CRUSHING BRICK BLENDS FOR SUB-BASE APPLICATIONS

Can recycled crushed brick blended with crushed concrete create effective sub-base applications? And if so, do such applications meet statutory specifications? Thurairatnam Aatheesan and Arul Arulrajah discuss the science.

Recycling and reuse of waste materials is a topic of global concern and of great international interest. The urgent need for recycling is driven mainly by environmental considerations, due to the increased scarcity of natural resources and the increasing cost of landfill in most countries. Construction and demolition (C&D) materials are generated by regeneration of infrastructure such as demolition activities and accounts for the major proportion of the waste materials present in landfills. Recycled crushed brick and crushed concrete are viable substitute materials for natural construction materials in engineering applications such as pavement sub-base and other road construction applications. Some countries have been using recycled C&D materials in civil engineering applications but there is still scope for wider engineering applications of such recycled materials. This paper primarily focuses on the applicability of crushed brick blends with crushed concrete in pavement sub-base material as well as bedding and backfill material for drainage systems.

The engineering properties of crushed brick blended with crushed concrete were investigated by means of laboratory testing. A suite of laboratory tests was conducted on blend mixes of 10 per cent, 15 per cent, 20 per cent, 25 per cent and 30 per cent of crushed brick with crushed concrete. The resulting engineering properties were compared with the existing local authority specifications for flexible pavement sub-base and drainage material.

EXISTING LOCAL SPECIFICATIONS

Pavement sub-base

VicRoads is a statutory authority responsible for managing the road network (roads and bridges) in Victoria, Australia. It classifies recycled crushed concrete for pavement sub-base and light duty base as Class CC2, Class CC3 and Class CC4 (VicRoads, 2006). This classification is based on the physical and mechanical properties of crushed concrete.

Table 1 presents the physical properties of crushed concrete as specified by VicRoads. Table 2 presents the before compaction grading limits for 20mm Class CC3 crushed concrete. Table 3 presents the after compaction grading requirements for Class 3 crushed rock sub-base which is applicable for crushed concrete.

<table>
<thead>
<tr>
<th>SIEVE SIZE AS (MM)</th>
<th>TARGET GRADING (% PASSING)</th>
<th>LIMIT OF GRADING TEST VALUE BEFORE COMPACTION (% PASSING)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>19.0</td>
<td>100</td>
<td>90-100</td>
</tr>
<tr>
<td>13.2</td>
<td>85</td>
<td>75-95</td>
</tr>
<tr>
<td>9.50</td>
<td>75</td>
<td>60-90</td>
</tr>
<tr>
<td>4.75</td>
<td>59</td>
<td>42-76</td>
</tr>
<tr>
<td>2.36</td>
<td>44</td>
<td>28-60</td>
</tr>
<tr>
<td>0.425</td>
<td>19</td>
<td>10-28</td>
</tr>
<tr>
<td>0.075</td>
<td>6</td>
<td>2-10</td>
</tr>
</tbody>
</table>

Table 2: Grading requirement for 20mm Class CC3 crushed concrete (VicRoads, 2007).
Bedding and backfill material
Melbourne Water is the authorised governing body for local drainage systems. Melbourne Water classifies backfill and bedding material as “Grade A” and “Grade B” material. Melbourne Water specification for the supply of crushed rock to their work sites is summarised in Tables 4 and Table 5 (Melbourne Water, 2001).

ENGINEERING PROPERTIES OF CRUSHED BRICK BLENDS
Samples of crushed brick and crushed concrete were collected from the Alex Fraser Group recycling site at Laverton North, Victoria, as well as the Delta Group recycling site at Sunshine, Victoria, Australia. Alex Fraser Group and Delta Group are the leading suppliers of high-quality sustainable civil construction materials in Australia, supplying recycled materials such as crushed brick, crushed concrete and crushed rock in various classes. The crushed brick and crushed concrete used in this research had a maximum aggregate size of 20mm.

Laboratory tests were undertaken on blended mixtures of 10 per cent, 15 per cent, 20 per cent, 25 per cent and 30 per cent crushed brick with crushed concrete. The laboratory tests included modified compaction, particle density, water absorption, California Bearing Ratio (CBR), Los Angeles abrasion, Atterberg limit, pH, organic content, wet and dry strength and clay content. The blend mixtures were prepared by hand mixing to the required percentages by weight. Crushed brick from Alex Fraser Recycling site typically consists of 70 per cent brick and 30 per cent other materials such as asphalt, concrete and rock. Crushed brick from the Delta recycling site on the other hand typically comprises 40 per cent brick, 55 per cent crushed concrete and five per cent asphalt.

The laboratory tests were performed in accordance with Australian Standards AS 1141 (1996) and AS 1289 (1998). Particle density and water absorption tests were performed in both coarse (retained on 4.75mm sieve) and fine (passing 4.75mm sieve) material. The physical characteristics of crushed brick blends with crushed concrete obtained from the laboratory tests are summarised in Table 6 (see page 16). The particle size distribution results prior to compaction and after compaction for crushed brick blended with crushed concrete (Class 3) is summarised in Tables 7 and Table 8 (see page 17).

