Utilization of CO_2 in High Performance Building and Infrastructure Products

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Developing the Technologies and
Infrastructure for CCS
August 20-22, 2013

Presentation Outline

- Project Overview
- Project Benefit Statement
- 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

Technical Status - Vision

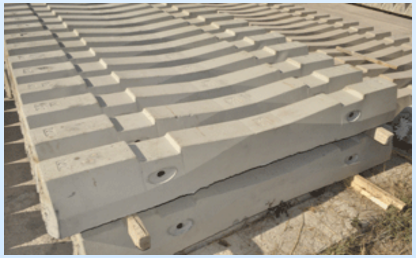
Solution……..

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)

Portland Cement Manufacturing Ravena, NY

Sequester 300 kg CO_2 / t of cement used in CO_2-cured concrete products



Railroad Ties

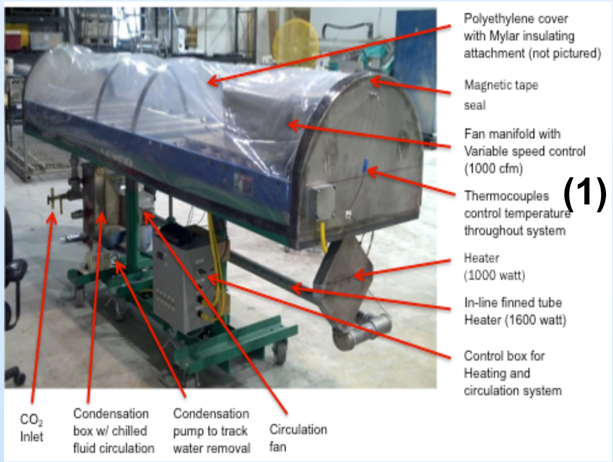
Hollow Core Slabs

Aerated Concrete

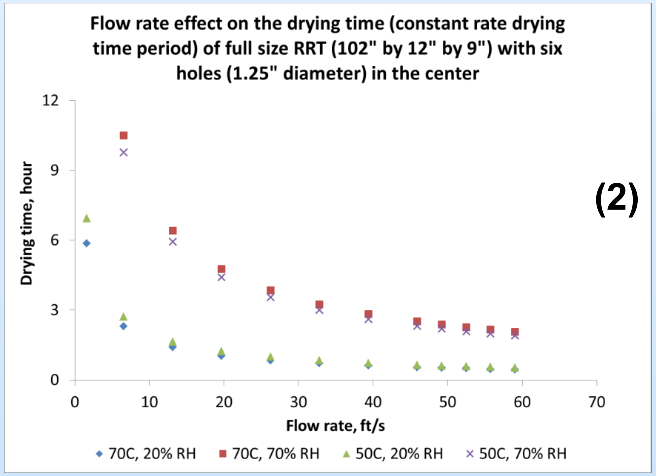
Address Entire OPC Market
Reduce Global CO_2 Emissions by ~ 1.6 Gt / yr

Accomplishments to Date

- *Developed analytical techniques capable of tracking the $CaSiO_3 + CO_2 \rightarrow SiO_2 + CaCO_3$ hydrothermal reaction*
- *Demonstrated reaction rates as a function of $CaSiO_3$ 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)**

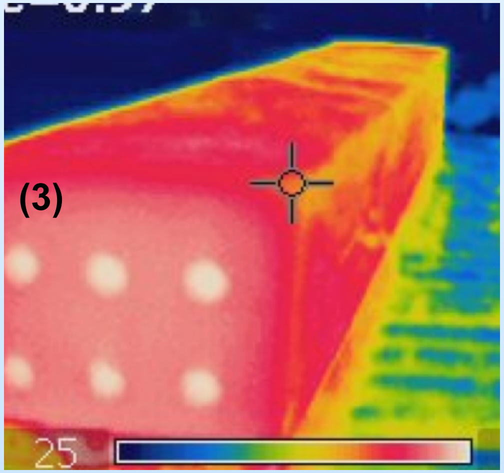


(1)



(2)

