SUITABLE SEPARATION TREATMENT OF STONY COMPONENTS IN CONSTRUCTION AND DEMOLITION WASTE (CDW)

Charles F. Hendriks (1), Weihong Xing (2)

(1) Delft University of Technology, faculty of CiTG, The Netherlands
(2) Wuhan University of Technology, China

Abstract ID Number: 353

Author contacts

<table>
<thead>
<tr>
<th>Authors</th>
<th>E-Mail</th>
<th>Fax</th>
<th>Postal address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof Dr Ir Charles F. Hendriks</td>
<td><a href="mailto:ch.hendriks@citg.tudelft.nl">ch.hendriks@citg.tudelft.nl</a></td>
<td>+ 31 (15) 2788162</td>
<td>PO Box 5048 2600 GA DELFT The Netherlands</td>
</tr>
<tr>
<td>Mrs. Dr Weihong Xing</td>
<td><a href="mailto:axwh@hotmail.com">axwh@hotmail.com</a></td>
<td></td>
<td>Wuhan University of Technology State Key Lab of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Advanced Technology for Material Synthesis and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Processing Wuhan 430070, P.R. China</td>
</tr>
</tbody>
</table>

Total number of pages of the paper (this one excluded): 8
SUITABLE SEPARATION TREATMENT OF STONY COMPONENTS IN CONSTRUCTION AND DEMOLITION WASTE (CDW)

Charles F. Hendriks (1), Weihong Xing (2)

(1) Delft University of Technology, faculty of CiTG, The Netherlands
(2) Wuhan University of Technology, China

Abstract

Worldwide most construction and demolition waste (CDW) is currently dumped. Even though it has been recycled in some countries for examples, the Netherlands, Belgium and Denmark, most of the recycled CDW are reused in low technical applications of road constructions. It is down-cycled. To close the building cycle and the building materials cycle by recycling CDW in high technical applications, the technical quality of stony materials must be improved. For this purpose, concrete rubbles and brick rubbles, the two major stony constituents of CDW, should be separated from each other. Based on the differences in density and content of Fe₂O₃ between the two materials, a wet method of jigging and a dry method of magnetic separation are effective, tested in laboratory.

Key words: CDW, concrete rubble, masonry rubble, upgrading, separation technique.
INTRODUCTION

Construction and demolition waste (CDW) is the waste released when buildings and other constructions such as roads and bridges are built, renovated, and demolished. Typical components in CDW are concrete, asphalt, brick, wood, metals, gypsum wallboard, and roofing. In Dutch CDW, stony materials including concrete rubble and masonry rubble are the majority, about 65%, which are suitable to be recycled as secondary raw building materials. Prompted by national policy, the amount of reused CDW is being increased in the Netherlands. In 2001, more than 90% (by mass) was reused. However, the reuse of CDW remains in low technical applications, because currently the main products are mixed aggregates, which contain concrete rubbles and masonry rubbles. Such aggregates are qualified to use in road constructions, but the technical quality is too low to use in concrete products because soft masonry materials may negatively affect mechanical properties of concrete products.

Aimed to find out suitable separation techniques, a laboratory study is executed on how to separate concrete rubble and brick rubble from each other in order to recycle them as secondary concrete aggregates in concrete products and secondary materials in clay bricks respectively.

Separation techniques

Usually the properties as basis of materials separation are: particle size and shape, density, magnetic susceptibility, and colour. The significant differences in properties between concrete and brick rubbles are differences in density, content of Fe₂O₃ and colour. The density of concrete is bigger than that of brick, so gravity methods of jigging separation, fluidised bed method, and spiral should be suitable to separate the two materials. Depending on the significant difference in colours, colour separation can be applied. The content of Fe₂O₃ in brick is higher than that in concrete. If brick is considered as a magnetic material, concrete will be a non-magnetic or weak magnetic material. Therefore magnetic separation could be a suitable method to remove brick rubble from concrete rubble. The suitable techniques are listed in Table 1. Magnetic and jigging separation methods were tested in laboratory.

