Production of carbonated manufactured aggregates from APCr from waste to energy plants

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Carbon8 Aggregates Ltd.
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• Background
• Introduction to Carbon8
• First commercial application
• ‘End of Waste’
• Scale of use/potential
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• Future and Summary
Accelerated Carbonation

- A minerals in thermal residues react with CO$_2$
- Mg/Ca silicates/oxides/hydroxides
- Amorphous or crystalline carbonates formed
- Formation of carbonate:
  - Changes pH
  - Stabilises metals such as Pb, Zn, Cu etc.
  - Fills porosity and ‘cements’ particles
- Reaction can be ‘managed’
- Carbonated products can be engineered

Original research on metal poisoning of stabilised/solidified waste.

Upon carbonation, C2S/C3S in cement react with CO₂ leaving a de-calcified silicate ‘phase’.

Work extended and applied to contaminated soil.

Amorphous carbonate or interlocking needles can be rapidly formed to give strength and change materials properties.
Processing variables

- Moisture Content
- Rotation Speed
- Mixing Time
- Batch Size

Scale: 5cm
Transmitted polarised light (ppl)
Applications

Proven at pilot or full-scale:

- Contaminated soil/soil washing residues
- PFA (‘Class F’ poorly reactive)
- CBD (reactive and can manufacture aggregate)
- Biomass ash (depends on feedstock)
- Paper ash (excellent aggregate formed)
- Non-reactive, problematic wastes to which a CO$_2$-reactive binder can be added (e.g. sludge/quarry fines)
CO$_2$ uptake/sequestration potential
Why MSW APCr?

• In 2006, Carbon8 had a proven solution for Contaminated Soils/ Drill cuttings/ Cement dusts

• But, the UK waste industry is risk adverse so we selected a problematic hazardous waste

• APCr from Energy from Waste (EfW)
  - Growing quantity of APCr (rising to >200kT/pa)
  - Hazardous waste landfill prices rising
  - No other viable alternative management options
  - EfW required ‘zero waste to landfill’ under Pfi
Process & Development

Proof of concept (1st stage funding)

• Trial at landfill site in August 2010
• EA Position Statement
• Flue gas from landfill gas flare
• Used 10% v/v CO₂ gas stream
Green light for ‘First’ commercial application

- 3.98 Mt (15%) of England’s MSW is incinerated each year *
- Produces just over 1 Mt/pa of ashes
- ca 80% is bottom ash (non-hazardous) and 20% is APCr (hazardous)
- 88% of APCr sent to landfill (ca. 190 kt/pa) at >£100 tonne
- APCr contains lime, carbon, M⁺, chloride and soluble salts
- Landfill derogation is ending
- Alternative management options needed

*[DEFRA, 2013]
Commercial-scale trial in December 2010

• Large-scale trial at Lignacite Suffolk (E. England) – 200 t produced

• Aggregate used to manufacture blocks by 2 UK companies

• Aggregate/ blocks independently tested for ‘fitness for purpose’
Brandon, Suffolk – first UK manufacturing plant
Brandon Aggregate Factory
Aggregate stockpiles
The Process:

*As required

<table>
<thead>
<tr>
<th>kg CO₂e /ton produced</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials</td>
<td>110.35</td>
</tr>
<tr>
<td>Energy consumption:</td>
<td>0.44</td>
</tr>
<tr>
<td>Transport:</td>
<td>18.98</td>
</tr>
<tr>
<td>CO₂ sequestrated:</td>
<td>-177.00</td>
</tr>
<tr>
<td>Final balance</td>
<td>-47.23</td>
</tr>
</tbody>
</table>

Municipal Waste Incinerator carbon. Air Pollution Control residues are assumed carbon neutral.

Grid electricity footprint.

Transfer of materials to the aggregate production based on actual distance, truck loads and fuel consumption.

