Construction of New Zealand's First 100% Recycled Road

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Abstract

The construction of New Zealand's first road using 100% recycled materials has been completed in July this year. Located behind the Palms Shopping Centre in Christchurch, Golf Links Road has been designed and built by Fulton Hogan for the Christchurch City Council using recycled crushed concrete (RCC) and reclaimed asphalt pavement (RAP).

Fulton Hogan first initiated this project to build a road using 100% recycled materials in 2003. The project has presented Fulton Hogan with many challenges from its inception, feasibility, location selection, materials design, pavement design and construction. Solutions have been found to these challenges by addressing initial concerns that a recycled pavement would be inferior to a traditional pavement using virgin aggregate and bituminous materials. Environmental concerns have also been addressed in the planning stages of the project, especially the assessment of stormwater contamination during construction.

The purpose of this paper is to highlight to the roading industry the applicability of recycled materials as it is required to move towards more sustainable outcomes.

1.0 Background

In a recent Centre for Advanced Engineering report it was stated that whereas a new car in New Zealand typically contains 70% recycled materials, a new building or road in New Zealand contains less than 1% recycled materials (CAE, 2003). One of the main reasons for this poor industry statistic in the roading industry has been that until recently recycled materials have been considered inferior products and only suitable for marginal applications. Virgin aggregates combined predominantly with refined petroleum-bitumen, have proved themselves to be technically suitable, readily available and relatively inexpensive in building New Zealand's roading infrastructure. However, in recent times natural resources have become much less available and more expensive. Recycled materials have consequently become more attractive.

Internationally recycled roading materials are widely used. Crushed concrete, steel slag and varieties of furnace ash are all commonly used in the construction of road subbase and basecourse in different parts of the world. Reclaimed Asphalt Product (RAP), melter slag and rubber are all used in road surfacing internationally. These materials have been used, particularly in Europe and the USA, for a number of years now and their use have turned waste materials into commodities. International trends also indicate that certain recycled materials, particularly crushed concrete basecourse, are considered to be technically superior to natural materials and are commonly sold at premium prices.

Recent legislation and policy embodied in the Land Transport Amendment Act 2004 and the New Zealand Waste Strategy 2002, reflect international moves towards sustainable practices including waste minimisation and whole of life analysis. The continued total use of non-renewable natural resources is not considered to be consistent with this new legalisation and policy. Transit New Zealand has also recently revised its specifications to allow more recycled materials (Alabaster, 2005).

However, while these changes to legislation, policy and specifications have been encouraging, general engineering practices have not changed. The use of recycled materials can still at best be considered to be marginal and certainly not mainstream engineering practice. Only limited amounts of recycled materials have been used on actual projects. Where recycled materials have been used they have only represented small percentages blended into natural materials or have formed a lower-quality adjunct to the main project.

Fulton Hogan's ongoing programme of research and development aims to promote recycled roading materials. As a quarry operators and bitumen consumer, the company knows well the supply limitations the industry faces.

