Assessing brick waste on domestic construction sites for future avoidance

Perry Forsythe, Kirsty Máté
UNSW, Sydney, Australia

Abstract: The problem of construction waste on building sites is not new and continues to be a significant problem to the waste stream. Much has been done to better understand and encourage re-use and recycling, but relatively little has been done on avoiding the occurrence of waste in the first place. A significant contributor to the waste stream on domestic housing sites in Australia is brick waste. A common solution to the problem is recycling the waste into crushed brick, used as a landscaping aggregate or low grade road base. This relies on the stability of recycling markets and so a more ideal situation is to avoid brick waste in the first place. This paper investigates the issue of brick waste and strategies for avoidance. From site investigations, it was found that bricks accounted for the main loose waste onsite (by weight). As much as 75% of this waste was caused from cutting waste – often in trying to obtain half bricks. Through experimentation it was found that the brick design could be marginally changed during manufacture to better facilitate a successful ‘first strike’ of the brick, providing a clean split and thereby reducing wastage through unsuccessful strikes. This simple change could see a reduction in brick waste on domestic construction sites in Australia.

Conference theme: indicators of sustainable development: space, energy, water, waste OR construction and materials
Keywords: construction; waste; brick, masonry

1. INTRODUCTION

In 2003 the Australian Bureau of Statistics (ABS) reported that Australians were consuming more resources and producing more waste than at any other time and that Australia was one of the top 10 solid waste producers amongst all OECD countries. A growing population and rising living standards are increasing consumption patterns (DEC NSW 2006). Whilst much of this consumption is for smaller and more durable goods, a change in population demographics has also seen an increase in the size of homes. When coupled with the reduction of household sizes and increasing urban sprawl (ABS 2006) this has the effect of intensifying construction waste problems. Australians have been adding to the building stock at 3.8% per annum and in 2005 new construction for separate houses accounted for 33 million m² and home improvements 7 million m² (Walker-Morison et al 2007). In addition, residential building size has increased by 40% over the period from 1985 to 2005 (Walker-Morison et al 2007).

Issues associated with waste on new domestic construction sites are not novel and pose economic as well as ecological problems (Formoso et al. 2002; Forsythe & Marsden 1999). The Australian Bureau of Statistics (2006) classify construction and demolition waste as "Waste which is mostly inert materials such as timber, bricks, plaster off cuts, concrete, rubble, steel, and excavated earth." Using this definition, construction and demolition waste accounted for over 13,000 million tonnes of waste between 2002-03, accounting for approximately 42% of the total waste produced. Of this 13,000 million tonnes, 57% was recycled, leaving nearly 6,000 million tonnes going to landfill (ABS 2006).

These growing patterns of consumption and waste in the construction industry are not sustainable. This paper addresses how avoidance, being the highest level of waste prevention, and brick waste, being the largest form of waste on new residential construction sites, can assist in alleviating construction waste issues.

1.1. Construction sites and waste

Many studies have been undertaken on the constitution of waste from construction sites around the world (Kharrufa 2006; Crowther 2000; Formoso et al. 2002; Forsythe & Marsden 1999; Skoyles 1976 ). Others have focused on how to reduce it (Tam V. & Tam C. 2006; Formoso et al. 2002; Poon et al. 2004; Ekanayake & Ofori 2004). However despite this knowledge, construction waste continues to be a major problem in Australia and elsewhere.

Some State Governments in Australia have had an influence on reducing construction and demolition (C&D) waste to landfill with the introduction of landfill levies (ABS 2006; Crowther 2000). These levies are paid on each tonne of waste tipped at landfill and have proven moderately successful in making reuse and recycling options more inviting – especially where heavy weight materials are involved. A down side is that in some cases it has also increased illegal dumping.

Construction sites in states such as NSW and the ACT are required to produce a waste management plan indicating how wastes will be sorted, separated and recycled or disposed of from site (Crowther 2000). Good practice guides such as...
the WasteWise Construction Handbook: Techniques for Reducing Construction Waste produced by the Commonwealth Government, (Bell & McWhinney 2000) also advise on the sorting and separation of wastes on construction sites. This practice has become more common place in recent years and with large amounts of waste created on building sites, has led to the creation of private collectors. These companies provide a service to collect recyclable material for reprocessing, saving builders increasing landfill levies and creating their own individual income streams.

