More than Recycled Content:

The Sustainable Characteristics of Structural Steel

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Over the past 20 years sustainable building practices and outcomes have moved from theory to practice. Today sustainable design considerations extend from site selection through building commissioning. The selection of a structural framing system has always been perceived as a major decision point in the optimization of the building's design from a sustainable perspective. Often, the selection of a structural steel framing system has provided significant contributions to the ultimate accomplishment of a green, sustainable structure. But this is not just because domestically produced and fabricated structural steel has a high percentage of recycled content.

Domestically produced and fabricated structural steel used for structural framing systems has an average recycled content of 93%. Structural steel products are comprised of recycled steel scrap with the steel industry being the largest recycler of waste by mass in the United States. In 2016 domestic structural steel mills produced 7.1 million tons of structural steel which contained recycled steel scrap from approximately 5 million automobiles, 1.7 million old appliances, 1.1 million tons of construction and industrial waste and a million tons of curbside recycling.

The success of steel recycling is a great example of sustainable practices on an industry wide scale. But discussions focusing on the high recycled content of structural steel often overshadow the other sustainable characteristics of domestically produced structural steel. Structural steel is not a single attribute material. It is a multi-attribute material that contributes to sustainable construction in a variety of ways.

Little Known Facts About Structural Steel

It is important in any discussion of structural steel to dispel any myths that may surround the industry and create false impressions regarding structural steel. For example many individuals express surprise when they discover that the vast majority of structural steel used in the United States is produced in domestic mills and not imported from overseas.

Some important facts to keep in mind are:

- Domestic structural steel mill capacity exceeds current and foreseeable domestic demand with more than 75% of current demand being met by domestic producers.
- Hot-rolled structural steel mills in the U.S. do not use iron ore, coke or limestone as primary feedstock material; no mining operations are required. They melt steel scrap and recycle it back into new structural steel products.
- Unlike legacy steel mills of the early 20th century, today's structural steel mills have highly sophisticated systems to minimize emissions. They are highly automated, environmentally conscious good neighbors in the communities where they are located.
- Structural steel does not lose any of its metallurgical properties when it is recycled. Consequently, the quality and properties of recycled steel are the same as virgin steel.
- Iron is a non-depletable resource as all steel can be recycled and any increase in demand beyond the available supply of scrap can be met by the earth's abundant supply of iron which comprises 35% of the earth's mass.
- Structural steel mills recycle all of the water they use and recover through a closed loop recycling system. Less than 70 gallons of water is consumed per ton of steel produced.
- There are close to 2,000 steel fabricating firms located throughout the U.S. that detail, cut, drill, bolt and weld structural steel for building projects, providing local employment and economic stimulus.

Three different types of structural steel are used in building construction: hot rolled sections (wide flange members, angles and channels), hollow structural sections (square, rectangular and round tubes) and plate. Of the structural steel used on projects approximately 80% are hot rolled sections, 15% hollow structural sections and 5% plate. In most cases the sustainable characteristics of each type of structural steel are identical, however there are some differences based on the mill production method being used.

Recycled Content

The recycled content of structural steel can be as high as 100% for steel produced using the electric arc furnace (EAF) method of production. All domestic hot-rolled structural shapes are produced using the EAF method. A limited amount of virgin material may be added during the process to achieve the proper metallurgical balance required for a particular grade of steel resulting in an average recycled content of 93% for hot rolled structural shapes. Hollow structural sections (HSS) are produced in a secondary process using hot rolled coil formed into the tube shape. The hot rolled coil can originate from either an EAF mill or a mill using a basic oxygen furnace (BOF). If the material is from an EAF mill the recycled content will be in the 90% to 100% range. If it is from a BOF mill the recycled content will be near 25%. Plate can also be produced in an EAF or BOF mill resulting is recycled content levels similar to those of HSS.

Recyclability

Independent of whether the structural steel originated from an EAF or BOF mill, all structural steel is 100% recyclable. In fact, all steel products are recyclable. The steel used in an automobile can be recycled into the steel used in an appliance which in turn can be recycled into a steel beam. It should be noted that this is true recycling without any loss of the material properties of the steel. Other materials such as concrete are primarily down-cycled into road base, not back into new concrete.

