Structural Steel Contributions
toward obtaining a LEED™ rating

Successful sustainable design results from a process of integrated decision making, beginning at project inception. Throughout every phase of a project, it is essential to consider the impact of each decision on all other aspects of the project. This paper provides a brief overview of sustainable building design and an outline of how a structural system can contribute to an environmental initiative.

The North American building industry has a tremendous impact on our environment, and a focused green design effort can bring benefits to all stakeholders. Sustainable design and construction practices can bring environmental, economic and social benefits that result from careful consideration of resource use and how the building will affect the environment. Additional benefits could be reduced operational costs, higher facility value, and increased worker productivity.

Today, sustainability, environmental design, and green building are generally interchangeable terms, becoming increasingly common to the language of building design and construction. The United Nation's Brundtland Commission Report of 1987 defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Such a broad statement does not provide a datum against which business practices, design solutions and construction practices can be measured. Architects, engineers, suppliers, fabricators, and builders need to understand how environmental design practices impact the design and construction industry.

Fortunately, The U.S. Green Building Council (USGBC) has developed the LEED™ (Leadership in Energy and Environmental Design) Green Building Rating System. This tool provides a framework under which building design and construction decisions can be made and sustainable building projects can be evaluated. LEED has rapidly become a design tool embraced by designers and owners interested in bringing additional value to their projects. This paper includes overview of the LEED system, and an outline of how the selection of a steel building structure can contribute to a LEED rating—most significantly in the Materials & Resources and Innovation & Design Process categories, explained in further detail herein.

Each structural system has opportunities and constraints when evaluated as a part of an environmental design effort. Market demands for steel production spur a significant amount of recycling, inherently contributing to sustainable design efforts. According to the Steel Recycling Institute, 67 million tons of steel were recycled in the U.S. alone in 2001. Worldwide, 400 million tons of steel were recycled - one and a half times the amount of all other recycled materials combined (including paper, glass, aluminum, and plastic). Approximately 40 million tons (59% of total recycled steel) were derived from construction and demolition waste, and the steel salvage market accounts for an additional 4 million tons per year. Each ton of recycled steel saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone.[1] In addition, recycling requires less energy, creates less waste, and releases less pollutants than producing the same amount of steel from virgin materials. Recycling, however, is only one aspect of how structural steel can contribute to green design efforts, and the steel frame is only one component of the overall structural system.

LEED RATING SYSTEM

The LEED rating system is designed for new and existing commercial, institutional, industrial, and multi-story residential buildings. Its purpose is to set an industry standard for green buildings, and in doing so, help drive the marketplace toward more sustainable development. It provides an accessible and understandable framework—a recognized reference for project teams to make decisions and evaluate the overall performance of a sustainable building design effort. LEED was developed by consensus of the membership of the USGBC, which includes companies from all segments of the building industry—a membership that has grown exponentially since 1998.

LEED is the most widely used green building rating system in the U.S. As of March 12, 2003, 44 LEED certified buildings have been completed, and more than 500 projects are registered with the USGBC seeking LEED certification. The certification process requires the project team to pursue and evaluate specific credits (see **www.aisc.org/sustainability**), to document requirements successfully met for each credit, and to submit credit documentation to the USGBC for review. Because the LEED rating system relies on the project team to generate proof of compliance, LEED is considered a self-certification system.

LEED credits are organized within six core categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation and Design Process. Prerequisites within several of these categories must be met for certification. Remaining green measures form an à la carte system of points, including both proven practices and

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emerging technologies. A brief description of the categories follows:

Sustainable Sites: Thoughtful site selection is important to preserving or restoring local ecology. Site selection can also influence credits that may not seem directly related to the site. For example, a site close to public transit or in an already developed area helps reduce the amount of driving by the building's occupants. Possible points in this category are 14.

Water Efficiency: According to the Worldwatch Institute, buildings account for one-sixth of fresh water withdrawals. Water is used in the manufacture of building components and in building operation. LEED offers credits for water efficient fixtures and landscape materials that do not require irrigation. Possible points in this category are 5.

Energy and Atmosphere: This category encompasses a number of strategies to help reduce energy use and protect the ozone layer. Credits are given for using renewable energy and purchasing green power. A credit for Fundamental Building Systems Commissioning and Measurement & Verification helps to ensure a building operates as designed. Possible points in this category are 17.

