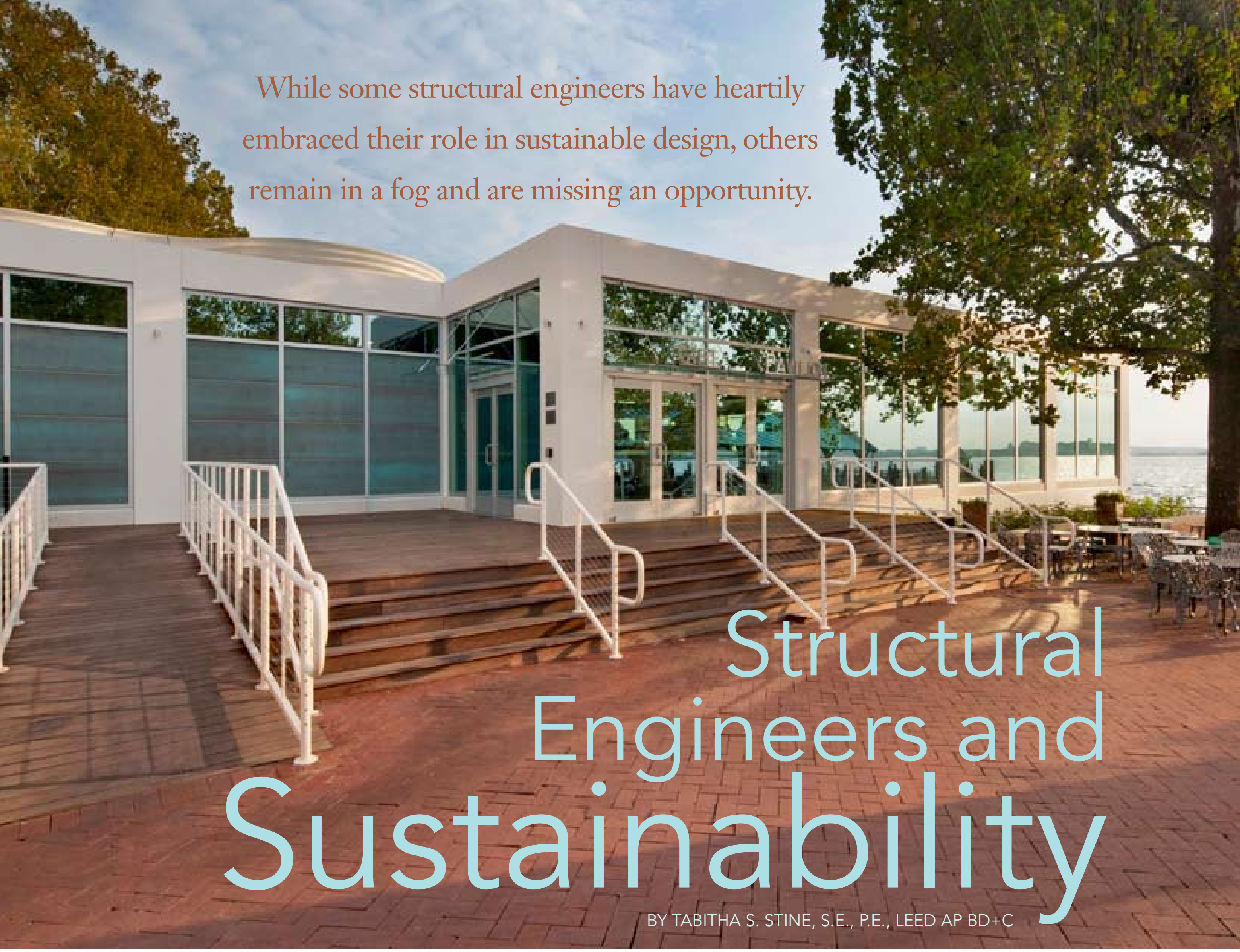

While some structural engineers have heartily embraced their role in sustainable design, others remain in a fog and are missing an opportunity.

