Green Concrete

Concrete Thinking … A Structural Approach

A structural engineer's guide to the use of concrete in sustainable development

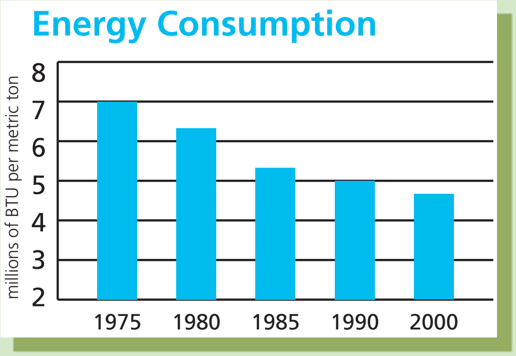
By David Shepherd, AIA

Green building — it's an industry buzz term these days, and it can mean a lot of things. But for a structural engineer, what does green building really mean? What building materials are environmentally sound and why? How can they be evaluated, specified, and applied in a manner that is energy efficient, cost effective, and environmentally responsible? How can you balance what makes sense for your project with what makes sense for the community as a whole?

Those questions are often subjective and difficult to answer. Due to great strides by the building and design industries, achieving recognition and certification for green buildings is becoming easier. But making the most environmentally conscious building decisions for sustainable development in the context of quality, durable construction is often confusing and time consuming. For example, the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system outlines green building standards, including recycled content, construction waste, and reuse of building material. But it does not directly address many qualities that are inherent factors in the sustainability of a structure, such as durability, deconstruction, or life-cycle assessment (LCA) factors like embodied energy.

To make a project "greener," a structural engineer can make those decisions based on an environmental rating system, such as LEED, or just a mindset of doing the right thing for future generations. As a general guide, structural engineers should consider the following for green construction:

- Material acquisition
- Local and regional resources
- Manufacturing processes
- Recycled content
- Efficiency of assembly
- Contribution to the building's energy and water use
- Indoor environmental quality
- Long-term durability and adaptability
- Potential for deconstruction
- Salvageable or recyclable components
- Waste
- Reuse of materials
- Reuse of existing building



Increased efficiency , new technology and equipment, and alternative fuels and raw materials have reduced energy consumption by one-third

Fundamentally, the structural engineer recognizes and appreciates the pieces that work together to make up a whole. Therefore, the structural engineer is in a unique position to make many critical design decisions that not only make sense for the building specifications, but also that contribute to a more environmentally sound project overall. By taking into account those general qualifications, a building can certainly be sustainable, even if it is not certified through an environmental rating system.

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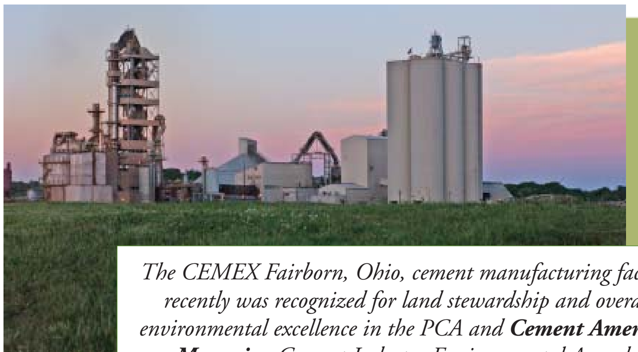
Concrete Example

To do the job well, the structural engineer needs to balance environmental concerns with optimum performance of the material. Concrete has long been relied upon as structurally stalwart. While many products are being modified and marketed to meet emerging green building standards, concrete has always been robust, durable, versatile, and recyclable. The use of concrete can bolster the environmental benefits of the structure, while contributing additional sustainable solutions to the whole project.



