TECHNOLOGIES THAT REDUCE WATER USE IN CEMENT AND CONCRETE HELP GLOBAL INDUSTRY ADDRESS MOUNTING CONCERNS OF WATER SCARCITY

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Authors: Vahit Atakan, Ph.D., Chief Scientist; Jitendra Jain, Ph.D., Senior Research Scientist; Deepak Ravikumar, Ph.D., Research Scientist; Larry McCandlish, Ph.D., Senior Research Scientist (Ret.); and Nicholas DeCristofaro, Ph.D., Chief Technology Officer, Solidia Technologies

Abstract

Water scarcity can lead to practical and business risks for a wide range of companies and sectors, including the cement industry, as noted by the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD) in Protocol for Water Reporting. Calling on cement and concrete producers to track how water is used, recycled or discarded, and to disclose where and how the water is drawn, the 2014 guide was a first step towards addressing water scarcity as a dire threat facing the industry. Building on the call for industry-wide water use reporting, CSI went one step further, releasing Guidance for Good Practices for Water Accounting in May 2016. Beyond monitoring and using best practices for reporting water use, it is critical that industry have access to modern technologies that can lower the usage, and thus the need, for water, with direct implications for global business continuation.

Concrete is the second most consumed substance in the world, after water. Portland cement-based concrete is made by mixing aggregates (both coarse and fine), ordinary Portland cement (OPC), admixtures (mineral or chemical) and water. Over 30 billion tons of concrete were produced in 2011, consuming over three billion tons of OPC. The water-to-cement ratio for a typical concrete formulation varies from 0.35 to 0.4 (0.35 ton of water per ton of cement). Based on these numbers, it is estimated that 1.3 to 1.5 billion tons of water (3×10^9 tons of cement x 0.35 ton of water per ton of cement = 1.3 billion tons of water) is chemically consumed annually during concrete production. Because concrete may take up to 28 days to fully cure, additional water is often added to the concrete to compensate for evaporation. When this added water is considered, the overall water consumed annually during OPC-based concrete production is estimated to be between 2.15 to 2.6 billion tons, or 2.15 to 2.6 trillion liters.

Solidia Technologies® has developed a new class of sustainable cement, hereafter referred to as Solidia Cement™, that reacts with gaseous CO_2 rather than with water to

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

form Solidia Concrete™.[1] *Like their OPC-based concrete counterparts, concrete objects made with this sustainable cement require the incorporation of water for shaping and forming only. However, the water used in concrete formulations based on Solidia Cement is not consumed chemically and can be recovered during the CO_2 -curing process.*

On average, 70 to 80% of the water used in the Solidia Concrete formulation can be recovered during CO_2-curing process. The remainder of the water is retained in the concrete and can be recovered if needed.

If Solidia Cement were used instead of OPC, the amount of water consumed during the production of concrete could be reduced by0.26 to 0.45 billion tons. This corresponds to an annual global water savings approaching two billion tons, or two trillion liters. Advancing new technologies and practices such as these are paramount for the industry's future success.

1. World water consumption

Water scarcity can lead to practical and business risks for a wide range of companies and sectors, including the cement industry, as noted by the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD) *Protocol for Water Reporting*. [1] Published in 2014, the guide recommends that cement and concrete producers track how water is used, recycled or discarded, and to disclose where and how the water is drawn. CSI recently addressed the issues industry-wide water consumption anew in *Guidance for Good Practices for Water Accounting*[2], published in May. While an important step, the industry must also have access to innovative practices and technologies that reduce water use in production.

Water is the most consumed substance in the world; the second is concrete, which ordinarily contributes to significant further use of water resources. Although the industry does not yet possess comprehensive, global data of its water use, global water withdrawals are rapidly increasing. Beyond accurate tracking of water consumption, the industry needs innovative technologies that can help reduce water consumption, as water scarcity mounts as a looming threat to business survival.

