Recycled demolition aggregates as a base course for roads

- Recycled demolition material may be made up of:
  - straight crushed concrete
  - comingled demolition materials containing:
    - brick and tile
    - asphalt
    - other unbound aggregates
- It should not contain any significant amounts of:
  - plaster or other friable material
  - timber
  - organics
  - asbestos or other hazardous materials
Welshpool Road

- Four different pavement profiles were constructed:
  - 250 mm of CDRB subbase and 150 mm of CGRB base
  - 400 mm of CDRB base
  - 250 mm of size 50 mm CDRB subbase and 150 mm of CCRB base
  - 400 mm of CCRB base.

Basic observations

- The maximum dry density (MDD) of the CDRB and CCRB materials was slightly lower than the MDD of the conventional roadbase (CGRB)
  - CDRB & CCRB: 1.95 t/m³
  - CGRB: 2.21 t/m³
- The optimum moisture content (OMC) of the CDRB and CCRB materials was considerably higher than the OMC of the CGRB
  - CDRB & CCRB: 11%
  - CGRB: 6%
Basic observations

• CDRB
  – very easy to work and finish
  – compacted easily with no spongy sections
  – very resistant to raveling from traffic

• CCRB
  – slightly harder to work and finish
  – required little more effort to compact & some spongy sections
  – very resistant to raveling from traffic

• CGRB
  – very easy to work and finish
  – compacted easily with some spongy sections
  – not resistant to raveling from traffic

FWD Test results

<table>
<thead>
<tr>
<th>Base</th>
<th>Subbase</th>
<th>Mean Curvature (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150mm CGRB (Conventional roadbase)</td>
<td>250mm CDRB (Recycled comingled)</td>
<td>0.21</td>
</tr>
<tr>
<td>150mm CDRB (Recycled comingled)</td>
<td>250mm CDRB (Recycled comingled)</td>
<td>0.15</td>
</tr>
<tr>
<td>150mm CCRB (Recycled Concrete)</td>
<td>250mm CDRB (50mm Recycled comingled)</td>
<td>0.13</td>
</tr>
<tr>
<td>150mm CCRB (Recycled Concrete)</td>
<td>250mm CCRB (Recycled Concrete)</td>
<td>0.15</td>
</tr>
</tbody>
</table>
EfromD3 analysis

<table>
<thead>
<tr>
<th>Base</th>
<th>Subbase</th>
<th>Calculated Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>150mm CGRB (Conventional roadbase)</td>
<td>250mm CDRB (Recycled comingled)</td>
<td>641</td>
</tr>
<tr>
<td>150mm CDRB (Recycled comingled)</td>
<td>250mm CDRB (Recycled comingled)</td>
<td>1024</td>
</tr>
<tr>
<td>150mm CCRB (Recycled Concrete)</td>
<td>250mm CDRB (50mm Recycled comingled)</td>
<td>1275</td>
</tr>
<tr>
<td>150mm CCRB (Recycled Concrete)</td>
<td>250mm CCRB (Recycled Concrete)</td>
<td>1042</td>
</tr>
</tbody>
</table>

Welshpool Road findings

- Recycled base is stiffer than new granite roadbase
- Lower curvature values increase asphalt fatigue life
- Possibility of excessive stiffness in recycled materials
- Possibility of long term shrinkage cracking
- Recycled materials resist ravelling from traffic
- Recycled materials are easy to work
Cost comparisons

<table>
<thead>
<tr>
<th>Material</th>
<th>Base price ($/t)</th>
<th>Transport Cost ($/t)</th>
<th>Insitu Cost ($/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Adjusted for backload</td>
<td>Actual</td>
</tr>
<tr>
<td>Limestone</td>
<td>6.60</td>
<td>5.50</td>
<td>22.38</td>
</tr>
<tr>
<td>Roadbase</td>
<td>10.80</td>
<td>3.14</td>
<td>30.80</td>
</tr>
<tr>
<td>Recycled Roadbase</td>
<td>8.80</td>
<td>2.36</td>
<td>21.76</td>
</tr>
</tbody>
</table>

Gilmore Ave Trials

- 1500m section south of Wellard Road
- 2 x 400m trial sections
  - common 30mm DGA surface
  - common 150mm Limestone subbase
  - variable 125mm Base course – CGRB and CDRB?
- Constructed by Town of Kwinana in April 2003
- Technical assistance from MRWA.
- 20 year design traffic 4.5 x 10^6 ESA.
- Subgrade design CBR of 12%

Source: Adapted from Cheema (2004).
Gilmore Ave – grading curves

<table>
<thead>
<tr>
<th>AS 1152 sieve size (mm)</th>
<th>MRWA Spec 501 specified limits (% passing)</th>
<th>Average grading (% passing)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
<td>Max.</td>
</tr>
<tr>
<td>26.5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>4.75</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>2.36</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>1.18</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>0.6</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>0.425</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>0.3</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>0.15</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>0.075</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: Adapted from Cheema (2004).