The CEMEX Fairborn, Ohio, cement manufacturing facility recently was recognized for land stewardship and overall environmental excellence in the PCA and ***Cement Americas Magazine*** *Cement Industry Environmental Awards. Photo courtesy of the Portland Cement Association.*

In material acquisition, cement is generally manufactured near urban areas from local materials. Although making cement requires a great deal of energy, cement is only a small portion (10 – 15 percent) of concrete. The other two main ingredients, aggregates and water, are generally obtained locally or regionally, and require very low energy to obtain — a green building advantage. As a result, it is possible to minimize the use of natural resources (not necessarily the use of cement in the mix) to build a concrete structure efficiently, economically, and environmentally sound. Recycled industrial byproducts, such as fly ash and slag, can be used to offset dependence on raw materials.

The predominant raw material for cement is limestone, the most abundant mineral on earth and readily available throughout North America. An environmental study recently concluded that aggregate quarries take less of an environmental toll than the acquisition of other materials, according to the ATHENA Sustainable Materials Institute. Quarries, the primary source of raw materials, can be readily reclaimed for recreational, residential, or commercial use, or restored to their natural state.

In manufacturing, the high temperatures needed for cement production make it energy intensive. The industry has decreased its energy usage by 33 percent in the past three decades, according to data collection by the Portland Cement Association (PCA). Research also has led to the use of recycled content in manufacturing. Foundry sands, mill scale, and bottom ash are just a few of the industrial byproducts used to make cement. Cement manufacturing also utilizes alternative fuels. In 2001, about 53 million tires were consumed as fuel in cement kilns, according to the Rubber Manufacturers Association. That removes them from landfills, reduces fossil fuel consumption, and helps reduce cement manufacturing nitrogen oxide emissions.

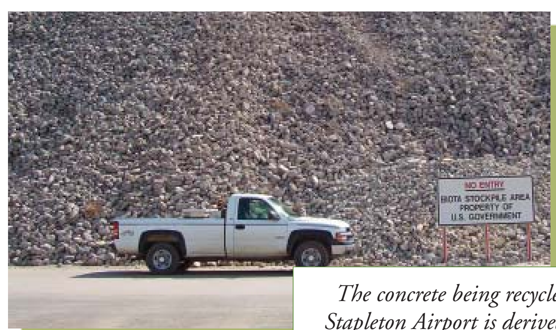
In the mix, the use of concrete is increasingly focused on creating optimal performance. Supplementary cementitious materials (SCMs), such as fly ash and slag, are a significant part of that equation. Properly proportioned, those recycled industrial byproducts provide more durability, strength, and finishability for concrete. In 2002, more than 16 million metric tons of fly ash and more than 3 million metric tons of slag were used by the concrete industry. They are also being used to help structural engineers qualify for more LEED points for recycled content. A concrete designed with one or more SCMs for the specific application can also optimize its performance — regardless of LEED.

In application and energy use, a life cycle assessment (LCA) reveals that initial energy invested to build a structure is more than made up for in energy savings during operations of the same structure over time. For example, the embodied energy and CO2 to build a concrete home is typically greater than other materials. But concrete homes in most climates can be expected to have greater energy savings than traditionally built homes.

For example, homes built with high performance concrete wall systems, such as insulating concrete form walls (ICFs), need less energy for daily heating and cooling. In research by Construction Technology Laboratories (CTL) for PCA the total embodied energy of a typical wood frame home surpassed that of an identical ICF home in five to seven years. With different climates and building types, the break-even point will vary, but the environmental benefit of concrete continues for as long as the home is utilized. Concrete also contributes to indoor air quality as new concrete does not have the off-gassing that is prevalent in many other new construction materials. For commercial structures, the environmental benefits abound, creating longer-lasting, more comfortable businesses that are providing healthier environments for employees.

In occupancy reuse, concrete is an extremely durable material. Life spans for concrete building products are frequently double or triple those of other common building materials. A green building should be built to last … and concrete does not rust, rot, warp, or burn. Concrete is virtually unaffected by heat and cold, ultraviolet rays, and moisture. That reduces the waste created by the removal and replacement of weathered or moisture damaged materials, decreases maintenance, and ultimately allows for longer use and reuse of the building.