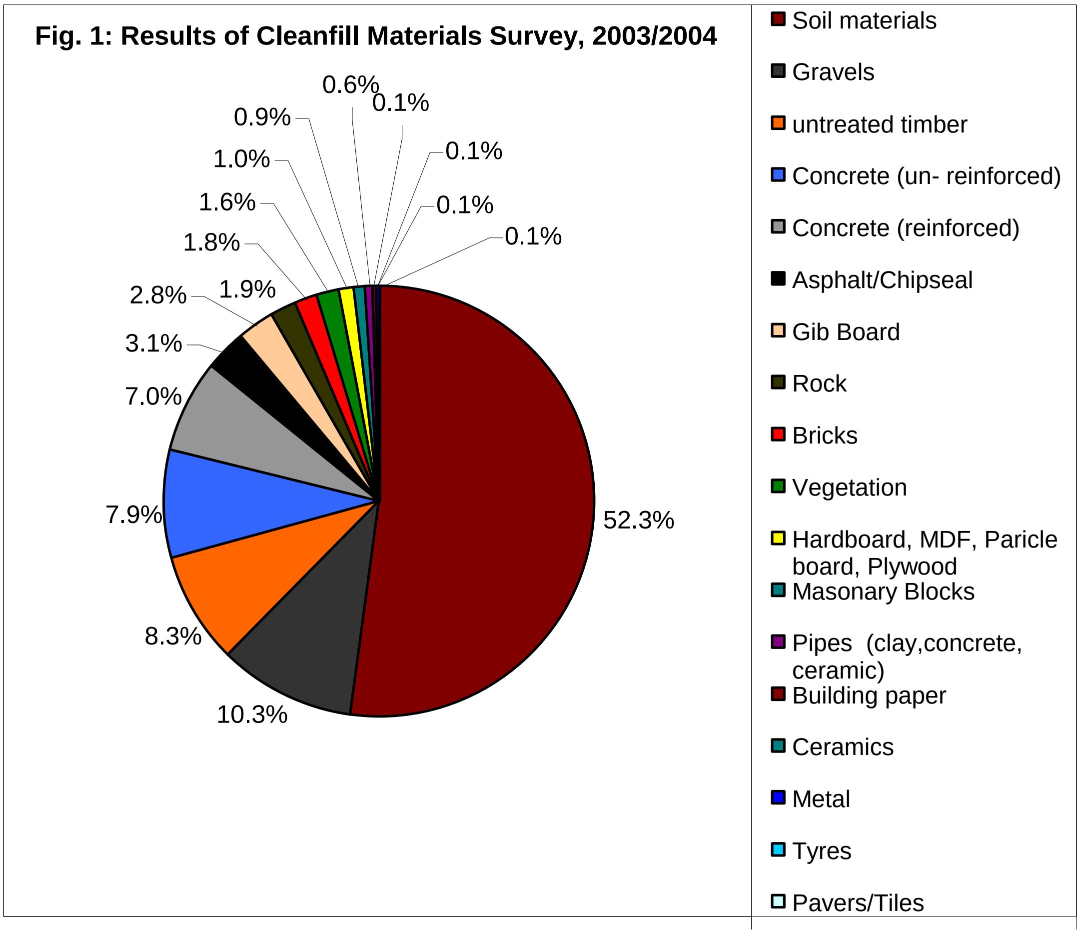
The project was initiated in late 2003 to showcase the attributes of recycled materials. The successful construction of a fully recycled road in a real roading situation was aimed at increasing the acceptance of recycled materials by roading engineers and others in the industry. Increasing the use of recycled materials is likely to become essential to the industry as it moves towards achieving sustainable outcomes

2.0 Selection of Materials

In late 2003 with a survey of current waste materials was undertaken to determine the quantity, quality and type of materials currently being sent to Fulton Hogan operated cleanfills in Canterbury. The results of the survey indicated that materials being sent to Fulton Hogan operated cleanfills alone was in excess of 225,000 tonnes per year. The estimated composition of these materials is shown in Fig. 1.

It was concluded from the survey of that significant quantities of material were being dumped in Fulton Hogan cleanfills that was potentially recyclable in roading projects (eg 30,000 tonnes of concrete per year and 7,000 tonnes of asphalt and chipseal materials).

A variety of waste materials from various sources were originally considered in an initial feasibility study for the construction of the 100% recycled road. A literature review indicated that recycled materials are used for all layers of road construction including subgrade, subbase, basecourse and topcourse applications. The extent to which different recycled materials are used internationally depends on their availability, cost and acceptance of technical properties. Likewise in New Zealand the availability of these materials varies geographically, as does their acceptance.



There was an initial desire to 'showcase' as many recycled materials as possible in the new road. However, it was also acknowledged that this was not going to be practicable to use all untried materials given the lack of availability and technical constraints. To develop a short list of potential materials to be used in the road wastes currently available were assessed and their various constraints identified. The availability of these materials in New Zealand and other potential constraints initially lead Fulton Hogan to short list a few specific waste materials that could be consider for the proposed road. These materials were:

- Recycled crushed concrete (RCC)
- Bottom and fly ash
- Reclaimed asphalt pavement (RAP)
- Melter slag

Recycled crushed concrete materials are widely available throughout New Zealand and potentially could be a premium product for basecourse construction. Crushed concrete aggregates generally exhibit good durability with resistance to weathering. Removing reinforcing and contamination can be labor intensive and increase the cost of these materials.

Fly and Bottom Ash sourced from coal-fired boilers represent an opportunity for either basecourse or sub-base applications where they assist in binding and strengthening the pavement.

RAP can easily be recycled by milling it from existing road pavement and then screened and reheated. RAP has been blended into asphalt mixes at 15 – 20%. However, the use of 100% RAP on a real road is unkown. The exact long-term performance of 2nd and 3rd generation RAP is still being investigated but it is possible that RAP could be recycled many times over and therefore could represent a truly sustainable roading material.

