Sustainable Development and the Concrete Industry

By

Christian Meyer

The Challenge

"Sustainable Development" has become one of the ubiquitous modern buzz words. Regardless to what degree we agree with the agenda of environmentalists, deep down we are all concerned about the world we will be leaving behind for future generations, that is, our children and their children. And the concrete industry is playing a much larger role in this regard than most of us may realize.

An appropriate point to start is a reminder that concrete is by far the most important, the most versatile, and the most widely used building material worldwide. It has achieved this predominance because of a number of decisive advantages. If properly designed, it has excellent mechanical properties and is so durable that it can basically last forever. It is moldable into any shape or form and adaptable to all kinds of different applications, geographies and climates. It has excellent fire resistance, is generally available and affordable. Maybe most important, it is an engineered material, which means that we can design mixes to satisfy almost any set of reasonable performance specifications and, if need be, reinforce it with regular steel bars, randomly distributed short fibers, or fiber mesh, thereby widening its range of applicability even further.

As a result of this worldwide popularity, the concrete industry has an enormous impact on the environment[1,2]:

1. Worldwide, over ten billion tons of concrete are being produced each year. In the United States, the annual production of over 500 million tons implies about two tons for each man, woman and child. Such volumes require vast amounts of natural resources for aggregate and cement production.
2. It has been estimated that the production of one ton of Portland cement causes the release of one ton of CO_2 into the atmosphere. CO_2 is known to be a greenhouse gas that contributes to global warming, and the cement industry alone generates worldwide about 7% of it.
3. The production of Portland cement is also very energy-intensive. Although the North American plants have improved their energy-efficiency considerably in recent decades to the point where it is now comparable to that of plants in Japan and Germany, it is technically next to impossible to increase that energy-efficiency much further below the current requirement of about 4 GJ per ton.
4. The demolition and disposal of concrete structures, pavements, etc., constitutes another environmental burden. Construction debris contributes a large fraction of

our solid waste disposal problem, and concrete constitutes the largest single component.
5. Finally, the water requirements are enormous and particularly burdensome in those regions of the earth that are not blessed with an abundance of fresh water. The concrete industry uses over 1 trillion gallons of water each year worldwide, and this does not even include wash water and curing water.

These numbers seem to indicate that the concrete industry has become a victim of its own success and therefore is now faced with tremendous challenges. These can be summarized as follows:

1. Reduction of required natural resources;
2. Reduction of energy consumption;
3. Reduction of CO_2 emissions;
4. Reduction of water consumption.

Tools and Strategies

The situation is not as bad as it might seem, because concrete itself is inherently a very environmentally friendly material, as can be demonstrated readily with a life-cycle analysis[4]. The challenges listed above result primarily from the fact that Portland cement is not environmentally friendly. In a world increasingly fixated on the demands of sustainable development, the industry's basic challenge is therefore to fully exploit the advantages of concrete, while relying less on Portland cement. There are four basic categories of tools and strategies at our disposal to achieve this goal:

1. Increased reliance on recycled materials. Since aggregate constitutes the bulk of concrete, the most effective recycling strategy will have to incorporate the substitution of recycled for virgin materials.
2. Improved durability. By doubling the service life of our structures, we can cut in half the amounts of materials needed for their replacement.
3. Improved mechanical properties. An increase in mechanical strength and similar properties leads to a reduction of materials needed. For example, doubling the concrete strength for strength-controlled members cuts the required amount of material in half.
4. Increased use of supplementary cementitious material. Since the production of Portland cement is energy intensive and responsible for CO_2 generation, the increased use of other materials, especially those that are byproducts of industrial processes, such as fly ash and slag, is bound to have a major positive impact.
5. Reuse of wash water. The recycling of wash water is readily achieved in practice and already required by law in some countries.

To implement effective strategies to lessen the environmental impact of the concrete industry by prudent use of those tools a concerted effort of the industry is required, starting with well-focused research and development. Even more important for success

are economic incentives to convince industry leaders that increased adherence to sustainable development principles is possible without adversely impacting the industry's profitability. On a less benign parallel track, political developments are imminent which are likely to force the industry to adapt changes to avoid losing market share. Bold initiatives are required that are not without risk, yet strict adherence to principles such as "we have always done it this way" is certainly not going to help, because the world around us will change anyway.