Recycled materials are an economic commodity, reliant on supply and demand markets for their economic value. An oversupply of material with a low demand can ‘flood’ the market, causing the economic value of the commodity to plummet. Such conditions can adversely affect the economic viability of recycling and make landfill a better option.

Projections for waste generation in C&D over the next 15 years are expected to continue to grow whilst recycling is expected to remain stable at 56-7%, presuming a continual demand for recycled product (ABS 2006). C&D waste disposed of to landfill therefore could nearly double by 2022-23 (ABS 2006).

A popular concept to reduce the universal problem of waste is the waste hierarchy concept. This concept was first introduced in the 1970’s as a consequence of the environment movement’s criticism on the practice of disposal-based waste management systems (Gertsakis & Lewis 2003). The waste management hierarchy is now evident in numerous environmental policies in both the private sector as well as government internationally, as an approach to reducing waste. At the top of the hierarchy is the intention to avoid waste followed by reuse, recycling and last of all disposal. Disposal is least desirable because in theoretical terms, the inherent physical value of the material becomes totally lost.

While the likes of re-use and recycling are beneficial as predominately ameliorative processes, avoidance has the benefit of being a preventative approach, maintaining the full value of a material (Gertsakis & Lewis 2003). With the expected growth pattern in C&D waste, coupled with a degree of uncertainty about the long term stability of re-use and recycle markets, avoidance has a valid role to play in reducing overall construction waste.

1.2. Bricks as a contributor to construction waste

Bricks remain a dominant material in residential construction (Page 2007; RMIT 2006) and can account for a large proportion of C&D waste on new residential construction sites (Crowther 2000; Formoso et al. 2002). It has been estimated in a recent study that the future demand of bricks over the next 50 years, will remain the second most significant building material, maintaining an average 25% share of the total building material requirements by mass (RMIT 2006). The use of brick is seen most significantly in single unit dwellings. While the future trend is towards multi-unit dwellings, which will mean a slight drop in demand for bricks, brick will remain the second most significant building material after concrete (RMIT 2006).

Bricks are largely treated as waste when broken or damaged from the brick production line or from construction and demolition sites (Crowther 2000; Formoso et al. 2002; Demir 2003; ABS 2006). Previous studies have shown that brick and concrete waste can constitute up to 75% of C&D waste from a construction site and that a large proportion of this waste is due to poor internal handling and excessive cutting (Crowther 2000; Formosa et al. 2002). (Note: statistical figures are combined for C&D waste and therefore could not be separated)

Given the previous discussion it was decided to undertake a study aimed at:

- Finding out how waste occurs in Australian brick construction on domestic housing sites;
- Responding to the above findings by trialling ways of redesigning brick construction to avoid brick waste – ultimately this resulted in a minor redesign of the standard brick to avoid waste from mis-cut bricks.

4. RESEARCHING CAUSES AND SOURCES OF BRICK WASTE

The research method revolved around a study of housing developments in Sydney comprising of 23 medium density housing projects and 20 detached dwelling projects. All were brick veneer construction and were used to find out how waste occurred in brick construction and how this could be avoided through brick design.

Both quantitative and qualitative data was collected from the sites including material quantity studies, landfill weigh bridge studies, site observations, site interviews and focus groups with bricklayers.

Ten separate causes of brick waste were evident from both qualitative and quantitative data analysis. The findings are are summarised in Table 1 which concentrates on causes and sources of the waste problems.
Table 1 Causes of brick waste in typical rank order of importance

