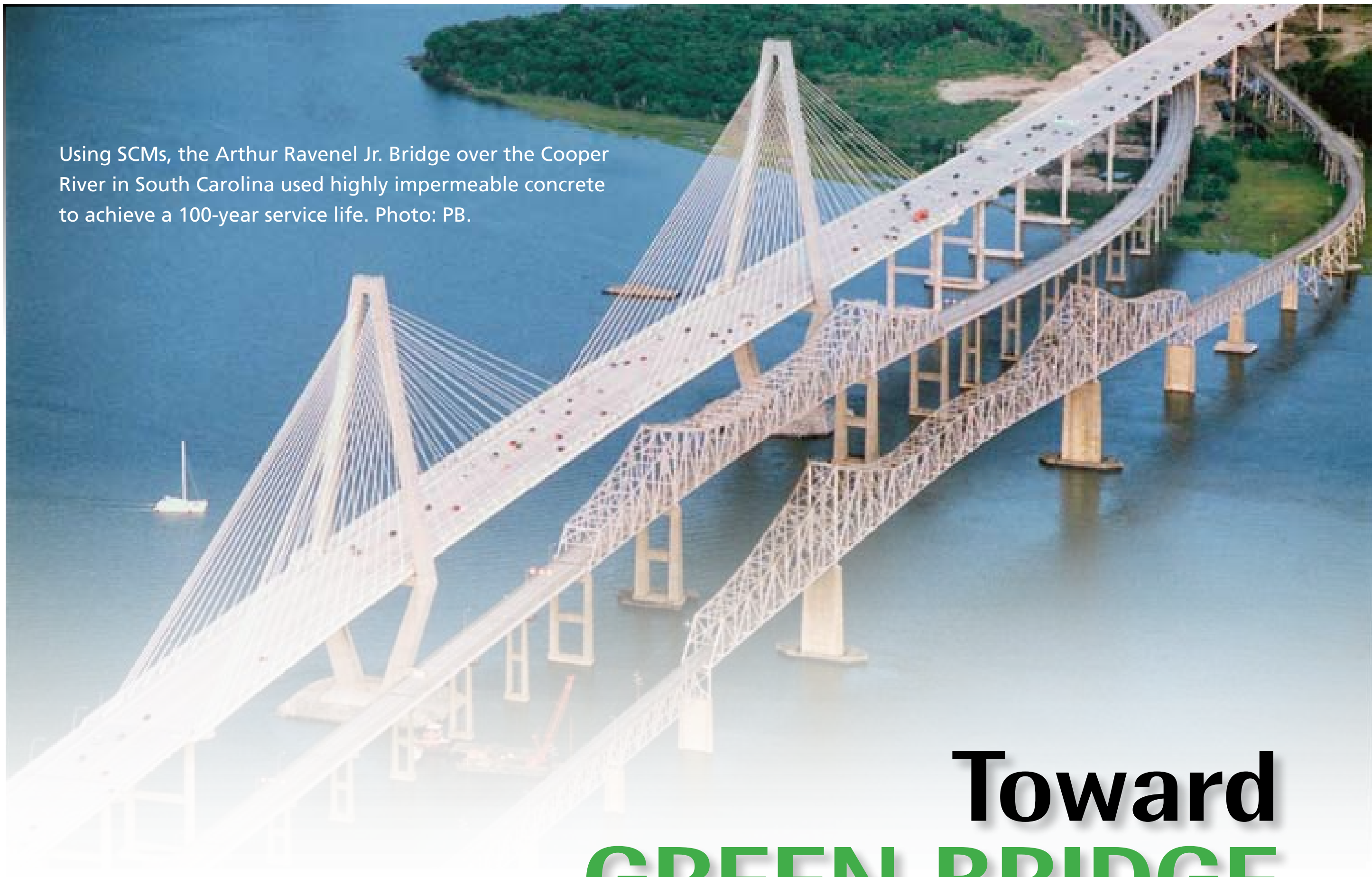

Using SCMs, the Arthur Ravenel Jr. Bridge over the Cooper River in South Carolina used highly impermeable concrete to achieve a 100-year service life. Photo: PB.

