USE OF RECYCLED GLASS IN PAVEMENT AGGREGATE

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ABSTRACT

Fulton Hogan has been adding glass to aggregate production (all passing 40mm) at differing concentrations since 2005. Tests done on the final product have yielded good results for particle size distribution and compaction. Operational crews have commented that the material was easy to work and produced a good finish. To date the performance of pavements constructed with the aggregate is very good.

Two methods of producing the aggregate have been trialled with varying successes and drawbacks. A major issue is getting the glass without contamination of other paper, cardboard and plastic wrappers, which contaminate the basecourse.

Fulton Hogan have strongly encouraged sustainability throughout its business and view the recycling of glass into roading aggregates as providing excellent community benefit. Not only does the practice extend the life of landfills, it also conserves virgin rock resource for premium aggregate products. Local cuncils and state highway authorities are now proactively looking to use the process.

INTRODUCTION

Historically New Zealand has been fortunate to have plentiful supplies of easily accessible aggregate to service its infrastructure needs. In more recent years, strong demand for aggregates has combined with factors, such as reduced allocations of alluvial (riverbed) sources and neighbour sensitivity issues, to change this balance. Deposits of aggregate with consents (permits) are now a treasured resource and hence greater consideration of recycled aggregates is taking place.

The second factor that has played a part in a move to recycling is the similar issues (from below) facing landfills and cleanfill operations (heightened environmental standards, cost of land, neighbour sensitivities and increasing transport costs). Indeed it is often more expensive to dump cleanfill than to buy lower grade quarry material.

Against this background the use of recycling glass as a basecourse aggregate in pavements has been trialled.

Sustainability

In addition to the issues above, there has been a growing realisation (both in New Zealand and globally) that we need to adopt a more sustainable approach to the way we live and do business. Many Central and Local Government agencies now seriously consider sustainability when passing legislation or procuring services and triple bottom line reporting has become the norm in the business world.

Since the early 1990's many local governments (councils) have adopted recycling policies ranging from kerbside collection to drop-off stations. Prior to 2005 there was a market for recycled glass which allowed councils to recover most of their costs of collecting used glass bottles. However, at this time a fall in prices for recycled glass meant the economics became unfavourable, particularly when freight distances were high; as a majority of recycled glass was required in Auckland, most South Island areas fell into this high transport cost category.

Additionally a requirement to separate glass into different colours and sort debris from it was very labour intensive and ultimately uneconomic.

At this time many authorities took to putting the collected glass materials back in with their waste streams. The logic was that it was better to continue to condition the public into recycling in the hope that the recycled materials would restore value in time. Perhaps not unexpectedly, public reaction was negative when it was reported the products they were separating at home were being remixed further down the process.

The Nelson City Council was keen to find a more long term solution, and in partnership with our company began looking at the potential to introduce the collected glass into roading aggregates.

Nelson is a city of approximately 50,000 people located at the top of the South Island of New Zealand. It has an excellent port but its geographic location makes road transport expensive, and Nelson does not have a rail link. The city collects between 2000 to 3000 tonnes of recycled glass per annum.

Benefit cost analysis

To appreciate the full benefits and costs of this process, it is important to take a holistic view. A summary of positive and negative tangible and intangible costs are:

Benefits	Cost
– Reduced cost of transporting glass to landfill or distant reprocessing site	– Kerbside collection (likely to be carried out anyway)
– Reduced use of landfill air space	– Crushing Glass
– Less virgin aggregate being consumed	– Mixing with basecourse
– Improving environmental awareness/ attitudes	

Historically the value of the use of the landfill air space was not considered in the equation as landfills were easy to establish and relatively cheap to exit. Nowadays landfill construction and remediation is a very expensive exercise and the real cost of this activity has flowed on to the user.

The cost of transporting and disposing of a tonne of waste in a modern landfill in New Zealand varies between $NZ 50 to $NZ 80, which is approximately two to four times the cost of crushing and blending the glass into aggregate.

Another factor that has generally not been considered historically is the volume of landfills that bottles, etc took up if they were dumped without processing (1.1m³/t vs 0.7m³/t once crushed). Therefore crushing or taking the glass out altogether will lengthen the life of the landfill. In Nelson's case, 2000 tonnes per year would equate to an extra 55,000 m³ of landfill void space over 25 years.

Clearly we believe that as with many other sustainability initiatives – recycling glass makes good business-sense when a full assessment of all costs and benefits is made.

Crushing process

The supply of glass bottles and other containers generally contains a myriad of debris and associated product as can be seen in Figure 1 below. The stockpiles contain an amount of sugary liquid, and vermin (rats, etc) can be an issue.