Between 1996 and 2005, the average annual consumption of water worldwide was over 9000 billion tons, although the availability of useable water varies dramatically from region to region around the world. [3] The annual renewable water per person is shown in Figure 1.[4] Less than 10 countries control 60% of the world's available fresh water.

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[1] Solidia Concrete and Solidia Cement are interdependent materials; Solidia Concrete can only be made with Solidia Cement. All calculations herein are based on trials using Solidia's patented processes. For more information, see the white papers, Solidia Cement™, published December 2013, and Solidia Concrete™, published February 2014.

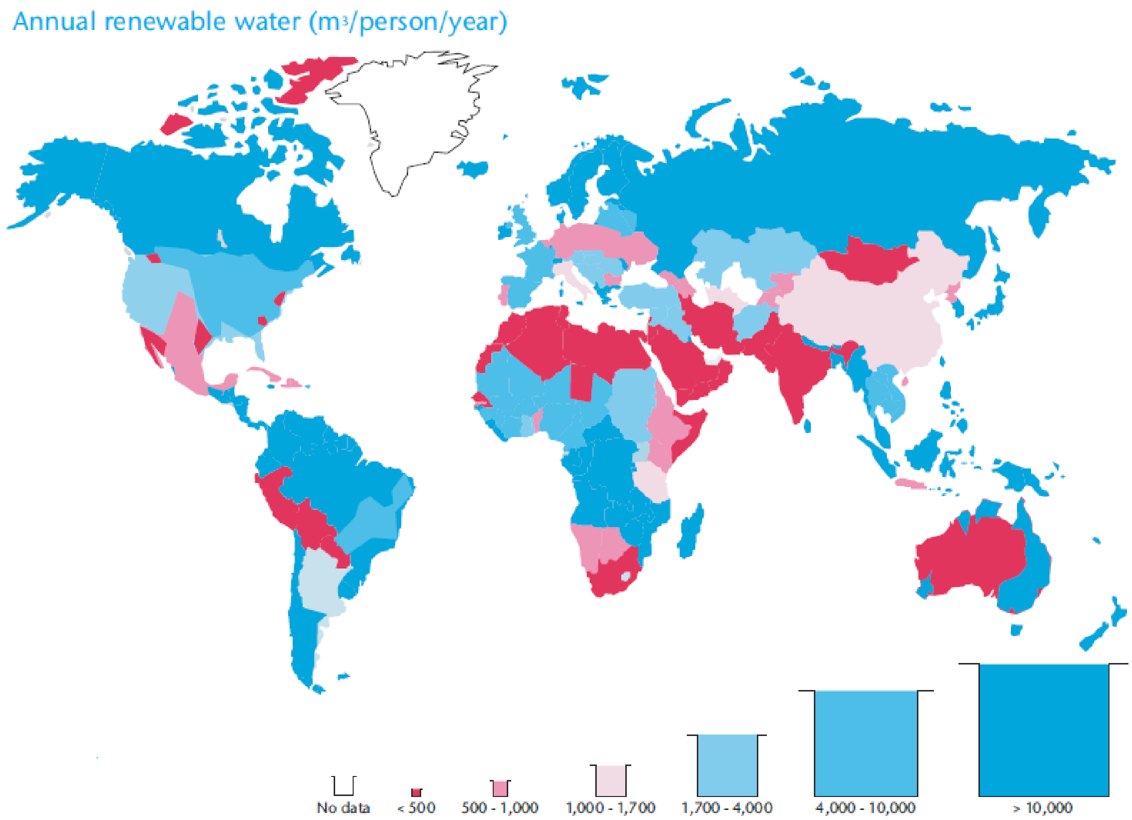

Figure 1. "Facts and Trends." UN Water.
World Business Council for Sustainable Development, Mar. 2006. Web.

According to Population Action International: "Based upon the UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress, or scarcity conditions by 2025," as shown in Figure 2.[5] By 2050, the number of countries facing water stress or scarcity could rise to 54, with a combined population of four billion people—about 40% of the projected global population of 9.4 billion. Thus, water conservation has grown as a global concern.

