Characterisation of Mineral Wastes, Resources and Processing technologies – Integrated waste management for the production of construction material

WRT 177 / WR0115

Case Study:

Foundry dust in facing bricks

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Introduction

Foundries produce metal castings from ferrous or non-ferrous alloys and they operate in various locations around the UK (Figure 1). The manufacturing process involves the melting of metal into a liquid, the pouring of molten metal into a cast, the removing of casting and the cleaning/finishing of the cast piece.

According to the Department for Environment, Food and Rural Affairs\textsuperscript{2}, during 2002, the manufacture of fabricated metal products produced in total 1.5 million tonnes of waste, of which 381,000 tonnes were disposed to land. Also 840,000 tonnes comprised metallic waste. Solid waste streams from foundries are primarily used foundry sand, foundry dust (collected by dry or wet electrostatic precipitators) or fabric filters, slag, scrap metal and various other types of waste arisings (Figure 2).
Potential applications for foundry dust

Potential uses for foundry dust are summarised in Table 1. Currently foundry dust has found proven application as filler fertiliser and in chemical/industrial applications.

Table 1: Potential utilisation routes for foundry dust

<table>
<thead>
<tr>
<th>End use category</th>
<th>Application</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction type uses</td>
<td>Insulation products</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Lightweight aggregate production</td>
<td>+</td>
</tr>
<tr>
<td>Soil type uses</td>
<td>Artificial topsoil</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Fertiliser filler</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Landfill – capping</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Landfill – liner</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Soil modifier / improver</td>
<td>+</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Chemical / industrial applications</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Slaked lime replacement</td>
<td>+</td>
</tr>
</tbody>
</table>

(+): re-use application, proven in theory, but not implemented in the UK
(x): proven re-use application with successful projects running in the UK
Brick manufacture

Brick manufacture is a historic industry and the process is well established. Brickworks commonly operate in close proximity to clay quarries, owned by the same company, so as to satisfy their needs for raw materials. The brick market has been presented with significant changes with the introduction of concrete blocks as the latter replaced common bricks in construction. This resulted to a shift of the market in producing facing bricks, used for aesthetic purposes.

The use of ‘facing bricks’, accounts for over 90% of demand and the production of facing bricks appears quite stable for the last seven years. Bricks are produced either by extrusion or by the ‘soft-mud’ process, but extrusion comprises the commonest option. Bricks are dried prior to firing and fired in a linear kiln (tunnel kiln), which commonly operates on natural gas.

Alternative materials are considered for use by brick manufacture as a potential cost effective solution to access materials with desirable compounds / properties that will satisfy the demand for large portfolios of products with different aesthetic properties. The sector’s view is that customer demand and expectations have changed significantly and a market for ‘green products’ is currently exists.

Barriers and Benefits (extracted from waste product pairing database)

Information on the contribution of foundry dust in brick making, the benefits, obstacles and analysis requirements were extracted from the WPP database and they are shown below:

1. Contribution to the brick product:
   Foundry dust primarily contributes as a colourant, but it may also be used as a filler material.

2. Potential benefits:
   - **Legal**:
     i. The inclusion of foundry dust into bricks results in products with a recycled content
   - **Environmental**:
     i. The utilisation of foundry dust has as a consequence the diversion of waste from land disposal
   - **Economic**:
     i. The use of foundry dust could substitute primary colourant materials and this way result in a cost benefit.
     ii. The brick manufacturer may charge a gate fee for accepting the foundry dust.

3. Potential barriers:
   - **Material related**:
     i. Small arisings of foundry dust are available
     ii. The properties of different types of foundry dust may not provide the desirable result in bricks
     iii. Foundry dust often contains heavy metals and other compounds, which could have an adverse impact to the end product, like efflorescence and scumming
     iv. The consistency of the composition of foundry dust is considered low; foundry dust may comprise a hazardous waste. For instance, foundry dust from stainless steel making may include high levels of chromium above the limits defined by waste acceptance criteria
• Analysis requirements:
  Testing is carried out to identify the properties and characteristics of alternative materials and end products, as well as to determine that the inclusion of certain alternative materials provide desirable results during lab-based experimentation.