Figure 1: Glass bottles with debris.

Two methods of producing the basecourse were trialled:

1. Introducing the glass into the raw feed of the parent aggregate.
2. Crushing the glass separately and blending this product into a separate basecourse crushing operation.

The first option involves the least cost, but has two major disadvantages:

(a) The amount of non-glass debris (paper, plastic, tops) is significant and even though its pulverised, it is still obvious in the aggregate, as shown in Figure 2. Improved quality expectation of glass supply and education of recyclers will reduce this issue.

Figure 2: Close-up of debris.

(b) Larger fragments of glass (particularly bottle bases) which, despite being rounded, still pose a safety risk to staff, pedestrians and vehicles coming into contact with the product.

This issue can be mitigated by using a shaping crushing plant (Barmac impactor or equivalent) in the crushing circuit.

In the second method the glass is screened out at 10mm and this appears to take out most of the debris. Figures 3 and 4 below show the operation used to manufacture the 10mm glass cutlet and the visual appearance of the basecourse with 5% glass added.

Figure 3: Process for crushing and screening glass.

Figure 4: Crushed glass blended into 40mm basecourse aggregate at 5%.

The process for crushing the glass separately involved a small jaw, hammermill and screen which returned product over 10mm in size. Periodically the oversize was ejected by which stage it generally consisted of pulverised plastic and metal. Higher wear of crushing plant was evident due to the high silica content of the glass. Additionally the daily outputs were quite low compared with crushing 100% rock.

Initially as a safety precaution full breathing apparatus was worn while crushing the glass. Tests on the dust reveal no greater risks compared with crushing standard aggregates.

The 10 mm down glass was then fed, at a rate of five percent by volume, into a plant producing 40 mm basecourse. A five percent blend was adopted in order to meet the requirements of the Transit New Zealand specification (TNZ M/4, 2006).

Product testing

Laboratory testing was carried out on the basecourse aggregate with and without the added crushed glass and the results are tabulated below. The addition of the glass did not render the basecourse aggregate incompliant with TNZ M/4 (2006) specification, and in fact, was undetectable by the tests specified by TNZ M/4 (2006), as show in Table 1 below. Nonetheless the glass particles were clearly visible in the aggregate.

Table 1: Production properties of aggregate with and without glass.

Criteria	Result		TNZ M/4 Specification
	0% Glass	5% Glass	
Percent passing 37.5 mm	100	100	100
Percent passing 19.0 mm	73	74	66 – 81
Percent passing 9.5 mm	51	54	43 – 57
Percent passing 4.75 mm	35	38	28 – 43
Percent passing 2.36 mm	24	25	19 – 33
Percent passing 1.18 mm	17	18	12 – 25
Percent passing 0.600 mm	12	12	7 – 19
Percent passing 0.300 mm	8	8	3 – 14
Percent passing 0.150 mm	6	4	0 – 10
Percent passing 0.075 mm	4	4	0 - 7
California Bearing Ratio (%)	210	270	80 minimum
Clay Index	2.7	2.8	3.0 maximum

Note: Particle size distribution results are derived from averaged data.

Further research on Repeat Load Triaxial testing of aggregates incorporating recycled glass is currently being carried out for Land Transport New Zealand.

Placement

Product containing 5% recycled glass was trialled on a street upgrade project for Nelson City Council. The Brook Street upgrade comprised 1.42 km of a dual carriageway rural/residential road. Of this 1.42 km, a 140 m section (chainage 1060 m to 1180 m) was constructed using the basecourse aggregate containing 5% glass.

Brook Street is moderately trafficked with traffic volumes of approximately 300 vehicles per day. The pavement design was 200mm thick granular pavement surfaced with a two coat chip seal.

Benkelman Beam rebound deflection testing was carried out on the site prior to application of the chip seal surfacing. The average deflection for the 0% glass basecourse was 0.96mm, while the average deflection for the 5% glass section was 0.98mm. These results are statistically identical hence the presence of the glass in the pavement structure is undetectable by the Benkelman Beam test.