<table>
<thead>
<tr>
<th>Causes of waste</th>
<th>Characteristic of waste variables</th>
<th>Source</th>
</tr>
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</table>
| 1. Cut bricks (i.e. off-cuts and breakages are rarely reused).                  | • Bricklayers often use a trowel instead of a bolster to cut bricks in half. This practice is used because it is faster but may cause multiple bricks to shatter before getting the desired half brick.  
• Bricks which are brittle or do not cut cleanly will increase the problem.  
• Some subcontractors are resistant to using a brick saw as they find it slow, changes their normal work processes, requires them to get off scaffolding, the equipment is expensive to purchase and maintain, and creates the need for an extra labourer to operate the saw.  
• Cutting increases with larger than normal amounts of sills, window reveals, raking cutting, offset walls or closing bond at the ends of blade walls.  
• ‘Fix only’ subcontracts rarely create motivation for bricklayers to re-use offcuts.  
• Poor “off-cuts” are not often suitable in “face” walls.  
• Work practices  
• Manufacture  
• Building design                                                                 |                                                                                                 |                             |
| 2. Handling and stacking breakages                                             | • Bricks delivered on inclined surfaces cause leaves in the brick stack to fall and break.  
• Muddy areas make handling more difficult and creates a risk of dirt contamination of bottom bricks.  
• The more re-stacking and barrowing, the higher the expected breakages.                                                                 | Work practices  
• Site management  
• Equipment technology                                                      |                                                                                                 |                             |
| 3. Ordering mistakes                                                           | • Inaccurate quantity take-off and/or over ordering ultimately create extra waste.  
• On large jobs, the risk of over ordering tends to be reduced because deliveries are made progressively through job and only the last order needs accurate take-off and ordering.                                                                 | Construction management |                             |
| 4. Incremental ordering problems on small jobs                                  | • Minor contributor on medium to large jobs.  
• Can be a significant contributor on small jobs if the bricks are only supplied in large order increments and only a small amount of the last order increment is required.  
• Incremental ordering problems will potentially worsen if the brickwork is made up of small amounts of different brick types – as may be required in blended brickwork. | Manufacturer/Supplier |
| Example: On a job requiring 1,100 bricks, 1,500 bricks must be ordered resulting in 27% waste. |                                                                                                 |                             |
| 5. Contracting issues                                                          | • Subcontract payment to bricklayers for labour only and based on the completed insitu brick count does not provide a payment system that encourages low wastage.                                                                 | Work practices |
| 6. Delivery waste                                                              | • No hard strap protectors at corners and edges of stacks can cause damage to bricks.  
• Hand unloading may increase waste.  
• Uneven landing pad for stacks can cause damage to bricks.                                                                 | Packaging during manufacturer  
• Construction management                                                      |                             |
| 7. Waste from setout problems                                                  | • Design not to bond.  
• Brick on edge used instead of stretcher bond where trying to create a level first course on an uneven footing.                                                                 | Building design  
• Manufacture                                                                   |                             |
| 8. Use of bricks for scaffolding and other unintended uses                     | • Mainly due to poor site control.                                                                 | Construction management |                             |
| 9. Bricks contaminated by dirt                                                 | • Bottom course may be effected. Bricks stacked on pallets are less likely to be effected                                                                 | Construction management |                             |
| 10. Theft                                                                     | • Situation specific. Large brick thefts are uncommon                                                                 | Societal issue              |                             |

Note: Despite the rank order, each cause will vary from job to job. The middle column identifies issues which may cause variation. This should be used to pick from “Ideal”, “Average” or “Upper range” waste margins.

Strategies attempting to address the Table 1 causes are shown in Table 2. These strategies were developed with the assistance of those involved in the research. The strategies have been listed in the context of short, medium and long term solutions - as set against the previously discussed concepts of avoidance, reuse and recycling.
### Table 2 Potential waste minimisation strategies for brickwork

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1 – Avoid waste</th>
<th>Alternative 2 – Re-use waste (on-site)</th>
<th>Alternative 3 – Re-cycle waste</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short term</strong></td>
<td>• Order bricks more accurately using best take-off practice.</td>
<td>• Take unwanted bricks back to brick yard for crushing and re-use in brick production.</td>
<td>• Take brick left-overs away to use as aggregate or landscaping cover.</td>
</tr>
<tr>
<td></td>
<td>• Ensure bottom layers of bricks remain useable by preventing soil contamination.</td>
<td>• Offer the customer left over (full) bricks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Store bricks in a stable flat area to avoid breakages from fall overs.</td>
<td>• Include a clean-up payment in the scope of the bricklayer's sub-contract to assist recycling and to discourage wasteful site practices.</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td><strong>Medium term</strong></td>
<td>• Determine a means for cutting bricks into half more accurately so that both halves can be used and breakages avoided.</td>
<td></td>
<td>• Develop an agreement where a contractor “sells back” the re-cycled waste from the original material supplier.</td>
</tr>
<tr>
<td></td>
<td>• Supplier to provide more flexible “fast pack” sizes i.e. a “fractional” pallet instead of a full pallet.</td>
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<td></td>
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<tr>
<td><strong>Long term</strong></td>
<td>• Manufacture half bricks.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The feasibility of the above strategies is dependent on efficient site collection and waste transportation.*

Clearly, a number of the more novel strategies in Table 2 require feasibility testing before they are likely to advance to active use in construction. Undertaking the full gamut of such testing is beyond the scope of this paper. However, in order to demonstrate new possibilities, it was decided to go some way in advancing the feasibility of strategies relating to waste from brick cutting, as this was identified in earlier stages of the research as the biggest contributor to brick waste. To this end, two manufacturing ideas were explored to avoid cutting waste. Each is discussed below.