Melter slag was considered feasible as a potential material for use in topcourse construction due to its cost effectiveness, level of supply and expected technical benefits. Produced by Glenbrook Steel Mill and sourced via SteelServ, the present prices for melter slag are similar to those for natural aggregates. The level of yearly melter slag supply is approximately 250,000 tonnes. The most promising application for melter slag would seem to be in surface course construction due to its high skid resistance properties.

3.0 Location and Environmental Considerations

Fulton Hogan approached engineering staff at the Christchurch City Council during May 2004. The Christchurch Council were keen to promote this sustainable initiative and suggested that 300 metres of Golf Links Road in Shirley be rebuilt using recycled materials.

Staff from both the Christchurch City Council and Environment Canterbury were briefed regarding the potential runoff and leachate issues surrounding the use of these materials. When a proposal to ensure water quality monitoring of the stormwater was undertaken following rainfall events on site, both local authorities gave their support for the proposal.

The selection of Golf Links Road in Christchurch for the project limited the materials available. Slag and ash products were effectively ruled out due to a lack of availability. As a result, it was proposed to solely focus on the use of crushed concrete and RAP as construction materials. It was considered that the use of these two materials would be extremely useful as they can be considered to be the most available and the most commonly used in other parts of the world.

Golf Links Road also presented a challenge for construction as it was a busy section of road behind a mall with high numbers of heavy service vehicles. Prior to reconstruction Golf Links Road had suffered untimely pavement failure due to increased mall traffic. Using recycled materials on this road would provide a true test of their constructabilty and durability. It was considered that if crushed concrete and RAP could work on this road, these materials could work anywhere.

4.0 Pavement Design

Given its unique nature the pavement was designed by Dr Bryan Pidwerbesky using a combination of engineering judgement, experience and first principles in pavement theory. The design referred to the AUSTROADS Guide to the Structural Design of Road Pavements.

Based on traffic data provided (AADT= 4500), and assumed proportion of HCV's (5%) with an average loading factor of 0.6 esa/HCV, the design loading was 1 million esa over 20 years. Based on in situ tests done in pits excavated along the site in

August 2004, It was assumed the design modulus of the subgrade is 30 MPa, based on visual observation of the subgrade material and Scala DCP values at depths of 500 mm to 600 mm below the subgrade level.

A design for the physical properties of the crushed concrete was developed to ensure the road would meet the City Council basecoure performance Standard Specification part 6. The properties of the crushed concrete that had to considered included: grain size distribution, moisture content, plasticity and strength. Initial laboratory testing of crushed concrete demonstrated that 'clean' uncontaminated concrete also achieved compliance with Transit New Zealands TNZM/4 basecourse and TNZM/4 subbase specifications. This was not surprising given that aggregate contained in concrete is typically of the same nature as that of basecourse.

However, when the crushed concrete contained other construction wastes (such as brick, wood, soil or plastic), the strength of the basecourse was compromised. Several sources of concrete rubble were rejected as a result of high levels of contamination.

Based on TNZM/4 basecourse specification the following design parameters for the crushed concrete tested to ensure contaminates did not reduce the finial strength of the material.

- Brick, glass, asphalt < 3.0%.
- Metal < 1.0%
- Clay, plaster, rubber < 1.0%.
- Wood, organics < 0.5%
- Asbestos Nil

(NB % by mass)

During processing different sources of passing concrete were blended and stockpiles rotated to ensure consistent material properties. To avoid alkaline runoff stockpiles were located away from stormwater drains and waterways.

Concrete rubble was crushed to AP65 specification using a primary jaw crusher, magnetic separation (to remove steel reinforcing) and then passed through a secondary cone crusher. AP40 specification was produced using a jaw crusher, magnetic separation, a hammer mill and then passed through a barmac. The production of both products required specialist equipment and were labor intensive when removing reinforcing and contamination. Tests demonstrated that both recycled cruched concrete materials complied with the grading enevolp specifications of Transit New Zealand M/3 and M/4.

Photo 1: Demolition materials stockpile prior to sorting for contamination.

Photo 2: Concrete crushing equipment.

