Gravity Concentration of CDW on Air Jigs

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Workshop on CDW recycling
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Jigging process

How jigging works?

\[ v_\infty = \left[ \frac{3gd_p (\rho_s - \rho_f)}{\rho_f} \right]^{1/2} \]

\[ v_\infty = \frac{(\rho_s - \rho_f) b d_p^2}{18 \mu} \]

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Background

Air jigs and CDW recycling plants:

A - Crushing and grain size separation

B - A
  + metals separation
  + complex sizing

C - B
  + specific separation process (gypsum, rubber, etc)

Level 1

Level 2

Level 3

Only ceramic + concrete
Mainly ceramic + concrete
Totally mixed CDW

© Adapted from Symonds Group, 1999.

Air jigs: Level 3 facilities
Literature review

“Construction and demolition waste”:

1974 – *Construction solid waste*. David A. Spivey ©;


1997 – *Building rubble treatment using the AllJig in Europe and USA*. A. Jungmann ©;

2006 – *A review on the viable technology for construction and waste recycling*. Vivian Tam et. Al ©;


2013 – *Environmental analysis of a construction and demolition waste recycling plant in Portugal, part I and part II*. Coelho & de Brito ©;

2014 – The potential to use air jigging to sort recycled aggregates. Cazacliu et Al. ©.

10 – 50 mm mixed CDW feed, 30.5 t/h

Dry density separation

Automatic X-ray transmission sorting

Decontaminated combustible, 5 t/h

Contaminated combustible (PVC, Br etc.), 0.5 t/h

Displaced aggregate, 2 t/h

Decontaminated aggregate, 25 t/h

Displaced organic, 1 t/h

Return stream, 3 t/h
Environmental analysis of a construction and demolition waste recycling plant in Portugal, part I and part II. Coelho & de Brito ©;
The potential to use air jigging to sort recycled aggregates.
Cazacliu et Al (2014).
Air jig (Laprom)

AllAir S 500® (AllMineral)

Operational parameters:
- Expansion ratio
- Frequency
- Jigging time

Jig chamber with assembly boxes

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Samples

a) Concrete (30 MPa at 28 days);
b) Solid clay bricks;
c) Gypsum blocks;
d) Wood: transport pallets;
e) Paper: wastes of drywall panels
Experimental procedure

a) Batch operation;

b) Samples: 100% free aggregates;

c) Particle size range: 4.8 to 20 mm;


© Adapted from Sampaio and Tavares, 2005.
Experimental procedure

Density measures:

<table>
<thead>
<tr>
<th>Material</th>
<th>Skeletal Density (g/cm³)</th>
<th>Envelope Density (g/cm³)</th>
<th>Bulk Density ± standard deviation (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>2.67</td>
<td>2.39</td>
<td>1.67 ± 0.037</td>
</tr>
<tr>
<td>Brick</td>
<td>2.59</td>
<td>2.26</td>
<td>0.84 ± 0.042</td>
</tr>
<tr>
<td>Gypsum</td>
<td>2.30</td>
<td>1.86</td>
<td>0.61 ± 0.046</td>
</tr>
</tbody>
</table>

Multipycnometer Quantchrome®

Waterproofing

Box of known volume
Binary mixture

1) Concrete + Brick (31.6 kg)

<table>
<thead>
<tr>
<th>Exp. Ratio:</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency:</td>
<td>160 rpm</td>
</tr>
<tr>
<td>Time:</td>
<td>120 s</td>
</tr>
<tr>
<td>OBS:</td>
<td>not optimized</td>
</tr>
</tbody>
</table>

57.9% mass

42.1% mass
1) Results to binary mixture

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>88.54%</td>
<td>69.49%</td>
<td>37.47%</td>
<td>8.98%</td>
</tr>
<tr>
<td>Brick</td>
<td>11.46%</td>
<td>30.47%</td>
<td>62.48%</td>
<td>90.98%</td>
</tr>
</tbody>
</table>

Brick removal = 73% mass
Concrete recovery = 48.6% mass
Ternary mixture

2) Concrete + Brick + Gypsum (39.7 kg)

- Particle size: 4 to 20 mm
- 6 layers

- Exp. Ratio: 80%
- Frequency: 150 rpm
- Time: 120 s
- OBS: Optimized

- 46% mass
- 34% mass
- 20% mass
Ternary mixture

2) Results to ternary mixture

Before jigging

After jigging
Ternary mixture

2) Results to ternary mixture:

Product (layer 1):
- Gypsum removal = 98.5%
- Brick removal = 75.2%
- Concrete recovery = 48.3%

