Solidia Cement™

Part One of a Two-Part Series Exploring the Chemical Properties and Performance Results of Sustainable Solidia Cement™ and Solidia Concrete™

December 17, 2013

Authors: Sada Sahu, Ph.D., Principal Scientist, Solidia Technologies, and Nicholas DeCristofaro, Ph.D., Chief Technology Officer, Solidia Technologies

Abstract

Solidia Cement™ is a non-hydraulic cement composed primarily of low-lime containing calcium silicate phases such as wollastonite / pseudowollastonite (CaO·SiO₂), and rankinite (3CaO·2SiO₂). This contrasts the high-lime alite (3CaO·SiO₂), belite (2CaO·SiO₂), tricalcium aluminate (3CaO·Al₂O₃), tetracalcium aluminum ferrite (4CaO·Al₂O₃·Fe₂O₃), and gypsum (CaSO₄·2H₂O) phases that comprise ordinary Portland cement (OPC). The setting and hardening characteristics of Solidia Cement are derived from a reaction between carbon dioxide (CO₂) and the calcium silicates. During the carbonation process, calcite (CaCO₃) and silica (SiO₂) form and are responsible for the strength development in concrete.

The technological process used to produce Solidia Cement is adaptable and flexible, allowing a wide variety of cement raw meal formulations and production methods. Solidia Cement is made from the same calcareous and siliceous raw materials as Portland cement. Its manufacture needs neither specialized equipment nor additional unit operations, and existing Portland cement plants can be used without modification. Solidia Cement can be manufactured in any part of the world, wherever Portland cement is produced. The clinker of Solidia Cement is produced at a temperature of about 1200°C, which is roughly 250°C lower than the sintering temperature used in Portland cement clinker manufacturing. Production of Solidia Cement reduces the emission of greenhouse gas-CO₂ by 30%.

Concrete products made with Solidia Cement are manufactured using the same, basic mixing and forming processes as Portland cement-based concrete. Concrete products made using Solidia Cement sequester up to 300 kg of CO₂ per tonne of cement used and have similar or better performance compared to traditional concrete products. When the reduced CO₂ emissions associated with Solidia Cement production are considered along with the ability of that cement to sequester CO₂ during concrete curing, the CO₂ footprint associated with the manufacturing and use of cement can be reduced by up to 70%.

11 Colonial Drive
Piscataway, New Jersey 08854
United States
www.solidiatech.com
1. Introduction

Concrete is the most consumed man-made material in the world. A typical concrete is made by mixing about 12 wt.% Portland cement, 8 wt.% water, and 80 wt.% aggregate (sand and crushed stone). Portland cement is a synthetic material made by burning a mixture of ground limestone and clay, or materials of similar composition, in a rotary kiln at a sintering temperature of 1450°C. Portland cement manufacturing is not only an energy-intensive process, but one which releases considerable quantities of greenhouse gas (CO₂). The cement industry accounts for approximately 5% of global anthropogenic carbon dioxide (CO₂) emissions.

A modern cement plant will release about 810 kg of CO₂ per tonne\(^1\) of cement clinker produced. More than 60% of this CO₂ comes from the chemical decomposition, or calcination, of limestone ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$). The balance comes from the combustion of fossil fuel to heat the kiln. A small amount of additional CO₂, approximately 90 kg per tonne of cement, is associated with the electricity required to grind and transport materials throughout the process. For the purpose of this paper, we will not consider the CO₂ contribution from electric energy usage.

The International Energy Agency (IEA) has created a roadmap to guide the long-term sustainability efforts of the cement industry. According to this roadmap, the cement industry must reduce its total CO₂ emissions from 2.0 Gt in 2007 to 1.55 Gt by 2050. Over this same period, however, cement production is projected to grow from 2.6 Gt to 4.4 Gt (from references 1 and 2).

To address this formidable challenge, the cement and concrete industries have adopted both evolutionary and revolutionary strategies. The evolutionary strategies include the implementation of energy-efficient production technologies, the use of alternative fuels, the development of new cement chemistries with low-lime content, and the reduction of the clinker factor in cement. The reduction in clinker factor is achieved by co-grinding cement clinker with supplementary cementitious materials, such as fly ash, slag, natural pozzolanic materials, and fillers, such as limestone. However, even the combined effect of these initiatives is likely to fall far short of the IEA roadmap goals. Thus, a revolutionary approach, such as the massive implementation of yet-to-be developed and potentially expensive carbon capture and storage technologies, will be required. This approach is expected to add significant additional cost to Portland cement manufacturing.