### 5. THE FEASIBILITY OF MANUFACTURING HALF BRICKS

It was suggested during the course of the research that manufacturers may be able to produce half bricks with little change to their production process. However, upon exploration of common manufacturing processes, key problems relating to this idea were found and included:

- Extra work for the brick manufacturer relating to marketing, stock control, ordering practices and administration.
- Varying colours between half and full bricks due to variance in overall mass.
- Hole patterns in some bricks occur at the half way point requiring expensive changes to production and product design.
- Half bricks may present a cheaper solution (overall) but in a direct comparison of production costs, a half brick will probably cost more to place on the market than a full brick.
- There would be a considerable time lag in changing and re-tooling the production process to make half bricks.

Given the above problems it was decided that the up-take of manufacturing half bricks was unlikely to be successful and subsequently greater attention was placed on the alternative idea of modifying standard brick design with a view to improving the ability to cut them in half more easily and accurately, thus minimising waste.

### 6. THE FEASIBILITY OF MANUFACTURING A FRACTURE GROOVE INTO STANDARD BRICKS

This idea aimed to test the concept of adding shallow grooves to the brick (i.e. during manufacture) to make it easier and more accurate to cut in half onsite. In essence, the grooves aimed to facilitate a fracture plane when the brick was hit with a bolster (as per traditional trade practice). The intended result was to obtain two useable half bricks from only a single blow from the bolster.

In order to determine the manufacturing feasibility of this idea, inquiries were made with a large Sydney based brick manufacturer. From this, it was decided that the least disruptive approach to manufacturing the grooves was to modify the cylindrically shaped “buttons” used to create the extrusion holes in bricks. These grooves would only be needed for the “buttons” creating the holes at the mid section of the brick and would result as opposing grooves on either sides of those holes as shown in Figures 1 and 2. It was unclear if the vertical grooves would be sufficient to create a fracture plane and so half the sample included an additional horizontal groove, tooled into the surface of the brick (refer Figure 3). Provision of such a groove would require a new point in the manufacturing process, but was considered realistically achievable, subject to production line modifications.
 Having determined the manufacturing feasibility of the groove incisions, mock-ups to replicate them were created. Here, a sample of 10 extruded bricks was taken from the aforementioned brick manufacturer’s production line in a pre-fired (green) state. Grooves approximately 1-2mm deep were cut into the brick using a hack saw blade. On half the bricks, only vertical grooves were provided (refer Figures 1, 2), on the other half, horizontal top grooves were added (refer Figure 3). After cutting the grooves the bricks were fired under normal conditions. After being removed from the kiln for approximately 2 weeks the bricks were cut using a 55mm wide bolster by striking it with a limp hammer. The results from this are shown in Table 3.

![Figure 1: Plan view of vertical grooves only](image1.png)

![Figure 2: Perspective showing vertical grooves only](image2.png)

![Figure 3: Perspective view of vertical and horizontal grooves](image3.png)
Table 3: Brick cutting results

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Fracture Groove Type</th>
<th>No. of bolster blows to brick</th>
<th>Comment</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>front face</td>
<td>rear face</td>
<td>top face</td>
</tr>
<tr>
<td>1</td>
<td>V</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>V</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>V</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>V</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>HV</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>HV</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>HV</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>HV</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>HV</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Legend:
V = Vertical grooves only
HV= Horizontal and vertical grooves

7. OBSERVATIONS AND FINDINGS FROM THE FEASIBILITY TESTING

Though only a small pilot sample was undertaken, it was found that groove depth was important to the efficiency and accuracy of cutting the bricks. For instance, the grooves were cut into the prototype bricks using simple hand sawing rather than precision machinery. As a result, groove depths varied slightly across the sample (a range of 0.75mm). Here it was found that bricks with grooves in the order of 1.5mm – 2.0mm deep, performed well in terms of a minimal number of blows from the bolster and a neat cut line. Bricks with a shallower groove in the order of 1.25mm deep (refer Cases 5 and 10 on Table 3) either required extra blows with the bolster (i.e. 3 blows) and also resulted in only one half of the brick being usable. This occurred irrespective of one brick having a vertical groove only (as in Case 5) and the other having both a vertical and horizontal groove (as in Case 10). As a result, it would seem that a groove depth of 1.5mm (min.) is an important design feature.