Recovery Rate

It is one thing if a material is recyclable, it is another thing altogether if the material is actually being recovered and recycled. 81% by weight of all steel products reaching the end of their life are recovered for recycling. This includes 85% of automobiles, 82% of appliances, 70% of containers, 72% of reinforcing bar and 98% of structural steel. The recycling rate for structural steel far exceeds the recycling rates of aluminum or the paper and wood. Recycling one ton of steel avoids the consumption of 2,500 pounds of iron ore, 1,400 pounds of coal and 120 pounds of limestone.

Reuse

Structural steel can not only be recycled it can be reused without recycling. At the present time only a small amount of recovered structural steel is refabricated and directly reused in new building projects. Appendix 5 of *The Specification for Structural Steel Buildings* (ANSI/AISC 360-16—available for free download at www.aisc.org/specifications) contains the testing requirements evaluation of the properties for steel being recovered and reused.

A significant amount of structural steel is reclaimed from the waste stream of deconstructed buildings and industrial facilities for reuse in non-building applications such as pipe racks, shoring and scaffolding. Industrial steel structures are at times disassembled at one location for reinstallation and reuse at another location, an opportunity not present with other framing materials.

Adaptive Reuse of an Existing Building

There are numerous examples of the structural steel frames of buildings being reused in place. In these cases the intended use of the building has changed, but rather than demolishing the existing building and constructing a new building, the structural steel framing system of the existing building is maintained. To address the owner's new program requirements a structural steel framing system can be field modified to handle new load requirements. The field adaptation of structural steel framed buildings has been as diverse as adapting a decommissioned coal fired electric generation facility into an office structure.

Resiliency

Increasing attention is being paid to the resiliency of communities, buildings, structural framing systems and construction materials. Of all framing system materials, steel is the most resilient. It leads in strength (typically 50,000 psi in both tension and compression with higher strengths available), elasticity (29,000 psi), durability, non-combustibility and resistance to decomposition.

Waste Generation

All steel waste from the production, fabrication or erection process is captured and recycled back into new steel products. A recent survey of 900 steel fabricators indicated that not a single fabricator sends steel waste to a disposal facility. The rationale expressed by the fabricators was straight forward, "Why would we pay to send waste to a landfill when it is possible to sell the scrap to a dealer who will pick it up at our facility." Non-ferrous waste generated in the fabrication process is minimal and limited to miscellaneous trash. All waste including dust at the mill facilities with any ferrous content is immediately recycled back into the steel production process. Non-ferrous waste is sold as by-products for other industries to use in their manufacturing processes. An example of the efficiency of the producing mills is highlighted at one facility where intact discarded automobiles are brought to the mill, shredded with the waste separated by material with the ferrous scrap flowing to the mill and non-ferrous materials sold to waste processors resulting in less than 1% of the original waste stream (the automobiles) transported to a landfill.

Water Consumption

Water consumption and discharge is minimal at mill facilities. While several thousand gallons of water are used to quench the molten steel sections (quenching not only cools the steel, it increases the strength of the steel) less than 70 gallons of water are actually consumed. The remaining water is recycled in a closed loop recycling process and reused in the process.

Energy Consumption

The melting of steel scrap in an electric arc furnace is an energy intensive process. The environmental impacts associated with the electricity required for this process are included in the life cycle assessments and environmental product declarations for structural steel products. Unlike concrete where a significant amount of greenhouse gas emissions occur as a function of the calcification process of the concrete, the greenhouse gas emissions associated with steel production are related to the external energy being used. This is significant as the environmental impacts associated with steel production are directly proportional to the emissions associated with electricity production. As renewable energy becomes a higher percentage of overall electricity production, the environmental impacts associated with steel production will decrease.

Interestingly, most structural steel mills utilize dispatchable energy contracts and attempt to schedule their melts to correspond with periods of low electricity demand using what could best be called waste electricity. Waste electricity is the electricity being generated during non-peak periods where coal fired facilities cannot be easily cycled down to lower levels of generation due to the increased emissions that occur during the cycling process. The steel industry does not take any credit against the environmental impacts of structural steel for using this waste energy.