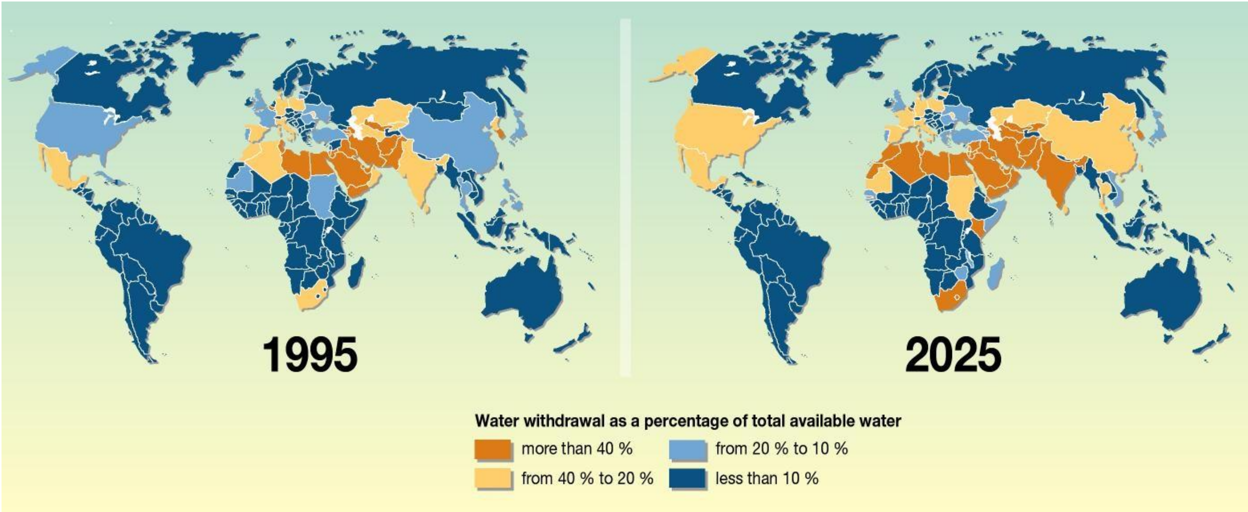

Figure 2. Increased global water stress
Vital Water Graphics, UNEP, 2008

According to UNESCO, “Global annual water use by industry is expected to rise from an estimated 725 km 3 in 1995 to about 1,170 km 3 by 2025, by which time industrial water usage will represent 24 percent of all water abstractions.”[6] Depending on the application and function, some of this water can be recovered. However, industrial water that is chemically consumed is no longer available for recovery or recycling.

It is critical that industry have access to modern technologies that can lower the usage, and thus the need, for water. In select markets across the world where water scarcity is an urgent concern, water consumption will become increasingly critical, particularly for industries highly dependent on water, such as cement and concrete. As economies are critically dependent on water, it is essential that industries ensure the water economy does not dry up. By implementing accounting standards across the industry, CSI will have a clearer vision of how to address and reduce water usage in cement and concrete. But reporting and best practices cannot solve the problem alone. That’s where technology steps in.

2. Water consumption during Portland cement-based concrete curing

Concrete is the second most consumed substance in the world, as mentioned above. Portland cement-based concrete is made by mixing aggregates (both coarse and fine), ordinary Portland cement (OPC), admixtures (mineral or chemical), and water. The water component of concrete plays two roles in concrete making. The first is to provide the required flow characteristics to the concrete mix, so that it can be shaped and formed. The second is to cure the concrete, i.e., to chemically react with OPC to form calcium silicate hydrate, calcium aluminum hydrate and calcium hydroxide.

This chemical reaction is responsible for the development of strength, hardness and durability in the cured concrete part. The water that is chemically bound within the calcium silicate hydrate, calcium aluminum hydrate and calcium hydroxide phases formed during curing is not available for recycling.

