CONSTRUCTION OF NEW ZEALANDS FIRST 100% RECYCLED ROAD
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1. Introduction

In a recent Centre for Advanced Engineering report it was stated that while 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 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 (Slaughter, 2006). 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 Pavement (RAP), melter slag and rubber are all used in road surfacing internationally. These materials have been used, particularly in Europe and North America, for a number of years 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 (Alabaster, 2005).

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 in the construction industry. 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 (Transit 2004).

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 operator and bitumen consumer, the company knows well the supply limitations the industry faces.

This project was initiated in late 2003 to showcase the attributes of recycled materials. The successful construction of a fully recycled road in a real life 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. Selection of Materials

In late 2003, 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 surfacing applications. The extent to which different recycled materials are used internationally depends on their availability, cost and acceptance of engineering properties. Likewise in New Zealand the availability of these materials varies geographically, as does their acceptance.

![Fig. 1: Results of Cleanfill Materials Survey, 2003/2004](image)

- Soil materials: 52.3%
- Gravels: 8.3%
- Untreated timber: 0.9%
- Concrete (un-reinforced): 1.0%
- Concrete (reinforced): 1.8%
- Asphalt/Chipseal: 1.9%
- Gib Board: 0.6%
- Rock: 7.9%
- Bricks: 3.1%
- Vegetation: 7.0%
- Hardboard, MDF, Particle board, Plywood: 7.0%
- Masonary Blocks: 0.6%
- Pipes (clay, concrete, ceramic): 0.1%
- Building paper: 0.1%
- Ceramics: 0.1%
- Metal: 0.1%
- Tyres: 0.1%
- Pavers/Tiles: 0.1%
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 led Fulton Hogan to solely focus on recycled crushed concrete (RCC) and reclaimed asphalt pavement (RAP).

**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.

**RAP** is easily obtained by milling from existing road pavements. RAP is normally blended into asphalt mixes at 15 – 20% by weight but the use of 100% RAP on a real road is unknown. 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.

### 3. Location and Environmental Considerations

Christchurch City Council was 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.

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

### 4. Pavement Design

Given its unique nature the pavement was designed 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 and was based on traffic data provided (AADT= 4500), and assumed proportion of heavy vehicles (5%). The design life was 20 years.

The properties of the crushed concrete that had to be considered included: particle size distribution, moisture content, shape, plasticity and strength. Initial laboratory testing of crushed concrete demonstrated that ‘clean’ uncontaminated concrete also achieved
compliance with Transit New Zealand M/4 basecourse and M/3 subbase specifications. This was not surprising given that aggregate contained in concrete is typically of the same quality as that of basecourse. However, when the crushed concrete contained other construction wastes as it often does (such as brick, wood, soil or plastic), the strength of the basecourse was compromised. Several sources of concrete rubble were rejected during the project as a result of high levels of contamination.

Based on TNZ M/4 basecourse specification the following criteria for the crushed concrete were applied to ensure contaminants did not degrade the final performance 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, concrete from different sources 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 TNZ M/3 AP65 specification using a primary jaw crusher, using magnetic separation to remove steel reinforcing and then passed through a secondary cone crusher. TNZ M/4 AP40 specification basecourse was produced using a jaw crusher, magnetic separation, a hammer mill and then passed through a Barmac™ impact crusher. The production of both products required specialist equipment and were labour intensive when removing reinforcing and contaminants. Tests demonstrated that both grades of recycled crushed concrete materials complied with the grading envelope specifications of Transit New Zealand M/3 and M/4.

Photo 1: Demolition materials stockpile prior to sorting for contamination.
The mix design for the RAP also needed thorough investigations. Trials conducted in the Fulton Hogan’s Quarry and at Transit New Zealand’s CAPTIF Test Track demonstrated that even though the stiffness modulus of a recycled asphalt composed of millings is greater than virgin mixes (and thus it would be expected to be more susceptible to fatigue cracking), even after significant deformation under loading, the RAP asphalt layer did not crack.

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 small amount (2%) liquid bitumen to asphalt millings would achieve the required binder content, density and asphalt volumetric and mechanical properties. A mix design comprising 98% RAP (from the airport source) and 2% penetration grade bitumen was specified.

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. Construction

The reconstruction of Golf Links Road was generally undertaken in accordance with conventional construction practices. Milling and excavation of the existing pavement occurred 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 laid to a thickness of 350mm well watered and then compacted. 100mm of AP40 basecourse was then placed directly on top and also watered and compacted. 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 only slightly 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.
Few issues occurred during this first stage of paving for the crew involved on the night of 7 July 2005. During paving two 8 tonne twin drum rollers and one 25 tonne pneumatic tyre roller was used due to the high viscosity of the aged binder. Nuclear density meter testing showed that compactive effort achieved 98% of target density and that the mix generally appeared to be dense and cohesive.

6.0 Economics

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 the recycled materials are compared with virgin aggregates and asphalt in Tables 1 & 2 below.
Table 1: Actual Costs of Recycled Materials in Golf Links Road

<table>
<thead>
<tr>
<th>Material</th>
<th>Volumes Required (m³)</th>
<th>Unit Cost ($ / m³)</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP65 (concrete)</td>
<td>2,400</td>
<td>16</td>
<td>38,400</td>
</tr>
<tr>
<td>AP40 (concrete)</td>
<td>600</td>
<td>24</td>
<td>14,400</td>
</tr>
<tr>
<td>RAP</td>
<td>520</td>
<td>130</td>
<td>68,000</td>
</tr>
</tbody>
</table>

$120,800

Table 2: Comparative Costs of Natural Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Volumes Required (m³)</th>
<th>Unit Cost ($ / m³)</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP65 (aggregate)</td>
<td>2,400</td>
<td>8</td>
<td>19,200</td>
</tr>
<tr>
<td>AP40 (aggregate)</td>
<td>600</td>
<td>12</td>
<td>7,200</td>
</tr>
<tr>
<td>Hot Mix Asphalt</td>
<td>520</td>
<td>150</td>
<td>77,600</td>
</tr>
</tbody>
</table>

$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 / m³ ($9 / tonne equivalent) at a cleanfill. If concrete can not meet this cleanfill criteria the City Council’s current landfill charge is $63 / m³ ($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

<table>
<thead>
<tr>
<th>Type</th>
<th>Rate x Volume</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleanfill</td>
<td>14 x 3,000m³</td>
<td>$42,000</td>
</tr>
<tr>
<td>Landfill</td>
<td>63 x 3,000m³</td>
<td>$189,000</td>
</tr>
</tbody>
</table>

When the waste disposal considerations are accounted for the project has had a whole of life savings of between $26,800 to $173,800. In other markets, such as Auckland, the use of crushed concrete as roading basecourse is currently 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. 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 testing is not proposed due to the lack of a hydraulic gradient through the pavement.

8.0 Conclusion

Fulton Hogan has moved this project from initial feasibility through materials selection, location selection, to pavement design and construction. Test results and visual observations suggest the road continue to perform for its 20 year design life.

This project indicates that costs related to producing quality recycled concrete materials can be higher than natural quarry aggregates. 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 to begin achieving sustainable outcomes. It is hoped that the project will encourage others in the roading industry to take up the challenge of using quality recycled materials in greater quantities.

9.0 Acknowledgement

The author would like to sincerely thank Peter McDonald and the Christchurch City Council for their cooperation and enthusiasm for the project.

10. References


