Quantifying the Benefits of Waste Minimisation

A LTNZ Research project
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Waste minimisation

- To develop a rational method to quantify the benefits of using waste minimisation techniques
A 2003 Working Group

Concluded that reasons for not using waste minimisation included:

- a lack of clear direction in the TNZ specifications
- a lack of experience and confidence in the use and performance of the technologies in a New Zealand context,
- no methodology to quantify the benefits
Progress

- All TNZ specifications have been reviewed
- Demonstration projects using RAP, rubber crumb
- Allowance of glass and crushed concrete
Limitation of this research

- The benefits have been estimated for the construction and not for the ‘whole of life’.
- The benefits can be used as an input into a whole of life NPV comparison where different pavement configurations have different performance.
Cost components

- Emissions = Energy + manufacture emissions
- Vehicle operating costs
- Traffic delay
- Resource Depletion
## Energy comparison

<table>
<thead>
<tr>
<th></th>
<th>unit</th>
<th>RRU 55</th>
<th>NCRP 85</th>
<th>ASCE 2005</th>
<th>Wrap</th>
<th>Vic University</th>
<th>Athena</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bitumen manufacture</strong></td>
<td>kj/t</td>
<td>7.0E+05</td>
<td>6.8E+05</td>
<td>6.0E+06</td>
<td>4.4E+07</td>
<td>4.6E+06</td>
<td></td>
</tr>
<tr>
<td><strong>Cement Manufacture</strong></td>
<td>kj/t</td>
<td>6.9E+06</td>
<td>8.4E+06</td>
<td>6.3E+07</td>
<td>4.7E+06</td>
<td>7.8E+06</td>
<td>5.5E+06</td>
</tr>
<tr>
<td><strong>Crushed Aggregate</strong></td>
<td>kj/t</td>
<td>8.0E+04</td>
<td>6.8E+04</td>
<td>5.3E+04</td>
<td>1.7E+04</td>
<td>4.0E+04</td>
<td>5.0E+04</td>
</tr>
<tr>
<td><strong>Hot mix manufacture</strong></td>
<td>kj/t</td>
<td>4.8E+05</td>
<td>2.3E+04</td>
<td>3.5E+05</td>
<td>2.5E+05</td>
<td>3.4E+06</td>
<td>4.8E+05</td>
</tr>
</tbody>
</table>
Transport Energy

Fuel vs Maximum weight (different loads)

- Fuel full: $y = 0.4751x + 27.457$, $R^2 = 0.9999$
- Fuel mt: $y = 0.0912x + 31.433$, $R^2 = 0.9814$
- Laden: $y = 0.35x + 28.7$

Partial weight = 0.93 * max. weight...on average
Empty weight = 0.39 * max. weight...on average
Transport Energy

- a 32 tonne load max load-empty return
  930kJ/t/km

14 tonne load max load-empty return
1825 kJ/t/km.
CO2 Conversion

- Energy kj to equivalent litres of diesel
  (3.87*10^4 kj/l)

- 2.7 kg CO2 /litre of diesel

- 7* 10^{-5} kg CO2 /kj
Aggregate v Concrete Crushing

- Aggregate in a quarry say 80% energy from electricity = 2.1 kg CO2/tonne

- Crushing concrete with a diesel powered generator = 3.5 kg CO2 /tonne

- Difference equivalent to approx 20km haul distance
Value of emissions

- CO2  =$40/tonne
- Heavy Vehicle particulate  20c/km
## Traffic Delay

<table>
<thead>
<tr>
<th></th>
<th>Morning peak</th>
<th>Daytime inter-peak</th>
<th>Afternoon peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume (ADT)</td>
<td>2000</td>
<td>7000</td>
<td>2000</td>
</tr>
<tr>
<td>Speed during</td>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>construction (km/hr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed before</td>
<td>60</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>construction (km/Hr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopping time (min)</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
## Composite Values of Travel Time—Combining Occupant Time, Vehicle Time and Freight Time in $/h (July 2002)

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arterial</td>
<td>Other</td>
</tr>
<tr>
<td>Morning Peak</td>
<td>15.13</td>
<td>16.23</td>
</tr>
<tr>
<td>Inter-Peak</td>
<td>17.95</td>
<td>16.23</td>
</tr>
<tr>
<td>Afternoon Peak</td>
<td>14.96</td>
<td>16.23</td>
</tr>
<tr>
<td></td>
<td>Strategic</td>
<td>Other</td>
</tr>
<tr>
<td>Morning Peak</td>
<td>23.25</td>
<td>22.72</td>
</tr>
<tr>
<td>Inter-Peak</td>
<td>23.25</td>
<td>22.72</td>
</tr>
<tr>
<td>Afternoon Peak</td>
<td>23.25</td>
<td>22.72</td>
</tr>
</tbody>
</table>
Vehicle operating costs - EEM