Structural Engineers and Sustainability

BY TABITHA S. STINE, S.E., P.E., LEED AP BD+C

WHATEVER YOUR LEVEL of interest or understanding, there's no question that the concept of sustainable/green/eco-friendly construction is increasingly affecting project teams, designs, and project specifications. The quest for sustainability is influencing decisions all across the design team, including the structural engineer.

Unfortunately, the Leadership in Energy and Environmental Design (LEED) rating system, which is the most commonly used rating system in North America, has reduced the role of the structural engineer in this process to that of "material selector." But structural engineers who step up and become involved early on, through collaborative design and decision making, have an opportunity to showcase how design decisions, not just material selection, have a huge impact on the sustainable footprint of any project. They also can demonstrate to owners that thoughtful structural engineering can provide them with an even better structure, both structurally and sustainably, today and into the future.

The Movement

For more than a decade the "green" movement has been increasing in relevance and importance with regard to the design and construction of buildings. In one form or another, sustainability now is being required on a variety of public and private jobs, often by including LEED certification as a project-specific requirement.

Even though today's market is tight and increasingly competitive, sustainability as a movement has not diminished but rather has become even more important as a benchmark for projects. Owners recognize the importance, viability, and long-term marketability of "green" buildings to current and future tenants, a trend that is forecast to continue. This creates new challenges and opportunities for structural engineers, who still need to meet tight schedules and budgets, while incorporating sustainable principles and processes into their designs.

The concept of sustainability is only achieved through the triple bottom line of achieving social, economic, *and* environmental core values. When all three of these are met, true sustainable benchmarks are achieved that owners can translate into measurable benefits on their future developments. As this movement continues, we anticipate that LEED will be pushed beyond its "checklist" format, which places the structural engineer in the role of material selector, into a more life-cycle-focused tool. However the LEED program progresses, the role of the structural engineer will grow and structural engineers will be at the forefront of building optimization as active participants.

The Problem

Energy and waste are two key sustainability issues, but how much of a problem are we talking about? In the United States,

Nothing about the new gift shop pavilion on Liberty Island, in New York Harbor, makes customers think it is anything out of the ordinary. However, the structure was designed for both easy construction and deconstruction through the use of bolted connections and an all-steel frame. Engineers also used steel pile caps to minimize the impact of the foundation work. The project was described in "Built for Deconstruction," in the January 2011 *MSC*, available at **www.modernsteel.com/backissues**.

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the construction and operation of buildings accounts for nearly 40% of all energy use. The construction and demolition of buildings accounts for more than 123 million metric tons of waste per year, or about ½ ton per person per year. It is not surprising that nearly all of the energy used in buildings is due to the operating cost of the structure itself (85% to 90%), with the remaining 10% to 15% being the embodied energy in the building materials and the construction process. However, driven by both environmental and economic factors, buildings are becoming more and more energy efficient. As operating costs and energy use are reduced over time, that translates into a relative increase in the environmental impact of the structural system.

There are many ways structural engineers can push their structures to a higher level of efficiency and sustainability, beginning with more efficient design, construction waste reduction and paperwork reduction. Additionally, early involvement of a steel fabricator can improve efficiency in shop drawing review, connection design and actual fabrication activities, and collaborating with other designers can improve on energy-saving efforts at various structural interfaces. All of these have the potential for major impact when considered alone or as a whole.

Early Involvement

Early collaborative design is an essential tool for optimizing design efficiencies, which can translate into more efficient framing layouts, better material handling, cost-effective connections, optimized erection techniques, and reduced construction schedules.

The Mercy St. Vincent Medical Center Heart Pavilion in Toledo, Ohio, is an example of the sustainable benefits of collaborative design. The conventional design-bid-build approach was originally considered for the project. After it came in over budget, structural

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The new Research Support Facilities (RSF) at the National Renewable Energy Laboratory's (NREL) campus in Golden, Colo., was designed as a prototype for the next generation of sustainable office space. Among other measures undertaken, the project team used salvaged oil and gas piping for the majority of columns on the structure. Read more about the project in "Greening Steel Construction," in the May 2011 *MSC*, available at **www.modernsteel.com/backissues**.

engineer Ruby + Associates, Farmington Hills, Mich., converted the project to a design-build delivery method in conjunction with the fabricator—Toledo, Ohio-based AISC member Art Iron, Inc.—which helped make the project more efficient.