Offsite Fabrication

Sustainability is more than just inventorying environmental impacts. The triple bottom line of sustainability also includes both economic and social impacts. The fact that structural steel is fabricated in fabrication shops rather than at the project site results in social benefits including improved worker safety and a centralized work location minimizing the requirement to travel to various project sites. With fabricated structural steel the product goes to the project site rather than the workers. Granted erection of the structural steel requires a field crew, but the size of a steel erection crew is significantly smaller than the number of workers required for stick built wood or formed cast-in-place concrete structures.

Environmental Product Declarations (EPD)

An analytic presentation of the environmental impacts of structural steel can be found in the EPDs published by AISC on behalf of the structural steel industry. A separate EPD is available for fabricated hot-rolled structural sections, fabricated hollow structural sections and fabricated plate. These EPDs satisfy the requirements of various standards and rating systems in that they document the environmental impact of these products as *delivered to the project site*. EPDs published by mill producers reflect only the impacts from the cradle-to-gate of the mill. The industry average EPDs, which are available at www.aisc.org/epd, document the environmental impacts from the cradle of the mill to the gate of the fabricator. The EPDs are based on life cycle assessment data provided to an independent consultant for both mill and fabricator activities and have been peer reviewed by a third-party reviewer.

<u>It is critical to note that these results must not be compared to each other</u>. The environmental impacts associated with a product are a function of the use of that product in a building system. The functionality of one ton of hot-rolled structural sections is not the same as the functionality of one ton of plate or one ton of hollow structural sections. The standards governing the development of life cycle assessments and environmental product declarations require that language be

All values are in short tons per short ton of steel	**Fabricated Hot Rolled Sections**	**Fabricated Hollow Structural Sections**	**Fabricated Plate**
Global Warming Potential (GWP)	1.16 CO_2 eq	2.39 CO_2 eq	1.47 CO_2 eq
Ozone Depletion (ODP)	2.25e-10 CFC-11 eq	2.23E-08 CFC-11 eq	4.82E-08 CFC-11 eq
Acidification (AP)	5.94e-03 SO_2 eq	8.73E-03 SO_2 eq	5.94E-03 SO_2 eq
Eutrophication (EP)	1.39E-02 N eq	4.38E-04 N eq	2.16E-04 N eq
Tropospheric ozone potential (POCP)	3.12E-02 O_3 eq	1.17E-01 O_3 eq	6.26E-02 O_3 eq

included instructing the user not to use the data to make comparison across product categories.

These results are industry average values that include fabrication. Different mill producers may opt to determine producer specific LCA values that will be published in producer specific EPDs. These EPDs may or may not include fabrication impacts. Fabrication impacts are also calculated on an industry average basis and were determined by a detailed survey of over 300 AISC full member fabrication firms. The fabrication contribution which is included in the values in the table above is:

All values are in short tons per short ton of steel	**Transportation and Fabrication Only**
Global Warming Potential (GWP)	0.12 CO_2 eq
Ozone Depletion (ODP)	3.49e-11 CFC-11 eq
Acidification (AP)	3.48e-04 SO_2 eq
Eutrophication (EP)	1.93E-05 N eq

It is important to realize that industry average values for fabrication give a clearer view of the environmental impacts associated with fabrication than could be obtained from fabricator specific values. Each structural steel building project is a unique set of products (beams, columns…) that require different levels of fabrication operations. If during one year a structural steel fabricator is involved in a series of steel-framed parking structures that utilize 60 foot beams that require minimal fabrication for connections, the environmental impacts on a per ton basis will be low. If that same fabricator a year later is working on a specialized project with a large number of short sections requiring complex connections, then the environmental impacts on a per ton basis will increase dramatically. Fabricator specific impact data is misleading and no attempt should be made to select a fabricator for a project based on environmental impact data as that data is project dependent.

Comparing the Environmental Impacts of Structural Framing Materials

The minimization of the environmental impacts associated with a building is a worthwhile goal being pursued by many designers. Regretfully, framing material selections are often being made based on misleading or inappropriate information resulting in the unintended consequence of increasing rather than decreasing the environmental footprint of the building.