70CC3 refers to 30 per cent crushed brick content blended with 70 per cent crushed concrete (CC3) by weight. Particle densities of coarse aggregates (retained on 4.75mm sieve) are higher than the fine aggregates (passing 4.75mm) and water absorptions of coarse aggregates are less than the fine aggregates. The coarse aggregates of blends may contain the natural aggregates used in concrete and the fine aggregates may contain cementitious mortar. This may lead to the higher particle density and lower water absorption in coarse aggregates and lower particle density and higher water absorption in finer aggregates. The pH values of all blends are over 7 and this indicates that the blends are alkaline by nature.

COMPARISON WITH LOCAL SPECIFICATIONS
Pavement sub-base
The laboratory test results were subsequently compared with existing local specifications for pavement sub-base applications. The Los Angeles abrasion loss values are clearly higher water absorption in finer aggregates and lower particle density and water absorptions of coarse aggregates are less than the fine aggregates. The coarse natural aggregates used in concrete and the fine aggregates may contain the cementitious mortar. This may lead to the higher particle density and lower water absorption in coarse aggregates and lower particle density and higher water absorption in finer aggregates. The pH values of all blends are over 7 and this indicates that the blends are alkaline by nature.

Melbourne Water classifies backfill and bedding material as “Grade A” and “Grade B” material. Melbourne Water specification for the supply of crushed rock to their work sites is summarised in Tables 4 and Table 5 (Melbourne Water, 2001).

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dry condition. Materials with wet and dry strength variations of less than 35 percent are considered durable (Lay, 1998).

As the clay content in all the blends was low, the plastic limit and liquid limit could not be obtained. This is because the Atterberg limit is directly related to clay mineralogy and so higher clay contents result in higher plasticity. This aspect may mean that some difficulties may occur with the workability of the crushed concrete blends as cohesion of particles and a “tight” prepared surface is usually a sought after characteristic. A field trial of the crushed concrete would best determine the degree of difficulties that may be experienced. The addition of small quantities of clayey sand or plastic crusher fines may overcome this potential issue.

The grading limits of all blends before compaction using 20mm Class CC3 crushed concrete were within VicRoads’ lower and upper bounds for Class CC3 crushed concrete sub-base application, as shown in Figure 1 (see page 17). The grading limits of all blends after compaction as compared with VicRoads’ requirements for Class 3 crushed rock sub-base in flexible pavement is shown in Figure 2 (see page 18). The grading limits of most blends were well within the upper bounds of the grading envelope. The “after compaction” grading curves show that some breakdown is occurring under compaction; however compliance with normal after compaction requirements is still achieved. The “before and after” compaction grading curves (ie degree of breakdown occurring during compaction) would suggest that a maximum of 15 per cent crushed brick should be added to a Class 3 crushed concrete sub-base in order to maintain an acceptable “after compaction” grading. It is likely that the breakdown is occurring in both the crushed brick and the crushed concrete components. The materials appear to be remaining reasonably well graded through the compaction process and this will generally aid the compaction process.

Figure 3 presents the CBR results for the crushed brick blends (see page 18). The CBR values of the tested blends were above 80 per cent and found to satisfy the VicRoads requirement for Class CC3 material. The differences in CBR results for the Series 1 and Series 2 tests could be due to slight differences in the aggregate strengths and proportions since they were carried out on different bulk samples and several months apart.

