Case Study:

Municipal Waste Incinerator Ash in manufactured Aggregate

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Introduction

**Municipal Solid Waste Incinerator Bottom ash**

Incinerator bottom ash is the coarse residue left on the grate of waste incinerators. It is primarily composed of a mix of ceramics, slags, and glassy material. It may contain metal material too, primarily ferrous. The composition is 15% of material unchanged by combustion (10% Glass, 2% soil, 2% metals, 1% organics). The other 85% is ash particles from combustion and melt products. This consists of 25% opaque glass, 20% isotropic glass, Sclieren 10%, Spinel group minerals (Magnetite, Chromite) 10%, Melite group minerals 20% (1). The incineration process means that some of these mineral phases are thermochemically unstable making BA susceptible to ageing/weathering by atmospheric water, oxygen, and carbon dioxide. This assemblage of metastable minerals and mineral phases are very liable to chemical and physical change at atmospheric temperatures and pressures (2). During weathering the soluble salts are washed off quickly (K, Na, Cl NO\textsubscript{3}), the rate of influx of CO\textsubscript{2} then controls the Ca, Mg, SO\textsubscript{4}, (and possibly Fe) mineralogy. After weathering the secondary phases produced are predicted to be similar to alkaline or volcanic soils.

**Potential applications for incinerator bottom ash**

Incinerator bottom ash (IBA) has been the focus of a great deal of research into its utilisation. This has primarily been focus on its use as a replacement aggregate often in concrete. Once weathered and aged and screened to produce the required grading it can be incorporated into relatively low grade applications. Such as embankment fill and road sub base. Often there may need to be a protective layer between the ash and soil if used unbound to prevent unwanted leaching. For a thorough understanding of potential applications see references 3, 4, & 5.

**Manufactured Aggregate**

Manufactured aggregates are almost lightweight aggregates (less than 1000kg/m\textsuperscript{3}) and are predominantly an expanded (or bloated) clay aggregate, aggregate made from pulverised fuel ash (PFA) from coal fired power stations. Their primary use is in lightweight construction blocks but they can also be used for lightweight fill, ground insulation layers in buildings and, where they have sufficient strength, in structural concrete.

The production of manufactured aggregate involves agglomeration usually on an inclined rotating pan in the presence of a small amount of moisture. The agglomerated pellets may then be dried prior to thermal processing. The pellets are then fed directly into a rotary kiln or onto a travelling grate furnace and fired at a temperature between 1100 -1200 °C. The rotary kilns are usually fired by fossil fuel burners. On discharging the aggregate will be cooled prior to stockpiling.
In addition a number of other materials have been researched to assess their possibility of being suitable for manufactured aggregate production. Such materials include River and harbour dredgings, quarrying fines and combustion ashes from power stations and waste incinerators. The manufactured aggregate used as a basis in this case study is that to be produced by RTAL of Tilbury in Essex who use a mix of PFA and London Clay with sewage sludge. This case study will consider the partial substitution of these materials with bottom ash.

This case study considers the addition of bottom ash manufactured aggregate produced from PFA and clay. The use of PFA in the production of lightweight aggregate is also well-established (9). Lytag is the trade name given to a LWA produced by sintering low carbon (circa 8%) fly ash. The resultant material is open textured with small voids that are interconnected and permeable to water. Lytag has a loose bulk density of approximately 825 kg/m³, and is capable of producing concretes with strengths in excess of 40 MPa. It is a well-established material and has been used in a number of large-scale projects such as, for example, the construction of North Sea oil production platforms (10).

**Barriers and Benefits** *(extracted from waste product pairing database)*

A commentary on generic barriers and benefits of utilising bottom ash in manufacture aggregates are as follows:

**Material related**
- i. Sulphates decompose when sintering this produces SO₂
- ii. Trace metals and elemental metal (such as Zn, Sn, Mn, V) can have detrimental effect on final product and possibly gas emissions
- iii. The size distribution and composition will necessitate screening and comminution prior to use.
- iv. May have a mineralogy that produces a gas when firing enabling the material to bloat and produce a lightweight material.

**Legal**
- i. Acidic gas production
- ii. The potential presence of trace metals may have implications for final product use

**Economic**
- i. The size distribution and composition will necessitate screening and comminution prior to use. All adding to processing costs and energy production
ii. May require gas abatement plant to reduce acid gases emissions
iii. Use to help produce a lightweight aggregate that has a higher sale price than use as a fill material.