  - **Analysis on alternative materials:**
    mineralogy & chemical analysis

  - **Analysis during lab-based experimentation:**
    appearance of test bricks after firing; shrinkage; experimentation with different substitution rates; decision upon the type of clay body; firing temperature

  - **Analysis on end products:**
    in accordance with BS EN 771-1\(^5\) on masonry products; colour; durability; green strength; water absorption; efflorescence; compression strength

**Foundry dust samples**

Samples of foundry dust were provided by William Cook Cast Products in Leeds. The plant produces steel casts and end products are primarily for the rail industry. Foundry dust is produced from various operations in the plant, which are collected in separate bag filters and subsequently mixed in skips prior to landfill disposal. The company produces approximately 100 tonnes of foundry dust per month from this plant, which are currently disposed to a non-hazardous landfill. Although the quantity of the produced waste material is considered small, alternatives to disposal are actively searched for, so as to minimise the cost of disposal and to ensure that an alternative solution is in place once the nearby landfill site is closed. Also the space for waste storage on site is limited and depending on production, quantities of generated waste may exceed the volume of storage facilities. William Cook Cast Products operate two additional plants in Sheffield that also produce foundry dust. Routine analysis of foundry dust is carried out to ensure compliance with the Waste Acceptance Criteria of the Landfill Directive.
Foundry dust characterisation results

Foundry dust samples were collected in 5 kg bags from five different points (bag filters) shown in Table 2. Characterisation of collected foundry dust samples was undertaken and the results are summarised in Table 3. Parameters such as the mineralogy, the particle size distribution, the particle density, the acid soluble chloride, the moisture content and the loss on ignition were determined.

<table>
<thead>
<tr>
<th>Table 2: Foundry dust samples collected from William Cook Rail plant in Leeds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>shotblast foundry dust (No 2)</td>
</tr>
<tr>
<td>weld, arc air foundry dust (No 33)</td>
</tr>
<tr>
<td>shotblast foundry dust (No 7)</td>
</tr>
</tbody>
</table>

The differences between foundry dust samples are apparent and it is anticipated that these will influence the appearance of the facing brick. Most dust samples include Fe-rich minerals which are considered valuable colourant compounds in brick making. The particle size of the foundry dust samples is very fine, for some samples over 90% of the cumulative weight passing is below 63µm. Also it can be seen that the moisture content of the arc air (No 8) and shotblast (No 7) foundry dust is much higher than the rest of the samples. Foundry dust is not stored indoors and atmospheric conditions (i.e. high humidity) may influence this material by increasing its moisture content. Depending on the particular characteristics of the manufacturing process, materials with high moisture content may need an additional drying stage. Such requirements however can only be determined by industrial trials.
Table 3: Foundry dust characterisation results.