Materials and Resources: The main objective of this category is to conserve raw materials and resources, such as fossil fuels. Methods include increasing recycling and recycled content, diverting material from landfills, and reducing travel distances for material transport. Structural steel can typically make the greatest contribution within this category. Possible points in this category are 13.

Indoor Environmental Quality: Because Americans spend 90% of their time indoors, the indoor environment has a large impact on health and productivity. Issues related to this include occupant comfort, air quality, thermal comfort, and access to daylight. Possible points in this category are 15.

Innovation and Design Process: The USGBC recognizes LEED is a relatively new system and provides this category to recognize the innovative solutions of project teams, which could range from substantially exceeding the requirements of a given credit or developing a completely new way to increase environmental responsiveness. Possible points in this category are 5.

LEED version 2.1 allows for a maximum of 69 possible points. Depending upon the total number of points achieved, a building can be classified as Certified (26-32 points), Silver (33-38 points), Gold (39-51points) or Platinum (52 or more points). As with any integrated design tool, the earlier LEED is considered in the design process, the easier it will be to achieve certification. Project teams may find that pursuing one credit may make it difficult or impossible to achieve another. It is not possible to achieve all 69 points.

Many project teams that have utilized the LEED system believe there is little, if any, additional construction cost required to obtain the LEED Certified level. However, as with any effort that brings additional value, additional costs may result, depending to some degree on the targeted certification level. These costs could result from additional project team fees (managing the LEED effort and assembling the documentation for submission to the USGBC), as well as increased construction costs.

The certification process is relatively simple. Any member of the project team can register a project with the USGBC, although discounts are available for USGBC members. Once a project is registered, the project team is given access to the online LEED *Reference Guide* and credit rulings from past projects. Because no two projects are alike, situations will arise that do not explicitly follow the listed requirements. In such a situation, the project team should first review the Intent of each LEED credit, as described in the *Reference Guide*. If the situation meets the Intent of a particular credit, the project team can pursue the credit. If the project team is attempting to obtain a credit, yet does not find a precedent for its situation, the online credit rulings (USGBC's formal answer to a question submitted from a previous project team) can be consulted to see if another project team has posted a similar question. If the credit rulings do not address the situation, a credit interpretation can be submitted. Each project is entitled to two free credit interpretations.

The project team submits a certification package to the USGBC for review after construction of the project is complete. The certification package must include documentation to prove requirements have been met for each credit. LEED Version 2.1 is intended to simplify required documentation by providing project teams a series of letter templates to be printed on company letterhead and signed by a team member certifying that the requirements have been met. The fill-in-the-blank documents prompt team members for information and compute whether a particular credit has been achieved. The USGBC reserves the right to audit credits on any submission to confirm backup information and will determine accepted and declined credits, or if additional documentation is necessary.

LEED MATERIALS AND RESOURCES

While the rating system is set up to evaluate an entire project in a holistic manner (not simply material selection), as a building material, structural steel can make the largest contribution to a LEED rating in this category. All materials selected for a project are evaluated based upon performance criteria, either by weight or cost, depending on the credit. The structural system can be a significant portion of the cost or weight of the building materials and contributes to points for almost every credit in this LEED category.

Credit 1. Building Reuse (2 possible points)

Building reuse enables development within existing buildings and previously developed areas, maintaining proximity to existing infrastructure and preserving open space. Materials that would have been utilized for a new building are conserved, and the environmental impacts from the transport of those materials are also eliminated. Usually, the owner's decision to reuse is based upon a real estate evaluation, renovation costs, and square footage requirements.

In the LEED rating system, if 75% of the building structure and shell (excluding windows) is preserved, the project earns one point. Structure includes foundations, slabs, and basement walls. If 100% of the building structure and shell is preserved, along with 50% of the walls, floors, and ceilings, the project earns two points.

Because the LEED templates consider the volume of materials saved, reusing a steel frame for an entire building can be advantageous. When a building is reused, it often must serve a completely new function, requiring modifications to the structure due to changes in loading conditions and relocated floor openings. Steel structures are more likely to be reused than other structures because they can be easily and cost effectively modified and reinforced, allowing flexibility and adaptability for the building's new use.