<table>
<thead>
<tr>
<th>Property</th>
<th>Brick</th>
<th>Concrete or mortar</th>
<th>Suitable separation techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1.6 to 1.8 g/cm³</td>
<td>2.3 to 2.5 g/cm³</td>
<td>jigging, fluidised bed method, spiral</td>
</tr>
<tr>
<td>Colour</td>
<td>red or yellow</td>
<td>grey</td>
<td>colour separation</td>
</tr>
<tr>
<td>Fe₂O₃%</td>
<td>3 to 4%</td>
<td>0 to 1%</td>
<td>magnetic separation</td>
</tr>
</tbody>
</table>
**Separation treatment of stony CDW**

**Magnetic separation**

A simple magnetic separator (Frantz Isodynamic separator) was used. Unit of volume of the material generates the separation of particles by a magnetic moment. The apparent magnetic susceptibility is \( \chi = \sin \alpha / (kI^2) \). In which, \( \alpha \) = angle, \( I \) = current [A], \( k = 4.1 \times 10^6 \). Therefore the electricity current and the tilting angle of machine are critical for magnetic field. Two forces, magnetic force and gravity act on a magnetic particle (see Figure 1). With a proper magnetic field, forces on a magnetic particle will achieve a balance. A non-magnetic particle is only acted by its gravity. Thus magnetic particles can be separated from non- or weak magnetic particles.

![Figure 1: Forces on a magnetic particle](image)

**Experimental samples**

To test the efficiency of magnetic separation, mixtures of Portland cement mortar (which has the same content of Fe\(_2\)O\(_3\) as concrete) and clay brick were tested with fixed ratios of clay brick to mortar: 50\%: 50\%, 70\%: 30\%, and 30\%: 70\% (by mass). The mortar used in mixtures contains 25\% Portland cement (PC) that contains 1 to 5\% Fe\(_2\)O\(_3\), this means that PC mortar contains less than 1.25\% Fe\(_2\)O\(_3\). Clay bricks contain 3 to 4\% Fe\(_2\)O\(_3\). The ideal separation result is that all brick particles end up in magnetic fraction and all mortar particles end up in non-magnetic fraction.

Due to the size of machine, the samples were crushed and milled to 0.15 to 2.36 mm. It is possible to build a large equipment based on the same working principle with a capacity of 100 to 200 kilotons annually.

**Separation results and discussion**

To obtain the optimal operation parameters of the machine, pure brick and mortar samples were tested. For each pure material, a median magnetic susceptibility is found at the point of a 50\% magnetic fraction. To reach this balance point between magnetic force and gravity, the machine angle should be selected between 10\(^{\circ}\) to 20\(^{\circ}\).

To separate the mixtures, the machine angle varies from 10\(^{\circ}\) to 20\(^{\circ}\) and the current is between 1.0 and 1.5\(A\). With a current smaller than 1\(A\), the magnetic field is too weak to separate both materials. With a current bigger than 1.5\(A\), the magnetic field is too strong and draws weak-magnetic mortar particles into magnetic fraction. This will reduce the purity and recovery of brick production.

The optimum results are shown in Table 2. It is known that when the ratio of brick to mortar is 1:1 at the machine angles of 15\(^{\circ}\) and 17\(^{\circ}\) with a current of 1.2\(A\), good separations are
obtained. At 17°, both purity and recovery are high. When the ratio is 3:7, a good separation is obtained at a machine angle of 17° with a current of 1.2 A; when it is 7:3, the optimal machine angle is 15° with the same current. Here, ‘good separation’ means that the separation is good for both brick and mortar, not only with high purity but also with high recovery.

Table 2: Optimal magnetic separation for mixtures of brick and mortar

<table>
<thead>
<tr>
<th>Ratio of brick to cement mortar</th>
<th>Current I (A)</th>
<th>Machine angle α</th>
<th>Percentage of brick (%)</th>
<th>Purity of brick</th>
<th>Purity of mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>hard red brick</td>
<td>50% : 50%</td>
<td>1.2</td>
<td>17°</td>
<td>54</td>
<td>good</td>
</tr>
<tr>
<td></td>
<td>30% : 70%</td>
<td>1.2</td>
<td>17°</td>
<td>33</td>
<td>good</td>
</tr>
<tr>
<td></td>
<td>70% : 30%</td>
<td>1.2</td>
<td>15°</td>
<td>71</td>
<td>best</td>
</tr>
<tr>
<td>red brick</td>
<td>50% : 50%</td>
<td>1.2</td>
<td>17°</td>
<td>57</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>30% : 70%</td>
<td>1.2</td>
<td>17°</td>
<td>36</td>
<td>good</td>
</tr>
<tr>
<td></td>
<td>70% : 30%</td>
<td>1.2</td>
<td>15°</td>
<td>71</td>
<td>best</td>
</tr>
</tbody>
</table>

For the mixture with a ratio of brick to mortar of 3:7, when the machine does not tilt enough (at an angle of 15°), some mortar particles contaminate the magnetic production, because the amount of mortar is higher than that of brick. On the contrary, when the ratio of brick to mortar is 7:3, if the separator tilts too much (at 17°), some brick particles go to the mortar product. Good separations are obtained at 17° for the mixture with a ratio of 3:7 and at 15° for the mixture with a ratio of 7:3.