The owner's original motivation was to shorten the schedule and thus allow earlier occupancy. By sharing electronic 3D files early in the design process, the two companies were able to both reduce the construction time and optimize the design and its process. This was particularly valuable because at the time the market was experiencing material volatility and the players needed to work together to best manage those risks. The owner believed that by developing a collaborative team, he could reduce the schedule requirements by eliminating the bidding process and allowing the construction team to begin prior to having a complete set of design documents in place.

In the end, the design team far exceeded the owner's expectations. The schedule was reduced by 17 weeks and the tonnage of steel went down by nearly 15%, which translated to the owner's saving a half million dollars on a steel package that originally came in at $2.8 million. Considering the reduced project tonnage and lower fabrication costs alone, this collaborative approach resulted in an estimated carbon footprint reduction for the steel package of 25%. The project also used electronic document sharing, which greatly reduced shop drawing turnaround time. Through close collaboration and coordination between the engineer and erector, shop labor was maximized and field labor was minimized, which greatly reduced construction material and labor costs. All of these savings were realized thanks to the structural engineer having the foresight to involve the fabricator early in the decision-making process.

Construction Documents

One of the biggest holdups on project schedules early in the shop drawing development phase is the number of requests for information (RFIs) seeking clarification of design intent. Sometimes these delays can add weeks to a schedule, and can result in major field errors when the design intent is unclear. Resources exist to help structural engineers understand what needs to be on construction documents to ensure completeness before passing them along to the project team for detailing and construction. The Council of American Structural Engineers' (CASE) document 962D provides checklists that do just that. Also, early collaboration with the fabricator will allow your team to discuss in detail what is expected upon final drawing submittal.

Higher quality and more accurate construction documents can lead to a project with fewer errors and less guesswork. That means less downtime in submitting/reviewing/responding to RFIs, less time in resolving field modification requests (FMRs) arising from poor quality documents due to vague details or a pure lack of information, and an overall faster schedule. A quicker construction schedule reduces equipment usage, paperwork and material handling. The bottom line is that the more complete the drawing set and/or model delivered to the subcontractor is, the more cost-effective and sustainable the project will be.

Design for Material Reuse

Another way structural engineers can enhance a project's sustainability is by thinking about the future. Anticipating future use of structural members highlights the importance of designing for deconstruction. As we move into the future of building reuse—another trend popular amongst the green building community—optimizing designs to allow materials another useful life beyond the original structure becomes very important. Some structures are moved to new locations; sometimes members themselves are salvaged for new structures. Two aspects of the structural engineer's work can contribute significantly to such deconstructability and reuse.

➤ **Connection and material selection.** Choose standard details and fasteners. Optimize connections that can be deconstructed, such as bolted assemblies. Use simple connections with clear load paths. In other words, design framing systems to be used again after they are deconstructed.

➤ **Good as-built final construction documents.** Ensuring long-term understanding of what was built is essential for future designers to know what they are working with in cases of reuse and deconstruction. Changes often require major construction modifications after the construction documents are issued. On future projects when designers don't know what is in place, they will be forced to assume a worse-case scenario in terms of material strength, which can be a true detriment to the optimization of a future structure. Demolition contractors also rely heavily on accurate as-built documents to anticipate the level of complexity in the structure and plan an efficient deconstruction for optimizing material integrity for reuse.

As a corollary to designing for deconstruction, consider the use of salvaged material. It's true that steel is a highly recycled and recyclable material, but in some cases reusing steel rather than recycling it into another new structural steel member becomes a valid option. "Reclaimed Structural Steel and LEED Credit MR 3—Materials Reuse" from the May 2010 issue of *MSC* explores this topic and can be found at **www.modernsteel.com/backissues**.

Design for Building Reuse

Designing structures to efficiently accommodate future tenant/owner desires is another critical role that the structural engineer can play. While all possible renovations cannot be anticipated, it is possible to design intelligently and sustainably for potential modifications. This is true not only for structural modifications but also for the feasibility of reusing a structure for its "next life." Structural engineers can approach this topic from several angles, all of which add value for the owner.