In material recyclability, the usefulness of concrete does not end after its original purpose. In most urban areas, almost all concrete is crushed and recycled for use in road base and backfill. In some cases, it is recycled for aggregate in new concrete. Research continues to find new applications for recycled concrete.



The concrete being recycled from the Old Stapleton Airport is derived from 975 acres of runways, taxiways and service drives and aprons with an average thickness of two feet.

Concrete Thinking

The green applications for concrete and cement-based materials are growing rapidly. Stucco, fiber — cement siding, and concrete roof tiles need minimal maintenance and provide long-lasting protection from the elements. These products are also useful at withstanding the elements in fire and hurricane prone areas.

In the interest of building for today without depleting the resources of tomorrow, a structural engineer must take the entire life cycle of the structure, and its many components, into consideration — aside from any certification or recognition. The long-term durability and

The ongoing transformation of old Stapleton Airport into a family-friendly residential and commercial community illustrates the recyclability of concrete.

adaptability of a structure, as well as its waste and recycling capabilities in deconstruction, are important to green building. These factors are just as important as material acquisition and recycled content.

But it is the mindset of the structural engineer — a sense of concrete thinking — in decision making throughout the design and specification of a project that will ultimately result in a sustainable structure. That concrete thinking is an extension of the day-to-day optimization of members and materials, so it is a natural progression. In that basic job function, the structural engineer can become an ambassador for green building.▪

David Shepherd, AIA, is Director — Sustainable Development for the PCA. He draws on more than 25 years' experience in the industry for his role at PCA, where he is proactively engaged and committed to advancing environmental stewardship and sustainable development. David can be reached at **dshepherd@cement.org**

World Record Recycling Project

Former Stapleton Airport recycled and revitalized

After 66 years of operations, Stapleton International Airport had grown to become one of the busiest airports in the United States, with its concrete runways and concourses sprawling over a large area of land outside of Denver, Colorado. In 1995, the venerable airport was replaced by ultra-modern Denver International Airport, and a massive construction project began to rebuild the Stapleton site. The ongoing transformation of old Stapleton Airport into a family-friendly residential and commercial community illustrates the durability, versatility, and sustainable properties of concrete.

Concrete can be readily recycled and reformed into a wide variety of structures, including roads, sidewalks, bridges, curbing materials, offices, retail centers, homes, and hospitals. The versatility of concrete is a particularly important factor in the revitalization of the Stapleton site. Soon after the airport closed, construction began on a massive mixed-use development, which includes commercial space, energy efficient homes, and schools. Developers are conserving resources by using the existing concrete from old Stapleton Airport and recycling it for use in the new Stapleton development and in other projects.

A study conducted by the Colorado School of Mines found that the concrete aggregate produced from the Stapleton recycling project is of equal or higher quality than virgin mixes. In the first five years of the development, two thirds of the six million tons of recycled concrete material had been sold for the new mixed-use development at Stapleton, and for various other construction projects throughout the Denver metropolitan area.

As builders become more educated about its benefits, demand for recycled concrete from the project continues to be strong. The concrete being recycled is derived from 975 acres of runways, taxiways and service drives and aprons with an average thickness of two feet. When the project is complete, enough material will have been recycled to construct a two-lane roadway roughly 10,000 miles in length.

While the challenge of redeveloping the Stapleton site is significant, developers also enjoy a major advantage by virtue of having building materials at their fingertips. With concrete as a common thread between two vastly different complexes, the transformation of Stapleton from airport to thriving residential and commercial community is occurring quickly and efficiently. Most importantly, construction is moving forward with a limited impact on our finite resources.▪

Project Team:
Recycled Materials Co. (RMC)
Forest City Enterprises, Cleveland, OH

RENEWABLE MATERIALS THROUGH RECYCLING
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