cit.*

³² Huang et al, (2008) *op. cit.*



Recycling and reuse can offer engineering, economic and environmental benefits. Recycled materials should get first consideration in materials selection. Determination of the use of recycled materials should include an initial review of engineering and environmental suitability. An assessment of economic benefits should follow in the selection process. Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications.

Melton, J.S. & Weymouth, S, (2005) "Development of National Specifications for Recycled Materials Use in the United States", Gjenbruksprosjektet 2002 - 2005 – BCRA workshop: Papers and presentations, USA

European countries already have legal requirements for the inclusion of recycled components in construction, and in the UK the government has indicated that as much as 25% of construction aggregate demand should in the future be met from secondary and recycled sources.³³

In the USA there exists a Beneficial Use Determination (BUD) process, which is composed of a list of recycled materials classified as a resources. As such, these resources cannot be sent to landfill. Used glass is consequently considered a resource and not "waste".

2.7 The Importance of Champions

We have touched on the importance of setting directives on the way recycled materials, in this case recycled glass, is viewed. In order to put these plans into action requires appropriately qualified resources. Having the appropriately qualified people in a role dedicated to promoting the use of recycled material programs within USA DOTs has met with success. Five state DOTs are known to have full time recycling coordinators. These states have reaped positive benefits from their programs, increasing awareness, acceptance and usage. The coordinator acts as the focal point to connect state DOT, state Environment Protection Agency, solid waste producers, and potential entrepreneurs to promote increased waste material use and to reduce barriers.³⁴

2.8 Crushing Facilities

In attempts by communities to recycle glass by crushing, some communities have trialled simply steamrolling the containers with heavy equipment, such as a front-end loader. This technique and the equipment used have produced a sharp and jagged cullet that has limited uses. Many communities' attempts at glass reclamation programs have been unsuccessful because of a lack of demand for the low-quality product produced.³⁵

Fulton Hogan found that crushing glass in a gravel crusher has proven to be abrasive on the machinery and calibration to achieve the right sieve size, time consuming. In

³³ International Road Federation, "Making the Most of Waste." *World Highways/Routes du Monde*, Vol. 8, No. 5, (July, 1999) pp. 51-52

³⁴ AASHTO (2005) *op. cit.*

³⁵ Berger et. al (2004) *op. cit.*

Western Australia, Pioneer Roads Services Pty Ltd has, for this very reason, ordered a specialist glass crusher from the USA.

Strategies for Success

In encouraging acceptance and usage, researchers have continually emphasised the importance of having the ‘end-user’ in mind when determining the crushing specifications. The product must be of the specified cullet size and shape to encourage the ready up-take by contractors. It is therefore extremely important to source and invest in appropriate pulverisation equipment.

In the USA there are a number of machines dedicated to glass crushing. Models can either be stationary, appropriate when a large supply is available, or medium to small sized, with the added benefit that the medium to small models are also mobile.³⁶

Montana State in the USA, with its smaller population and distance from the economic hub, is similar to many towns across New Zealand and Australia. Montana’s distance to major markets and its small population prevent traditional glass recycling. Instead, the emphasis is on finding local markets and applications for post consumer glass. Residents of nine counties in Montana participate in the recycling of glass where glass containers are crushed and the resulting product is used as aggregate in road-building. Residents of two other counties recycle glass that is crushed and used by a local cement factory.³⁷

In New Zealand stationary glass recycling facilities have proven uneconomical given the quantity of recycled glass available in isolated towns throughout New Zealand. The supply of glass, however, is significant when added up. To ensure usage of this valuable resource, a mobile crusher, coined “Krusher” (refer to Figure 5) has provided an alternative to the costly and economically unsustainable establishment of stationary recycling facilities in remote locations. The Krusher can process cullet size of 9.5mm at one tonne per hour with increments in time for smaller cullet sizes.³⁸

Figure 5 Crushing Glass in NZ – The mobile Krusher



Berger J, et al (2004) recommends a “smaller may be better” solution to a crushing system. It is argued that a mix of multiple stationary pulverisers or a few medium-sized

³⁶ Burgess, K, et al (2004) *op. cit.*

³⁷ Berger et. al (2004) *op. cit.*

³⁸ Glass Packaging Forum (2007) *Funded Initiatives - Mobile Glass Crusher*
<http://www.glassforum.org.nz/achievements.html#mobilecrusher>



mobile pulverizers is the 'best-fit' approach and will prove more efficient, economically feasible, and result in a standardised product.

Proper glass pulverisation equipment is essential. Specifications will provide the framework but in order to ensure uptake, the recycled glass must be converted into products that can be readily used by asphalt, sub-base and roadbase producers and contractors. The lack of end use planning was pointed to be the failure of glass recycling schemes in the USA.

Providing an appropriately accessible crushing facility can also increase overall rates of recycling. Exemplifying locally the same concept of crushing at source to increase the rate of recycling and save on transport costs, the Packaging Stewardship Forum, working in partnership with BottleCycler, has trialled mini-crushers that sit behind hotel bar establishments. Recycling at these bars has increased from 10% to 70%.³⁹

2.9 Test Methods & Classification (Performance based Specifications)

Recycled aggregates are subject to the same classification as virgin materials in the UK.⁴⁰ Several European countries have research programs that evaluate the in-service recycled material performance. This approach directly challenges the principle that recycled material must meet virgin material specifications.

The traditional belief that recycled materials must meet the same standards as virgin materials in many cases eliminates them from use, even though they may potentially perform well in service. The highway community is moving towards performance-based specifications; however it is a complicated program and will evolve over time. Another concern is the time and expense of testing. There is a strong need for more performance-based specifications in lieu of method or material specifications.⁴¹

2.10 Recycling Strategy Frameworks

In September 1999, the International Technology Scanning Program conducted a recycled materials technology scanning tour to Denmark, Sweden Germany, the Netherlands, and France. This investigation was jointly sponsored by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Recycled Materials Resource Center (RMRC) at the University of New Hampshire and included support from the U.S. recycling industry.

The purpose of the programme was to review and document innovative policies, programs and techniques in Europe and to evaluate their applicability to USA practices. The investigation, report and subsequent workshopping, included in the

³⁹ National Packaging Covenant, Department of the Environment, Water, Heritage and the Arts, Australia. - Media Release (2008) *BottleCycler gives empty bottles with nowhere to a new pick up line*, July

⁴⁰ Huang et al, (2008) *op. cit.*

⁴¹ Arnold, G., Wekmeister, S. & Alabaster, D. (2008) "Performance Tests for Road Aggregates and Alternative Materials", *Land Transport New Zealand Research Report No. 335*



following recommendations to provide a framework for the implementation of recycling strategies:⁴²

- » A recommendation to overcome communication limitations was for a jointly sponsored technology transfer outreach program and a web based system to transfer knowledge.
- » The private sector recycling industry does not seem to be doing enough advanced R&D work prior to introducing their products to the highway community.
- » There is limited publicity on positive recycling efforts.
- » There is a major misconception that if its recycled, it has to be cheaper than virgin material.
- » Include a recycling strategy in the sustainability aspect of strategic plans and long-range research priorities.
- » Create a framework to consider the use of recycled materials in project planning, alternatives analysis, and mitigation analysis.
- » Encourage long term materials supply plans and recycled materials availability plans.
- » Develop clear engineering and environmental guidelines at the State and Federal level that are available for suppliers and decision-makers.
- » Develop courses on recycling.
- » Evaluate contractors with respect to use of recycled materials or environmental protection during contract performance reviews.
- » Develop and implement the use of warranty and performance based specifications.⁴³

Many of the above recommendations could be adopted in Australia to aid in increasing the awareness and acceptance of crushed glass as an aggregate for use in asphalt and road-base.