Solidia Cement™, a revolutionary, new cement product developed by Solidia Technologies®, is poised to address these challenges (references 3 and 4). Solidia Cement is a reduced-lime, non-hydraulic version of cement and is capable of significantly reducing the energy requirement and CO₂ emissions of a cement plant. Additionally, Solidia Cement cures via a reaction with gaseous CO₂, thus offering the ability to permanently and safely sequester CO₂. Solidia’s technological process is adaptable and flexible, allowing Solidia cement to be produced under a variety of cement formulations and production methods across the globe. It offers cement manufacturers considerable savings in time, energy, water and costs.

\(^1\) All calculations are based on the tonne, also known as the metric ton, equaling 1,000 kilograms.
2. Raw Materials Used in Cement Manufacturing

The Solidia Cement chemistry can be created from the same basic raw materials that are used in Portland cement manufacturing. Both cement chemistries are primarily composed of calcium silicates. Thus, both rely on limestone as a source of lime (CaO) and sand, shale or clay as a source of silica (SiO₂), albeit in different proportions.

Solidia Cement, composed primarily of low-lime wollastonite / pseudowollastonite (CaO·SiO₂ or CS in cement chemist notation) and rankinite (C₃S₂) phases, requires a raw materials mix typically consisting of about 50% limestone. Portland cement, which contains mainly high-lime alite (C₃S) and belite (C₂S), but also includes minor amounts of tricalcium aluminate (C₃A), tetracalcium aluminoferrite (C₄AF) and gypsum, requires about 70% limestone. Depending on the purities of the raw materials available at the manufacturing site, Portland cement production may require additions of bauxite as a source of alumina and laterite as a source of iron oxide. The relative oxide content of Solidia Cement and Portland cement are compared in the ternary CaO-SiO₂-Al₂O₃ diagram in Figure 1.

The simple, low-lime chemistry of Solidia Cement permits the use of low-grade limestone in cement formulation and obviates the need for bauxite and laterite additions. These factors may allow significant flexibility and cost reduction opportunities in the manufacturing of Solidia Cement clinker.

![Figure 1. Ternary diagram showing the region of oxide composition of Portland cement and Solidia Cement.](image)

---

2 Cement chemist’s notation: CaO = C, SiO₂ = S, Al₂O₃ = A, Fe₂O₃ = F
3. Cement Production Processes

3.1 Portland Cement Production

Portland cement, also commonly known as ordinary Portland cement (OPC), was invented by Joseph Aspdin in 1824. Since its invention, Portland cement has been made from a calcareous material, such as limestone or chalk, and from silica found in sand, clay or shale. The raw materials required to manufacture Portland cement are truly ubiquitous; they can be found in all corners of the world.

The process for manufacturing Portland cement consists of grinding the quarried raw materials, blended in the proper proportions, into a fine powder. The powder, referred to as raw meal, is fed into a rotary kiln and heated to a temperature of about 1450°C. During this process, the raw meal goes through dehydroxylation and calcination steps, and ultimately sinters and partially fuses together to form clinker nodules. The clinker is cooled, mixed with gypsum, and then ground to fine powder of 100 μm or below.

There are several pyro-processing technologies available for making Portland cement clinker, such as the “wet process” (in a long rotary kiln), the “semi-wet process” (in a vertical shaft kiln), and the “dry-process” (typically in a short rotary kiln). The two former methods mix the raw meal with water to form slurry (in the wet process) or nodules (in the semi-wet process). In the dry process, the raw meal is often partially calcined prior to entering the kiln. Once inside the kiln, the raw meal is heated to about 1450°C. To maintain such high kiln temperatures, fuels of high calorific values, such as coal, petcoke, natural gas, and oil, are normally used.

The cooling of Portland cement clinker is a sensitive process requiring a certain degree of fast cooling. The fast cooling prevents reversion of C₃S to C₂S + C. However, if the cooling is too fast, the clinker will end up with a significant amount of glassy phase, which will negatively impact the hydration necessary for concrete hardening. Broadly, there are three distinct types of coolers in use in cement plants: rotary, planetary, and grate coolers. Rotary and planetary coolers are used in older plants, while grate coolers are used in newer plants. The coolers are designed in a way to enable maximum heat recovery.