The design modulus of the asphalt layer, which consists entirely of high recycled asphalt pavement millings, was assumed to be 3500 MPa. Trials conducted in the Fulton Hogan Canterbury yard and in CAPTIF demonstrated that even though the stiffness modulus of recycled asphalt composed of millings is greater than virgin mixes (and thus it would be expected that such mixes to be more susceptible to fatigue cracking), even after significant deformation under loading, the RAP asphalt layer did not crack; the deflection of the layers under the RAP were purposely controlled to be < 1 mm.

However, early lab testing of 100% RAP mixes was not encouraging. Test blocks constructed from 100% RAP lacked density and strength, crumbling easily under stress. It was therefore determined that additional bitumen binder would need to be added to the mix. It was determined that the addition of only a small amount (2%) liquid bitumen to asphalt millings sourced from Christchurch Airport would achieve the required binder content, density and size distribution. and other necessary properties to pass Transit's TNZ M/10 asphalt mix specification. A mix design comprising 98% RAP (from the airport source) and 2% liquid bitumen was specified.

The results of the lab tests were then verified in lay-down trials in floor of Fulton Hogan's Pound Road Quarry. The results of the lay-down trials generally confirmed that both the crushed concrete and asphalt preformed to standard. The trial of the concrete demonstrated that a high moisture content was required to achieve compaction.

The design of the pavement consisted of the following over the 300 metre length of Golf Links Road.

80 mm thick layer of RAP (nominal top size of 14 mm)

100 mm thick basecourse layer of AP40 recycled crushed concrete

350 mm thick subbase layer of AP65 recycled crushed concrete

5.0 Construction Process

The reconstruction of Golf Links Road was generally undertaken in accordance with conventional construction practices. Milling and excavation of the existing pavement occur during early June 2005.

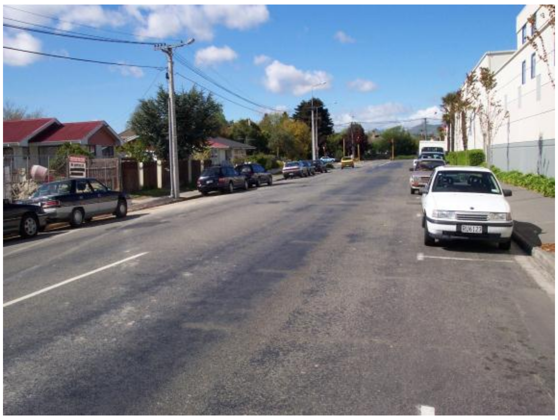


Photo 3: Golf Links Road, December 2004 prior to reconstruction. Pavement failure modes included flushed wheel tracks, undulations and surface cracking.

Photo 4: The excavation of the existing pavement, 10 June 2005.

AP 65 subbase material was layed to a thickness of 350mm well-watered and then compacted. 100mm of AP40 basecourse was then constructed directly on top and also compacted and watered. Benkelman beam test results on the top of the compacted basecourse had an average pavement deflection of 0.90mm and a range of 0.35mm – 1.19mm.

The high water content required within the concrete subbase and basecourse made the winter construction of the road during June and July ideal. The water quality monitoring of stormwater was undertaken following five rainfall runoff events during construction. Results of this monitoring indicated that stormwater runoff was generally not alkaline with an average pH of 7.5 and range of pH 6.7 – 8.2.

Photo 5: Subbase construction. Water quality monitoring of pH and alkalinity was ongoing throughout construction following rainfall.

Photo 6: The surface of the AP40 basecourse ready for the 100% RAP topcourse.

Few issues occurred during this first stage of paving for the crew involved on the night of 7 July 2005. During paving two 8tonne twin drum rollers and one 25 tonne pneumatic tyre roller was used due to the stiffness of the mix and high viscosity of the aged binder. Nuclear density meter testing showed that compactive effort achieved 98% pf target density and that the mix generally appeared to be dense and coherent.

Photo 7: Night paving of the RAP mix, 7 July 2005.

Photo 8: First 150m of the road paved with RAP, 8 July 2005.