2.11 Summary

A summary of the Health, Safety & Environment, Quality and Technical Specifications finding as a result of this review are provided in Table 6.

⁴² FHWA (2000), *Partnerships for Sustainability: A New Approach to Highway Material - A Report on the Houston Workshop*, <http://www.fhwa.dot.gov/pavement/recycling/houston.cfm>

⁴³ Holts, K. & Eighmy, T.T. (2000) "Scanning European Advances in the Use of Recycled in Highway Construction", AASHRO



Table 6 Crushed glass in asphalt and granular base materials

No	Issue	Finding
Health, Safety & Environment		
1	Handling	<p>Particles crushed to <19mm pose no greater risk of cuts than conventional crushed construction aggregates.</p> <p>Particles <6mm are benign.</p> <p>Can be a greater skin irritant, however correct Personal Protective Equipment (PPE) controls this risk.</p>
2	Inhalation	<p>Glass dust is an inherent nuisance dust.</p> <p>Inhalation will cause no significant biological effect, though may result in discomfort.</p> <p>There is no evidence that inhalation of glass dust causes permanent damage to the respiratory system.</p>
3	Silicosis	<p>Recycled container glass contains <1% crystalline silica.</p> <p>Dust generated by glass cullet is not considered hazardous and does not contribute to silicosis or cancer.</p>
4	Leaching	<p>The use of crushed container glass in road construction does not result in the leaching of toxic chemical residue.</p>
Quality		
6	Tyre damage	<p>Particles in asphalt <4.75mm do not cause additional tyre wear.</p>
7	Production/ crushing	<p>Crushing glass is more abrasive than crushing rock.</p> <p>Specialist crushers are required.</p> <p>Crushing to a smaller (<4.75mm) particle size is more time consuming/costly.</p> <p>Crushing to <4.75mm ensures a readily usable product.</p>
Technical Specifications		
8	Rutting/ breakdown	<p>Asphalt mixes including up to 20% crushed glass have performed well in testing, showing no significant increase in rutting when compared to control samples.</p> <p>Research suggests inclusion of <15% crushed glass to insure against rutting of asphalt.</p>



No	Issue	Finding
9	Stripping	Ensuring particles are <4.75mm and the inclusion of a lime stabiliser aid in negating the propensity towards stripping of glass in asphalt.
10	Particle size	Particle size at <4.75mm displays similar properties to natural sand.
11	Adhesion	Lime stabiliser at 2% has been found to be advantageous in aiding adhesion of crushed glass in asphalt.
12	Polished Stone Value	Skid resistance has been shown to increase with the inclusion of a percentage of crushed glass.
13	Compaction	73-76% compaction has been achieved with sand+glass mixtures.



3. Australian Standards, Specifications & Organisations

At a national level there exists many opportunities and avenues in which the advancement of crushed glass as an aggregate in road construction can be considered. There are, however, significant barriers that must be overcome before common acceptance. The challenges faced in marketing recycled products are considered in Figure 6.

Figure 6 Market Development for Recycled Content Products

...choosing recycled content products is still not a widespread practice. Extensive research conducted for DEC across industry, state and local government clearly identified price and performance as the major drivers for purchase for goods and services.

Many recycled content products find it difficult to compete on price. This is because reduced demand leads to smaller production runs, which in turn increases the per unit price. Solving this depends on encouraging purchase by more users, especially larger buyers such as big corporations and governments, but there is a reluctance to adopt new products without clear evidence of an economic benefit from their use.

Governments and major companies therefore have a clear role to play in market development as they have considerable purchasing power and can influence demand for environmentally friendly products.

Other key barriers include lack of information about availability of alternatives, environmental benefits and product performance as well as lack of warranties or guarantees. In the absence of reliable technical data on the applications and the benefits of products with recycled content, adoption will continue to be slow. Other barriers to purchasing recycled content products include organisational structure, lack of leadership and corporate procurement policy drivers, and fear of changing established purchasing practices.

DECC NSW (2007), *NSW Waste Avoidance and Resource Recovery Strategy 2007*, http://www.environment.nsw.gov.au/resources/warr/07226_WARRreport07.pdf, pg 26

To advance the acceptance and use of crushed glass as an aggregate in road construction, State/Territory Road Authorities (SRAs), Local Government Authorities (LGAs) and industry organisations and associations need to play a role in testing and the development of specifications and standards.

3.1 Australian Standards

The Australian Standards applicable to asphalt and base and sub-base include:

- » HB 152:2002 Asphalt Guide (Austroads/AAPA);
- » AS1141 – Methods for Sampling and Testing Aggregates;



- » AS2150 – Hot Mix Asphalt- A guide to good practice;
- » AS2758.5 – Aggregates and Rock for Engineering Purposes, Part 5: Asphalt Aggregates; and
- » AS2891 – Methods of Sampling and Testing Asphalt.

The above listed Australian Standards that specify an “...aggregate may be produced from rock, gravel, metallurgical slag or suitable synthetic materials”.⁴⁴ The Asphalt Guide states:

Aggregate may be produced from:

- » Crushed and screened quarry products;
- » Natural sands and gravels;
- » Manufactured aggregates; and
- » Recycled materials.

Austrroads Inc. & AAPA (2002), *Asphalt Guide*, 3.2 Sources of Aggregate, pg 18

The Asphalt Guide and the Australian Standards do not preclude crushed glass from inclusion as an aggregate so long as it exhibits the required properties for its proposed use, and that appropriate and approved testing confirms that the mix in which it is included can meet the required performance specifications.

SRAs and LGAs make reference to and develop their own standards and specifications from the above listed Australian Standards and Asphalt Guide.

Demonstrating that a crushed glass product, or mix containing crushed glass, complies with these standards may encourage SRAs and LGAs to further consider the possibility of including and considering crushed glass as an accepted aggregate in their own specifications.

3.2 National Industry Associations

National industry associations provide opportunities for promoting and raising awareness of the crushed glass product through, for example, association publications, tabling of papers, collaboration for and/or sponsorship of research and testing and presentation at technical forums. Such associations include:

- » Australian Asphalt Pavement Association (AAPA);
- » Australian Stabilised Pavements Association;
- » Austrroads;
- » ARRB Group;
- » Waste Management Association;
- » National Packaging Covenant;
- » Roads Australia (Australian Road Forum);

⁴⁴ Australian Standard Committee (1996), *Aggregates and rock for engineering purposes, Part 5: Asphalt aggregates*, pg 4



- » Institute of Public Works Engineering Australia (IPWEA); and
- » Australian Local Government Association.

To fund and conduct effective testing may require the enlistment of one, or a collaboration, of the above listed associations in testing will first require defining what role the crushed glass as an aggregate is to take within the asphalt or basecourse mix. The specifications and appropriate test methods the mix will then need to be graded against can then be identified and laboratory and field trials can commence.

The following Sections of the Business Case discuss the potential for the use of crushed glass in road construction in Australia and on a state-by-state basis. Each State/Territory Road Authority's specification has been reviewed and specific barriers to and opportunities for promoting a crushed glass product are discussed.

Where unreferenced, the theories and opinions within this report are based on interview and conversation with personnel within the asphalt and roads industries. A full list of contributors is provided in Appendix B.