The clinker is then mixed with about 5% gypsum and ground in a ball mill or vertical roller mill. During the grinding process, water is sprayed into the mill to keep the material temperature below 105°C, to prevent dehydration of gypsum and avoid the false setting of the cement. The finished cement powder is stored in silos for delivery to concrete manufacturers.

3.2 Solidia Cement Production

Solidia Cement is made from the same calcareous and siliceous raw materials as Portland cement. Thus, this cement can be manufactured in any part of the world, wherever Portland cement is produced. Manufacturing of Solidia Cement needs neither specialized equipment nor additional unit operations, and existing Portland cement plants can be used without modification.

All of the pyro-processing technologies available for making Portland cement clinker are applicable to the production of Solidia Cement clinker. The major difference in pyro-processing of the two cements is that Solidia Cement clinker can be made at about 1200°C. An example of the production of Solidia clinker in a rotary kiln is shown in Figure 2. The raw materials mix
forms nodules similar to Portland cement clinker. An example of Solidia Cement clinker is shown in Figure 3.

As the peak temperature in the burning zone is about 250°C lower than that used for Portland cement manufacturing, fuels of lower calorific value can be used. This will allow the use of alternative fuels with lower calorific value than that of coal.

The absence of C₃S in Solidia Cement clinker renders it less sensitive to cooling rate once it exits the kiln. Because rapid cooling of the clinker is not necessary, heat losses from the cooler should be markedly reduced. This may permit the cost-effective production of Solidia Cement clinker in less efficient, older generation coolers.

The non-hydraulic nature of Solidia Cement eliminates the need for gypsum addition as a set-controlling component, and the need to spray cool the cement product. Additionally, Solidia Cement is not prone to hydration, so no special storage arrangements are needed.

Figure 2. Formation of Solidia Cement clinker nodules in the kiln

Figure 3. Example of produced Solidia Cement clinker nodules
4. Energy Requirements and CO₂ Emissions During Cement Manufacturing

Both Portland cement and Solidia Cement manufacturing require significant amounts of energy and emit significant quantities of CO₂. Heat energy is needed to dry the raw meal, calcine the limestone, react the oxide components, and form the cement clinker. Electrical energy is needed to crush and grind the raw materials, to comminute the clinker, and to transport materials throughout the process. The differences in energy consumption and CO₂ emission are illustrated below.

4.1 Portland Cement

4.1.1 Portland Cement Energy Requirements

In modern cement plants, the production of one tonne of Portland cement clinker requires heat energy totaling 3.2 GJ, and electrical energy totaling 0.4 GJ (110 kWh) (from reference 5).

From a theoretical perspective, the thermal energy consumed in producing one tonne of Portland cement clinker is about 1.757 GJ. The breakdown of that enthalpy into the various pyro-processing steps is provided in Table 1 (from reference 6). While the overall process is endothermic, note that the process step in which the cement phases are formed is exothermic in nature. The difference between the actual and theoretical heat requirements is due to heat retained in clinker, heat losses from kiln dust and exit gases, and heat losses from radiation.

As can be seen from Table 1, the pyro-processing step that consumes the most heat energy is the endothermic decomposition of calcium carbonate (calcination). The most electrical energy-intensive step is clinker grinding, which typically consumes between 30 and 40% of the total electrical energy usage, depending on the mill type and performance.

4.1.2 Portland Cement CO₂ Emissions

According to historical EPA estimates, between 900 and 1,100 kg of CO₂ is emitted for every tonne of Portland cement produced in the U.S. The exact quantity depends on the fuel type, raw ingredients used and the energy efficiency of the cement plant (see reference 7). However, the most efficient Portland cement facilities report CO₂ emission as low as about 900 kg/tonne of clinker (see references 2 and 8).

There are three sources of CO₂ emission in cement production:

1) the chemical decomposition of the calcium carbonate within the limestone according to the formula CaCO₃ → CaO + CO₂;
2) the combustion of fossil fuel to heat the kiln for pyro-processing the raw meal; and,
3) the generation of electricity needed to drive the grinding mills and materials transportation systems.

The CO₂ emission from chemical decomposition of calcium carbonate depends on the lime content of the clinker product (~70% for Portland cement). The CO₂ emission from pyro-processing depends on the fossil fuel type (for example, ~3.0 ton of CO₂ per ton of coal consumed). The CO₂ emission from electricity depends on the source of electricity in the grid.
and transmission losses. The carbon footprint from electricity consumption for cement production is about 90 kg/tonne in the USA (see references 9 and 10).