<table>
<thead>
<tr>
<th>SAMPLE DESCRIPTION</th>
<th>70CC3</th>
<th>75CC3</th>
<th>80CC3</th>
<th>85CC3</th>
<th>90CC3</th>
<th>100CC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick content (%) by weight</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Material source</td>
<td>AFR</td>
<td>DR</td>
<td>AFR</td>
<td>DR</td>
<td>AFR</td>
<td>AFR</td>
</tr>
<tr>
<td>Test description</td>
<td>Test results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle density (Coarse) (t/m³) - Series 1</td>
<td>2.67</td>
<td>2.69</td>
<td>3.08</td>
<td>2.73</td>
<td>2.68</td>
<td>2.71</td>
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<tr>
<td>Particle density (Coarse) (t/m³) - Series 2</td>
<td>2.71</td>
<td>2.71</td>
<td>2.71</td>
<td>2.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle density (Fine) (t/m³)</td>
<td>2.43</td>
<td></td>
<td>2.60</td>
<td></td>
<td>2.41</td>
<td></td>
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<tr>
<td>Water absorption (Coarse) (%) - Series 1</td>
<td>5.56</td>
<td>4.84</td>
<td>5.23</td>
<td>4.95</td>
<td>5.36</td>
<td>5.69</td>
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<tr>
<td>Water absorption (Coarse) (%) - Series 2</td>
<td>5.4</td>
<td>5.7</td>
<td>5.5</td>
<td></td>
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<tr>
<td>Water absorption (Fine) (%)</td>
<td>6.9</td>
<td>7.5</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CBR (%)</td>
<td>Series 1</td>
<td>117</td>
<td>102</td>
<td>113</td>
<td>104</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Series 2</td>
<td>190</td>
<td>141</td>
<td>152</td>
<td>132</td>
<td>177</td>
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<tr>
<td>Los Angeles abrasion</td>
<td></td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>pH</td>
<td></td>
<td>11.11</td>
<td>11.44</td>
<td>11.30</td>
<td>10.88</td>
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<tr>
<td>Compaction (modified)</td>
<td>Max dry density (t/m³)</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.95</td>
<td>1.99</td>
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<tr>
<td></td>
<td>Opt moisture content (%)</td>
<td>12.50</td>
<td>12.50</td>
<td>12.00</td>
<td>12.50</td>
<td>11.70</td>
</tr>
<tr>
<td>Wet and dry strength (kN)</td>
<td>Wet</td>
<td>115</td>
<td>127</td>
<td>121</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>127</td>
<td>134</td>
<td>127</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Strength variation (%)</td>
<td>94</td>
<td>5.2</td>
<td>4.7</td>
<td></td>
<td></td>
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<tr>
<td>Atterberg limit</td>
<td>Plastic limit</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Liquid limit</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Plasticity Index</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Clay content (%)</td>
<td>1.20</td>
<td>0.40</td>
<td>0.50</td>
<td>0.50</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

Note: AFR - Alex Fraser Recycling; DR - Delta Recycling; 70CC3 refers to 30 per cent crushed brick content blended with 70 per cent crushed concrete (CC3) by weight. NO – Not obtainable. NP – Non-plastic.

Table 6: Engineering properties of crushed brick blended with crushed concrete (Class 3).
Bedding and backfill material

The laboratory test results were also compared with local specifications for bedding and backfill material. The grading curves of all blends as compared with Melbourne Water specifications for Grades A and B materials are presented in Figures 4 and 5 respectively (see page 18). The grading limits of all blends for Grades A and B bedding and backfill material were found to be within the Melbourne Water specified lower and upper bounds. However, some finer particles for Grade B materials were found to be on the limit. The tests results of the crushed brick blends satisfied all Melbourne Water requirements for both Grades A and B materials except the Los Angeles requirements for Grade A material which were found to be on the limit.

**CONCLUSIONS AND RECOMMENDATIONS**

The results of the laboratory testing undertaken in this research has shown overall that the incorporation of “crushed brick” into crushed concrete has “low to minimal effect” on the physical and mechanical properties of the original material. Therefore, the crushed brick blends with crushed concrete were demonstrated to satisfactorily meet the current VicRoads specification requirements.

The research indicates that initially up to 15 per cent “crushed brick” could be safely added to Class 3 crushed concrete blends. The degree of breakdown occurring in the crushed brick blend is on the limit of what would be acceptable for this material. Depending on the results of field trials, it may be possible to increase the percentage of crushed brick added in the future.

The grading limits of all crushed brick blends, “before and after” compaction were also within VicRoads specified upper and lower bounds for crushed concrete (CC3) while some grading for the crushed brick blends were close to the specified limits.

The wet and dry strength variation tests showed low variations (less than 10 per cent) for a number of blends. This indicates that there is little deterioration in strength from a dry to a saturated condition.

The grading limits of all crushed brick blends with up to 30 per cent crushed brick content were found to be within Melbourne Water upper and lower bound grading curves for “Grade A” and “Grade B” backfill and bedding material. The crushed brick blends satisfied all Melbourne Water requirements for both Grades A and B materials except the Los Angeles requirements for Grade A material which were found to be on the limit.
for both Grade A and Grade B materials except the Los Angeles Abrasion requirements for Grade A material, where further testing of different blends is recommended.

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ABOUT CENTRE FOR SUSTAINABLE RESEARCH, SWINBURNE
Civil infrastructure research at Swinburne University of Technology is undertaken within the Centre for Sustainable Infrastructure, commonly known as CSI-Swinburne.

CSI provides a focus for multi-disciplinary research in the field of sustainable civil infrastructure, which is a topic of national importance in the 21st century, and will expand research links through collaboration both nationally and internationally in a manner consistent with the Federal Government’s research model of “hubs and spokes”. CSI has three major research programs consisting of a series of projects involving industry partners, centre staff, research fellows and graduate students. The three research program areas are as follows: Advanced Structural and Geotechnical Systems (ASGS), Transportation Systems (TS) and Water Resources Modelling (WRM).

Swinburne University is continuing its
research focus on recycled materials with the potential to replace quarried products.

Associate Professor Arul Arulrajah, Centre for Sustainable Research, Swinburne University of Technology, welcomes industry inquiries, email aarulrajah@swin.edu.au •

REFERENCES