Over 30 billion tons of concrete were produced in 2011, consuming over three billion tons of ordinary Portland cement.[7] The water-to-cement ratio for a typical concrete formulation varies from 0.35 to 0.4 (0.35 ton of water per ton of cement) . Based on these numbers, it is estimated that 1.3 to 1.5 billion tons of water (3×10^9 tons of cement x 0.35 ton of water per ton of cement = 1.3 billion tons of water) is chemically consumed annually during concrete production.

It is well known that OPC-based concretes cure slowly, often requiring up to 28 days to reach target hardness. In many concrete-making operations, water must be continuously added to the concrete part during curing, to compensate for evaporation of water during the extended curing process. The amount of additional water required is based on environmental conditions such as wind speed, temperature and relative humidity.[8] In these cases, the amount of additional water varies from 65 to 75% of that used in the original formulation. Overall, the annual water consumption during OPC-based concrete production is estimated to be between 2.15 to 2.6 billion tons.

3. Water savings in Solidia Cement–based concrete production

Solidia Technologies® has developed a new class of sustainable cement, hereafter referred to as Solidia Cement™, that reacts with gaseous CO_2 rather than with water to form Solidia Concrete™. Like their OPC-based concrete counterparts, concrete objects made with this sustainable cement require the incorporation of water for shaping and forming only. However, the water used in concrete formulations based on Solidia Cement is not consumed chemically and can be recovered during the CO_2 -curing process.

The CO_2-curing process is carried out in a high concentration CO_2 environment. This environment can be achieved by processes as simple as placing a sealed tarp over the concrete part and pumping in CO_2 to achieve 60 to 90% concentration. Solidia Cement-based concrete curing is a counter diffusion process in which CO_2 molecules replace water molecules inside the pores. Solidia Cement reacts with CO_2 gas in the presence of water to form calcium carbonate and silica. This carbonation reaction is an exothermic process, releasing around 87 kj/mol of heat during curing. The heat is dissipated through the evaporation of water contained in the concrete formulation. The evaporated water can be condensed during circulation of the gas mixture and collected in the condenser unit.[9] On average, 70 to 80% of the water used in the Solidia Concrete formulation can be recovered during CO_2-curing process.

A typical water recovery curve is shown in Figure 3.

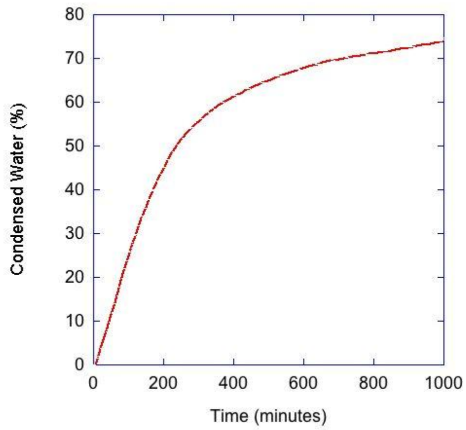

Figure 3. A typical % water recovery curve for curing a 20 ft-long hollow core Solidia Concrete slab.

Note: The data is presented as a function of curing time. The condensed water percentage is based on the initial water content of the formulation. Additional water savings due to the evaporative losses, which are present in OPC-based concrete but absent in Solidia Cement-based concrete, are not included.

In a recent semi-industrial trial, 34 tons of Solidia Concrete was cured at a precast concrete plant. During this trial, 1.6 tons of water, which is about 80% of the mix water, was recovered during curing.

If needed, the remainder of the water retained in the concrete can be recovered by heating the concrete in an enclosure to fully dry for collection. If water grows to be more valuable than energy, which is not inconceivable, this ability to recover water might become even more desirable by addressing a business necessity.

4. Examples of water saving performance

For comparison purposes, the water savings for two different kinds of concrete formulations are discussed.