(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**

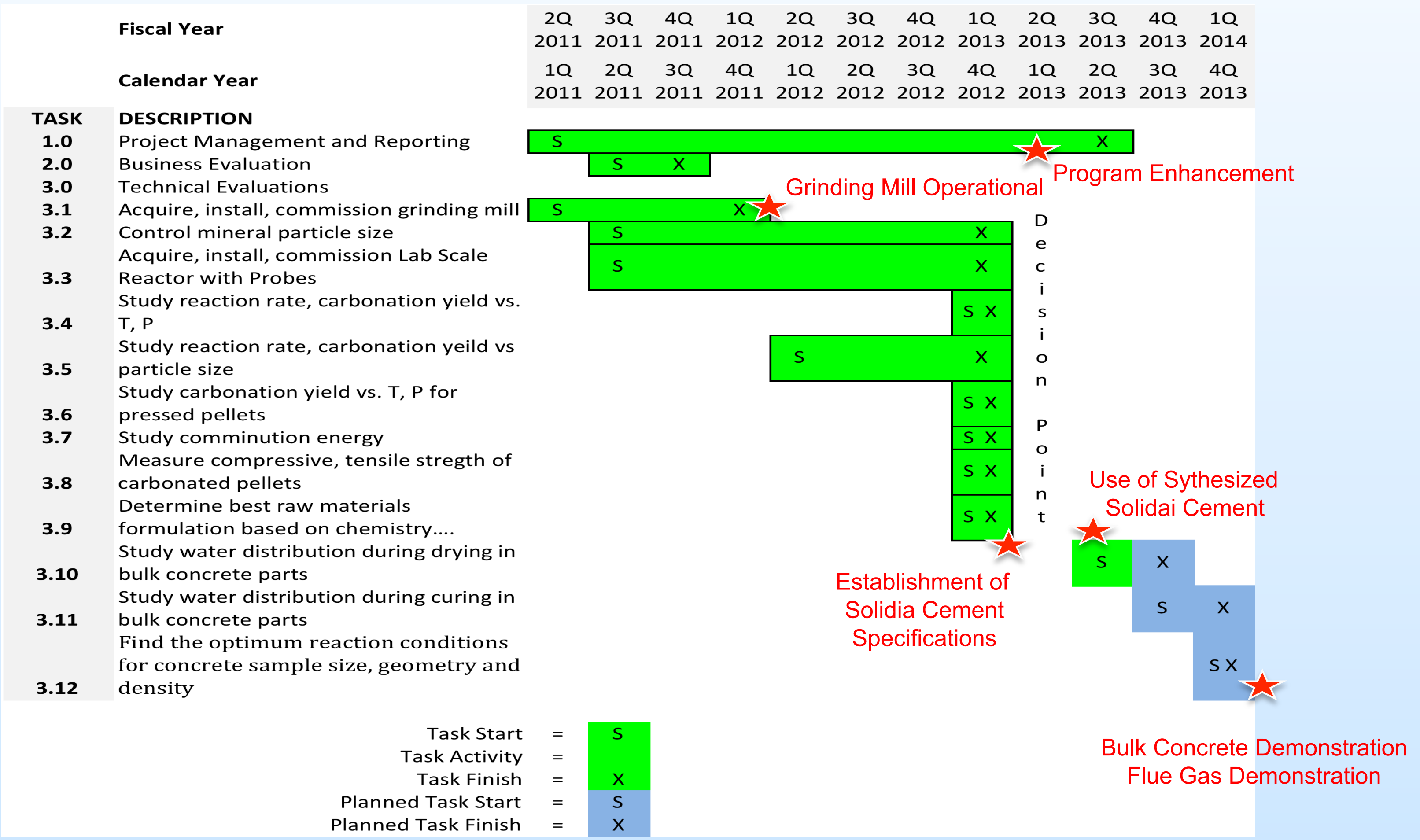
– **Demonstration of bulk concrete curing in real or simulated flue gas**

Appendix

Organization Chart

Rutgers University • Materials science • Analytical techniques		Task	Solidia Technologies • Cement & concrete production/analysis • Applications	
• **R. Riman,** Ph.D. Mat. Sci.	Project Mgmt.	1	• **L. McCandlish,** Ph.D. Chem.	Proj. Mgmt.
		2	• **G. Badiozamani,** MBA • **J. Krishnanan,** MBA	Market / Impact Analysis
• **M. Bitello,** grad student, Mat. Sci. • **Q. Li,** Ph.D. Chem. • **R. Riman**	General Equipment/Milling Reaction kinertics Analytical techniques	3.1 thru 3.9	• **L. McCandlish**	CO_2 sequestration chemistry
		3.10 thru 3.12	• **N. DeCristofaro,** Ph.D. Mat. Sci. • **O. Deo** Ph.D. CE • **X. Hu,** Ph.D. Chem. E. • **L. McCandlish** • **D. Ravikumar,** Ph.D. CE	General Particle size effects Process modeling Aerated concrete Hollow core slab Railroad tie

Gantt Chart



Fiscal Year
2Q 2011
3Q 2011
4Q 2011
1Q 2012
2Q 2012
3Q 2012
4Q 2012
1Q 2013
2Q 2013
3Q 2013
4Q 2013
1Q 2014
Calendar Year
1Q 2011
2Q 2011
3Q 2011
4Q 2011
1Q 2012
2Q 2012
3Q 2012
4Q 2012
1Q 2013
2Q 2013
3Q 2013
4Q 2013
TASK
DESCRIPTION
1.0 Project Management and Reporting
2.0 Business Evaluation
3.0 Technical Evaluations
3.1 Acquire, install, commission grinding mill
3.2 Control mineral particle size
3.3 Acquire, install, commission Lab Scale Reactor with Probes
3.4 Study reaction rate, carbonation yield vs. T, P
3.5 Study reaction rate, carbonation yeild vs particle size
3.6 Study carbonation yield vs. T, P for pressed pellets
3.7 Study comminution energy
3.8 Measure compressive, tensile stregth of carbonated pellets
3.9 Determine best raw materials formulation based on chemistry....
3.10 Study water distribution during drying in bulk concrete parts
3.11 Study water distribution during curing in bulk concrete parts
3.12 Find the optimum reaction conditions for concrete sample size, geometry and density
Grinding Mill Operational
Program Enhancement
Decision Point
Use of Sythesized Solidai Cement
Establishment of Solidia Cement Specifications
Bulk Concrete Demonstration
Flue Gas Demonstration
Task Start = S
Task Activity =
Task Finish = X
Planned Task Start = S
Planned Task Finish = X

Bibliography

Peer reviewed publications generated from project

Journal, one author:

– None

Journal, multiple authors:

– None

Publication:

– None