Changing Political Landscape

The US Green Building Council has developed a rating system for the Federal Government as a guide for green and sustainable design. This system, called "Leadership in Energy & Environmental Design" (LEED™)[3], has become a standard adopted by several governmental agencies in its original form or some modified versions of it. It assigns points in five different categories:

1. Sustainable Sites, 14 possible points
2. Water Efficiency, 5 possible points
3. Energy & Atmosphere, 17 possible points
4. Materials & Resources, 13 possible points
5. Indoor Environmental Quality, 15 possible points
6. Innovation & Design Process, 5 possible points

In order to become "certified", a project requires at least 26 out of the total of 69 points. Projects with 33 points are "Silver"-rated, those with 39 points are "Gold"-rated, and to reach the highest rating of "Platinum", 52 points are required. Means and methods to increase the number of points for a concrete building can be found elsewhere[4]. Here it suffices to point out that under the current system, only a rather small number of points can be earned by making concrete more environmentally friendly. For example, in a mix design that contains 15% cementitious material, the replacement of 30% of Portland cement by fly ash will introduce only 4.5% recycled material. The associated reward in terms of LEED points in no way reflects the gain in environmental friendliness, as measured by the reduction of CO_2 generation and energy consumption. This example illustrates that the LEED rating system, as currently formulated and administered, places concrete at a disadvantage. This situation can be changed only through a concerted effort of the concrete community. Such an initiative is likely to be most successful if spearheaded by a well-respected organization such as ACI to act as representative of the entire industry. In fact, ACI has already launched this initiative under the energetic leadership of former President Terry Holland and the ACI Board Advisory Committee on Sustainable Development.

The LEED rating system is gaining significance because numerous governing bodies on the federal, state, and local levels have embraced the principles of sustainable development and are either requiring LEED rating for their own projects (such as the General Services Administration and the U.S. Army Corps of Engineers), or offering tax

credits for projects within their jurisdictions. Developers are paying attention, especially since they are discovering that "green design" can favorably affect their bottom line. In New York City, the Battery Park Development Authority has developed guidelines for green building construction, which are among the most progressive in the country. The successful completion of the Solaire, the first residential green high-rise building in the US, has demonstrated that it is possible to develop such a building in New York. Similarly, the Conde Nast Building at 4 Times Square, the country's first green high-rise office building, is proof that the pairing of a progressive developer with a "green" architect can lead to a successful development of such a project.

The environmental community, with active or passive support of a large segment of society at large, is becoming increasingly aggressive in demanding that future developments adhere to the principles of sustainable development. If the concrete industry does not adjust on time to the changing political and societal climate, it could easily be losing the market share, which it had worked so hard to obtain during the last few decades.

What can we do? We have to start immediately refining the five tools mentioned above. For example, there is no question that it should be possible to substitute at least some of the rock excavated for the Second Avenue Subway tunnel for virgin aggregate. Compared with the amount of material that "comes out" of the tunnel, the amount that needs to "go back in" constitutes a very small percentage. The logistics of reaching productive cooperation between owners, construction managers, engineers, contractors and suppliers will not be easy, but the industry is well acquainted with tasks that are not easy. By the same argument, it would not be particularly difficult to utilize some small fraction of the material excavated from the Third Water Tunnel and use it as aggregate for the concrete that goes back into the tunnel. All it takes is a little bit of research and development and an open mind of those in responsible positions. "Throwing it away" may still be the least expensive way of disposing of the rock under the current rules, but it reflects an old mindset and could very easily be changed by governmental decree. If the industry wants to present itself as progressive and in concordance with mainstream development, it is well advised to be proactive rather than reactive.

As another example, the advantages of partially replacing Portland cement by supplementary cementitious material such as fly ash or ground granulated blast furnace slag have been demonstrated all over the world. It has been proven beyond a doubt that improvements in mechanical and durability properties can be achieved, even if the rate of early strength gain is lower. But for structural components that are not expected to be fully loaded within months, high 24-hour strengths are likely to be irrelevant.

There are numerous other examples where one person's waste or byproduct becomes another person's valuable resource. Work at Columbia University has been successful beyond imagination in adding value to waste glass, that otherwise would fill up scarce landfill space at increasing tipping fees, to produce tiles, panels, and table tops with stunning esthetic effects. Recycled carpet fibers can easily be substituted for virgin nylon fibers as a means of shrinkage crack control. The material dredged from New York

Harbor, because of its reputation of being highly contaminated as a result of hundreds of years of industrial pollution, requires the Port Authority to expend huge sums for its safe disposal. Yet, it is relatively easy to add value to this material by inexpensive treatment methods. Research at Columbia University has shown that the material has certain properties not found in any material mined on land. With modest investments in research and development, it should be possible to identify similar inherent valuable properties in other industrial byproducts and thereby beneficiating them. Yet, it will not happen unless the leaders of our industry display vision and courage, which includes a certain amount of risk taking as well as potentially lucrative returns. Most important of all, the environment will benefit, and future generations will thank us for it.

References

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