There have been cases of designers selecting a framing system material based on a graphic portraying the total CO_2 eq emissions by industry. The fact that the concrete or steel industries may produce a significant amount of greenhouse gas emissions in total has absolutely nothing to do with the impacts of the materials used on a specific project. Total industry emissions are a function of the overall use of the material which in steel's case includes everything from automobiles to containers to reinforcing steel. A material's contribution to the environmental impacts of a project are a function of the amount of material used on that project, the process used to make the material and the impacts directly associated with the specific material.

Framing materials cannot be compared directly to each other. Simply put a ton of steel is not the same as a ton of concrete or a ton of wood. Structural steel is a stronger more durable material. Less structural steel is required to carry the same structural load as would be required for concrete or wood. The only basis of meaningful comparison is to compare the quantities of each material required to satisfy the structural requirements of the building and to take into account secondary changes to the buildings that may occur based on the selection of the framing material. For example, a structural steel framed building is lighter than a concrete framed building reducing the foundation requirements of the building and therefore requires less foundation material which in turn reduces the environmental footprint of the building.

An accurate comparison can only be made when impacts are measured based on the actual quantities of materials used in alternative building designs are considered—in other words a whole building life cycle assessment (LCA).

A whole building LCA is a means of providing an objective comparison between two building alternatives with a goal of selecting the building alternative that will result in the least impact on environment. The whole building LCA is a multi-attribute evaluation of a variety of different environmental impact categories and is commonly contrasted to the selection of building products and materials based on a single attribute such as recycled, regional or bio-based content.

While the goal of the whole building LCA is noble, the process of conducting a whole building LCA is far from being simple and straight forward. The LCA novice may mistakenly believe that all that is needed to conduct a LCA comparison is a schematic design of building, a list of the environmental impacts associated with all of the materials that will be used in the building and a simple drop-in the numbers estimation tool to create a legitimate building comparison. Pushing a "smart" button and receiving an accurate list of comparative environmental impacts for two building alternatives is not possible. In fact, nothing could be farther from the truth.

In order to conduct a meaningful whole building LCA certain key questions must be answered:

- What portions of the building are to be considered in the analysis?
- How are the building alternatives selected?
- What is the basis of comparison between the two building alternatives—materials or design?
- At what stage of design should the comparison be performed?
- How will the quantity of materials used in the two alternative building designs be determined?
- How accurate are the material quantities being used?
- Is operating energy to be included in the evaluation?
- What was the scope of the collection of the environmental impact inventories for each material or product?
- Are all product inventories consistently using the same scope?
- What methodology and assumptions were used in determining the environmental impact inventories for each product or material?
- What is the veracity of the environmental impact inventories used for each material or product?
- What environmental impact categories will be evaluated?
- What level of environmental improvement is desired for each category?
- What level of environmental detriment will be tolerated in each category?
- How will impact categories be prioritized against one another?

ASTM E2921-13 "Standard Practice of Minimum Criteria for Comparing Whole Building Life Cycle Assessments for Use with Building Codes and Rating Systems" defines the portions of the building under consideration to be "the complete building enclosure, structural systems, interior walls, and interior finishes and trim of a building, which may include operating energy, but excludes furniture and attached cabinetry." Cleary this is much more than simply comparing a structural steel framing system to a concrete or wood framing system. A whole building LCA is just that—A WHOLE BUILDING LCA—with all of the building products and materials taken into account. Yet, at the same time certain electrical, mechanical, plumbing, fire control and conveyance systems are not to be included as their selection should be governed by efficiency rather than material impacts.

The two building designs to be compared must be able to satisfy the same design program and be of the same location, orientation, size and function. Does this mean that the designer must design a second building to the same level of detail as the first design? Or can a simplified reference building be used? Or can an existing building satisfying the same function in the same area be scaled to match the first design? Or can the designer simply take the first building and start to substitute materials and products—steel for wood, glass for brick, pre-cast plank for reinforced concrete—adjusting the design for each change? While the answer is often debated, the fact is that unless an actual design of an alternative building is undertaken the comparison of environmental impacts will not be accurate.