The deflection results are graphed below, with the 0% glass data in blue, and the 5% glass data in red:

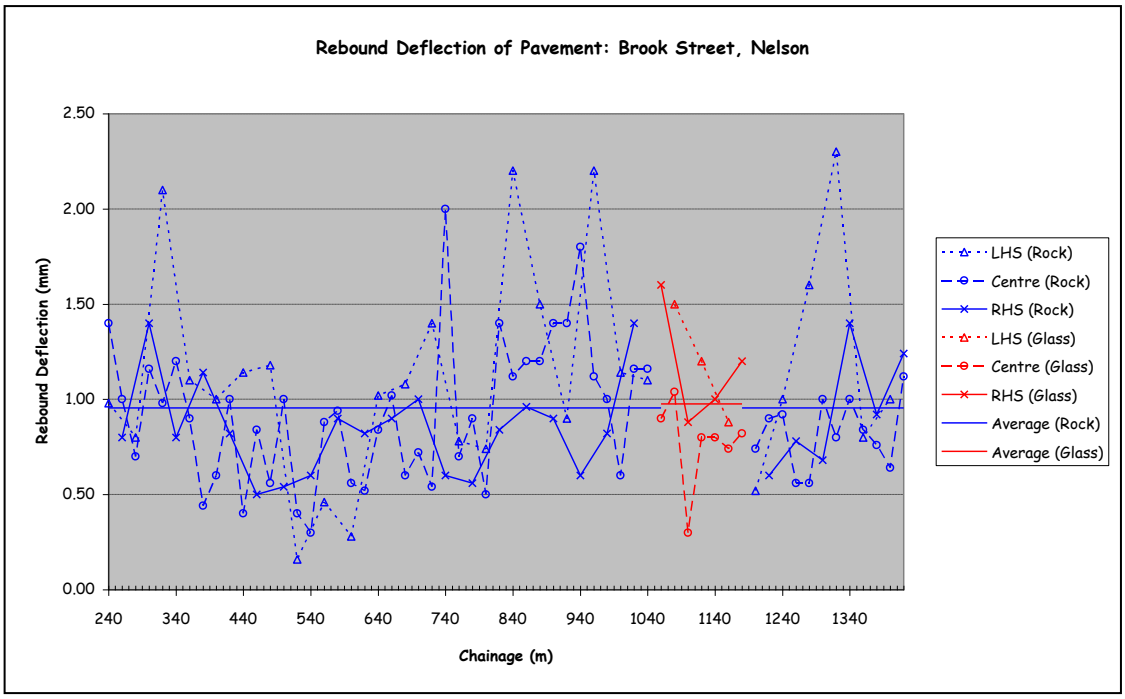

Figure 5: Deflection test results for pavements with 0% and 5% glass content.

Because the glass is impervious, basecourse with crushed glass in it will have a lower optimum moisture content during the compaction process. Whilst not significant in the Nelson trial this may well be advantageous in areas with water restrictions or where higher percentages of glass were used.

Performance to date

A visual assessment of performance to date shows no difference between the sections of road constructed with recycled glass and the virgin aggregate sections. Neither exhibit any rutting or distress. Figures 6 and 7 indicate the typical traffic environment of Brook Street and the identical performance after one year (based on visual assessment).

Figure 6: Brook Street: 5% glass in basecourse section.

Figure 7: Brook Street: 0% glass in basecourse section.

Further work

It is recommended that trials of product utilizing concentrations of glass greater than 5% are carried out particularly where the volumes of glass available warrant it.

As well as testing at concentrations greater than 5%, there is also merit in trialling a glass cutlet of greater than 10mm top size. Additionally the manufacturing of an all-in 20 mm product including 5 to 10% recycled glass is worthwhile to see if debris levels are significantly reduced at this reduced maximum particle size.

CONCLUSION

The use of recycled glass in aggregate is an excellent initiative to promote sustainable practices. Despite some minor difficulties with stockpiling and crushing, the product is a feasible replacement to virgin aggregate at the current specification levels (5%). To date the insitu performance of pavements of moderate traffic volumes where recycled glass basecourse has been used is identical to the performance of similar pavements where 100% virgin aggregate has been used.

The environmental preference of reducing carbon emissions resulting from transporting the glass long distances (eg Nelson to Auckland for recycling, or to increasingly more isolated landfill site's) is clear. However, it is the extension of the life of both landfills and quarries that really make this sustainability initiative worthy of raising one's glass to.

REFERENCES

TNZ M/4 (2006) "Specification for Un bound basecourse aggregate". Transit New Zealand, Wellington, New Zealand, www.transitnz.govt.nz

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After graduating with a BE (Civil Engineering) from the University of Canterbury in 1986, Bob Fulton worked for local authorities and consultants in New Zealand and Britain prior to joining Fulton Hogan in 1992. He held positions of Project Manager, Regional Manager and General Manager in Dunedin and Wellington before returning to Christchurch and his current role of South Island Manager in 2006.

Bob has a strong interest in all aspects of the Quarry business and provides an overview for this Industry sector for the wider Fulton Hogan company. In addition he is a Director on a number of the Joint Venture Quarry Companies in which Fulton Hogan has an ownership.

