WATER SAVINGS IN CONCRETE MADE FROM SOLIDIA CEMENT™

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Abstract

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 ordinary Portland cement. 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 x 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 CO₂ 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 CO₂-curing process.

On average, 70 to 80% of the water used in the Solidia Concrete formulation can be recovered during CO₂-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 around 0.26 to 0.45 billion tons. This corresponds to an annual global water savings approaching two billion tons, or two trillion liters.

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.

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1. World water consumption

Water is the most consumed material in the world. Between 1996 and 2005, the average annual consumption of water was over 9000 billion tons [1]. The availability of useable water varies dramatically from region to region around the world [2]. The annual renewable water per person is shown in Figure 1 [3]. Less than 10 countries control 60% of world’s available fresh water.

![Annual renewable water (m^3/person/year)](image)

**Figure 1.** The annual renewable water per person per region.
“Will there be enough water?” Earth Trends, October 2000, C. Revenga.

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 [4]. By that time, 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 is quickly becoming a global concern.
Approximately 20% of the consumed water is used by industry [5]. 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.

2. Water consumption during Portland cement-based concrete curing

Concrete is the second most consumed substance in the world. 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 [6]. 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 x 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 [7]. 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 CO₂ rather than with water [8] 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 CO₂-curing process.

The CO₂-curing process is carried out in a high concentration CO₂ environment. This environment can be achieved by processes as simple as placing a sealed tarp over the concrete part and pumping in CO₂ to achieve 60 to 90% concentration. Solidia Cement-based concrete curing is a counter diffusion process in which CO₂ molecules replace water molecules inside the pores. Solidia Cement reacts with CO₂ 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 [8]. On average, 70 to 80% of the water used in the Solidia Concrete formulation can be recovered during CO₂-curing process. The remainder of the water is retained in the concrete and can be recovered if needed. A typical water recovery curve is shown in Figure 3.

![Figure 3](image_url)

**Figure 3.** A typical % water recovery curve for curing a 20 ft-long hollow core Solidia Cement-based concrete slab. The data are 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 the graph.
4. Examples

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 was consumed in concrete production. If Solidia Cement were used instead of OPC, the amount of water consumed could be reduced around 0.26 to 0.45 billion tons. This corresponds to an annual global water savings approaching two billion tons, or two trillion liters.
6. 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. Suitable for large- and small-scale applications, Solidia’s technology starts with a sustainable cement, cures concrete with carbon dioxide (CO2) instead of water, reduces carbon emissions up to 70%, and recycles 60 to 100% of the water used in production. Using the same raw materials and existing equipment as traditional concretes, the resulting CO2-cured concrete products are higher performing, cost less to produce, and cure in less than 24 hours as compared to the 28 days required for traditional concretes.

Currently in commercialization, Solidia’s technology and product development is reinforced by additional third-party research collaboration and testing, including ongoing research in concrete applications with industry leader Lafarge and 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 U.S. Department of Energy features Solidia as an energy efficiency success story of the Office of Energy Efficiency & Renewable Energy. The original generation of the technology was developed at Rutgers, the State University of New Jersey, where long-term research continues.

Solidia was honored with the 2013 R&D Top 100 Award, named a finalist in both the 2014 CCEMC Grand Challenge First Round and the 2013 Katerva Award, shortlisted to both the 2013 Cleantech 100 and MIT’s Climate CoLab, and named a 2014 Best Place to Work in NJ. 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.