This brings up an even more important philosophical question. If a whole building LCA is to be integrated into the design process of a building should it be focused on product substitution or design enhancement? Is the goal to compare a concrete structure to a wood structure? Or is the goal to select the products that best fit the design program of the project and then optimize the use of those materials for an environmental perspective through an iterative design process? The comparison, optimization and the use of innovative structural systems can often reduce the amount of materials and the environmental impacts associated with those materials by 10 to 20 percent. The real opportunity for verifiable environmental improvement is often best focused on design improvements rather than material selection.

And, at what stage of the design should the comparison be made? Conceptual? Schematic? Design development? Construction drawings? The greater the level of design detail, the greater level of accuracy in the comparison. Some individuals with little background in LCAs are attempting to perform whole building LCAs at a conceptual level. Material and product quantities at the conceptual level are, at best, +/- 20%—with some simplified tools yielding results when compared to actual design quantities that vary by as much as 50%—yet decisions regarding framing materials are being made based on a 5% improvement in environmental impacts.

Many whole building LCAs are based on parametric estimates of material quantities without any structural design work being performed. The quantity of ceiling or floor coverings may be able to be calculated on a square foot basis from an architect's conceptual plan, but the quantities of structural material required to meet the span and load requirements of the structure can't be accurately estimated on a square foot basis. A licensed design professional competent in the practice of structural engineering must develop those estimates if they are to have any basis in reality.

The material quantities used in the LCA are only half of the necessary data upon which the calculations are to be performed. The other half are the values associated with the inventory of the environmental impacts of the product. Not all product manufacturers and material producers report their environmental impacts using the same scope. Some report cradle-to-producer gate impacts (basically the material production process), some report cradle-to-manufacturer gate impacts (for example, impacts that would include the structural steel fabrication process) while others report cradle-to-building (includes construction and installation), others cradle-through-operation and others still cradle-to-cradle (including deconstruction and recycling/reuse or landfilling). Which is correct? They all are. The challenge is that any whole building LCA must ensure that all comparisons are being performed using data for all materials and products that are consistent with respect to the scope of the inventory of environmental impacts.

Not only do the inventories of environmental impact data need to reflect the same scope—they need to be based on the same methodology of calculating the impacts. Are the future uses of by-products considered? Is credit given for future recycling? How is sequestering of carbon and subsequent release of CO_2 equivalents treated? Is the electric grid viewed from a national or regional grid perspective? Has the data been third party reviewed, published and publicly available?

And what environmental impact categories are being evaluated? Many whole building LCA program requirements list six impact categories: global warming, ozone depletion, acidification, eutrophication, smog potential, and primary energy use. Yet these are not the only six impact categories. As many as 25 impact categories have been identified. A comprehensive whole building LCA should report all of these categories if it is truly attempting to be a multi-attribute evaluation of comparative products. Clearly impacts such as toxicity, resource depletion, land use and water use are critical for inclusion beyond the "big" six.

And which are most important? Which need to show the greatest reductions in impacts? Debatable. Some of these impacts are global in nature (global warming, ozone depletion, human health, land use) while others are more regional (smog potential, eutrophication, water use). Some programs require a 20% reduction in a minimum of three categories one of which must be global warming potential. Other programs look for a 5% improvement in two categories. There is little consistency, not to mention the ridiculousness of attempting to justify a 5% improvement in an impact category when the base data may be off by 20%.

The challenge is that when a product or material substitution occurs, some impact categories show improvement while others show degradation. How much degradation in one category is permissible to justify improvement in another? Should the designer be willing to accept an increase in eutrophication impacts in Los Angeles in exchange for a decrease in smog potential and water use? While a designer in Chicago might be willing to sacrifice water use and smog potential for a decrease in eutrophication? The answer to both questions is probably yes.

This does not mean that whole building life cycle assessments are an unworkable idea that needs to be abandoned. They are complex and expensive to do correctly. Whole building life cycle assessment is a growing specialty field that will develop a pool of qualified practitioners skilled in the LCA process. But until then caution must be exercised in the use of whole building LCAs.