4. Australian Capital Territory

4.1 Existing Specification

The ACT road authority, Roads ACT, defines roadbase as being made up of three distinct layers; base, sub-base and sub-grade material. The inclusion of glass in each of these layers is specified in Table 7. It is to be noted that this specification has not been written with the intent of including crushed glass as an aggregate, but rather makes allowances for the inclusion of glass as a foreign material.

Table 7 ACT – Inclusion of glass in granular layers⁴⁵

No.	Layer	% of non compressible high density materials such as mortar, metal, glass, asphalt, ceramics and slag permitted
1	Base	3%
2	Sub-base	3%
3	Sub-grade	25%

Section 4.05.3 of the TAMS Flexible Pavement (2002) specification details the materials permitted in the surfacing asphalt layer. This specification does not allow for the inclusion of glass as an aggregate or foreign material for any asphalt mix.

4.2 Barriers & Opportunities

4.2.1 Awareness

There appears to be little awareness of the feasibility of using crushed glass as an aggregate in asphalt or granular roadbase. As stated above, the inclusion of glass in the specifications is purely to cater for chance foreign materials being present in base and sub-base layers.

4.2.2 Perception

The perceived issues with the inclusion of crushed glass as an aggregate in asphalt and granular layers were primarily stated as being concerns surrounding strength and cohesion. More specifically, concerns were raised regarding the potential for glass to breakdown over time, decreasing the aggregate's structural strength. Additionally, it was perceived that there exists a low adhesion potential for the binder (eg bitumen) to adhere to the glass aggregate.

⁴⁵ Territory and Municipal Services (2002), *Standard Specification for Urban Infrastructure Works, Section 4, Flexible Pavement Construction*, http://www.tams.act.gov.au/___data/assets/pdf_file/0008/34685/SS04_Flexible_Pavement_01_00.pdf, pp 6-11



4.2.3 Infrastructure

There exist three major recycling centres in the ACT, supported by 4 smaller regional centres. Glass crushing facilities are, however, not available. Glass fines that cannot be recycled are currently sent to landfill or may be transported inter-state to crushing facilities in NSW.

4.2.4 Market Size

The comparatively small population of the ACT limits the market potential for the creation of and up-take of a crushed glass product. A 1998/99 study found that 4,096 tonnes of glass from municipal (domestic and council) waste was going straight to landfill.⁴⁶ While rates of recycling have increased steadily since this time, from 60% in 200-01 to 75% in 2005-06⁴⁷, there still exists a potential market for glass fines. Further study needs to be undertaken to define this market and to aid in determining potential markets and the optimal infrastructure to process this waste glass.

4.2.5 Research and Testing

Roads ACT is open to innovation but performance must be guaranteed.

Publishing and promoting reputable national and international research results may encourage uptake of this innovation. If the research is accepted by Roads ACT, then there exists the possibility to update the specifications to reflect this.

Roads ACT are currently requesting tenders for an Asset Management Plan for Roads for 2008-2011. Roads ACT could actively be encouraged to include the review/assessment of the use of crushed glass as an alternative product as part of the long term asset strategy, and include specific measures or timeframes for this.

4.2.6 Policy

The ACT has in place several sustainability, waste reduction and greenhouse policies. Additionally, sustainability must be considered in the process of procurement. The Territory Government prides itself on being committed to considering environmental issues in the performance of its activities. The following policies are to be supported by government agencies and complied with, as is possible:

- » **People, Place and Prosperity: A Policy for Sustainability in the ACT** - outlines a set of principles that clarify the concept of sustainability. These principles include using resources prudently and taking all costs and benefits into account.
- » **No Waste by 2010** - aims to improve markets for recyclable materials, encourages the purchase of recycled products and seeks to minimise the amount of waste sent to landfill arising from Government operations.

⁴⁶ ACT Government (2000), *The Next Step in the No Waste Strategy*, http://www.tams.act.gov.au/_data/assets/pdf_file/0015/12462/thenextstepinthenowwastestrategy.pdf, pg 6

⁴⁷ Australian Bureau of Statistics (2007), *1307.8 – Australian Capital Territory in Focus*, <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/A33E74BE4D1B16D0CA2573A1007B33F6?opendocument>



- » **ACT Greenhouse Strategy** - seeks to reduce Greenhouse gas emissions resulting from government procurement.
- » **The Sustainable Procurement Circular 2007/08** - requires that agencies consider existing Government Policies, design for the environment, environmental performance; and demand management opportunities when undertaking procurement.

The above policies provide a platform from which the use of crushed glass as an aggregate in asphalt and roadbase can be promoted. Specifically, raising the awareness of personnel within Roads ACT in the sustainability/environment and contract/project management groups may aid the acceptance and use of crushed glass as an aggregate.

5. New South Wales

5.1 Existing Specification

The RTA allows the inclusion of glass in base, sub-base and formation, as detailed in Table 8. These allowances are also applicable to stabilised base and sub-base, as per specification R75 *In Situ Pavement Recycling by Deep-Lift Cementitious Stabilisation*.

Table 8 Limits of foreign material for recycled building material

Foreign material type	Traffic category	Maximum limit by mass (test method RTA T276)		
		Base	Sub-base	Formation
Type I: metal, glass, asphalt, stone, ceramics and slag (other than blast furnace slag)	1, 2(a) and 2(b)	3%	5%	5%
	2(c) and 2(d)	5%	5%	5%

Inclusion of glass in wearing courses, including asphalt mixes, is limited. Table 9 provides details of the materials permitted within each wearing course type. To date the use of crushed glass has been limited to inclusion in Coloured Surface Coatings for Bus Lanes and Cycleways. Although the majority of the other listed specifications do not exclude crushed glass as an aggregate, crushed glass has not been accepted as an aggregate to date. Submission for testing of a mix containing crushed glass would provide a test of these specifications.

Figure 7 Bus lane



Table 9 NSW – Material Inclusions in Wearing Courses

No.	Wearing Course Type	Specification No.	Material inclusion
1	Unbound and Modified Pavement Course	R71	Unbound or modified pavement material must comply with RTA 3051 (refer to Table 8 above).
2	Heavily Bound Pavement Coarse (Plant Mixed Using Slow Setting Binders)	R73	Either manufactured or derived from natural deposits.



No.	Wearing Course Type	Specification No.	Material inclusion
3	In Situ Pavement Recycling by Deep-Lift Cementitious Stabilisation	R75	Materials to be stabilised in accordance with this Specification may include: additional pavement material; existing base, sub-base or selected formation material which may already be bound; and any combination of these materials, together with the existing bituminous seal, or asphalt wearing coarse, and/or patching materials unless such latter materials have been explicitly excluded in the Contract documents.
4	Coloured Surface Coatings for Bus Lanes and Cycleways	R110	Natural stone or synthetic material.
5	Dense Graded and Open Graded	R116	Crushed rock, metallurgic slag or gravel.
6	Stone Mastic Asphalt	121	... aggregates must conform to the requirements of AS 2758.5... [...aggregate may be produced from rock, gravel, metallurgic slag or suitable synthetic materials.]
7	Thin Open Graded Asphalt Surfacing (TOGAS)	R123	... aggregates shall conform to the requirements of AS 2758.5 ... [...aggregate may be produced from rock, gravel, metallurgic slag or suitable synthetic materials.]

5.2 Barriers & Opportunities

5.2.1 Awareness

Although included in the mix for Coloured Surface Coatings for Bus Lanes and Cycleways, personnel at the RTA were primarily unaware of the feasibility of using crushed glass as a replacement aggregate in asphalt and/or roadbase.