Toward GREEN BRIDGE Standards

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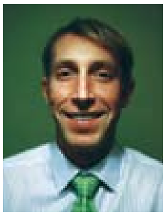

by Scott Snelling,
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Sustainable or "green" design has entered the public consciousness and the mainstream media. Taxpayers, voters, politicians, and policymakers want assurance that public funds are being used to build environmentally sensitive infrastructure. The American Society of Civil Engineers (ASCE) recently launched an initiative to create a standard for defining and certifying green infrastructure projects and design professionals. While it is not yet clear when ASCE will be ready to introduce such a standard or if another organization will become pre-eminent, it is clear that sooner than later, a green standard will be incorporated into the bridge industry in the United States. In the concluding section of this article, the framework of a future green bridge standard is proposed from a review of the existing green standards that have been put into practice in other segments of the construction industry.

Existing Green Standards

These standards include LEED, SPiRiT, and Greenroads. LEED is the acronym for Leadership in Energy & Environmental Design; this standard certifies green building and neighborhoods. LEED is administered by the United States Green Building Council, a non-profit organization founded in 1993. SPiRiT is the Sustainable Project Rating Tool developed by the U.S. Army for their facilities. Since 2000, all new army facilities have been required to be built to LEED or SPiRiT standards. Greenroads was introduced in 2009 to certify roadway and pavement projects. This standard was developed at the University of Washington with funding from the United States Department of Transportation and several state departments of transportation. Greenroads' documentation states, "A future system focused on structures [i.e., bridges, tunnels, and walls] could be incorporated into Greenroads, but none currently exists."

Evaluating Infrastructure Projects

Engineers can calculate the energy required to construct and maintain competing proposed design alternatives for specific projects by performing life-cycle assessments (LCA). One tool that enables LCA was developed by the Carnegie Mellon University Green Design Institute, (2008), titled, *Economic Input-Output Life Cycle Assessment (EIO-LCA)*, US 2002 Industry Benchmark model. It is available from: www.eiolca.net. LCA published by Horvath (1998), Dennison (2004), and Struble (2004) indicate that embodied energy and greenhouse gas emissions tend to be lower for portland cement concrete bridges when compared with structural steel bridges. Concrete bridges using high percentages of supplemental cementitious materials (SCMs) and recycled materials further widen the gap.

Concrete Bridges

Concrete bridges significantly save on maintenance resources by eliminating the need for painting. Bojidar Yanev of the New York City DOT, in his book, *Bridge Management*, writes, "Empirical evidence therefore suggests that annual maintenance level amounting to 1% of the replacement cost is a threshold below which deterioration accelerates." Of these maintenance costs, 66% is attributed to repainting and spot painting for steel bridges.

Concrete can be crushed and recycled—downcycled—as aggregate or fill, but has no scrap value. By-products, such as mine tailings, can be used instead of virgin aggregate. However, the most significant environmental impacts of concrete are associated with cement production. The amount of energy consumed and greenhouse gas emitted when concrete is produced varies drastically depending on the cements used.

Most pozzolanic admixtures or SCMs are by-products of industrial processes. These include materials such as fly ash, silica fume, and blast furnace slag. On projects that use design-bid-build procurement, designers often specify portland cement-based mixes as a matter of standard practice. Typical bridge specifications call for 15% SCMs and 85% portland cement. Meanwhile, the majority of potential industrial by-product SCMs is sent to landfills. There is substantial opportunity for bridge engineers to economically specify higher percentages of SCMs in concrete.

The Roslyn Viaduct Bridge on Route 25A over Hempstead Harbor, Long Island, N.Y., designed by Hardesty & Hanover, New York, N.Y., is a context sensitive design created in concert with the community and uses both high strength and high performance concrete to ensure a 75-year service life. Rendering: Hardesty & Hanover LLP.