- **Simple design.** By repeating elements and forgoing the concept of "least weight is least cost," a building will be more cost-effective to build and more streamlined to assemble. Remember, in a typical steel construction package, only 30% of the cost is due to material; the other 70% is due to labor—fabrication and erection. By reducing the surprises future engineers will discover in the layout and the connections, the structure can be more easily adapted when it is up for potential renovation, expansion or remodeling.
- **Independent systems.** As mechanical and HVAC systems are changed and upgraded, or as building envelopes are modified for whatever reason well in advance of the end of the structure's "useful life," it is much easier to modify and adapt them if they are kept separate from the structure. For example, they can be located within their own independent vertical chases or raised floor systems. Providing easily accessible connections from the façade to the structure provides great benefits as well.

Recycled Materials and Local Supply

The LEED system and other standards support the concept of locally manufactured material, both structural and non-structural, and include minimum thresholds for recycled content. The structural engineer should involve the structural steel fabricator early in order to understand how to best optimize the steel supply chain based on the unique project sustainability requirements. AISC provides industry averages for structural steel recycled content values; the publication *Steel Takes LEED with Recycled Content* is considered acceptable documentation by the USGBC for submitting recycled content information for LEED certification purposes. It is available as a free download at **www.aisc.org/sustainability**.

Designers also have the option of contacting the fabricator or contractor for recycled content information, in cases where these may be higher than industry averages. In addition, AISC also has a network of steel fabricators that can be good resources for answers to questions such as "How do I handle this on my project?" or "What did you do on your last project that was interesting or innovative?" In the future, recycled content may be handled differently in LEED documentation; the system continues to evolve, with the next version of LEED due to be released later in 2012. But in the end, recycled content documentation will still be necessary for green-related codes and standards, as well as green-minded architects and owners.

Moreover, structural engineers should do their best to optimize the sustainable use of every material going into each individual project. This can be realized when structural engineers work in a collaborative BIM (building information modeling) environment where all inputs and outputs of the project are measured. BIM can quantify the inputs and outputs to help the designer adjust the design "on the fly" to truly optimize the life-cycle impacts on the project in all phases: construction, operation, and deconstruction.

Where to Learn More

Sustainable design and construction will only increase as we move forward. By being vocal, valuable and knowledgeable in the area of sustainability, structural engineers can raise their profile and increase their value to project team members and owners.

The Sustainability Committee of the Structural Engineering Institute of the American Society of Civil Engineers recently published a book entitled *Sustainability Guidelines for the Structural Engineer*, which is a great resource to explore when considering the role of structural engineer. The sustainability section of AISC's website, **www.aisc.org/sustainability**, is a valuable cache of information as well. Before your next project, explore this site as a good starting point for learning how you can become more knowledgeable and play a more vital role in designing for sustainability. MSC

Trending Upward, Leading Forward

The sustainability trend has taken hold as a powerful driver of the construction sector, with nearly 58% of all 2010 projects having LEED-inspired requirements. This trend is widely anticipated to continue, with estimates that sustainable projects will total more than $120 billion by 2015. Structural engineers need to be involved, not only on structural optimization but also in terms of considering the impacts that structure has on non-structural assemblies and building energy use.

Beyond design, engineers can contribute to sustainability by participating in the development of green energy codes, standards and rating systems. Groups such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the United States Green Building Council (USGBC), which created LEED, and the International Code Council (ICC) all have committees working on various sustainability efforts. These committees can always use more designers, such as structural engineers, to ensure that balanced decisions are made—particularly considering the impacts they have on the profession. Other groups, such as the Sustainability Committee of the Structural Engineering Institute (**www.seisustainability.org**), provide engineers with a platform to form a stronger common voice supporting the informed opinions of the structural engineering profession when working with code bodies on proposed specification language.

Structural engineers have always valued their role as technical experts on projects. As the level of scrutiny on each facet/process of the building that impacts sustainability increases, structural engineers need to apply their analytical expertise to provide the best and most sustainable design solutions.