The purities of separated fractions are determined by comparing to the mixtures with known purities, prepared in laboratory, shown in Figure 2.

![brick: 93%; mortar: 87%](image)

Figure 2: Magnetic separation results

From this experiment, it is clear that magnetic separation is an effective method to separate brick and mortar from each other. Because the contents of Fe₂O₃ in mortar and in concrete are same, magnetic separation should also be effective to separate brick and concrete rubbles from each other in actual construction and demolition waste by a large separator.

**Jigging separation**

**Jig separator**

Jigging separation is generally used to concentrate relatively coarse materials down to 3 mm. In a jig, the separation of materials with different densities is accomplished in a bed that is rendered fluid by a pulsating current of water. When water is put under pressure by a plunger, the particles fall with different speeds to the bottom, depending on their densities.
The heavy particles will sink first and be discharged at the bottom of the apparatus (see Figure 3).

Sharpness of materials division by jigging depends on the ratio of densities: \( q = \frac{\rho_{\text{heavy}} - \rho_{\text{water}}}{\rho_{\text{light}} - \rho_{\text{water}}} \). In which, \( \rho_{\text{heavy}} \) is the density of heavy particles, \( \rho_{\text{light}} \) is the density of light particles, and \( \rho_{\text{water}} \) is the density of water, it is 1 g/cm\(^3\). Sharpness of separation increases when the ratio of densities \( q \) increases. The bigger the density difference between particles, the better the separation result.

To separate concrete (\( \rho_{\text{concrete}} = 2.4 \) g/cm\(^3\)) and brick (\( \rho_{\text{brick}} = 1.7 \) g/cm\(^3\)) by jigging, \( q = \frac{2.4 - 1}{1.7 - 1} = 2 \). If we use air instead of water, \( q' = \frac{2.4 - 0}{1.7 - 0} = 1.4 \). So the separation of concrete and brick in water should be more effective than in air.

Figure 3: Sketch of a jig

To obtain good separation results, the critical operating parameters for separation are:

- Feed particle size: a good separation can be obtained if size and shape of particles are within close range.
- Hutch water flow rate: higher water flow rate results better separation because light particles are affected more significantly than heavy particles by friction, which is provided by the upflow of water.
- Frequency of oscillation: a slower frequency results in a good separation for larger particles. In contrast, a faster frequency should be applied to finer feed.
- Amplitude of displacement: to obtain a good separation for a dense feed, more space is needed with greater amplitude.

Separation results

To make separation effective, the particles should be relatively similar in size. Four fractions of CDW obtained by wet sieving: 2 to 5 mm, 5 to 10 mm, 10 to 19 mm, and >19 mm, are separated by jigging respectively.
For each fraction, two concentrates are obtained, i.e. one on the top of the container with a light density and another on the bottom of the container with a heavy density. The upper concentrate is the brick fraction and the lower is the concrete fraction. Figure 4 shows the separation results of coarse fraction (>19 mm), both purities of brick fraction (89.0%) and concrete fraction (99.4%) are high. For the fine fraction (2~5 mm), it needs carefully control of operating parameters to obtain good separation result.

The results show that jigging is an effective wet method to separate light and heavy stony particles from each other, especially for coarse fractions. After separation, the concrete fraction is cleaned enough and can be recycled as concrete aggregates directly, but the brick fraction should be dried and milled for use in fired clay bricks.

Explanation of the separation of concrete and brick by jigging

The bulk densities of the two coarse fractions obtained by jigging separation (>19 mm) were tested by wire-basket method. Their bulk densities change under water with time and reach constant values in about 30 minutes as shown in Figure 5. From beginning to the water-saturated situation, there is always a distinguished difference in bulk density between the two materials as we can see in Figure 5. This makes jigging separation possible and effective.

![Figure 4: Jigging separation results of coarse CDW (>19 mm)](image1)

![Figure 5: Bulk densities change with time under water](image2)
CONCLUSION

From the laboratory study, it is known that magnetic separation and jigging separation are effective to separate concrete rubbles from masonry rubbles. After treatment, the generated concrete and brick fractions are suitable to be recycled as secondary concrete aggregates for concrete products and secondary materials for fired clay brick products respectively.

The magnetic separator in laboratory is a small one. To treat large quantities of CDW with big particle sizes, big equipment can be built based on the same working principle. By the wet method of jig, washable and soluble components are removed together with slurry. The concrete fraction obtained by jigging separation is clean enough to be directly reused as secondary concrete aggregates due to the wet process. While the brick rubbles should be dried before reuse.

REFERENCES


