Carbonation of alkaline residues in the manufacture of lightweight aggregate

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• History of Carbon8 Systems
• Products from carbonation
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Carbonation & Mineralisation

- Carbonation can be accelerated by using increased concentration of CO$_2$
- Calcium and Magnesium silicates, oxides and hydroxides can react with CO$_2$ to form carbonates
- These minerals can be found in
  - Basic and ultrabasic rocks (basalts, serpentinites, dunites)
  - Industrial thermal residues (steel slags, ashes from EfWs, cement and concrete residues etc)
- Reaction is exothermic
- Does not require large amounts of energy for the transformation of the CO$_2$ molecule
- Permanent capture of CO$_2$
- Can use pure CO$_2$ or CO$_2$ directly captured from flue stacks or the air (DAC)
Conditions of Carbonation

Two main conditions of carbonation

1. Wet water: solid ratios > 1:1 alkaline water leading to precipitation of carbonate in the water.

2. Semi-dry or thin film: Carbonate nucleates on the grains or replaces the grains of the residue and can help bind the grains together.
   - The reaction can be performed at atmospheric temperatures and pressures or at a range of elevated temperatures and pressures up to super critical CO₂ conditions
Carbon8 Systems

- Formed in 2006 after +10 years research into carbonation
- Particularly, treatment of contaminated soils with UK EA and USEPA
- Early patent using a modification of cement stabilization to treat hazardous wastes
- Use semi-dry carbonation, at atmospheric temperature and pressure conditions
- Commercialised the technology in 2010 via a license for the treatment of APCr from EfW
- Currently, three plants treating APCr in the UK using pure CO₂ delivered in a tanker
- From 2018, developed technology to use CO₂ directly from flue gas
- Two demonstration deployments in Ontario 2018 and UK 2019
- First commercial deployment with Vicat Cement Group in France 2021
Contaminated Land Remediation

- ACT can be applied to contaminated soils – through the addition of a carbonatable binder
- Modified form of cement stabilisation/solidification (S/S)
- Reduced pH
- Final granular product generated in minutes rather than hours for traditional S/S

Treatment of soil washing residues, Olympic Park

Treatment of heavy metal contaminated soil.

Metals leached during TCLP testing from treated and untreated soil from an ex-pyrotechnics site

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Applicable residues
Carbon Sequestration Potential

The total amount of CO₂ that could be sequestered globally through C8S Accelerated Carbonation Technology processes is theoretically 1,045Mt per year but 500 Mt per year more realistic.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Sequestration (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>411Mt</td>
</tr>
<tr>
<td>Cement</td>
<td>192Mt</td>
</tr>
<tr>
<td>CDW</td>
<td>178Mt</td>
</tr>
<tr>
<td>Biomass</td>
<td>174Mt</td>
</tr>
<tr>
<td>Steel</td>
<td>79Mt</td>
</tr>
<tr>
<td>Oil shale</td>
<td>5Mt</td>
</tr>
<tr>
<td>EfW</td>
<td>4Mt</td>
</tr>
<tr>
<td>Paper &amp; pulp</td>
<td>1Mt</td>
</tr>
</tbody>
</table>

All figures based on annual production of residues, excluding legacy wastes.

This information is based on external academic papers as well as internal know how.
Air Pollution Control Residues

- Thermal residues from Energy from Waste Plants: Air Pollution Control residues (APCr)
- APCr treated using Accelerated Carbonation Technology
- Treated APCr mixed with binders and fillers and then pelletised with further carbonation.
- 3 plants in the UK treating APCr under licence
  - Use pure CO₂ delivered in tanker
  - Treating 40,000 t APCr /year
  - End of Waste acceptance by Environment Agency
- Demonstration of CO₂ntainer for treatment of APCr in 2020 at AVR in Netherlands
Use of Flue Gas derived CO$_2$

- Work with UCL in 2006 showed that higher concentrations of CO$_2$ resulted in lower conversion rates
- Thus, there were benefits to using flue gas derived CO$_2$ directly
- This was supported by our work in 2010 using landfill derived CO$_2$
- Pure CO$_2$ is expensive and can be in short supply
- In 2018, returned to using point sources of CO$_2$
Early deployments of the CO₂ntainer
The CO₂ntainer – Carbon Capture in a Box

Introducing the Plug ‘n Play CCUS solution: retrofittable into any existing industry plants

- **CO₂ capture**: Direct capture solution, 1,500 tonnes – 4,000 tonnes CO₂ per annum
- **12,000 tonnes**: Waste treated per annum
- **100% automation**: Manual or automatic operation
- **Seamless integration**: No interference with production

CO₂ntainer at Vicat Group in Montalieu, France
Cement By Pass Dust

- By-pass dust produced primarily as a result of change to alternative fuels
  - Chlorides etc in the refuse derived fuel need to be prevented from getting into the clinker
  - Can cause clogging in the kiln
- Annual global cement production is 4100 Mt (2020)
- Production of CKD and CBD between 250 and 400 Mt per year.
- >40 Mt of CO2 could be captured per year.
  - Assuming an average of 15% \(\text{CO}_2\) reactivity
- Compared with using natural aggregate the use CBD aggregate in concrete can lower its the overall carbon footprint by >10%.
## Properties of By-pass Dust

<table>
<thead>
<tr>
<th>Property</th>
<th>min</th>
<th>max</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2) uptake (wt%)</td>
<td>7</td>
<td>33</td>
<td>18</td>
</tr>
<tr>
<td>Loose bulk density (kg/m(^3))</td>
<td>276</td>
<td>910</td>
<td>625</td>
</tr>
<tr>
<td>Chloride content (wt%)</td>
<td>2</td>
<td>23</td>
<td>10</td>
</tr>
</tbody>
</table>

- By-pass dust variable between plants and within a plant
  - Variable composition of fuel and amount burnt
- Undertake “mix design development” project for each new plant
  - Assessment of technological and economic viability of CO\(_2\)ntainer deployment
## Properties of Aggregate

<table>
<thead>
<tr>
<th></th>
<th>Vicat ACT aggregate</th>
<th>Leca</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ uptake (weight %)</td>
<td>10-15%</td>
<td>-</td>
</tr>
<tr>
<td>Strength (Mpa)</td>
<td>&gt;1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Los Angeles Abrasion (%)</td>
<td>&lt;40</td>
<td>Not tested</td>
</tr>
<tr>
<td>Loose Bulk Density (kg/m³)</td>
<td>&lt;1100</td>
<td>350</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>&lt;25</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Water soluble chloride (%)</td>
<td>&lt;2.0</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Acid soluble sulfate (%)</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
</tbody>
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Applications in Construction

- Concrete blocks
- Ready-mix Concrete
- Asphalt
- Pipe bedding
- Floor screeds
Benefits – Economic sustainability

A circular solution to industrial waste and CO₂ capture

1. Direct cost savings
   Divert residues from landfill with sustainable waste management and offset associated costs

2. Carbon footprint reduction
   Permanently and safely store CO₂ from point source

3. High-value manufactured products
   Enable circularity through implementing sustainable alternative building materials in production or market them for a profit