Although typical of most large organisations, the difficulty of targeting the decision makers within the bureaucracy of the RTA, and raising their awareness and acceptance, was noted as a particular challenge.



5.2.2 Perception

The view has been expressed that the use of crushed glass as a pipe embedment material was imposed upon Sydney Water Corporation by the Department of Environment and Conservation. Given this, there still appears to be a natural resistance to adoption by project managers and engineers.

Although there is a strong sustainability and environmental argument for the use of crushed glass in road construction, the product itself has positive attributes such as excellent compaction properties, light reflecting characteristics, skid resistance properties and stability value, that should support the argument for using the product on an engineering basis, given use in the right circumstances.

5.2.3 Infrastructure

Major recycling facilities in NSW including glass crushing facilities are operated by Thiess Services and Visy Industries. The Thiess glass crushing plant in the Hunter Valley processes 2,600 tonnes of glass per annum for alternate use. This glass would have previously been sent to landfill.⁴⁸

Visy Industries, in partnership with Benedict Sand and Gravel, are in the process of establishing a major glass fines processing plant in Moorebank, NSW. This plant has received funding from the National Packaging Covenant and will process 20,000 tonnes of glass fines, previously stockpiled or sent to landfill.⁴⁹

5.2.4 Market Size

It is estimated, on an annual basis, that there exists a potential 75,000 tonnes of glass fines material available in NSW for use as a crushed glass product, including usage in road construction.⁵⁰

5.2.5 Research and Testing

The RTA currently has projects underway to investigate and test the potential for the use of crushed glass in concrete. Following on from these projects, there exists the opportunity to maintain the momentum, particularly if met with success. If successful, the exposure of personnel and decision makers within the RTA to the potential applications and advantages of using crushed glass will provide a springboard, creating an optimum opportunity for acceptance to explore the potential of expanding the use of crushed glass to asphalt and roadbase.

⁴⁸ Thiess Services Pty Ltd (2008), *Hunter Valley Materials Recycling Facility*, http://www.milbrodale-p.schools.nsw.edu.au/Photos/2008/Thiess/mrf_bro2.pdf, pg 4

⁴⁹ The National Packaging Covenant (2007), *Current Projects, Establishment of Glass Fines Processing Infrastructure in Sydney Metropolitan Region*, <http://www.packagingcovenant.org.au/page.php?name=establishmentofglassfinesprocessinginfrastructureinnsydneymetropolitanregion>

⁵⁰ Department of Environment & Climate Change NSW (2007) *op. cit.*, pg 2



Benedict Sand and Gravel are producing crushed glass and have been involved in the trials and testing for crushed glass as a pipe embedment material. Additional research and testing is in progress, including testing of asphalt with a crushed glass content.

5.2.6 Policy

RTA Policy

The RTA has in place a Waste Minimisation Policy, in-line with the NSW Government's Waste Reduction Purchasing Policy (WRAPP), 1997. WRAPP includes the requirement for State Government agencies to act as model waste managers, including purchasing recycled-content road construction and maintenance materials.

The RTA's Waste Minimisation Policy includes the following provision:

RTA contractors are now required to propose recycled-content materials where they are cost- and performance-competitive and are at least the environmental equivalent of the non-recycled alternatives. The cost competitiveness of a product or material must be assessed on a project lifecycle basis, considering issues such as impacts on construction practices, future maintenance and disposal requirements. Contractors are also required to report waste minimisation quantities, initiatives and barriers.

RTA NSW (2006) *Waste Minimisation*, <http://www.rta.nsw.gov.au/environment/wasteminimisation/index.html>

Within its annual report, the RTA is to report on the Authority's progress in implementing WRAPP, additionally the RTA provides a comprehensive WRAPP progress report to the Department of Environment and Conservation (DEC) every two years.⁵¹

Opportunity exists for the RTA to improve its performance under WRAPP by actively encouraging the use of crushed glass in road construction.

Greenspec

In 2003 Resource NSW released its first "GreenSpec", see Figure 8 for details. This specification aims to increase the use of recycled concrete, brick and asphalt materials in the public works engineering sector.

Figure 8 Resource NSW GreenSpec

Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage

The Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage is the first industry wide specification for the use of recycled materials in local roads, other pavements and civil works.

The Specification outlines a variety of uses of recycled aggregates including:

- » Roadbase material suitable for a range of traffic conditions;
- » Select fill for improving sub grade performance and also for raising site levels;

⁵¹ RTA NSW (2006) *op. cit.*



- » Bedding material suitable for use as a base layer for pavers; and
- » Drainage medium for backfilling drainage structures.

The Specification is about providing standards that are performance based.

The Specification sets the standard for the recovery industry to supply quality recycled materials. This in turn provides the confidence required in the marketplace for designers, specifiers, councils and contractors.

Resource NSW (2003), *Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage*, <http://www.environment.nsw.gov.au/warr/greenspec.htm>

Opportunity exists to follow on from this *GreenSpec* and encourage the development of other specifications that will encourage industry uptake of alternative products, such as crushed glass. There are potential sponsorship opportunities to support a crushed glass specific specification. Following on from trials and publishing, industry conferences, technical seminars and/or roadshows could be used as a vehicle to promote the product and raise awareness. The Department of Environment and Conservation NSW also support the push for the development of such a specification.⁵²

⁵² Department of Environment & Climate Change NSW (2007), *NSW Waste Avoidance and Resource Recovery Strategy 2007*, http://www.environment.nsw.gov.au/resources/warr/07226_WARRreport07.pdf, pg 26



6. Northern Territory

6.1 Existing Specification

The aggregate component of asphalt mixes as defined by the Northern Territory Transport Group specification state that fine aggregate is to be natural sand and/or material manufactured from crushed stone and coarse aggregate is to be sourced from crushed stone. No provision is made for the use of recycled or reclaimed materials, including crushed glass.

It is noted, however that the specification for Pavements and Shoulders (06, 2006) does not specify the source material for Sand Clay, but has performance based measures. This clause could be interpreted to allow for crushed glass in the form of manufactured sand, however it must be considered that this was not the original intent of the clause.

6.2 Barriers & Opportunities

6.2.1 Awareness

There appeared to be very little awareness of the feasibility of using crushed glass as an aggregate in asphalt mix or roadbase.

Within NT Transport Group, the policy and specification changes are largely driven by the project managers and personnel on the ground. This suggests that the influencers to enlist in driving change towards the adoption of crushed glass as an aggregate in asphalt and roadbase are the project managers, rather than the policy makers.

6.2.2 Perception

There is no existing specification in the Northern Territory for the use of recycled products, such as reclaimed asphalt or crushed concrete. While discussions with NT Transport Group indicated that the organisation is “open to innovation”, similar barriers experienced in other states when implementing and gaining acceptance of the use of reclaimed asphalt and crushed concrete would be expected.

6.2.3 Infrastructure

There are currently no crushing facilities in the Northern Territory. Given the remote nature of the towns and centres within the Territory, a mobile crusher may be best suited. A cost-benefit analysis may be beneficial to determine the best type of glass crushing infrastructure to cater for the population and environment.

6.2.4 Market Size

With a population of approximately 220,000 people, the generation of potential waste glass to be used as a resource for the use in asphalt and road-base is limited.



6.2.5 Research and Testing

Above Capricorn Technologies received a grant from the Packaging Stewardship Forum / Environment Grants Program to conduct a study to establish the glass recycling opportunities within the Northern Territory.

