Sustainable construction products containing sewage sludge ash

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INTRODUCTION
Prior to 1998 sewage sludge in the UK was primarily disposed of by sea dumping or spreading on agricultural land. Sea disposal of sewage sludge was banned by the Urban Water and Wastewater Treatment Directive (1998), and land spreading can be problematic and has come under increasing scrutiny from the British Retail Consortium. This has reduced the application of sludge to agricultural land. Incineration of sewage sludge reduces the volume by 90-95% making disposal much easier. Approximately 25% of UK sewage sludge is currently incinerated, producing around 100,000 tonnes of incinerated sewage sludge ash (ISSA) per annum.¹ This is expected to increase in the future.

The solids that collect at the bottom of sedimentation tanks at sewage works are around 5% dry solids (DS) by weight. These are thickened by centrifugation or belt pressing to a DS content of 25%. At this solids content sewage sludge has a caloric value of 12-20MJ/kg (coal is ~30MJ/kg) making incineration feasible.

The UK construction industry is responsible for ~10% of UK greenhouse gas emissions and produces over 70 M tonnes of waste annually. The development of low embodied energy construction materials that are manufactured from industrial by-products is essential if the industry is to become more sustainable.

OBJECTIVES
The objective of this research is to develop sustainable, low-energy construction products that beneficially use incinerated sewage sludge ash. Materials from major UK sludge incinerators are being used in this research.

EXPERIMENTAL
X-ray florescence data for ISSA was supplied by Akristos Ltd. Major crystalline phases in ISSA were determined by X-ray diffraction (XRD) using Cu Kα radiation at an acceleration voltage of 40kV and a current of 40mA (Philips PW 1700). Particle size distribution (PSD) was analysed by laser diffraction (Coulter LS100) over the size range 0.4-900 μm. ISSA has been activated using physical and chemical processes and may aggregate materials manufactured by a process involving mixing, pelletising and accelerated curing.

RESULTS
Table 1 below compares the typical oxide composition of ISSA with cement and two other pozzolanic industrial by-products widely used in construction applications. Broad similarities exist regarding major oxides present except for P₂O₅ and Fe₂O₃.

Table 1 – Oxide composition of cement and other useful wastes

<table>
<thead>
<tr>
<th></th>
<th>SiO₂ (%)</th>
<th>Al₂O₃ (%)</th>
<th>P₂O₅ (%)</th>
<th>CaO (%)</th>
<th>MgO (%)</th>
<th>K₂O (%)</th>
<th>TiO₂ (%)</th>
<th>Fe₂O₃ (%)</th>
<th>S₂O₅ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Widnes ISSA</td>
<td>36</td>
<td>11</td>
<td>12</td>
<td>17</td>
<td>2</td>
<td>1.5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulverised Fuel Ash¹</td>
<td>41</td>
<td>25</td>
<td>0.7</td>
<td>7</td>
<td>5</td>
<td>2.5</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast Furnace Slag²</td>
<td>36</td>
<td>12</td>
<td>0.4</td>
<td>42</td>
<td>9</td>
<td>0.2</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portland Cement³</td>
<td>21</td>
<td>4.6</td>
<td>2.3</td>
<td>66</td>
<td>1.2</td>
<td>0.8</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ – Widnes ISSA
² – Pulverised Fuel Ash
³ – Portland Cement

The effect of milling ISSA is likely to increase the reactivity and workability compared to as-received material. The particle size data in Figure 3 demonstrates the effect of milling on the particle size distribution (PSD).

DISCUSSION
The mineral composition and PSD of milled ISSA suggests that it could be used in the manufacture of aggregates for lightweight thermally insulating blocks. Sintering of ISSA produces lightweight aggregate suitable for production of lightweight blocks and concrete (4). However, this is not environmentally or economically attractive. Alternative approaches to produce sustainable construction products containing ISSA are currently under investigation, and these include:

a) Foaming reaction of ISSA with Al metal and alkali

ISSA/cement mixes containing trace Al metal produce H₂:

\[ 2Al + Ca(OH)_2 + 2H_2O \rightarrow CaAl(OH)_4 + 3H_2 \]

Hydrogen bubbles create significant porosity at room temperature and this may result in a low embodied energy, lightweight material with low thermal conductivity.

b) Pozzolanic properties for strength development

Experiments are investigating activation of ISSA by milling, chemical addition and elevated temperature curing. ISSA may show pozzolanic properties (5) – which means reactive silica phases present react with free calcium to form strength-providing C-S-H phases. The use of pozzolanic waste substitutes in cement can improve concrete durability, reduce costs and contribute to lowering the CO₂ emissions of the industry.

CONCLUSIONS
The manufacture of value-added construction products containing ISSA is being developed to allow improved resource efficiency. This is involving:

- Activation of the pozzolanic properties of ISSA to produce products with useful compressive strengths and other physical properties;
- Formation of ‘foamed’ ISSA, to make lightweight, thermally insulating aggregate and block products.

ACKNOWLEDGEMENTS
This is an Industrial CASE award research project funded by the UK Engineering and Physical Sciences Research Council (EPSRC) through the Resource Efficiency Knowledge Transfer Network (KTN) supported by Akristos Ltd.

REFERENCES