Product (layer 1 and 2):
- Gypsum removal = 96.8%
- Brick removal = 43.8%
- Concrete recovery = 79%

Composition:
- Concrete = 80.2%
- Brick = 19.2%
- Gypsum = 0.6%

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2) “Horizontal segregation” (convection cells):

© Adapted from Xue et Al. (2012) ©
Multicomponent mixture

3) Concrete + Brick + Gypsum + Wood + Paper (33.7 kg)

Exp. Ratio: 80%
Frequency: 140 rpm
Time: 120 s
OBS: Optimized

54% mass 40% mass 1.8% mass 1.7% mass 0.9% mass
Multicomponent mixture

3) Results to multicomponent mixture:

Before jigging

After jigging
Multicomponent mixture

3) Results to multicomponent mixture:

Product (layer 1):
- Paper removal = 99.9%
- Wood removal = 100%
- Gypsum removal = 98.4%
- Brick removal = 84.3%
- Concrete recovery = 48.3%

<table>
<thead>
<tr>
<th>Mass fraction (%)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>93.65%</td>
<td>79.16%</td>
<td>27.08%</td>
<td>4.99%</td>
<td>0.66%</td>
</tr>
<tr>
<td>75%</td>
<td>6.27%</td>
<td>20.54%</td>
<td>70.47%</td>
<td>89.05%</td>
<td>53.62%</td>
</tr>
<tr>
<td>50%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>2.43%</td>
<td>5.28%</td>
<td>6.45%</td>
</tr>
<tr>
<td>25%</td>
<td>0.03%</td>
<td>0.26%</td>
<td>24.3%</td>
<td>5.28%</td>
<td>6.45%</td>
</tr>
<tr>
<td>0%</td>
<td>0.05%</td>
<td>0.03%</td>
<td>0.00%</td>
<td>0.11%</td>
<td>13.38%</td>
</tr>
</tbody>
</table>

Legend:
- Paper
- Wood
- Gypsum
- Brick
- Concrete
### RCA quality

<table>
<thead>
<tr>
<th>Mixture used in the test</th>
<th>RCA composition (% mass)</th>
<th>Operational Conditions of jigging</th>
<th>Quality standard classification (composition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Concrete + Brick</td>
<td>88.5% Concrete 11.5% Brick</td>
<td>Not optimized</td>
<td>ARM (NBR 15.116) ARB 2 (DIN 4226-100) ARB 2 (LNEC)</td>
</tr>
<tr>
<td>2) Concrete + Brick + Gypsum</td>
<td>91.3% Concrete 8.4% Brick 0.3% Gypsum</td>
<td>Optimized</td>
<td>ARB (NBR 15.116) ARB 1 (DIN 4226-100) ARB 1 (LNEC)</td>
</tr>
<tr>
<td>3) 2 + Wood + Paper</td>
<td>93.6% Concrete 6.3% Brick 0.03% Gypsum 0.05% Paper</td>
<td>Optimized</td>
<td>ARB (NBR 15.116) ARB 1 (DIN 4226-100) ARB 1 (LNEC)</td>
</tr>
</tbody>
</table>
Technical comparison

Heavy fraction (water x dry process):

### Water jig (AllJig S 400®)

<table>
<thead>
<tr>
<th>Material</th>
<th>Inferior layer</th>
<th>Middle layer</th>
<th>Superior layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum</td>
<td>0.10%</td>
<td>5.10%</td>
<td>89.60%</td>
</tr>
<tr>
<td>Brick</td>
<td>8%</td>
<td>82.10%</td>
<td>10%</td>
</tr>
<tr>
<td>Concrete</td>
<td>91.90%</td>
<td>12.80%</td>
<td>0.40%</td>
</tr>
</tbody>
</table>

### Air jig (AllAir S 500®)

<table>
<thead>
<tr>
<th>Material</th>
<th>Inferior layer</th>
<th>Middle layer</th>
<th>Superior layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum</td>
<td>0.60%</td>
<td>9.50%</td>
<td>90.19%</td>
</tr>
<tr>
<td>Brick</td>
<td>19%</td>
<td>63.83%</td>
<td>9%</td>
</tr>
<tr>
<td>Concrete</td>
<td>80.17%</td>
<td>26.65%</td>
<td>0.67%</td>
</tr>
</tbody>
</table>

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## Technical comparison

Removal of contaminants (sorter x air jig):