The project is nearing completion, with the final report due for release in October 2008. The project aims are to:

- » Identify the volumes and types of glass entering the Darwin region and the NT;
- » Investigate glass management systems in use;
- » Document a range of waste glass management options, including mobile glass crushing plant; and
- » Investigate local end-uses such as the development of crushed glass products suitable for abrasive grit or reflective paints on roads, coloured glass landscape pebbles, speciality bench tops, crushed glass in walking trail construction, glass 'sand' for asphalt.⁵³

Potential exists to use the information established during this study to undertake testing or trials of recommended actions in association with Above Capricorn Technologies and the NT Government.

6.2.6 Policy

The Northern Territory Government recognises the potential environmental benefit that can be achieved through:

- » Buying goods and services that seek to minimise possible environmental impact;
- » Government processes such as procurement, waste management/resource efficiency policies and support resources; and
- » Establishing agency-wide waste management policies.

Despite the above, the prominence of policy and guidelines for waste management, procurement and sustainability within the Department of Planning and Infrastructure and more specifically the NT Infrastructure Group, has limited exposure in the public forum.

⁵³ Northern Territory Government (2007), *Environmental Grants 2007-08*, <http://nreta.nt.gov.au/nreta/environment/grants/200708/individual.html>



7. Queensland

Main Roads is committed to managing its road network in a manner that optimises environmental outcomes for natural, human and built environments.

Department of Main Roads (2008), *Looking After Queensland's Environment*,

<http://www.mainroads.qld.gov.au/web/careerCR.nsf/DOCINDEX/Looking+after+Queensland's+environment>

7.1 Existing Specification

Main Roads Queensland's specifications for asphalt (MRS11.30, MRS11.34, MRS11.36) do not include provision for any recycled product, including crushed glass, as an aggregate. The aggregates permitted are summarised in Table 10.

Table 10 Main Roads Queensland Asphalt Aggregates

No.	Aggregate	Source
1	Coarse aggregate	Crushed rock or crushed gravel
2	Fine aggregate	Natural sand particles and/or crushed rock or crushed gravel particles
3	Filler	Natural sand particles and/or crushed rock or crushed gravel particles

The specification for base and sub-base state that material is to be sourced from a quarry that has Main Roads' certification. There is no existing specification for the use of recycled crushed concrete as an aggregate in base or sub-base, however it was indicated by personnel at Main Roads, that where the properties of a base or sub-base mix could be shown to be equivalent to a quarry-sourced mix, the use of crushed concrete may be approved. The inclusion and acceptance of glass within a recycled crushed-concrete mix is not clear.

7.2 Barriers & Opportunities

7.2.1 Awareness

There is limited awareness within organisations in Queensland of the potential for the use of crushed glass in asphalt and road-base.

Munduberra Shire Council in Northern Queensland has, however, shown interest in the use of crushed glass in drainage and road base. This interest has been spearheaded by the local Lions group.



7.2.2 Perception

Given the lack of Main Roads specification for inclusion of any recycled materials, there may be significant resistance and/or cultural barriers to the acceptance of crushed glass as an accepted material.

7.2.3 Infrastructure

Visy operates the major glass crushing facility in Queensland. Currently there is no process for the recycling of glass fines.

7.2.4 Market Size

The potential market size for glass fines in Queensland is considerable with a 2004 study reported 83,203 tonnes of glass going to landfill.

7.2.5 Research and Testing

Representatives of Main Roads (Qld) expressed particular interest in the characteristic of crushed glass to increase skid resistance when included in an asphalt mix, for example, Su & Chen (2002).

Given the ability for crushed glass to improve skid resistance, there is opportunity for crushed glass to be classified as an Additive. Main Roads (Qld) specifications state; "an additive may be proposed provided that full details of the type of additive are provided and the mix design standards of Clause 8.3 are attained".⁵⁴

7.2.6 Policy

Local Government Authorities in Queensland tend to base their specification on that of Main Roads (Qld), and therefore the opportunity to innovate and introduce a crushed glass product is heavily reliant on acceptance and approval from Main Roads (Qld) in the first instance.

⁵⁴ Main Roads Queensland (2006), *Main Roads Standard Specification, Open Graded Asphalt Surfacing*, clause 8.2.6, pg 5



8. South Australia

8.1 Existing Specification

In South Australia the existing Transport (SA) specifications clearly define the source of materials. There is extensive scope for inclusion of recycled materials in base and sub-base, inclusive of recycled crushed concrete. However, this is limited to brick, tile and asphalt. No recycled materials are permitted for inclusion in asphalt aggregate. Refer to Table 11 for Transport (SA) recycled product inclusions.

It is of note that the specification for stabilised pavement material does not specifically exclude the use of crushed glass, stating that where approved, recycled materials may be used. Additionally, where specified that quarried materials are to be used, the contractor may request that Recycled Material be used in lieu.⁵⁵ To date, crushed glass has not been proposed or accepted as a recycled material for use in base or sub-base by Transport (SA).

Table 11 Pavement Material Specification: Part 215 Appendix 1

No.	Recycled material permitted	Product
1	No recycled material is permitted to be included.	Spalls source materials Road ballast source materials Class 3 quarried pavement material (grading based) source materials Class 2 quarried pavement material (grading based) source materials Class 2 quarried pavement material (performance based) source materials Class 1 quarried pavement material (grading based) source materials Class 1 quarried pavement material (performance based) source materials Class 1 heavy duty quarried pavement material (grading based) source materials Sealing aggregate source materials Sand source materials Asphalt aggregate source materials
2	Supplementary source materials may comprise brick, tile and asphalt (20% by mass).	Class 3 recycled pavement material (grading based) source materials Class 2 recycled pavement material

⁵⁵ Department for Transport, Energy and Infrastructure (SA) (2008), *Specification: Part 215 Supply of Pavement Materials*, pg 7



No.	Recycled material permitted	Product
		(grading based) source materials Class 2 recycled pavement material (performance based) source materials Class 1 recycled pavement material (grading based) source materials Class 1 recycled pavement material (performance based) source materials
3	Where approved, recycled materials.	Stabilised pavement material (binder control) source materials Stabilised pavement material (strength control) source materials

8.2 Barriers & Opportunities

8.2.1 Awareness

There is limited awareness within both the road construction and environmental policy sectors regarding the potential use of crushed glass as an aggregate.

8.2.2 Perception

In discussion with representatives from Transport (SA) and the Department for Environment and Heritage, it was made clear that there is a perception in South Australia that the Container Deposit scheme caters for glass container recycling and there is limited glass going to landfill that could be potentially utilised as a resource for use such as crushed glass in asphalt or roadbase.

8.2.3 Infrastructure

Veolia and Visy both have plants in South Australia. Infrastructure has been developed to encourage the recycling and re-use of construction materials, however crushed glass is not considered as a resource in this respect.

8.2.4 Market Size

There are no studies available detailing the tonnage of glass that goes to landfill, either from failure to use the Container Depots and kerbside collection, or as glass fines from the Depots that are unsuitable for recycling. It is arguable that there is a significant glass resource available that is not collected as part of the container deposit scheme, for example wine bottles and other glass food containers, that could be diverted from landfill. Further research is required to substantiate the potential of glass fines that could be diverted from landfill in South Australia.



With a population of approximately one and a half million people, the generation of potential waste glass to be used as a resource for the use in asphalt and road-base is limited.