In the first case, a high-strength concrete formulation (compressive strength >8000 psi) with a water to cement ratio of 0.34 was studied. For this formulation, both OPC-based and Solidia Cement-based concretes will require 127 kg of mixing water per cubic meter of finished concrete parts. In the case of OPC-based concrete, up to an additional 84 kg may be required to compensate for the evaporation losses during a curing period of seven days. Thus the total amount of water consumed is 211 kg per cubic meter of concrete. However, in the case of Solidia Cement-based concrete, no additional water is required, and about 100 kg of water is recovered during carbonation curing process. The net water usage is 27 kg per cubic meter of concrete. The total water savings realized is 184 kg per cubic meter of finished concrete.

In the second case, a normal-strength concrete formulation (compressive strength ~4000 psi) with a water to cement ratio of 0.37 is examined. For this formulation, both OPC-based and Solidia Cement-based concretes require 110 kg of water per cubic meter of finished concrete. In the case of the OPC-based concrete, up to an additional 84 kg is required to compensate for the evaporation losses during the curing period of seven days. Thus the total amount of water consumed is 194 kg per cubic meter of OPC-based. In the case of Solidia Cement-based concrete, no additional water is required, and 88 kg of water is recovered during carbonation curing. The net water usage is 22 kg per cubic meter of concrete. The total water savings of 172 kg per cubic meter of concrete produced.

On average, when Solidia Cement is compared with OPC for a similar performance concrete, the water savings are around 88%.

5. Global environmental impact

As discussed earlier, it is estimated that 2.15 to 2.6 billion tons of water are consumed in concrete production annually. If Solidia Cement was used instead of OPC, the amount of water consumed could be reduced by 0.26 to 0.45 billion tons each year. This corresponds to an annual global water savings approaching two billion tons, or two trillion liters.

The integration of lasting water conservation practices into industry starts with being accountable in water usage measurement and reporting, as advocated by CSI. Innovative technology that advances water reduction in production will play an increasingly vital role as the new water economy comes on line. Solidia Cement and CO_2-cured Solidia Concrete offer one such solution, providing a high-tech, high-quality, and easily adoptable solution for water management to the global cement and concrete industries.

6. References

[1] "Protocol for Water Reporting." Cement Sustainability Intiative, 2014. Web. 12 July 2016.

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[6] "Water for People, Water for Life." United Nations Educational, Scientific and Cultural Organization. UNESCO Publishing, Mar. 2003. Web. 7 July 2016.

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[8] "Guide for Curing Portland Cement Concrete Pavements, II." *U.S. Department of Transportation.* Federal Highway Administration Research and Technology. Jan. 2013. Web.

[9] Atakan Et. al. "Why CO2 matters – advances in a new class of cement." *Solidia Technologies.* ZKG International Issue 3, Mar.2014.

About Solidia Technologies®

Solidia Technologies® is a cement and concrete technology company that makes it easy and profitable to use CO_2 to create superior and sustainable building and construction materials. Solidia's patented processes start with a sustainable cement, cure concrete with CO_2 instead of water, reduce carbon emissions of cement and concrete up to 70%, and recycle 60 to 80% of the water used in production. Using the same raw materials and existing equipment as traditional concretes, the resulting CO_2-cured concrete products are higher performing, cost less to produce, and cure in less than 24 hours.

Currently in commercialization for large- and small-scale applications, Solidia's R&D collaborators have included LafargeHolcim, Air Liquide, CDS Group, DOT's Federal Highway Administration, DOE's National Energy Technology Laboratory, the EPA, Rutgers University, Purdue University, Ohio University, and the University of South Florida.

Based in Piscataway, N.J. (USA), Solidia's investors include Kleiner Perkins Caufield & Byers, Bright Capital, BASF, BP, LafargeHolcim, Total Energy Ventures, Bill Joy and other private investors. Honors include: 2016 Sustainia 100; 2015 NJBiz Business of the Year; 2014 Global Cleantech 100; 2013 R&D Top 100; 2014 Best Place to Work in NJ; 2014 CCEMC Grand Challenge First Round finalist; 2013 Katerva Award finalist; and MIT's Climate CoLab shortlist. Follow Solidia at www.solidiatech.com and on LinkedIn, YouTube and Twitter: @SolidiaCO2.