Recent design-build projects have seen the successful use of concretes with high percentages of SCMs such as ground granulated blast-furnace slag—up to 85%—because they have proven to be the lowest-priced concrete meeting the required physical properties. The reductions in energy use, greenhouse gas emissions, and landfill volume have been regarded as beneficial side-effects. Such concretes may take hours longer to set, but once cured, can result in higher strength and lower permeability. For example, the Arthur Ravenel Jr. Bridge over the Cooper River in Charleston, S.C., was designed to meet its 100-year service life using uncoated reinforcement and low permeability, high SCM content concrete. Meanwhile, the new St. Anthony Falls Bridge in Minneapolis, Minn., received positive coverage in the media for its use of environmentally friendly, high-performance concrete. In the piers, 85% of the cementitious materials were SCMs. In California, the San Francisco-Oakland Bay Bridge consisted of four distinct construction projects. From the beginning, specifications required a minimum 25% fly ash concrete, principally to mitigate alkali-silica reactivity. In one case, the contractor was permitted to use 50% ground granulated blast-furnace slag in lieu of fly ash. In areas needing thermal curing controls, mixtures of cements containing up to 50% fly ash mixes were used. In 2006, the Environmental Protection Agency recognized Caltrans as a leader in the construction use of waste products.

The Roslyn Viaduct Bridge on Route 25A over Hempstead Harbor, Long Island, N.Y. Photo: Rich Lorenzen.

The San Francisco-Oakland Bay Bridge incorporated up to 50% SCMs in portions of its construction.

Proposed Green Bridge Standard

The following proposal is intended as a starting point for the development of a standard for the certification of green bridges. Ultimately, the formulation of such a standard would be through a committee of bridge professionals.

This proposed green bridge standard has a total of six prerequisites and 39 possible credits grouped into seven categories. The seven categories are materials and resources; alternative transportation; project delivery process; construction activity; maintenance and access; environment and water; and energy.

These categories of criteria would be used to award credits to a bridge project. A designated minimum point value—say, 15 credits, for example—would be required before a bridge project could be certified as green. All the prerequisites would have to be met.

Materials and Resources

SIX CREDITS: Use materials that are recycled, recyclable, and industrial by-products. One credit is earned for recycled material content of 20%. Additional credits would be earned for 40%, 60%, 80%, and 90% recycled material content. Use "regionally" extracted and manufactured materials to reduce the effects of shipping. Regional is defined as an 800-km (500-mile) radius from the project site.

Alternative Transportation

FIVE CREDITS: Encourage transportation alternatives to single occupancy motor vehicles. Provide pathways for pedestrians and cyclists. Provide designated lanes for buses, light-rail transit, car pools, and low-emission vehicles.

Project Delivery Process

ONE PREREQUISITE:

Perform bridge life-cycle cost analysis in accordance with NCHRP Report 483. Perform life-cycle assessments to compare the environmental impacts of competing bridge proposals.

SEVEN CREDITS:

Use design charettes to develop context-sensitive solutions. Consider future uses, demolition cost, and salvage value of the bridge. Use innovative designs. Include green design accredited professionals.

Construction Activity

THREE PREREQUISITES:

- Divert 75% of the on-site construction and demolition waste from landfills for reuse or recycling (refer to the online Construction Waste Management Database developed by the National Institute of Building Science).
- Control erosion and storm water runoff.
- Prepare a construction noise mitigation plan.

SIX CREDITS:

Account for water and electricity use. Provide on-site environmental awareness training. Reduce fossil fuel use and emissions of construction equipment.

Maintenance and Access

TWO CREDITS:

Produce a maintenance manual at the time of design, including estimated maintenance activities, frequencies, and costs. Provide safe and productive maintenance access.

Environment and Water

ONE PREREQUISITE:

Comply with the applicable environmental laws.

NINE CREDITS:

Minimize destruction to the local ecology around the bridge construction site. Minimize erosion; storm water sedimentation; construction dust; and particulate, noise, and light pollution. Minimize the heat island effect. Prefer the redevelopment of brown field or urban sites instead of developing agricultural or wetland sites. Use native vegetation with no irrigation.

Energy

ONE PREREQUISITE:

Monitor the bridge electrical systems after construction to verify that the actual energy used conforms to the design values.

FOUR CREDITS:

Sign a multiyear contract to procure grid-source green electricity. Minimize the life-cycle costs of the bridge electrical equipment and lighting.

The Future

Green building has grown from minor influence to a major market impact with tens of billions of dollars worth of projects constructed each year. State DOTs have built hundreds of green buildings and are beginning to apply the relevant lessons learned to their infrastructure projects. A green bridge standard will reward innovation and encourage existing best practices to be used more widely, while reducing life-cycle costs. Now is the time for bridge engineers to adopt a green bridge standard.

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