Environmental
i. Sulphur dioxide will have potentially serious effect of acidic emissions.
ii. Trace metals and elemental metal (such as Zn, Sn, Mn, V) can have detrimental effect on final product and possibly gas emissions
iii. Incorporation in aggregate reduces the leaching potential
iv. Large scale use of material in a higher grade application than un-treated bottom ash

Specific materials characterisation results

This case study considers work undertaken to incorporate bottom ash in to a standard material that were undergoing commercial scale trials. The commercial trials used PFA and clay (excavation from tunnelling and other ground works). Table 1 and Figure 1 show the basic characterisation of the materials used to make a manufactured lightweight aggregate and the grading of the bottom ash used respectively. The grading of the ash only show the fraction under 6mm. the bottom ash was pre-processed by crushing in a jaw crusher, only the fraction under 600 µm was used for aggregate production. Figure 2 shows the materials prior to there use.

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Loss on Ignition % (775 °C)</th>
<th>Moisture Content (% dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulverised fuel ash</td>
<td>1.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Clay</td>
<td>19.5</td>
<td>1.0</td>
</tr>
<tr>
<td>IBA</td>
<td>8.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Table 1: Moisture content and Loss on ignition of feedstock materials
<table>
<thead>
<tr>
<th>Microns</th>
<th>Cumulative % passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>100.00</td>
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<tr>
<td>425</td>
<td>78.85</td>
</tr>
<tr>
<td>300</td>
<td>51.69</td>
</tr>
<tr>
<td>250</td>
<td>42.69</td>
</tr>
<tr>
<td>212</td>
<td>32.66</td>
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<tr>
<td>150</td>
<td>16.46</td>
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<tr>
<td>125</td>
<td>11.21</td>
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<tr>
<td>90</td>
<td>7.13</td>
</tr>
<tr>
<td>75</td>
<td>3.71</td>
</tr>
<tr>
<td>63</td>
<td>2.12</td>
</tr>
<tr>
<td>45</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Figure 1: Grading curve of Incinerator bottom ash

Figure 2: The materials used to produce manufactured aggregate
(*Use of APC residue is not covered in this case study)
Results of Laboratory / Pilot product demonstration test-work

Laboratory scale work has been undertaken on utilising crushed IBA (<600μm) in manufactured aggregate produced from PFA and clay. The PFA clay and bottom ash were mixed in a planetary mixer and then extruded and kibbled into a rotating drum to produce spherical pellets of 10 - 14 mm in diameter. Once dried these pellets were fired in a rotary kiln at ~1100 °C were a degree of bloating of the aggregate occurred. The aggregate produced was tested for water absorption and density - two key properties of manufactured aggregates. The properties of some of the aggregates produced can be seen in Table 2. Figure 3 shows material containing bottom ash PFA and clay. The results in Table 2 suggest that additions of bottom ash have limited impact of water absorption and density of the aggregates.

<table>
<thead>
<tr>
<th>Composition ( % BA Replacement)</th>
<th>Relative Density</th>
<th>Water Absorption (% dry weight)</th>
<th>Loose bulk Density (Kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base mix</td>
<td>2.1</td>
<td>14.2</td>
<td>764</td>
</tr>
<tr>
<td>50 % clay, 50 % PFA</td>
<td>2.0</td>
<td>10.4</td>
<td>795</td>
</tr>
<tr>
<td>10% IBA, 45 % clay, 45 % PFA</td>
<td>2.0</td>
<td>8.9</td>
<td>776</td>
</tr>
<tr>
<td>20% IBA, 40 % clay, 40% PFA</td>
<td>2.0</td>
<td>12.4</td>
<td>711</td>
</tr>
<tr>
<td>40% IBA, 30 % clay, 30% PFA</td>
<td>2.1</td>
<td>12.6</td>
<td>732</td>
</tr>
<tr>
<td>60% IBA, 20 % clay 20 % PFA</td>
<td>2.1</td>
<td>12.6</td>
<td>732</td>
</tr>
</tbody>
</table>

Table 2: Aggregate properties produced as bottom ash is incorporated

Figure 3: Aggregate produced from PFA, clay and incinerator bottom ash
**Conclusions and further work required**

Incinerator bottom ash can be incorporated into manufactured aggregates as a replacement for PFA and clay. Other research (11, 12, 13) has shown that it may be possible to utilise IBA on its own. There are concerns over the production of sulphur dioxide (SO$_2$) during processing and the need to reduce the size of the IBA using mineral milling process. Further applied research may undertaken by potential aggregate producers would help assess the impact of these potential difficulties posed by these concerns. Further work in the along the lines of Riley (14) would assess the noted bloating nature of bottom ash during sintering this may lead to the production of additives that may help bloating during firing of PFA / clay and other potential manufactured aggregate feedstock to produce a lightweight material.
References


8. Wainwright, P.J., Cresswell, D.J.F, & van der Sloot, H.A. 2002 The Production of Synthetic Aggregate from an Innovative Style Rotary Kiln. Waste Management & Research v.20 pp279-