Credit 2. Construction Waste Recycling (2 possible points)

Commercial construction generates between two and two and one-half pounds of solid waste per square foot[2]. LEED defines construction waste as both demolition waste and waste as a by-product of construction. As landfill space becomes more scarce, the cost to dump wastes, tipping fees, etc. become more expensive. To avoid these higher costs, diverting as much waste as possible proves beneficial. To achieve this credit, waste can be diverted by recycling or reusing. Points are awarded for diverting 50% (1 point) or 75% (2 points) of waste as calculated by weight or volume. As mentioned earlier, steel is the most recycled material in the world, ensuring that virtually any steel on a construction site can be recycled or reused.

Credit 3. Resource Reuse (2 possible points)

LEED awards points for using 5% (1 point) to 10% (2 points) salvaged or refurbished materials (by cost), relative to the total cost of materials for the project. This credit encourages the use of existing materials, as energy is required to produce new materials regardless of whether they are extracted from recycled or virgin stock.

While it is possible to return steel to a fabricator at the end of a building's useful life, it is much more common to recycle steel. Innovations in the production process have resulted in a 35% decline in steel material costs between 1983 and 1998. Therefore, even with increased costs in fabrication and construction labor within the same time frame, the net change in the cost of installed structural steel within the 15-year period is 0%.[3] Furthermore, the energy required to produce new steel has decreased 45% over the last 25 years1, largely due to improvements in yield. Before, 100 tons of raw material produced 60 tons of steel product, and now, the same 100 tons produces 90 tons of steel product. Lastly, the production of steel structural shapes is completed through a method of continuous casting, whereby materials transform directly from liquid form to near final shape. (Prior to continuous casting, steel was first made into square ingots and then reheated to roll beams, a process that required more energy and significantly more time.) Currently, the relatively low cost for new steel does not favor the salvage and reuse of structural steel members in building projects.[4]

In cases where steel is reused, it often occurs on the job site where the laws of supply and demand dictate how construction and waste haulers will dispose of a particular material. Although uncommon, steel salvage can occur when structures are relocated. One example of complete reuse of a steel system is Beaver Stadium at Penn State University. In this instance, the entire building was relocated from one end of the campus to the other.

Credit 4. Recycled Content (2 possible points)

The greatest advantage of steel construction is its contribution to recycled content. Steel production can occur through one of two processes. The basic oxygen furnace (BOF) process uses 25%-35% existing steel to make new steel. The electric arc furnace (EAF) process uses almost 100% existing steel. In the U.S., the structural steel industry has embraced the EAF process for the production of steel for structural shapes, along with the continuous casting method. All three U.S producers of structural shapes W14×43 and larger use the EAF process. According to the Steel Recycling Institute, the post-consumer recycled content (steel that has previously been used in another consumer product—automobile, refrigerator, etc.) is 64%, and post-industrial recycled content (steel that is waste/surplus of another industrial production process) is 30%.[5]

LEED requires documentation verifying which steel production process was used for the steel on the project. AISC's website contains letters from the largest U.S. structural steel producers, certifying recycled content from their facilities. This letter can be accessed at **www.aisc.org/ sustainability**. The requirement for this type of letter to be produced by a fabricator is becoming more common in project specifications when LEED certification for a project is being pursued.

The equations for calculating recycled steel content favor post-consumer recycled content as opposed to post-industrial recycled content. Process scraps that can easily be used as feedstock are not considered recycled content. Calculations for this credit can be confusing and were modified in Version 2.1 to become less complicated. Because many projects that were previously registered continue to work with LEED 2.0, we have described the calculations for both versions.

Under LEED 2.0 (for one point) the value of recycled content materials had to comprise at least 25% of the total value of materials on the project, with at least 20% post-consumer recycled content or 40% post-industrial recycled content in aggregate using a weighted average per the following equation:

$$\text{Recycled content value} = \text{Recycled content value of the material} \times \left| \frac{\text{post-consumer \%}}{20\%} + \frac{\text{post-industrial \%}}{40\%} \right|$$

If a material exceeded 20% post-consumer recycled content or 40% post-industrial recycled content, it was rewarded with a higher value. For example, $100,000 worth of steel with 64% post-consumer recycled content and 30% post-industrial recycled content would be equivalent to $395,000 worth of material. A second point would be achieved if the total value of recycled content was 50% of the total value of materials for the project.