Table 2 compares the sources of CO₂ emission in the production of cement clinkers.

4.2 Solidia Cement

4.2.1 Solidia Cement Energy Requirements

The total lime content of Solidia Cement clinker is in the range of 45-50 wt.%, representing approximately a 30% reduction from that required for Portland cement. This reduction in lime translates directly into a 30% reduction in the major component of the theoretical enthalpy, that is, the calcination step. Solidia Cement and Portland cement are roughly equivalent in terms of the enthalpy required to decompose the clay component of the raw meal and the exothermic reaction associated with the formation of the cement phases. Dominated by the large difference in calcination step, the total enthalpy of formation of Solidia Cement clinker is expected to be about 1.051 GJ, almost 40% less than that of Portland cement clinker (see Table 1).

From a practical perspective, Solidia Cement clinker is burned at temperatures approximately 250°C lower than those used in Portland cement manufacturing, and with the potential for significantly reduced system-wide heat losses than that experienced in Portland cement manufacturing. This is expected to translate into a reduction in fossil fuel consumption by as much as 30%. The relatively soft Solidia Cement clinker is expected to grind more easily than its Portland cement counterpart. This may translate into additional savings in the electrical energy required for clinker grinding.

4.2.2 Solidia Cement CO₂ Emissions

The unique, low-lime content of Solidia Cement clinker enables two separate opportunities to reduce the CO₂ emissions associated with cement production.

As referenced above, the low-lime chemistry allows the reaction between lime and silica to occur at a clinker temperature of 1200°C, which is 250°C lower than the temperature required for Portland cement clinker formation. During the production of Solidia Cement, the CO₂ emissions associated with the burning of fossil fuel to heat the kiln are expected to be 190 kg per tonne of clinker, compared to 270 kg per tonne of Portland cement clinker.

The second opportunity can be traced to the chemical decomposition of the calcium carbonate in limestone. Reduction in the lime content of the cement from 70% (for Portland cement) to 50% (for Solidia Cement) enables a proportionate reduction in this form of CO₂ emission. Thus, the CO₂ released from the chemical decomposition of limestone will be reduced from 540 kg per tonne of Portland cement clinker to about 375 kg of CO₂ per tonne of Solidia Cement clinker.

The total CO₂ emissions associated with Portland cement and Solidia Cement manufacturing are compared in Table 2. Note that Solidia Cement clinker production offers the potential to reduce CO₂ release associated with cement manufacturing by as much as 30%.
Table 1. Theoretical enthalpy of formation of 1 tonne of clinker (Portland cement clinker values are from reference 6; Solidia Cement clinker values are based on a modeled clinker and may vary slightly depending on the phase composition.)

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Portland Cement Clinker $\Delta H$ (GJ)</th>
<th>Solidia Cement Clinker $\Delta H$ (GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcination</td>
<td>+2.138</td>
<td>+1.514</td>
</tr>
<tr>
<td>Decomposition of clay</td>
<td>+0.063</td>
<td>+0.075</td>
</tr>
<tr>
<td>Formation of cement phases</td>
<td>-0.377</td>
<td>-0.538</td>
</tr>
<tr>
<td>Total</td>
<td>1.757</td>
<td>1.051</td>
</tr>
</tbody>
</table>

Table 2. CO$_2$ emissions during the production of Portland cement and Solidia Cement clinker (Note: The CO$_2$ associated with the electrical energy usage in the cement making process is not considered.)

<table>
<thead>
<tr>
<th>CO$_2$ emissions from:</th>
<th>Per tonne of Portland Cement clinker</th>
<th>Per tonne of Solidia Cement clinker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone decomposition</td>
<td>540 kg</td>
<td>375 kg</td>
</tr>
<tr>
<td>Fossil fuel combustion</td>
<td>270 kg</td>
<td>190 kg</td>
</tr>
<tr>
<td>Total CO$_2$ emissions</td>
<td>810 kg</td>
<td>565 kg</td>
</tr>
</tbody>
</table>

5. Concrete Mixing, Forming and Curing Processes

Concrete products made with Portland cement or Solidia Cement are manufactured using the same, basic mixing and forming processes. Concrete production typically begins by mixing the dry (cement, sand and crushed stone) and the liquid (water and chemical additives) components of the concrete. The water and chemical additive control the flow behavior of the concrete mix while it is in the plastic stage.