8.2.5 Research and Testing

The potential resource (glass fines current disposed of in landfill) that could be used in asphalt and/or road-base could be quantified. Once established, this information and the opportunity for use of crushed glass in asphalt and road-base should be disseminated to influencers in Transport (SA) and the Department for Environment and Heritage.

8.2.6 Policy

There is opportunity to raise the awareness of the existence of the glass fines market and promote the use of crushed glass as an aggregate through the Zero Waste SA Board. The use of glass fines within road construction is an opportunity to demonstrate compliance with the Zero Waste SA Act 2004.



9. Tasmania

There are many potential resources being deposited to landfill every day, some of which are too costly to re-use or reprocess, whereas others may be easily recovered. There is also a high amount of incomplete recycling/re-use occurring at present, where many items with recycling/re-use systems in place are still ending up as litter or in landfill.

Department of Environment, Parks, Heritage and the Arts, Tasmania (2008) *Living Environment Program, Waste Management*, http://www.environment.tas.gov.au/lep_waste_management.html

9.1 Existing Specification

The Tasmanian Department of Infrastructure, Energy and Resources state in their Roadworks Specification (R40, 2008) that the aggregate in pavement base and sub-base “shall be produced from natural gravel, crushed rock or a mixture of both”. There is no provision for crushed concrete or foreign materials, including glass.

Aggregate for asphalt is also limited to those produced from source rocks, natural gravel and reclaimed asphalt.⁵⁶ There is no provision for the inclusion of foreign materials in the mixes specified.

9.2 Barriers & Opportunities

9.2.1 Awareness

There appears to be little awareness of the feasibility of using crushed glass as an aggregate in asphalt mix or roadbase within the LGAs and SRA.

A representative from the Department of Infrastructure, Energy and Resources has requested information regarding the existing use and possible applications for crushed glass in roads for circulation and tabling within the Department. The Department to date has been unaware of the potential for the use of crushed glass as an aggregate.

9.2.2 Perception

In discussion with stakeholders in Tasmania, it was perceived that there exists an eagerness to further establish the benefits and opportunities for the use of crushed glass in road construction.

9.2.3 Infrastructure

Funding has been provided through the National Packaging Covenant to Veolia for the establishment of a Hobart Glass Crushing Plant, to process the recovered glass

⁵⁶ Department of Infrastructure, Energy and Resources (2006), *Roadworks Specification, G7 – Asphalt Production*, http://www.transport.tas.gov.au/road_bridges_tas/specifications2/specification_listings



enabling use of the glass fines product as an aggregate for a range of end purposes. Building of the proposed plant is yet to commence.⁵⁷

9.2.4 Market Size

With a population of approximately half a million people, the generation of potential waste glass to be used as a resource for the use in asphalt and road-base is limited.

The major glass recycler in Tasmania, Veolia, estimates a potential market for glass fines of 4,000 tonnes per annum from their existing recycling plant.⁵⁸ There is opportunity, with the establishment of a glass crushing facility in Hobart, for the plant to process further glass fines from additional sources.

9.2.5 Research and Testing

The Resource Recovery Project, funded by the Department of Environment, Parks, Heritage and the Arts, offers grants to financially support case studies and the promotion of outcomes for funded projects, designed to increase the recovery of resources in Tasmania. The next round of grants will not be awarded until at least 2010. There is potential and opportunity for an organisation or consortium to apply for State assistance to fund research into the establishment of crushing facilities and/or the use of crushed glass as an aggregate in asphalt and road-base.

Samples of crushed glass have been submitted to Roadways Pty Ltd (Roadways) for testing as a component of asphalt. Glenorchy, Clarence and Hobart Councils have expressed interest in using, as is appropriate, asphalt with a crushed glass component. There exists interest and opportunity for the identification of an appropriate road within one of the local government areas for the trial of asphalt containing crushed glass, in partnership with Roadways.

9.2.6 Policy

The Tasmanian Landfill Sustainability Guide

Compliance by landfill operators with the state Landfill Sustainability Guide, 2004, is expected by 30 June 2009.⁵⁹ The guide includes requirements for resource conservation, land management and landfill waste avoidance. Opportunity exists to lobby landfill operators, in partnership with councils and the state government, to support or invest in the investigation for and establishment of glass recycling/crushing facilities. Participation by landfill operators would actively demonstrate their willingness to comply with the Landfill Sustainability Guide.

⁵⁷ Parker, R (2008) In conversation with, Veolia

⁵⁸ National Packaging Covenant (2007) *op. cit.*

⁵⁹ Department of Environment, Parks, Heritage and the Arts (2004), *Landfill Sustainability Guide 2004*, http://www.environment.tas.gov.au/_downloads/Landfill_Sustainability_Guide%202004.pdf



Procurement Principles

The Tasmanian government *Procurement Principles: building and construction/roads and bridges*, specify that:

“Agencies must pursue value for money purchasing outcomes.

Value for money means achieving the desired outcome at the best possible price. The assessment of value for money includes:

- » fitness for purpose;
- » weighing up the benefits of the construction against the cost of purchase;
- » maintenance costs;
- » climate change and environmental considerations (including energy conservation);
and
- » risks.”⁶⁰

Clearly demonstrating and establishing the costs and benefits associated with the adoption of the use of crushed glass as an aggregate, in place of a natural resource, would aid with government departments (and local councils, where a comparable procurement policy exists) with demonstrating compliance with these principles. This in turn, could aid in creating momentum towards accepted use of a crushed glass product.

⁶⁰ Department of Treasury and Finance (2008), *Tl. 1201 - Procurement Principles: building and construction/roads and bridges*, <http://www.treasury.tas.gov.au/domino/df/df.nsf/v-ti/3DE082FDC20420D7CA257474000E4C16>



10. Victoria

10.1 Existing Specification

VicRoads' Specifications for Class 2, 3 and 4 sub-base and asphalt aggregates are based on Specification 801, which specifies the types of source rocks permitted and provides use of other sources as approved and permitted by the superintendent, given specific testing and quality control.

The specification does not allow for the inclusion of crushed glass in crushed rock subbases or asphalt mixes specifically. The specification does, however, provide for the submission of mixes outside the specification as long as they can meet specified performance criteria. One asphalt mix containing crushed glass has been given Conditional Approval.

Glass is permitted in recycled crushed concrete, however this is as a foreign material, rather than as an aggregate. The percentages permitted are provided in Table 12.

Table 12 VicRoads - Foreign Materials Permitted in Recycled Crushed Concrete (maximum allowable %)

Foreign Material Type	Class CC2	Class CC3	Class CC4
High density materials such as metal, glass and brick	2	3	5
Low density materials such as plastic, rubber, plaster, clay lumps and other friable material	0.5	1	3
Wood and other vegetable or decomposable matter	0.1	0.2	0.5

10.2 Barriers & Opportunities

10.2.1 Awareness

Local Government Authorities, including Hume, Melton, Yarra, Brimbank and Knox are using, or have expressed interest in using, crushed glass in road construction. Melton Council have trialled using a basecourse product containing crushed glass in one road construction project. The product has initially shown good performance. Monitoring of this project and advertising of the results could encourage other LGAs to use a similar product.

Council representatives stated that they could not specify a preference in tender specifications for the use of crushed glass over natural aggregate (as has been done in City of Canning WA), as this would conflict with competition/tender guidelines, as there is only one provider of the product in Victoria (Alex Fraser). It could be argued



however, that if a clause were included, manufactures would soon provide a conforming product. Additionally, Visy and Benedict Sand and Gravel are in the process of opening a plant in Victoria that will stock a competing product.