Version 2.1 eliminates the weighted average and offers two options for calculating recycled content. The first option is for post-consumer recycled content to comprise at least 5% of the total value of materials on the project. The second is for all the post-consumer recycled content plus ½ of the post-industrial recycled content to equal 10% of the value of all materials on the project. As with the Version 2.0 method, if these quantities are doubled another point is available.

Using the Nucor-Yamato Steel Company breakdown as an example, $100,000 worth of steel is calculated as follows. This credit does not consider the 10% in-house crops and pit scrap as recycled content. Therefore the total recycled content must be considered to be over 80% rather than over 90%. The contribution of structural steel in this example to the overall project goal of 10% of the materials value is:

% of post-consumer	% of post-industrial	Value of post-consumer (A)	Value of post-industrial (B)	Recycled value: A+(B/2)
75%	5%	$75,000	$5,000	$77,500

For a project where the total value of materials is $1,000,000 (C) and steel is the only recycled content material (unlikely), compliance with LEED requirements is as follows:

Post-consumer value as a % of total value (A/C)	Post-consumer plus half of post-industrial value as % of total value (B/C)
7.5% which is more than 5% but less than 10%	7.75% which is more than 5% but less than 10%

Because structural steel is not a composite material, the recycled content is simply the percentage of recycled steel in the new product. For composite materials like concrete, the recycled content of the assembly must first be determined by dividing the weight of the recycled content by the total weight of material in the item, then multiplying the resulting percentage by the total value of the item.

Credit 5. Local/Regional Materials (2 possible points)

For the first part of this credit, LEED requires materials to be manufactured within 500 miles of the project site. Manufacturing refers to the final assembly of components into the building product that is furnished and installed by the tradesmen. A February 2004 credit interpretation ruling established that, for structural steel, the fabrication shop is considered the location where the final manufacture of the product occurred. Fabricators cut steel members to their appropriate length, punch or drill holes, weld on connection plates, and add the necessary camber to members. Fabricators may also build the steel into standard assemblies, such as trusses or frames. Steel fabricators are available within 500 miles of any location in the United States and the use of local fabricators fosters local economies for the product, which reinforces the intent of the credit.

The second point of this credit is available for raw materials extracted or harvested within 500 miles of the project site. For steel, this credit refers to the location where the metal served its last useful purpose before it became scrap. Steel mills typically acquire scrap from brokers, who obtain materials from projects and products throughout the country, which are selected based upon metallurgical needs and cost. For example, Nucor-Yamato uses nine to 12 different types of ferrous scrap, classified in various gradations including: #1, #2, tin plate bundles, shredded, municipal, cast iron, plate, structural, and turnings. The David Joseph Company, its primary supplier, obtains 85% of its material from domestic sources. However, there is no way to track where the raw materials for a particular piece of steel came from, making this second point difficult to achieve.

LEED INNOVATION & DESIGN PROCESS

Structural steel can also impact credits earned in this category. Up to four points can be awarded in this category for strategies that go above and beyond what is required in the 64 core credits, either by a completely new idea or by greatly exceeding the requirement from an existing LEED credit. A separate point is available for having a LEED Accredited Professional on the project. While the USGBC does list credit interpretation rulings for specific requests submitted by registered projects, they have not yet published a list of specific ideas for Innovation & Design Process that have been accepted on certified projects. The following are suggestions that may qualify for innovation points.

1. **Structure as finish.** It is possible to expose a steel structure and avoid installing finish products such as ceiling tiles or drywall. Any time a product is eliminated, the energy to extract, produce, install, and dispose of that product is saved.
2. **Light-weight materials.** Steel is naturally light in weight, making it beneficial for girders can also be used compositely with floor systems to reduce weight of the structural system. Based upon past credit rulings, in order to achieve this credit, the project team must clearly describe a conventional building for a baseline and then demonstrate significant savings. The Utah Olympic Oval, for example, uses an innovative cable suspension system to support a very shallow steel truss roof. This design reduces the total arena volume by 2.6 million cubic feet (making it easier to heat and cool) and weighs over 950 tons less than competing solutions.[8]
3. **Recyclability.** Utilizing a high percentage of steel, such as a steel plate shear wall, maximizes the amount of materials in a building that can be recycled in the future. If the building is dismantled in a later project, the LEED Construction and Demolition Waste Credits could be achieved.
4. **Deconstruction.** Structural steel can be welded or bolted. If the structure is designed with bolted connections, thus allowing it to be easily disassembled, it is more likely that members can be reused on other projects. Werner Sobek, a recognized German structural engineer, has utilized this philosophy extensively. His residence at Römerstrasse 128 (Stuttgart) is designed so that the entire steel structure can be disassembled and reused.[9]
5. **Structure as Plumbing.** The Greater London Authority building, designed by architect Foster and Partners, used HSS structure members in the atrium. Hot water runs through the members, creating a giant radiator. This is an example of true integrated design and economy of materials.[10]