<table>
<thead>
<tr>
<th>Source</th>
<th>Shotblast (No 2)</th>
<th>Weld, arc air, fettle (No 33)</th>
<th>Knockout (No 11)</th>
<th>Arc air (No 8)</th>
<th>Shotblast (No 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual description</td>
<td>Dark grey coloured powder</td>
<td>Dark grey coloured powder</td>
<td>Dark grey coloured powder</td>
<td>Dark grey coloured powder</td>
<td>Dark grey coloured powder</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>Magnetite (Fe_3O_4), haematite (Fe_2O_3), cristobalite (SiO_2), wustite (FeO), iron (Fe), Calcite (CaCO_3), Vaterite (CaCO_3)</td>
<td>Magnetite (Fe_3O_4), quartz (SiO_2), cristobalite (SiO_2), corundum (Al_2O_3)</td>
<td>Quartz (SiO_2), cristobalite (SiO_2), maghemite (Fe_2O_3), corundum (Al_2O_3), vaterite (CaCO_3)</td>
<td>Maghemite (Fe_2O_3)</td>
<td>Quartz (SiO_2), cristobalite (SiO_2), maghemite (Fe_2O_3), corundum (alumina), vaterite (CaCO_3)</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>100% passing 1.0 mm; 100% passing 0.5 mm; 100% passing 0.25 mm; 100% passing 0.125 mm; 99.7% passing 0.063 mm.</td>
<td>100% passing 0.25 mm; 99% passing 0.125 mm; 96.2% passing 0.063 mm.</td>
<td>100% passing 1.0 mm; 100% passing 0.5 mm; 83% passing 0.25 mm; 64% passing 0.125 mm; 54.3% passing 0.063 mm.</td>
<td>100% passing 1.0 mm; 99% passing 0.5 mm; 96% passing 0.25 mm; 89% passing 0.125 mm; 79.3% passing 0.063 mm.</td>
<td>100% passing 1.0 mm; 91% passing 0.5 mm; 61% passing 0.25 mm; 37% passing 0.125 mm; 34.6% passing 0.063 mm.</td>
</tr>
<tr>
<td>Particle density</td>
<td>4.47 Mg/m³</td>
<td>4.43 Mg/m³</td>
<td>2.46 Mg/m³</td>
<td>4.77 Mg/m³</td>
<td>2.92 Mg/m³</td>
</tr>
<tr>
<td>Water absorption</td>
<td>Material too fine to test</td>
<td>Material too fine to test</td>
<td>11%</td>
<td>17%</td>
<td>23%</td>
</tr>
<tr>
<td>Acid soluble chloride (%)</td>
<td>0.023</td>
<td>0.016</td>
<td>0.001</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>Total sulphur (%)</td>
<td>0.06</td>
<td>0.26</td>
<td>0.02</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>0.36</td>
<td>0.51</td>
<td>7.00</td>
<td>11.32</td>
<td>11.32</td>
</tr>
<tr>
<td>Loss on ignition (%)</td>
<td>Gain 3.1</td>
<td>Gain 2.95</td>
<td>23.26</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Results of Laboratory/Pilot product demonstration test-work

Laboratory trials were carried out to investigate the potential utilisation of foundry dust as a colourant component into facing bricks. The objective of this work was to explore if the addition of foundry dust resulted into bricks with darker/lighter colours or/and reduction marks, produced from the reduction of iron compounds within the clay during firing, on the face surface.

The control material comprised a brick shale and foundry dust was added in 2.5 and 5% (by weight) to the brick shale. Laboratory characterisation was undertaken by Hargreaves Mineral Services. The appearance after firing, the moisture content, the loss on ignition, the fired temperature and the water absorption were recorded for all different samples.

Results showed that different foundry dust samples produced a diverse range of colours varying from orange/red to brown (Figure 3 & Figure). Not all samples responded in a positive way that is to say they did not have any effect to the appearance of the end product. Some of the samples
also produced reduction marks on the brick surface, as well as improved water absorption. The loss on ignition and moisture content were within the same levels as in the control sample.

Figure 3: Test bricks with foundry dust addition. The first sample on the left of the picture comprises the control sample (100% brick shale)
Results for foundry dust samples that produced reduction marks and darker tones of the red/orange coloured clay on the surface of the brick were considered desirable. In order to evaluate the consistency of these data a second batch of tests will be required. Once results from repeated test prove positive then work may continue with a small scale trial and eventually a full scale trial.

Conclusions and further work required

The incorporation of certain foundry dust samples into facing bricks produced desirable appearance effects, such as colour and reduction marks. Although foundry dust arisings are small, the weight percentage inclusion into bricks is also small (2.5 to 5% maximum), so it is thought that local brickworks could utilise this materials. Looking at the geographical location of foundries in the UK, it becomes apparent that brickworks found in geographical proximity could benefit by using foundry dust as a colourant into their products. Further experimental work though small scale and large scale trials is required to establish the use of this material.

Figure 4: Ceramic test tiles with foundry dust additions. The control sample is highlighted (100% brick shale)
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References