<table>
<thead>
<tr>
<th>TOMRA near-infrared sorting (GmbH – Germany) © Vegas et al. (2015)</th>
<th>AllAir S 500®</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stony fraction:</strong> 52% Concrete</td>
<td><strong>Stony fraction:</strong> 54% Concrete</td>
</tr>
<tr>
<td>27% Ceramic</td>
<td>40% Brick</td>
</tr>
<tr>
<td>15% Unbound stones</td>
<td></td>
</tr>
<tr>
<td>1% Asphalt/Glass</td>
<td></td>
</tr>
<tr>
<td><strong>Contaminants:</strong> Gypsum, Wood Paper, Rubber</td>
<td><strong>Contaminants:</strong> Gypsum, Wood Paper</td>
</tr>
<tr>
<td>(≈ 3% in mass)</td>
<td>(= 5% in mass)</td>
</tr>
<tr>
<td><strong>Best removal efficiency:</strong> 97%</td>
<td><strong>Removal efficiency:</strong> 96%</td>
</tr>
</tbody>
</table>

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Comparison of costs (sorter x air jig):

**TOMRA near-infrared sorting**  
(GmbH – Germany)  
© Vegas et al. (2015)

- Input: Mixed CDW (d > 6 mm)
- Capacity: 30 ton/h
- Fixed costs: 320,000 €/unit
- Operational costs: 80,000 €/year
- **Treatment cost: 0.8 €/ton**

**Air Jig**  
(Recycling plant – Portugal)  
© Coelho & de Brito (2013)

- Input: Mixed CDW (d > 4 mm)
- Capacity: 30 ton/h
- Fixed costs: 690,000 €/unit
- Operational costs: 30,000 €/year
- **Treatment cost: 0.3 €/ton**

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Environmental aspects

CDW recycling plant (Lisbon, Portugal):

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Rated power, kW/unit</th>
<th>Energy used</th>
<th>Primary energy consumption, kgoe/year</th>
<th>CO$_2$eq emission, kgCO$_2$eq/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scales</td>
<td>0.05</td>
<td>Electricity</td>
<td>35</td>
<td>42</td>
</tr>
<tr>
<td>Excavator</td>
<td>90</td>
<td>Diesel</td>
<td>18576</td>
<td>56322</td>
</tr>
<tr>
<td>Vibrating feeder</td>
<td>16.2</td>
<td>Electricity</td>
<td>11275</td>
<td>13530</td>
</tr>
<tr>
<td>Magnet (ferrous metals)</td>
<td>6.5</td>
<td>Electricity</td>
<td>4524</td>
<td>5429</td>
</tr>
<tr>
<td>Manual separation cabinet</td>
<td>0.28</td>
<td>Electricity</td>
<td>136</td>
<td>164</td>
</tr>
<tr>
<td>Crusher</td>
<td>110</td>
<td>Electricity</td>
<td>76560</td>
<td>91872</td>
</tr>
<tr>
<td>Horizontal screen 1</td>
<td>18.5</td>
<td>Electricity</td>
<td>12876</td>
<td>15451</td>
</tr>
<tr>
<td>Air sifter</td>
<td>6.3</td>
<td>Electricity</td>
<td>9135</td>
<td>10962</td>
</tr>
<tr>
<td>Eddy current generator (non-ferrous metals)</td>
<td>16.4</td>
<td>Electricity</td>
<td>7990</td>
<td>9588</td>
</tr>
<tr>
<td>Horizontal screen 2</td>
<td>22.3</td>
<td>Electricity</td>
<td>15544</td>
<td>18653</td>
</tr>
<tr>
<td><strong>Air jig</strong></td>
<td><strong>127</strong></td>
<td><strong>Electricity</strong></td>
<td><strong>476189</strong></td>
<td><strong>571427</strong></td>
</tr>
<tr>
<td>Spirals</td>
<td>27</td>
<td>Electricity</td>
<td>114631</td>
<td>137557</td>
</tr>
<tr>
<td>Conveyors</td>
<td>Variable</td>
<td>Electricity</td>
<td>49010</td>
<td>58812</td>
</tr>
</tbody>
</table>

© Coelho & de Brito (2013)
Preliminary conclusions

-Air jigs are a versatile gravity concentrator which show good performance to sorter as heavy as lighter particles;

-Air jigs are a very competitive equipments to CDW beneficiation and are technically compared with NIR sorter;

- The air jig has potential to deliver RAs that meet the main quality standards requests;

- More studies have been done concerning the environmental impact of air jigs inside the CO2eq balance inside the recycling plant.
Future topics

- Tests with bound aggregates;

- Quality tests with the output concrete;

- Granular convection and its influence on segregation;

- Link between air jig and other separation techniques.
THANK YOU / MERCI / OBRIGADO