COMPARISONS BETWEEN STEEL AND CONCRETE

In order to better understand the impact of structural material selection on LEED certification, a survey was conducted of the LEED certified buildings to date. The survey identified the material for the primary structural system for each project by speaking directly with the architect and/or structural engineer of record. A total of 44 projects were surveyed—the complete list of LEED certified projects as of March 12, 2003. A summary table of these survey results can be accessed at **www.aisc.org/sustainability**.

Steel buildings represent a large portion of this group, exceeding their market share representation among building construction projects throughout the U.S. Buildings in which steel framing is the primary structural system comprise 50% of the LEED certified buildings. When projects with more than one structural system are considered (mixed systems), structural steel is included in 68% of the LEED certified projects. Structural steel has successfully been employed across a wide variety of building type, building size, and geographic location in LEED-certified projects.

While those surveyed indicated that structural systems were selected based upon a variety of criteria, including initial cost, serviceability, building type, bay size, and geographic location, they also frequently cited the advantages of using structural steel when seeking LEED certification, especially contributions to the percentage of recycled materials used for a project.

Table 1 evaluates the contributions major structural building materials (steel and concrete) could make to a LEED design effort. The table demonstrates that material selection also has an impact in areas not directly related to the building's structural system (note *Other Considerations* column).

CONCLUSION

Each structural system brings benefits to different LEED credits. A clear environmental advantage to either a steel frame or a concrete frame is not clear in regard to the LEED certification process. LEED is a performance standard, not a prescriptive standard. It does not favor one structural system over another.

As LEED certification becomes more popular among design professionals and building owners, further studies of the relationship between primary structural material and LEED certification will be possible. In the meantime, structural steel remains a strong option, which can bring a variety of advantages to environmental design and a LEED certification effort.

An integrated design process that thoughtfully considers the implications of the structural system on other building systems, and its impact on the environmental design effort, will bring value to the project, the owner, the user and, in a broader sense, to the community. ★

RESOURCES

For further information please see the following resources:

www.aisc.org/sustainability
www.recycle-steel.org
www.usgbc.org

Table 1. Comparison of Possible LEED points for Steel Frame vs. Concrete Frame Construction

LEED™ Category	Steel Frame	Concrete Frame	Other Considerations
Sustainable Sites			
Stormwater Management (2 possible points)	Not relevant	Not relevant	Special concrete pavement mixes that are pervious allow stormwater to infiltrate rather than creating runoff
Reduce Heat Islands (2 possible points)	Not relevant	Not relevant	Concrete's light color reflects heat instead of absorbing it
Energy and Atmosphere			
Energy Optimization (10 possible points)	Not relevant	Not relevant	Concrete cladding and flooring contributes to thermal mass and may provide energy savings.
Materials and Resources			
Building Reuse (2 possible points)	Steel buildings are flexible and adaptable and easily reinforced.	Concrete buildings can be reused, but it is more challenging and costly.	
Construction Waste Management (2 possible points)	Steel is consistently recycled or salvaged	Concrete is consistently crushed and reused as fill material. Steel rebar is removed and recycled.	
Resource Reuse (2 possible points)	Structural steel can be re-fabricated and reused	Due to its monolithic nature, cast-in-place concrete affords little opportunity for salvage and reuse	
Recycled Content (2 possible points)	Steel has close to 100% recycled content from scrap steel.	Recycled content typically applies to only the cement portion of concrete and the steel reinforcing bars. In some cases fly ash can be substituted for up to 50% of the cement.	
Local/Regional Materials (2 possible points)	Locally manufactured, but not locally extracted materials are available.	Both locally manufactured and locally extracted materials are available.	
Innovation and Design Process			
(4 possible points for Innovation)	The following ideas may apply: Exposing structure. Using composite members. Design for future recyclability. Designing for deconstruction. Using structure for plumbing.		Exposing structure and thus using fewer materials may apply.

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