Both Portland cement and Solidia Cement-based concretes can be mixed in standard concrete mixers. Similarly, they can be formed into the final concrete part shape by the same processes and equipment. These processes include casting, extrusion, rolling and pressing.

Portland cement and Solidia Cement-based concrete (hereafter referred to as PCC and SCC, respectively) differ in the chemical process by which they set and harden. These processes are collectively referred to as “curing.”

5.1 Portland Cement Concrete Curing

When Portland cement comes in contact with water, a series of hydration reactions initiate with a release of significant amount of heat. These hydration reactions are responsible
for the setting and hardening of PCC. In a very simplistic way, the curing process involves reactions between:

- $C_3A$, gypsum and water, to produce ettringite;
- $C_3S$ and water, to produce a complex calcium silicate hydrate and calcium hydroxide; and,
- $C_2S$ and water, which also yields calcium silicate hydrate and calcium hydroxide.

The complex calcium silicate hydrate is an amorphous phase wherein the Ca:Si ratio can vary during the hydration period.

The hydration of calcium silicate components of Portland cement begins as soon as the Portland cement comes into contact with water but proceeds at a relatively slow pace. PCC must stay moist throughout the entire process, which may take up to 28 days. Under normal curing conditions, and without chemical accelerators, roughly 70% of the cement particles are hydrated.

The microstructure of hydrated Portland cement paste shows that two distinct types of calcium silicate hydrate form in the system: an “inner product” and an “outer product.” The outer product forms early in the curing process, is highly porous, and precipitates in the open spaces within the concrete structure. The inner product forms late in the curing process, is denser than the outer product, and forms near the original cement particles.

### 5.2 Solidia Cement Concrete Curing

The low-lime, $CS$ and $C_3S_2$ components of Solidia Cement do not hydrate when exposed to water during the concrete mixing and forming processes. Formed SCC parts will not cure until they are simultaneously exposed to water and gaseous $CO_2$. SCC curing is a mildly exothermic reaction in which the low-lime calcium silicates in the Solidia Cement react with $CO_2$ in the presence of water to produce calcite ($CaCO_3$) and silica ($SiO_2$) as follows:

$$CaO·SiO_2 + CO_2 \overset{H_2O}{\rightarrow} CaCO_3 + SiO_2$$

$$3CaO·2SiO_2 + 3CO_2 \rightarrow 3CaCO_3 + 2SiO_2$$

The above reaction processes require a $CO_2$-rich atmosphere. However, the process can be conducted at ambient gas pressures and at moderate temperatures (20 to 60°C). These parameters are well within the capabilities of most precast concrete manufacturers.

Unlike the hydration reaction in PCC, the carbonation reaction in SCC is a relatively speedy process. Full curing of SCC is limited only by the ability of gaseous $CO_2$ to diffuse throughout the part. Thin concrete products such as roof tiles (~10 mm thick) can be cured in less than 10 hours. Larger concrete parts, such as those in railroad sleepers (~250 mm thick),

---

3 Solidia's ongoing technology and product development is reinforced by third-party research collaboration and testing. Current collaborations include additional research in concrete applications with Lafarge, the world’s largest cement manufacturer, as well as a Cooperative Research and Development Agreement with the U.S. Department of Transportation’s Federal Highway Administration to examine transportation infrastructure applications at the Turner-Fairbank Highway Research Center, a U.S. Federal laboratory. The original generation of the technology was developed at Rutgers, the State University of New Jersey.
can be cured within a 24-hour period. This rapid curing process can potentially enhance the productivity of an existing precast operation.

A microstructural evaluation of SCC shows the reaction products calcite (CaCO$_3$) and amorphous silica (SiO$_2$) as well as uncarbonated cement particles. A typical microstructure of CO$_2$-cured Solidia Cement is illustrated in Figure 4. The calcite fills the pore space within the SCC, creating a dense microstructure. As the silica is relatively insoluble in the prevailing conditions of the carbonation process, it forms at the outer surface of the reacting cement particle. Unlike Portland cement-based concretes, concrete products hardened with CO$_2$-cured Solidia Cement do not consume water.