10.2.2 Perception

Although VicRoads are progressive in their application of crushed glass and have given conditional approval for one asphalt mix containing crushed glass, there are still apparent some misconceptions in relation to the technical characteristics of crushed glass. There was concern expressed that the glass would breakdown over time and that glass in wearing course layers would pose a safety hazard. This demonstrates a need or opportunity for education, awareness raising and testing.

It is argued by the suppliers that the costs for crushed glass are identical to virgin product, and the product is more environmentally friendly and sustainable. In contrast to this, VicRoads are of the impression that to obtain the required nominal size, additional, expensive grinding is required, and therefore the costs are greater.

10.2.3 Infrastructure

Alex Fraser is currently crushing glass fines and producing products using this as a substitute aggregate. Glass Granulates (Visy and Benedict) also has commenced operation at Visy's Laverton site in Victoria in March 2008 and will be expecting to produce in excess of 10,000 tonnes/month of GlassSand for several markets.⁶¹

10.2.4 Market Size

In Victoria in 2002/03, 21,250 tonnes of glass was recorded as not being suitable for recycling into glass containers.⁶² These glass fines could potentially be captured for use in road construction.

10.2.5 Research and Testing

It was stated by one council that there is not enough work to pursue the testing and specification development for the use of crushed glass in crushed rock roadbase. Collaboration between industry and councils Victoria-wide may identify a large enough potential market to warrant such research and development.

10.2.6 Policy

VicRoads Approval

In Victoria it is estimated that 80% of councils would not accept road construction specifications containing crushed glass without prior mix approval from VicRoads.

⁶¹ Benedict Industries (2008), *Company Profile*, <http://www.benedict.com.au/profile.html>

⁶² EcoRecycle Victoria (2004), *Glass Recycling*, http://www.ecorecycle.sustainability.vic.gov.au/resources/documents/Info_7_-_Glass.doc



Conditional Mix Approved

One mix has been approved by VicRoads as Conditional. Conditional mixes are defined as “Mixes which do not comply in all respects with the requirements of Code of Practice RC500.01 but which are considered appropriate for use subject to conditions attached to the registration”.⁶³ There is an opportunity to promote the use of this asphalt mix and report on its successful application to encourage further acceptance and development, submission and approval of other mixes containing a crushed glass component.

VicRoads – Resources and Recycling

VicRoads states that they promote the use of recycled materials and sustainable procurement and that “recycled materials can be used in road construction, provided they meet specified performance criteria”.⁶⁴ An opportunity exists to challenge VicRoads to act on this statement and further encourage and endorse the inclusion of crushed glass in road construction as well as participate in industry research and testing.

Sustainable Design and Construction Guidelines for Capital Works Projects

The Victorian Department of Sustainability and Environment released in 2003 guidelines titled Principles and Guidelines for Capital Works Projects. These Guidelines include the provision to “maximise the use of recycled content material where there is a cost difference of less than 5%”.⁶⁵ A cost-benefit analysis could be conducted to demonstrate a cost difference of less than 5% between crushed glass and equivalent virgin material (for example natural sand). This would then create an obligation on government agencies to replace sand with crushed glass, where it meets the technical performance specifications.

⁶³ VicRoads (2006) *Section 407 - Hot Mix Asphalt Specification*, pg 7

⁶⁴ VicRoads (2008), *Resources and Recycling*,
<http://www.vicroads.vic.gov.au/Home/PublicTransportAndEnvironment/Environment/EnvironmentalProtection/ResourcesAndRecycling.htm>

⁶⁵ Department of Sustainability and Environment (2003), *Principles and Guidelines for Capital Works Projects*,
[http://www.dse.vic.gov.au/dse/nrence.nsf/93a98744f6ec41bd4a256c8e00013aa9/50f990be90fcedc2ca256ee00027bd61/\\$FILE/ESDC%20Guidelines%20-%20Vers%201B%2020031210.pdf](http://www.dse.vic.gov.au/dse/nrence.nsf/93a98744f6ec41bd4a256c8e00013aa9/50f990be90fcedc2ca256ee00027bd61/$FILE/ESDC%20Guidelines%20-%20Vers%201B%2020031210.pdf), pg 8



11. Western Australia

11.1 Existing Specification

The MainRoads (WA) Asphalt Surfacing Specification (504, 2008), specifies coarse and fine aggregate used in the manufacture of asphalt shall consist of crushed rock material. This excludes the possibility of using crushed glass as an aggregate.

Glass is permitted in Crushed Recycled Concrete Sub-base and is classified as a foreign material, as shown in Table 13. No specific allowance for glass is made for the inclusion of glass in crushed rock base or sub-base.

Table 13 WA - Glass inclusion in Crushed Recycled Concrete Sub-base

No.	Layer	% of glass permitted as a foreign material
1	Basecourse	5%
2	Sub-base	15%

11.2 Barriers & Opportunities

11.2.1 Awareness

Having a champion for crushed glass within such a strategic organisation is a significant opportunity to promote the acceptance and use of crushed glass in road applications. To take advantage and to continue the progress made by LGAs in the use of crushed glass in road construction, appropriate champions within the LGAs and related associations could be targeted to act as an advocate for the material. Providing such champions with up to date information in the form of material properties, examples of test results and sample specifications could aid in effectively disseminating accurate information and raising awareness and profile of the crushed glass product.

The Local Government Authorities in Western Australia, specifically City Canning and City of Gosnells, appear to be the most active in championing the use of crushed glass in asphalt and roadbase. Using the success of implementation and adoption in these Councils, and the research and trials already conducted, provides opportunity to promote further use and uptake by Local Government Authorities in Western Australia and nationally.



Figure 9 City of Canning Recycled Materials Specification

City of Canning - Use of Recycled Materials

Up to 10% by weight of RAP will be included in any mix used within the City, and increased proportions may be requested in certain cases.

In addition, in order to maximize the use of recycled products, the City will encourage the use of up to 10% recycled container glass in a significant portion of the overlay programme on projects nominated by the Superintending Officer, and in certain trials may request higher percentages to be used.

The use of other recycled products will be well regarded and preference will be given to Contractors indicating willingness to further research into the use of recycled materials in asphalt.

The City will also encourage research into the inclusion of crushed waste high tensile plate glass.

City of Canning Council (2006), *Technical Specification- Hot Asphalt 07, Use of Recycled Materials*, Clause 2.1.4

11.2.2 Perception

Community

As the collectors of used glass containers for recycling, there is opportunity for councils to complete the recycling loop, using glass collected at the kerbside as crushed glass in road construction. This provides ratepayers with a practical demonstration of the contribution their recycling can make. In turn, this visibility may aid in increasing community awareness of recycling and endorsement and/or demand for the preference for recycled construction materials as opposed to virgin resources used by Council and, in turn, government authorities, including MainRoads.

MainRoads Acceptance

Despite the acceptance of crushed concrete as an aggregate for base and sub-base in other states, debate and discussion continued for approximately 5 years before trials of the product started and MainRoads accepted crushed concrete as a potential aggregate. Similar barriers can be expected on the introduction of discussion to promote the use of crushed glass in asphalt and roadbase. Discussion with MainRoads and other industry representatives indicated that, as experienced in other states, there exists a barrier to the acceptance of crushed glass at the project manager and engineer level.

