The Time to Begin Addressing the Environmental Impacts of Bridge Construction Is Now

by Emily Lorenz

EDITOR'S NOTE

Articles related to bridge preservation have appeared in the Concrete Bridge Preservation series since 2010. While preservation remains a key focus of ASPIRE®, we have recognized that the series needs to be expanded to also address other important topics such as sustainability, resiliency, and system management. Therefore, we are introducing the rebranded series, Concrete Bridge Stewardship, which will encompass the wider scope of topics. Please contact us at info@aspirebridge.org to let us know what you think, and to send us your ideas for topics.

When PCI issued its first guidance related to sustainability and precast concrete back in 2010,[1] it focused primarily on best practices related to sustainable building design made popular by the LEED rating system. As the precast concrete industry and others sought to determine the environmental impacts of their products and systems, they undertook life-cycle assessments (LCAs) and developed environmental product declarations (EPDs) to transparently report the results. Yet this revolution of sustainability-minded thinking in the building industry is only just awakening in the transportation market. This article discusses the current state of practice in the transportation market related to sustainability as well as where the industry might be headed in the near future based on precedents in the building market.

Starting at the Beginning

Even though it has been 35 years since the Brundtland Commission of the United Nations defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs,"[2] the design and construction communities still struggle to define sustainability.

As a concept, sustainability is often associated with three principles—referred to as three pillars—namely, economy, society, and environment. As the sustainability movement has gained momentum in the construction industry, the focus has been primarily on the environmental pillar.

There are several reasons for this focus on the environment. Societal impacts are more difficult to quantify than environmental ones, and there are fewer internationally recognized and objective indicators in the building market related to the market's impact on society. For infrastructure projects, societal impacts are more likely to be considered in terms of public benefit or inconvenience. This trend is changing in the building market, however, as indicators for societal impacts related to equity and inclusion are increasingly being developed.

Economic impacts have not been the focus of sustainable design because economics usually take care of themselves in a capitalist society: owners will generally not go forward with design choices that they cannot afford.

Thus, the emphasis on environmental impacts has been due to the relative ease of their quantification (compared with societal impacts) and because they had not previously been the focus of design decisions (unlike economic impacts). LCA is a well-defined, straightforward way to quantify environmental impact potentials. As a methodology, LCA has been used in practice for decades, and the standards that define LCA (ISO 14040[3] and ISO 14044[4]) are internationally recognized and used. LCA

Key Sustainability Terms

Environmental product declaration (EPD): A Type III environmental label (defined by ISO 14025[5]) that is peer-reviewed and reports the findings of a life-cycle assessment (LCA). EPDs developed for products for buildings and civil engineering works must conform to ISO 21930.[6]

Global warming potential (GWP): An environmental impact category that "describes potential changes in local, regional, or global surface temperatures caused by an increased concentration of GHGs [greenhouse gases] in the atmosphere, which traps heat from solar radiation through the 'greenhouse effect.'"[7] The gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are considered greenhouse gases; therefore, they can be grouped together in the GWP impact category. In terms of GWP, 1 lb of CH_4 is 30 times more potent than 1 lb of CO_2, and 1 lb of N_2O is 298 times more potent than 1 lb of CO_2. Therefore, CO_2 is assigned a weighting factor of 1, CH_4 a factor of 30, and N_2O a factor of 298. GWP is reported in terms of carbon dioxide equivalent, CO_2e.

Embodied carbon: The GWP from the following life-cycle stages: raw material extraction, transportation, manufacturing, construction, maintenance, renovation, and end of life. It includes the GWP from all life-cycle stages except those due to operational energy use.

can be used to quantify environmental impacts for a complicated system, such as a building or bridge, or for a simple product, such as a bolt.

LEED Rating System for Buildings

The LEED rating system, developed by the U.S. Green Building Council, is partly responsible for the "sustainability awakening" within the design and construction industry in the building market. Its simplified, point-based system is accessible for designers seeking to reduce environmental impacts in their designs. The system also has the added benefit of familiarizing designers with the basics of sustainability.

In the LEED system, the categories for earning points—such as increased recycled content, using local materials, and reusing materials—were based on trends realized from past work in LCA. The developers of the LEED system knew that, *in general*,

- recycled-content and reused materials have less environmental impact than virgin materials, and
- local materials require less transportation, and therefore have less environmental impact, than materials shipped from farther away.

The LEED rating system thus encourages reductions in environmental impacts without having to educate designers in the building market about the intricacies of LCA.

Rating Systems in the Transportation Industry

In 2010, when the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure launched the ENVISION rating system, they saw the advantages of a simplified approach for infrastructure projects and therefore mimicked the LEED rating system. Federal and state agencies also began developing programs to educate and raise awareness within the infrastructure design community on sustainable design principles.

One of the more mature sustainability-related programs within the Federal Highway Administration (FHWA) is the Sustainable Pavement Program (SPP). Beginning with workshops in the late 2000s, two roadmaps and many programs have been created to educate stakeholders and to develop tools for design and construction of more-sustainable pavements. Like sustainability efforts in the building industry, the SPP focuses more on reducing environmental impacts and less on societal impacts. But, unique to the transportation industry, a focus on life-cycle cost accounting (LCCA) is also part of the SPP roadmap.