Gilmore Ave – CBR & MDD test results

- **CBR test results**
  - CDRB: 5 tests ranging 165% to 200%
  - CGRB: 4 tests ranging 130% to 170%

- **MDD test results**
  - CDRB: 1.989t/m³ @ 11.4% OMC
  - CGRB: 2.362t/m³ @ 5.8% OMC

Source: Adapted from Cheema (2004).
Gilmore Ave – UCS test results

- Limited UCS testing was undertaken on CDRB
- Results were variable but typically <1.0MPa
- Conclusion reached that:
  - 15% brick could be used in subbase
  - 5% brick in basecourse material
  - limited to <5 x 10^6 ESA

Source: Adapted from Cheema (2004).

### Gilmore Ave – Benkelman Beam test results

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Curvature values (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May-03</td>
</tr>
<tr>
<td>CGRB</td>
<td>0.15</td>
</tr>
<tr>
<td>CDRB</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: Adapted from Cheema (2004).
Transport South Australia – Resilient modulus

![Comparative Resilient Modulus](image)


Curtin testing – Unconfined compressive strength

<table>
<thead>
<tr>
<th>Supplier</th>
<th>UCS 1 day cure (kPa)</th>
<th>UCS 28 day cure (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Demolition</td>
<td>668</td>
<td>1625</td>
</tr>
<tr>
<td>C&amp;D Recycling</td>
<td>220</td>
<td>474</td>
</tr>
<tr>
<td>All Earth</td>
<td>541</td>
<td>1323</td>
</tr>
</tbody>
</table>

Additional testing – All Earth

<table>
<thead>
<tr>
<th>Day</th>
<th>UCS (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>625</td>
</tr>
<tr>
<td>7</td>
<td>979</td>
</tr>
<tr>
<td>28</td>
<td>1023</td>
</tr>
</tbody>
</table>
Curtin modulus results at 80% OMC

Curtin modulus results at 60% OMC
Curtin testing – Axial modulus with curing

VARIATION OF MODULUS WITH TIME
All Earth Material

Advantages of Recycled Pavement Materials

- Environmental
  - reduced drain on new resources
  - reduced habitat destruction
  - energy savings in processing
  - reduced landfill area
  - reduced fuel usage by backloading

- Economic
  - savings in material costs
  - savings in fuel costs and vehicle costs
  - reduced road wear
Further definition for recycled materials

- Based on composition of source material
  - CGRB – conventional new roadbase manufactured from virgin granite rock
  - CCRB(S) – crushed concrete roadbase containing only concrete sourced mainly from structural grade concrete
  - CCRB(N) – crushed concrete roadbase containing only concrete sourced mainly from non-structural grade concrete
  - CDRB(x) – crushed demolition roadbase containing a mix of predominantly concrete with clay brick, tile and sand containing approximately x% concrete.

Possible applications

- Application of specific class roadbase
  - CCRB(S) may be suitable under thick layers of asphalt, or as a subbase for heavy trafficked pavements.
  - It may not be suitable for a heavy trafficked pavement with thin asphalt due to possible fatigue cracking.
  - CCRB(S) can be blended with clay brick or tile to form CDRB(90), ie 90% concrete with 10% foreign material to limit potential cracking under thin asphalt.

- Research is proceeding
Conclusion

- Recycled materials can be successfully used in road construction
- There are considerable environmental and economic benefits in using recycled materials
- Recycled materials can be used with confidence as a base in light traffic roads and sub-base in heavy traffic roads
- Recycled materials are likely to be suitable as a base in heavy trafficked roads.
Completed Recycled Concrete Base

Completed Commingled Recycled Base
Gilmore Ave – CDRB section

Gilmore Ave – Source material
Asbestos

• Asbestos raised as an issue
  – Reasons:
    • vested interests
    • more vested interests
    • any other vested interest
  – But no sound basis
  – Asbestos testing for Gt Eastern Hwy showed no asbestos
  – There is background asbestos everywhere
  – There are multiple asbestos ducts and pipes under many urban roads
  – Process control minimises risk

Why does it crack (sometimes)

<table>
<thead>
<tr>
<th>City of Gosnells</th>
<th>City of Canning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single coat primer seal 1.3l/m² 60%CRS</td>
<td>Double coat primer seal 2.5l/m² 60%CRS</td>
</tr>
<tr>
<td>Base only around 175mm</td>
<td>Base and subbase around 400mm</td>
</tr>
<tr>
<td>Dryback period?</td>
<td>Dryback period generally weeks</td>
</tr>
<tr>
<td>Conventional construction methods</td>
<td>Conventional construction methods</td>
</tr>
<tr>
<td>High stiffness</td>
<td>High stiffness</td>
</tr>
<tr>
<td>Cracks occur</td>
<td>No cracks have occurred</td>
</tr>
</tbody>
</table>