Cost was raised as being a particular barrier in Western Australia. It is viewed that the cost of natural products is such that there exists no cost advantage to using recycled products, specifically crushed glass as compared to natural sand. A cost-benefit analysis taking into account the unique West Australian environment may aid in demonstrating the holistic costs associated with using natural versus recycled products.



11.2.3 Infrastructure

Pioneer Road Services is in the process of importing glass crushing plant from the USA. This facility will be used to process glass for many end uses, including road construction.

The LGA of Augusta is also in the process of establishing a glass crushing plant, funded by the National Packaging Covenant, which will be available to service the surrounding LGAs. The project aims to divert over 800 tonnes of glass waste from landfill and is expected to commence in September 2008. It is anticipated to be in full production by February 2009, achieving its target of 870 tonnes within 12 months of production.⁶⁶

11.2.4 Market Size

A 2006 study found that 80,000-90,000 tonnes of container glass is generated in WA annually. Approximately 20,000 tonnes is recovered for recycling (trained to SA).⁶⁷ The remaining 60,000-70,000 tonnes is either sent to landfill, stockpiled or utilised in existing glass fines projects.

11.2.5 Research and Testing

City of Canning Council and Pioneer Road Services are both currently undertaking research and testing of asphalt and road constructions containing a crushed glass component.

11.2.6 Policy

MainRoads 2007 Action Plan for Resource Conservation

The MainRoads 2007 Action Plan for Resource Conservation, as required by the Sustainability Code of Practice for Government Agencies, includes the following action points:

- » Measure and report imported materials (includes sand and aggregate) used in road construction and waste to landfill; and
- » Evaluate environmental benefits of using recycled product in road building.

⁶⁶ Shire of Augusta (2008), Media Release – Shire plans to process glass for local market, <http://www.amrsc.wa.gov.au/exec/files/080724ProcessingGlassForTheLocalMarket.pdf>

⁶⁷ Prince Consulting Pty Ltd (2006), Market Development Study – Used Glass, pg 27



12. Summary & Recommendations

International research and on-road trials have demonstrated that crushed glass can be successfully used as an aggregate in asphalt and roadbase. The acceptance and use of the crushed glass product in road construction in Australia is also gaining momentum.

Currently the SRA's in Australia do not accept crushed glass as an aggregate within their specifications. This does not, however, preclude crushed glass from being used. For there to be acceptance of crushed glass as an aggregate, it must be demonstrated that an asphalt or roadbase mix can meet the required properties and performance measures. These results, together with successful field trials and corporate procurement and sustainability policies, will provide a strong argument for acceptance by the SRAs.

There are opportunities for research and testing to be jointly funded and undertaken by industry partners and interested LGAs and SRAs. Additionally, many state and federal departments offer funding for research into waste management and resource sustainability.

A growing number of LGAs in Australia, particularly in Western Australia, are accepting the use of crushed glass as an aggregate in their specifications. Given that LGAs manage and maintain lower trafficked roads than SRAs and the political environment within which they operate (ie sustainability and procurement policies and objectives), in the short-term there may be an increased scope in the ability to influence and encourage the use of crushed glass in road construction.

Throughout SRAs and LGAs there is little known on the possibility and feasibility of utilising crushed glass as an aggregate. Where aware of a crushed glass product, there exist many misconceptions in regards to its properties and safety. A marketing campaign, together with the industry leaders in crushed glass production, could greatly aid in increasing the size of the informed-market. In addition to targeting road and asphalt engineers, sustainability and procurement policy makers and managers should also be targeted for improving awareness, and potentially could aid in championing a crushed glass product.

Where great scepticism exists in regards to availability and costs, for example in Western Australia and South Australia, it may be beneficial to complete a detailed cost-benefit analysis to provide quantitative evidence for or against the potential for a crushed glass product and road construction market.

Providing sound and proven analysis and results for performance and benefits, including both environmental and technical advantages, will not only aid in breaking the barrier of misinformation and lack of awareness, but will also aid in overcoming the cultural barriers to change. A proposed action list to begin this process is as follows:

1. Establishment of an interest group incorporating stakeholders from industry, LGAs and associations (ARRB, APPA, IPWEA) to confirm the status of existing testing



and research, and develop specifications and requirements for further testing to aid in gaining acceptance of the crushed glass product.

2. Source funding for and engage ARRB to complete testing, publishing the results, possibly including State Departments and resulting in a GreenSpec, or similar.
3. Launch an awareness campaign targeting key personnel, such as environmental policy makers and asphalt engineers within LGAs and SRAs. The contributors listed in Appendix B of this report could also be included.
4. Support and encourage the establishment of appropriate crushing infrastructure in regions that have adequate market size and local champions.
5. Lobby the AAPA and SRAs to include crushed glass as a recognised aggregate in road construction in their relevant specifications.

Appendix A

Definitions & Abbreviations

Unless marked otherwise, the definitions in Table 14 have been sourced from VicRoads Specification 407.02.

Table 14 Definitions and Abbreviations

Term	Definition
Added Filler	Additive
Additive	A fine granular material, the majority of which passes a 0.075mm sieve, which is added to an asphalt mix to supplement or modify the properties of filler in the mixture. (AS 2150-2005)
Adhesion agent	A substance for the purpose of promoting the adhesion between a bituminous binder and aggregate. The term usually refers to adhesion in the presence of water. (AS 2150-2005)
Binder	Binder is bitumen, multigrade binder or polymer modified binder (PMB) used to hold a mixture of aggregates together as a cohesive mass.
Coarse Aggregate	General term used to differentiate between various sizes of aggregate, usually material retained on a 4.75mm sieve. (AS 2150-2005)
Dense-graded Asphalt	Asphaltic Concrete.
DOT	Department of Transportation
Fibre	An additive for reducing binder drain-off in stone mastic and open-graded asphalt mixes. (AS 2150-2005)
Filler	Material derived from aggregate or other granular material passing a 0.075mm sieve. (AS 2150-2005)
Fine Aggregate	General term used to differentiate between various sizes of aggregate, usually material passing a 4.75mm sieve. (AS 2150-2005)
Gap-graded aggregate	A graded aggregate in which one or more of the intermediate sizes are absent or present in small proportions. (AS 2150-2005)

Term	Definition
Manufactured Sand	Manufactured sand is a material passing the 4.75 mm sieve produced by crushing igneous or metamorphic rock spalls or washed gravel.
Mineral Matter	Mineral matter includes coarse and fine aggregates, plus filler.
OGA	Open Graded Asphalt/Mix – See Open Graded Mix
Open Graded Mix	Bituminous mix using aggregate containing only small amounts of fine material, and providing a high percentage of air voids. (AS 2758.5)
Polished Stone Value (PSV)	A measure of the resistance of aggregate to the polishing action of a pneumatic tyre under conditions similar to those occurring on the wearing course of a road. The PSV is a major indicator of potential for surface skidding.
PPE	Personal Protective Equipment
RAP	Reclaimed Asphalt Pavement
Reclaimed Asphalt Pavement	Asphalt removed from an existing asphalt pavement, and re-processed by crushing and/or screening for recycling into new asphalt.
Select Material Layer	The lower course of the pavement below the sub-base. The sub-grade layer.
SMA	Stone Mastic Asphalt
Spalls	A fragment broken off from the edge or face of stone or ore.
SRA	State Road Authority
UTA	Ultra Thin Asphalt

Appendix B

Contributors

Table 15 Contributors

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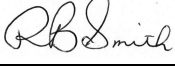
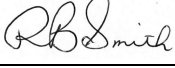
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