Based on the latest roadmap published by FHWA,[8] four goal areas have been developed: pavement systems, assessing pavement sustainability, guidance and outreach, and implementation. Several resources were also developed, including the following:

- A sustainable pavement design reference document
- Starter guidelines on how to implement LCA
- Tech briefs and training on LCCA, LCA, and other sustainability-related topics
- Case studies on sustainable pavements
- A free LCA software tool, LCA Pave, specifically for pavements

Unfortunately, FHWA does not have a program similar to SPP for bridges. But the bridge industry can efficiently develop the tools it needs to assess the sustainability of bridges based on past work in the building and pavement industries.

Current Procurement Regulations Affecting the Transportation Industry

The time of overlooking the environmental impacts of our bridges is coming to an end. The federal government, as well as the public, will increasingly be requiring engineers to minimize the environmental impacts of bridge designs. In December 2021, President Biden issued executive order (EO) 14057, "Catalyzing Clean Energy Industries and Jobs through Federal Sustainability."[9] Goal 5 of the EO focuses on net-zero emissions from federal procurement, including a "Buy Clean" policy to promote the use of construction materials with lower embodied-carbon emissions. Passed in November 2021, the Infrastructure Investment and Jobs Act includes a focus on low-carbon technologies. In addition, states are also implementing Buy Clean or green procurement laws for public projects.

As these laws are applied, contractors, bridge engineers, and material suppliers will need to understand basic concepts related to sustainability and how to meet the legal requirements. Given the increasing threat of climate change, much of the focus of these Buy Clean or green specification requirements has been on reducing the greenhouse gas emissions related to products and projects.

As an example of green specification requirements, the General Services Administration (GSA) has issued new national standards[10] for low embodied-carbon for ready-mixed concrete and asphalt in response to EO 14057. These requirements apply to

> ***all GSA projects, both capital and small, regardless of funding source: paving upgrades, modernizations, new construction, customer-funded projects through BA80 Reimbursable Work Authorizations, privately financed projects such as Energy Savings Performance Contracts, and all*** *Bipartisan Infrastructure Law* ***projects.***[11]

The standard for concrete requires construction contractors to submit EPDs to verify the global warming potential (GWP) requirements of the standard have been met (**Table 1**).

The numbers used in the GSA standards are also significant because they are an example of green specification requirements that were developed incorrectly. The GSA references benchmark GWP values from a report by the New Buildings Institute that were developed based on a geographically limited data set and without any industry input.[12] Without an understanding of regional differences among concrete suppliers, these benchmark values may be easy for all producers to meet in one part of the United States, and nearly impossible to meet in another part. A better starting point for the GSA numbers would have been the GWP values developed by the National Ready Mixed Concrete Association (NRMCA).[13]

Marin County, Calif., is attributed as the first jurisdiction in the United

Table 1. Maximum global warming potential limits for the General Services Administration's low embodied-carbon concrete

Specified concrete compressive strength, psi	Maximum global warming potential limits, kg CO_2e/m^3		
	Standard concrete	High-early-strength concrete	Lightweight concrete
Up to 2499	242	326	462
2500 to 3499	306	413	462
3500 to 4499	346	466	501
4500 to 5499	385	519	540
5500 to 6499	404	546	N/A
6500 and up	414	544	N/A

Source: Data from the General Services Administration (2021).
Note: These values reflect a 20% reduction from global warming potential (CO_2e) limits in proposed code language from the New Buildings Institute (2022). N/A = not applicable. 1 kg = 2.205 lb; 1 m^3 = 1.308 yd^3; 1 psi = 6.895 kPa.

States to develop a low-embodied-carbon concrete code.[14] And while many jurisdictions would like to "copy" what Marin County did, few understand the background of how those GWP numbers were developed. When researching what GWP limits to use in Marin County, an advisory committee analyzed local GWP data from averages supplied by NRMCA—an LCA practitioner—and 400 mixture proportions used by structural engineers through the Structural Engineers Association of Northern California. From that data analysis, the committee developed GWP limits that were applicable to their region.

Another output of the Marin County process was the development of a summary document that identifies keys to success for setting GWP limits, including the following important considerations,[15] which were not followed by GSA in developing its guidelines:

- *Consider the range of projects and ensure that the code structure is accessible by all affected project types.*
- *Conduct a review of existing mixes by engaging local engineers and concrete suppliers.*
- *Compare these findings to a benchmark such as the NRMCA averages, and take into account that regional mixes vary by availability and quality of raw materials for concrete; environmental conditions that may require different concrete performance; standards of practice; and market economics. The findings for the Bay Area will be different from other regions.*

This list of points illustrates why it is important for all of us in the concrete bridge industry—suppliers, contractors, owners, engineers—to understand how environmental impacts are calculated and what makes sense from a benchmarking perspective.

Getting Up to Speed

Owners, bridge engineers, contractors, material suppliers, and procurement specialists should begin by educating themselves on the basics of sustainability. Many of the available resources related to general sustainability concepts are applicable to the bridge market. Chapter 1 of the *PCI Bridge Design Manual*[16] contains a primer on sustainability concepts related to bridges.

Once they are familiar with basic concepts, bridge industry professionals should feel more comfortable educating themselves on more advanced topics such as LCA, EPDs, and how to compare or create benchmarks for the environmental impacts of bridge systems.

To increase competence in the area of sustainability, the bridge industry can do the following:

- Prioritize sustainability education at industry events.
- Develop a framework for LCA for bridges that applies across all materials.
- Write and disseminate articles and case studies about successes in the industry.

The transportation industry has the opportunity to improve the environmental impacts of our bridges and infrastructure. But it cannot wait to implement sustainability concepts any longer. The time to act is now.

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