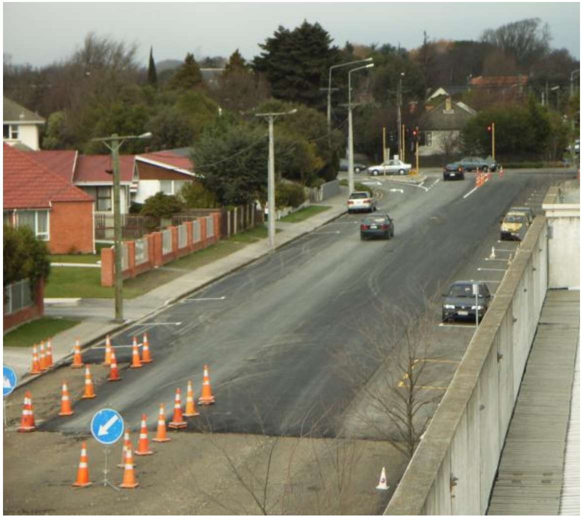


Photo 9: The surface of the RAP appeared dense and coherent.

6.0 Economic Assessment

Although the physical construction costs of the project have been comparable with other jobs of a similar nature, materials costs have differed. The cost of (Tables 1 & 2).

Table 1: Actual Costs of Recycled Materials in Golf Links Road

	Volumes Required (m3)	Unit Cost ($ / m^3)	Total Costs
AP65 (concrete)	2,400	16	38,400
AP40 (concrete)	600	24	14,400
RAP	520	130	68,000
			$120,800

Table 2: Comparative Costs of Natural Materials

	Volumes Required (m^3	Unit Cost (\$ / m^3)	Total Costs
AP65 (aggregate)	2,400	8	19,200
AP40 (aggregate)	600	12	7,200
Hot Mix Asphalt	520	150	77,600
			$104,000

When comparing the cost of materials used only, the use of recycled materials had an additional cost of $15,200 than the conventional use of natural materials. However, this comparison does not take into account a whole of life consideration for the disposal of the materials involved.

It should be noted that waste asphalt typically attracts no disposal cost as it can usually be reused as low-value asphalt millings for sub base applications. Concrete in the current Christchurch market is regarded as a waste and traditionally is sent to cleanfill or landfill. If concrete can meet the cleanfill waste criteria it can be disposed for \$14 / m^3 (\$9 / tonne equivalent) at a cleanfill. If concrete can not meet this cleanfill criteria the City Council's current landfill charge is \$63 / m^3 (\$40.50 / tonne equivalent). Total savings from not dumping concrete material are therefore significant at between $42,000- $189,000 (Table 3).

Table 3: Current Costs of Concrete Disposal

	Rate x Volume	Total Cost
Cleanfill	14 x 3,000m^3	$42,000
Landfill	63 x 3,000 m^3	$189,000

When the waste disposal considerations are accounted for the project has had a whole of life savings of between $26,800 to $173,800.

Other issues of note are that the cost of natural aggregate used in Table 1 are relatively low. Canterbury aggregates remain relatively inexpensive compared with other regions. As the value of aggregate increases, as they are expected to, the attractiveness of using recycled crushed concrete and RAP will increase. In other markets, such as Auckland, the use of crushed concrete as roading basecourse would currently be directly competitive. As stated previously this does not take into account the premium product status crushed concrete could attract in the future.

Overall it can be concluded that the use of recycled materials have significant commercial benefits, particularly when disposal costs are considered.

7.0 Ongoing Monitoring

An ongoing schedule of monitoring has been specified for the completed pavement in consultation with the pavement designer and the client. Annual FWD and NAASRA roughness surveys are proposed over the 20 year design life of the road. Ongoing water quality tesing is not proposed due to the that lack of a hydraulic gradient through the pavement.

8.0 Conclusions

Fulton Hogan has moved this project from initial feasibility to materials selection, location selection, pavement design and construction. The final success of or failure of this trial road may not be known for a number of years to come. However, to date test results have been encouraging and view observations suggest the road holding up well.

Water quality monitoring from the lab and field indicates that the use of crushed concrete has not generated levels of alkaline runoff that present a risk to the aquatic environment.

This project indicates that costs related to producing quality recycled concrete materials can be more expensive than natural quarry materials. However, when the potential disposal costs are considered, this type of construction can present a Net saving to the contractor and client. Construction using recycled materials in the North Island (particularly Auckland) will be even more cost effective.

The construction of 100% recycled roads in all situations is not a realistic or desirable option. However the roading industry must increase its current use of recycled materials used to begin achieving sustainable outcomes. It is hoped that the project will encourage the roading industry to take up the challenge of using recycled materials in greater quantities.

9.0 Acknowledgements

10. References

CAE (2003) Centre for Advanced Engineering Information Bulletin Number 24, May 2003. Waste – Using More, Creating Less: Redirecting Construction Waste.