VOC =

base running costs by speed and gradient +
Road roughness costs +
Road surface texture costs +
pavement elastic deflection costs +
Congestion costs +
Bottleneck costs +
Speed change cycle costs
Vehicle operating costs - EEM

VOC = base running costs by speed
    + Congestion costs
    + Speed change cycle costs
Aggregate Resource Depletion

Britain use £ 1.60 / tonne
(approx NZ $4.00/tonne)
Not included

- Landfill costs
- Extra traffic wear
- Job creation
Insitu stabilisation
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>500m</td>
</tr>
<tr>
<td>Width</td>
<td>10m</td>
</tr>
<tr>
<td>AADT</td>
<td>15,000</td>
</tr>
<tr>
<td>Morning peak veh</td>
<td>3,000</td>
</tr>
<tr>
<td>Inter peak veh</td>
<td>9,000</td>
</tr>
<tr>
<td>Evening peak veh</td>
<td>3,000</td>
</tr>
<tr>
<td>Electricity % in processing aggregate</td>
<td>80%</td>
</tr>
<tr>
<td>Aggregate crushed or screened</td>
<td>All crushed</td>
</tr>
<tr>
<td>Transport distance plant to site km</td>
<td>20</td>
</tr>
<tr>
<td>Distance to dump km</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Convention</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Construction time Days</td>
<td>15</td>
</tr>
<tr>
<td>Basecourse thickness</td>
<td>150mm</td>
</tr>
<tr>
<td>Subase mm</td>
<td>300</td>
</tr>
<tr>
<td>Stabilised insitu mm</td>
<td>250</td>
</tr>
<tr>
<td>Additive</td>
<td>1.5% cement</td>
</tr>
<tr>
<td>Excavated to waste Chip</td>
<td>450mm</td>
</tr>
<tr>
<td>Surface</td>
<td>Chip</td>
</tr>
</tbody>
</table>
CO2 emissions
CO2 conversion for Electricity

- NZ approx 63% of electricity comes from hydro
- 6.5% from geothermal
- $1.6 \times 10^{-5}$ kg CO2/kj
- 4 times lower than from diesel
CO₂ Emissions tonnes

- **Conventional Insitu Stabilisation**
  - VOC
  - Cart Waste
  - Construction
  - Transport
  - Manufacture

CO₂ Emissions (Total tonnes)
Energy consumption
Energy Consumption

Option

- Manufacture (MJ)
- Construction (MJ)
- Transport (MJ)
- Waste (MJ)
Costs
Materials
Comparison of Materials Used

Option

- Traditional
- Insitu stabilised

Tonnes

- New Agg
- Waste
- Recycle
- Cement
- Bitumen

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
CO2 Footprint of Recycled Concrete for use in the Christchurch Southern Motorway
Transit has requested Opus to:
Determine the Carbon Footprint of different methods of obtaining 60,000m³ of AP65 Subbase for use in construction of the Christchurch Southern Motorway.

The cases modelled:
• Aggregate from the Waimakariri riverbed to placement
• Recycled concrete to stockpile and then placement
Cost

- Crushed concrete delivered to site is more expensive than the river sourced material
- $34.25/cum v $28/cum

- Why should NZTA (LTNZ) pay more?
Transport

- Crushed Concrete 15km round trip
- River sourced 50km round trip
Aggregate Processing

- Crushed Concrete – diesel powered
- River Sourced – electric powered screening and crushing 10% of material
Aggregate v Concrete Crushing

- Aggregate in a quarry say 80% energy from electricity = 2.1 kg CO2/tonne

- Crushing concrete with a diesel powered generator = 3.5 kg CO2/tonne
CO₂ Emissions (Total tonnes)

CO₂ Emissions tonnes

Recycled Concrete  
River Gravel 10% crushed

Transport  
Manufacture
European research suggests that carbonation of crushed concrete can result in an uptake of CO2 of 4% of the mass of the concrete.
CO2 Uptake

- 125,000 tonnes of concrete @ 4%

= 5,000 tonnes of CO2
Transport to Waste of the Concrete

- Round trip of 50 kilometres equivalent to 1000 tonnes of CO2
Conclusion

- For the Christchurch Southern Motorway the CO2 footprint comparison of the manufacture and transport of crushed concrete and river sourced show they are very similar.
Conclusions

- If the more intangible factors such as CO2 absorption and the transportation of the crushed concrete to waste are considered then there is a significant advantage to using crushed concrete
BUT !!!!!
Aggregate needs to be taken from the Waimakariri riverbed for flood protection!!
Outcome

- Crushed concrete is being used on the motorway
Thanks