Except for the case mentioned above, all the other cases resulted in two usable half bricks. Such results were encouraging in terms of meeting one of the main aims of the feasibility testing. In terms of the number of bolster blows required to cut bricks in half, one to two medium blows were found to be sufficient to cut most of the bricks in half. Some required three blows which was thought to be boarding on an undesirable work feature. One such case was possibly caused by the shallow groove problem discussed previously (as in Case 10). Another two occurred where two blows to the front face were insufficient to cut the brick, so a third blow was made to another face (i.e. the top face as in Case 2, and the rear face as in Case 3).

Within the above context, early cases in the sample were dealt with by attempting one to two blows to the front face of the brick to encourage simplicity in work practice and to try and ensure a neat cut to the exposed face of the resulting half bricks. But this was not always successful. For instance as alluded to previously, occasional extra blows were required to other faces and in Case 8 the emphasis on blows to the front face create a fracture line but also caused this line to fracture splay sideways at the back of the brick. Here, one half of the brick had a jutting rear piece and the other half had a corresponding missing piece. Though this did not prevent both halves from being used, the regular occurrence of such a result onsite would ultimately mean extra work for the bricklayer in trimming the jutting piece off. To counteract this problem the remaining bricks were treated differently with a single blow to either the top or rear of the brick first, followed by face blows. This seemed to benefit the process. Though the sample is too small to judge this with any certainty, it can be said that a blow to the rear of the brick first, followed by a heavier blow to the front face, seemed to work best (as in Cases 1, 3, 5). In two other instances (Cases 4 and 9), one rear blow was sufficient to cut the brick. Interestingly this did not prevent the front face from cutting accurately.

Apart from these observations, no obvious pattern emerged regarding the usefulness of the top groove in the half the bricks.

8. DISCUSSION ABOUT ONGOING TESTING

Clearly, the experiment is insufficient in size to provide broad generalised findings. Its main purpose was simply to test the feasibility of modifying the basic brick design to assist site cutting. Further design development is required as is
further testing. This should consider the usefulness of the previously discussed horizontal groove. Another option would be to consider an additional vertical groove located on the rear (unseen) face of the brick.

Other variables that require further testing include bricks with different hole patterns which may effect the accuracy of the fracture line. Variability in the baked clay itself, may also influence the accuracy of the fracture line.

Apart from laboratory testing, it must also be tested by bricklayers on site, to obtain feedback on its workability and to provide statistics on the anticipated reduced brick waste.

CONCLUSION

It has been found that bricks are the second most significant building material by mass after concrete in Australia. It accounts for a large proportion of C&D waste in new residential construction. Waste through inaccurate brick cutting – primarily by chopping at bricks with a trowel – creates the main amount of that waste. Strategies exist in terms of avoidance, reuse and recycling.

Focusing on the avoidance issue, this research concluded that the manufacturing half bricks was unlikely to be taken up by manufacturers. However, it has shown that through a simple re-design of the common brick (via fracture grooves manufactured into the brick) there is considerable potential to allow more efficient and accurate cutting of bricks on site. As such, there is potential that much waste can be avoided. The research also indicates that this can be achieved with minimum disruption to existing brick production processes. Initial results are promising with 80% of the bricks successfully cut to provide two useable half bricks. Bricks with grooves at least 1.5mm deep were found easy and fast to cut with a bolster. Based on the above results and the potential for further design improvements, there is likelihood that 1-2 medium bolster blows will be sufficient to cut a brick. If this is achieved then a simple yet viable means of avoiding waste may be possible. However while the concept shows promise, it is still at an early stage of development. A much broader and thorough range of testing is required. It is hoped that such testing and further development may come from brick manufacturers.

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