Concretes with different strengths can be designed by using Solidia cement. Compressive strengths up to 70 MPa (> 10,000 psi) and flexural strengths up to 8 MPa (> 1,100 psi) have been measured in SCC parts. These results demonstrate that concrete with similar or superior strengths and durability can be obtained with Solidia Cement and with shorter curing periods.

![Figure 4: Microstructure of CO$_2$-cured Solidia Cement (The green area is calcite (CaCO$_3$), the red area is amorphous silica (SiO$_2$), and the yellow area is unreacted wollastonite (CaO·SiO$_2$).)](image)

**5.3 Carbon Sequestration in Solidia Cement Concrete**

The unique ability of Solidia Cement to avoid hydration and cure via a reaction with gaseous CO$_2$ opens the possibility for the permanent sequestration of CO$_2$ in cured concrete structure. The curing processes, described in Section 4.2, enables SCC to sequester up to 300 kg of CO$_2$ per tonne of Solidia Cement used in the concrete formulation. The CO$_2$ used in the curing process and captured within SCC is industrial-grade CO$_2$ sourced from waste flue gas streams. Depending on the specific ratios of sand, aggregate and Solidia Cement used in the concrete mix, the final SCC part may contain between about 3 and 7 wt.% of sequestered CO$_2$. 

6. Conclusions

The production of Solidia Cement and its use in CO\textsubscript{2}-cured concrete open multiple possibilities for revolutionizing the cement and concrete industries.

Compared to Portland cement, the simple, low-lime chemistry of Solidia Cement offers a wide variety of manufacturing and material benefits to the cement industry:

- Solidia Cement manufacturing will consume less limestone.
- Solidia Cement can also be made using lower-grade limestone. This and the above benefit offer the potential of extending the lifetimes of the limestone quarries that are co-located with cement plants.
- Solidia Cement does not require costly additions of bauxite, laterite and gypsum.
- Solidia Cement is synthesized at reduced kiln temperatures and does not require quick cooling of the cement clinker product.
- These factors allow for more efficient heat management throughout the cement-making process.
- The reduced kiln temperatures may allow the burning of low-caloric value, alternative fuels.
- The energy consumption associated with cement production can be reduced by up to 30%.
- The CO\textsubscript{2} emissions associated with cement production can be reduced by up to 30%.

The non-hydraulic nature of Solidia Cement also brings benefits to the concrete industry:

- Solidia Cement is not prone to hydration, so no special storage arrangements are needed.
- Freshly made SCC can be recycled easily.
- Concretes based on Solidia Cement can fully harden within 24 hours vs. a 28-day curing cycle required for Portland cement-based concretes.
- CO\textsubscript{2}-cured concretes demonstrate similar or superior strengths and durability when compared to their hydrated counterparts.
- CO\textsubscript{2}-cured concretes can permanently and safely sequester up to 300 kg of CO\textsubscript{2} per tonne of cement incorporated in the concrete formulation.
- Depending on the specific ratios of sand, aggregate and Solidia Cement used in the concrete mix, the final carbonated concrete part may contain between about 3 and 7 wt.% of sequestered CO\textsubscript{2}.

When the reduced CO\textsubscript{2} emissions associated with Solidia Cement production are considered along with the ability of that cement to sequester CO\textsubscript{2} during concrete curing, the CO\textsubscript{2} footprint associated with the manufacturing and use of cement can be reduced by up to 70%. Most importantly, all of the above can be accomplished in a manner that is compatible with the raw materials supply-chains, manufacturing equipment and unit processes of the cement and concrete industries. Rising global concerns around water scarcity, particularly in select regions of the world, heighten the demand for non-hydraulic building materials, adding to the potential value of non-hydraulic Solidia Cement as a material of the future.

Solidia Concrete™ will be explored in a companion paper to be released January 2014.
7. References


About Solidia Technologies®
Solidia Technologies® is a cement and concrete technology company with patented processes that make it easy and profitable to use CO₂ to create superior and sustainable building, construction and industrial products. A winner of the 2013 R&D Top 100 Award and shortlisted for the 2013 Cleantech 100, Solidia’s processes cure concrete with CO₂ instead of water and use a sustainable cement as binder, reducing the carbon footprint of concrete products up to 70 percent, lowering production costs, and enhancing performance. Based in Piscataway, N.J. (USA), Solidia’s investors include Kleiner Perkins Caufield & Byers, Bright Capital, BASF, and BP. Follow Solidia Technologies at www.solidiatech.com and on LinkedIn and Twitter: @SolidiaCO2.