Utilization of CO2 in High Performance Building and Infrastructure Products

Nicholas DeCristofaro
Solidia Technologies

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Developing the Technologies and Infrastructure for CCS
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Presentation Outline

• Project Overview
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• Technical Status
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Project Benefit Statement

• Project benefits statement
  – This research project will demonstrate a new construction material that can replace conventional concrete, and is capable of:
    • Reducing or eliminating the CO$_2$ emissions associated with cement production;
    • Permanently sequestering CO$_2$ (in the form of CaCO$_3$) during concrete curing, and;
    • *Accomplishing the above while preserving the existing infrastructures of the cement and concrete industries.*
  – When successfully demonstrated, and when applied industry-wide, these capabilities will enable the reduction in CO$_2$ emissions of up to 0.7 Gt/yr.....PLUS......the sequestration of CO$_2$ up to 0.9 Gt/yr.
  – This technology supports the Carbon Storage Program effort to develop / validate technologies which can assure 99% storage effectiveness.
Project Overview: Goals and Objectives

The development of alternative construction materials that can replace ordinary Portland cement (OPC) concrete while consuming less energy and generating less CO$_2$

**Why?**
- Cement industry is the second largest industrial emitter of CO$_2$ (>2.4 Gt annually, or ~5% of global anthropogenic CO$_2$ emissions)
- Concrete is the second most utilized substance on earth (~ 20 Gt annually, second only to water)

**How?**
- Replace OPC with mineral or synthetic Wollastonite (CaSiO$_3$)
- Cure resulting concrete with CO$_2$

**Criteria**
- Cement production with 30-90% reduction in CO$_2$ emission
- Concrete production with CO$_2$ sequestration ~30% of cement wt.
- Carbonated concrete properties > hydrated concrete properties
Technical Status - Background

Original Premise:
Mineral wollastonite (CaSiO$_3$) can be used as cementitious materials in CO$_2$-cured concrete products:

- CaSiO$_3$ + CO$_2$ $\rightarrow$ SiO$_2$ + CaCO$_3$
- ~ 40% weight gain, ~ 60% volume expansion
- Effective cementitious bonding of sand and aggregate

This will yield carbon-neutral, high performance concrete products.

Early Project Tasks verified the above:

Demonstrated:

- CaSiO$_3$ preparation requirements
- Analytical techniques to track carbonation
- CO$_2$-cured façade panels

Mineral CaSiO$_3$ production is limited:

- N.A. wollastonite production ~ $10^5$ t/yr
- N.A. OPC production ~ $10^8$ t/yr

Address 0.1% of OPC market
Reduce global CO$_2$ emissions by ~ 2 Mt / yr
Solution……..

Synthesize CaSiO$_3$ compounds (Solidia Cement™) with the same cement kilns, processing equipment and raw materials (limestone, sand and clay) used in OPC production:

- CO$_2$ emissions from cement production reduced by 30%, or 250 kg CO2 / t of cement (from 800 kg / t of cement to 550 kg / t of cement)

Sequester 300 kg CO$_2$ / t of cement used in CO$_2$-cured concrete products

Address Entire OPC Market
Reduce Global CO$_2$ Emissions by ~ 1.6 Gt / yr
Accomplishments to Date

- Developed analytical techniques capable of tracking the reaction: $\text{CaSiO}_3 + \text{CO}_2 \rightarrow \text{SiO}_2 + \text{CaCO}_3$
- Demonstrated reaction rates as a function of $\text{CaSiO}_3$ particle size
- Identified factors effecting curing rates in bulk concrete samples (water / CO$_2$ concentration and distribution)
- Initiated measurements of sample drying to optimize these factors
  - Curing systems tailored for specific precast concrete parts (1)
  - Measurement of part drying times (2)
  - In-situ observation of drying uniformity (3)
Summary

Key Findings / Lessons Learned

- CaSiO$_3$ size and morphology control reaction rate on microscopic (local) scale
- Water / CO$_2$ concentration and distribution control reaction rate on macroscopic (bulk) scale
- Ability to synthesize Solidia Cement in OPC facilities opens pathway to significant CO$_2$ reduction/sequestration

Future Plans

- Transition knowledge on CaSiO$_3$ reactivity and macroscopic drying phenomena to the CO$_2$-curing of bulk concrete parts
- Demonstration of bulk concrete curing in real or simulated flue gas
Appendix
### Rutgers University
- Materials science
- Analytical techniques

### Solidia Technologies
- Cement & concrete production/analysis
- Applications

<table>
<thead>
<tr>
<th>Task</th>
<th>Rutgers University</th>
<th>Solidia Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R. Riman, Ph.D. Mat. Sci.</td>
<td>L. McCandlish, Ph.D. Chem.</td>
</tr>
<tr>
<td>2</td>
<td>M. Bitello, grad student, Mat. Sci. Q. Li, Ph.D. Chem. R. Riman</td>
<td>G. Badiozamani, MBA J. Krishnanan, MBA</td>
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<tr>
<td>3.1 thru 3.9</td>
<td>General Equipment/Milling Reaction kinetics Analytical techniques</td>
<td>L. McCandlish</td>
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Gantt Chart

Fiscal Year

Calendar Year

<table>
<thead>
<tr>
<th>TASK</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1.0</td>
<td>Project Management and Reporting</td>
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<tr>
<td>2.0</td>
<td>Business Evaluation</td>
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<tr>
<td>3.0</td>
<td>Technical Evaluations</td>
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<tr>
<td>3.1</td>
<td>Acquire, install, commission grinding mill</td>
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<tr>
<td>3.2</td>
<td>Control mineral particle size</td>
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<tr>
<td>3.3</td>
<td>Acquire, install, commission Lab Scale Reactor with Probes</td>
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<tr>
<td>3.4</td>
<td>Study reaction rate, carbonation yield vs. T, P</td>
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<tr>
<td>3.5</td>
<td>Study reaction rate, carbonation yield vs particle size</td>
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<td>3.6</td>
<td>Study carbonation yield vs. T, P for pressed pellets</td>
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<td>3.7</td>
<td>Study comminution energy</td>
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<tr>
<td>3.8</td>
<td>Measure compressive, tensile strength of carbonated pellets</td>
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<tr>
<td>3.9</td>
<td>Determine best raw materials</td>
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<tr>
<td>3.10</td>
<td>Study water distribution during drying in bulk concrete parts</td>
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<tr>
<td>3.11</td>
<td>Study water distribution during curing in bulk concrete parts</td>
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<tr>
<td>3.12</td>
<td>Find the optimum reaction conditions for concrete sample size, geometry and density</td>
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Task Start = S
Task Activity = X
Task Finish = X
Planned Task Start = S
Planned Task Finish = X

Grinding Mill Operational Program Enhancement
Use of Synthesized Solidia Cement
Establishment of Solidia Cement Specifications
Bulk Concrete Demonstration
Flue Gas Demonstration
Bibliography

Peer reviewed publications generated from project

Journal, one author:
- None

Journal, multiple authors:
- None

Publication:
- None