Utilization of CO₂ in High Performance Building and Infrastructure Products
DE-FE0004222

DOE NETL Carbon Storage
Pittsburgh, PA
August 18-20, 2015
### Solidia Cement™ Chemistry

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Portland Cement (wt.%)</th>
<th>Solidia Cement (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>60 - 67</td>
<td>43</td>
</tr>
<tr>
<td>SiO₂</td>
<td>17 - 25</td>
<td>45</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3 - 8</td>
<td>6</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.5 – 6.0</td>
<td>2.5</td>
</tr>
<tr>
<td>MgO</td>
<td>0.5-4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Alkali-oxide (Na, K)</td>
<td>0.3 – 1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Mineral phases CaSiO₃ and Ca₃Si₂O₇ will react with CO₂

Solidia Cement is a **low-lime alternative** to ordinary Portland cement
CO$_2$-Curing of Solidia Concrete™

CaSiO$_3$ + CO$_2$(g) $\rightarrow$ CaCO$_3$ + SiO$_2$

CaCO$_3$ in Solidia Concrete acts in a manner similar to that of C-S-H gel in Portland cement concrete
## CO₂ Footprint Comparison

### Portland Cement Concrete vs. Solidia Concrete

<table>
<thead>
<tr>
<th></th>
<th>Portland Cement Concrete</th>
<th>Solidia Concrete</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. CO₂ emitted/t of cement made</td>
<td>0.81 t</td>
<td>0.56 t</td>
<td>0.25 t of CO₂ emissions avoided at cement plant</td>
</tr>
<tr>
<td>b. CO₂ captured/t of cement used</td>
<td>0.00 t</td>
<td>0.25 t</td>
<td>0.25 t of CO₂ captured at concrete plant</td>
</tr>
<tr>
<td>c. Total CO₂ footprint/t of cement used (a-b)</td>
<td>0.81 t</td>
<td>0.31 t</td>
<td>0.50 t of CO₂ &quot;saved&quot;</td>
</tr>
</tbody>
</table>
DE-FE0004222 Program Status

Technical Evaluation (Task 3.0) → Complete 6/2014

Demonstration of Solidia Cement Produced at Commercial Cement Plant (Subtask 4.1) → Complete 12/2014

Demonstration of Solidia Concrete Utility in Commercial Concrete Products (Subtask 4.2) → Complete 6/2015

Implement CO$_2$-Curing At Commercial Concrete Plant (Subtask 4.3) → In Progress
Description of Concrete Curing System

Company: Paver and Block Manufacturer #2
Plant Location: New Jersey
Cement Usage: 25,000 t/yr
Target Product: Vibro-cast Concrete Pavers

Curing System consists of 18 bays:

Each bay:
• 5 ft. x 17 ft. x 75 ft.
• 240 boards
• 25 to 60 t concrete

Construction
• Roll down doors
• Sheet metal walls
• *Not sealed*

No internal ducting
Concrete Plant Conversion Process

• Gas Flow and Distribution Within the Curing Bay
• Bay Preparation and Sealing
• Ductwork Design and Installation
• Door Fabrication and Installation
• Gas Conditioning System
• Other Site Preparation
• Carbon Footprint Calculation
**Objective:**
Achieve uniform temperature, relative humidity and CO₂ concentration throughout curing bay.

**Challenge:**
Bay interior is divided into 14 distinct levels by solid boards bearing concrete parts.

**Approach:**
- Construct computational fluid dynamic (CFD) model of fully loaded bay interior
- Define interior duct and inlet design
- Defines blower, heat exchanger capacity
Bay Preparation and Sealing

Objective:
Prevent CO\textsubscript{2} leakage during CO\textsubscript{2}-curing.

Challenge:
Bay walls are constructed from sheet metal / fiberboard panels, and contain multiple ports.

Approach:
• Seal large gaps
• Coat bay interior
• With material that is impermeable to CO\textsubscript{2}
Ducts fabricated from sheet steel as per CFD design
Door Fabrication and Installation

Objective:
Replace roll-down door with solid metal door to prevent CO$_2$ leakage.

Challenge:
Concrete is placed within curing bays by robotic loading mechanism, limiting access to bay front.

Approach:
• Store doors in magazine mounted aside bays.
• Move and lower door onto bay front via trolley mechanism.
Gas Conditioning System

Objective:
Feed warm, dry CO₂ into curing bay and recondition wet CO₂ exiting curing bay.

Challenge:
Low cost, energy efficient system to achieve the above. Dehumidify at high rates early in process.

Approach:
- Cross flow heat exchanger, water cooled chiller (to store energy from exit gas, dehumidify gas, and recapture energy prior to heater/blower)
- Electrical or gas fired heater
- High capacity blower
Other Site Preparation

Concrete Pad for CO₂ Storage Tank

Dedicated Silo for Solidia Cement
## Site / US CO₂ Footprint

<table>
<thead>
<tr>
<th>Plant Conversion</th>
<th>Tons of Portland Cement replaced by Solidia Cement</th>
<th>CO₂ &quot;saved&quot; per ton of cement</th>
<th>Total CO₂ &quot;saved&quot;</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% (1 bay)</td>
<td>1,250</td>
<td>0.50</td>
<td>625 t</td>
<td>2016</td>
</tr>
<tr>
<td>50%</td>
<td>12,500</td>
<td>0.50</td>
<td>6,250 t</td>
<td>2018</td>
</tr>
<tr>
<td>100%</td>
<td>25,000</td>
<td>0.50</td>
<td>12,500 t</td>
<td>2020</td>
</tr>
</tbody>
</table>

- Startup at Paver and Block Manufacturer #2 scheduled for 9/2015
- If applied to all precast concrete in US............
  - 20% of concrete production ~ 20 million tons of cement
  - ~10 million tons of CO₂ can be "saved"
Full Plant Conversion

Operating Logic

CO₂ Conditioning System

Chamber loaded with product (~1hr)

Curing Chambers
Full Plant Conversion

Operating Logic

CO₂ Conditioning System

Curing ramp-up (~1hr) -> Curing Chambers

Chamber loaded with product (~1hr) -> Curing Chambers

Full Plant Conversion

Operating Logic

Curing Chambers
Full Plant Conversion

Operating Logic

CO₂ Conditioning System

Steady state curing

Curing ramp-up (~1hr)

Chamber loaded with product (~1hr)

Curing Chambers

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Steady state curing

CO₂ Conditioning System

Curing Chambers

Steady state curing

Chamber loaded with product (~1hr)

Full Plant Conversion

Operating Logic

CO₂

Full Plant Conversion

Operating Logic

Curing Chambers

Steady state curing

CO₂

Curing ramp-up (~1hr)

Chamber loaded with product (~1hr)
Full Plant Conversion

Operating Logic

CO₂ Conditioning System

Empty Chamber and Reload

Steady state curing

Steady state curing

Curing ramp-up (~1hr)

Chamber loaded with product (~1hr)

Curing Chambers