Carbon dioxide chemically bound in the process.
Successes

• Support from Carbon Trust (Incubator company), Innovate (TSB), Companies with vision – Grundon Waste Management, Lignacite

• ‘End of waste’ achieved 2011 (moves APCr up the waste hierarchy)

• Aggregate is carbon negative (ca. 50kg/t CO$_2$), target: negative 100kg/t CO$_2$

• Processing 2000 t APCr/month, and is a zero emissions process

• 31,000 t APCr treated since commissioning

• 2015 capturing 5000 t CO$_2$/pa

• Long-term contracts with EfW Plants, allowing ‘Zero Waste to Landfill’

• Awards: incl. (1) IChemE Green Chemical Technology Award, (2) Shell Springboard Innovation Award (National Winner), (3) CIWEM Innovation Award and (4) UK Recycled Product of the Year (2013-14)
Some considerations

- Environmental Legislation
  - Driver and handicap
- ‘End of waste’ for aggregate product
  - Decision making process is slow, inconsistently applied
- Requires Environmental Permit
  - Bespoke installation c.f. EfW
- Construction industry conservative
  - No incentives for low carbon building
- Requires all-year round market for product
  - Concrete block manufacturer - Lignacite
End of Waste process (EoW)

European Waste Directive
• Product is distinct and marketable
• Used and stored with no worse environmental effect that the material it replaces
• Submission of detailed technical data
• Product specification—leaching and physical/mechanical properties
• Need to demonstrate there is a market and you have business (contracts/commercial information)

EoW status
• Hugely beneficial to growth of business
• Enhanced credibility / ‘seal of approval’
• Advantage over competitors operating without EoW

But...NOT consistently interpreted/applied across the EU and this is a BARRIER to innovation and business development
Scale of CO$_2$ capture?

• Thermal residues uptake CO$_2$ at 5-20% w/w, depending on waste chemistry/mineralogy

• MSW APCr up to 20% w/w, but CO$_2$ is expensive and so use minimised

• CO$_2$ used is approximately 7-10% w/w, and enough to stabilise M$^+$ and solidify the product

• If carbon credits can be realised, then more CO$_2$ could be used
Carbonated APCr Aggregate

Lightweight
- Loose bulk density 950 -1100 kg/m³

Carbon Negative
- More carbon dioxide is captured in the process than is used in the running of the plant and transport of materials
- Value varies with source of residue, but process development suggests -100kg/t possible

Grading
- For block manufacture – 15mm down
- Other grading/size/products available

Manufactured to specification agreed with the EA
- Certified to ISO 9001, 14001 and OSHAS 18001
Block Production

Currently used by a number of block producers

• Production of 50,000 tonnes per year at Brandon

• Successful trials by majority of major block makers

• Lignacite producing Carbon Buster, the world’s first Carbon negative concrete construction block
Block properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Without APCr Aggregate</th>
<th>With APCr Aggregate</th>
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</thead>
<tbody>
<tr>
<td>Density (kg/m$^3$)</td>
<td>1660</td>
<td>1730</td>
</tr>
<tr>
<td>Compressive Strength (MPa)</td>
<td>11.8</td>
<td>11.2</td>
</tr>
<tr>
<td>Transverse Failure Load (kN)</td>
<td>7.75</td>
<td>7.78</td>
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<tr>
<td>Flatness (mm)</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Parallelism (mm)</td>
<td>1.2</td>
<td>1.0</td>
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<tr>
<td>Drying Shrinkage (mm)</td>
<td>0.38</td>
<td>0.34</td>
</tr>
<tr>
<td>Moisture Expansion (mm)</td>
<td>0.13</td>
<td>0.11</td>
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Testing (in France) to NF EN 206-1 shows similarity to expanded clay and suitability for load bearing walls.
Applications
Commercial considerations

- No Aggregate Tax
- Competitively priced
- Variety of gradings can be produced
- Sustainable
- 4 New UK production plants – 100,000 tonnes each
UK Plant 2-Avonmouth
Finally.....

Carbon8 Aggregates Avonmouth Facility – operational late 2015

Imagine......capturing this much carbon dioxide every year
Summary

- Hazardous wastes incl. MSW APCr can be valorised by carbonation in products that are ‘fit for purpose’ and meet EoW

- Commercially successful now: 300kt/pa aggregate produced by 2016 with x10kt CO₂ being mineralised

- Industry accepted e.g. by award of UK Recycled Product of the Year

- An established history of use in place –very important for confidence!

- EU drive to sustainable production (the circular economy)

- Increasing EU interest in mineralisation –ETS?

- ‘End of waste’/waste regulations vary across EU, and is an impediment to the commercial development of innovative processes
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