Recommendations for the use of whole building LCAs in today's marketplace include:

- While simplified tools that estimate environmental impacts may be interesting to play with, they should not be relied upon to accurately determine the relative environmental impacts of two alternative building designs
- Any whole building LCA comparison must be based on structural quantities determined by a licensed design professional competent in the practice of structural engineering
- Just as a competent structural engineer should be determining material quantities, a competent professional skilled and experienced in the performance of whole building LCAs should be performing the LCA. The LCA task should not be assigned to a member of the design team unskilled in the use and interpretation of LCAs
- At this point in the evolution of whole building LCAs the comparison of iterative designs using similar products and materials is much more instructive, reliable and worthwhile than attempting to compare buildings with dissimilar materials and products
- Evaluation of building operating energy is best performed outside of the LCA by energy professionals using tools specifically designed for that level of analysis

- Material producers and product manufacturers should be encouraged to publish environmental impact inventories for their products that clearly delineate the scope and methodology used to determine those impacts
- Any comparison of materials, products or combinations of materials and products into assemblies and/or the whole building should only be performed when all products and materials are using consistent scopes and methodologies
- Rather than rely on a cookbook approach to determining the relative importance of increases and decreases in environmental impacts, the design team should evaluate a broad range of impacts in the context of global, regional and local priorities

Whole building LCAs should not be reduced to the pushing of a “smart” button by an individual not trained in the nuances of life cycle assessments. Whole Building LCAs are a valuable tool in improving the environmental performance of buildings, but only if they are based on reliable, consistent data and performed by qualified, experienced professionals.

Designers often focus attention on which structural material should be selected for the framing system of a building. While the selection of the framing material is important and can lead to reduced environmental impacts, the optimization of the use of that material is even more important. Decisions can be made during the design process that can easily reduce the environmental impacts associated with the structural framing system of a building by 20% through the reduction of material in the structure or minimization of fabrication operations. Strategies to minimize the environmental impacts of structural steel at the project level include:

Early Involvement of the Structural Steel Fabricator with the Project Design Team

The inclusion of an experienced structural steel fabricator in design discussions as early as the conceptual phase of the project can provide major benefits in the optimization of the structural system from a material, fabrication, cost and environmental impact perspective. The structural steel fabricator is an expert in steel fabrication and can give direct guidance on how to optimize the structure for greatest efficiency.

St. Vincent Medical Center Heart Pavilion in Toledo, Ohio is an excellent example of the benefits that a project can gain from the early involvement of a fabricator. The project was originally designed under a design-bid-build project delivery model that did not include any fabricator input. The resulting design was over budget. The steel package was valued at $2.8 million dollars for 910 tons of structural steel. The owner transitioned the project to a design-build model that included the steel fabricator as part of the project team. Based on input from the fabricator the steel package was reduced to 772 tons at a cost of $2.35 million with no change to the owner's building program. The global warming impacts associated with the reduction in tonnage moved from 1,056 tons of CO_2 eq to 895 tons of CO_2 eq—a savings of 15%. Additional savings were gained in the simplification of fabrication operations evidenced by a reduction in the per ton cost of the fabricated steel. The process also reduced the project schedule by 16 weeks from 52 weeks to 36 weeks.

Designing to the Maximize the Characteristics of the Material

Architectural designs properly begin with the project program from which a preliminary layout is developed without reference to a structural framing material. However, an architect's prior experience may create an unintended bias in the layout to favor concrete, wood or steel. The result is that the layout may not take full advantage of the engineering characteristics of the material particularly with respect to the selection of bay sizes. In order to minimize the environmental impacts of the structural framing material the design process must not attempt to superimpose a framing material on a building layout, but within reason adjust the building layout to take full advantage of the structural framing material's attributes.

Specifying the Use of Domestic Material

The environmental impacts associated with fabricated structural steel assume that the material is produced and fabricated domestically. Most structural steel originating outside of the United States will not have been produced using the electric arc furnace process but legacy processes lacking the same level of environmental controls present in the United States. The result is two to three times higher levels of environmental impact for each ton of steel that used.

Specification of higher strength material

The tonnage of structural steel required for the project may be reduced by specifying higher strength grades of structural steel that are currently available in the marketplace. Most structural steel projects use grade A992 hot rolled structural sections and A500 hollow structural sections.

Grade A992 became the standard grade for hot rolled sections in 1998 and represented a 40% increase in the strength of structural sections from 36 ksi to 50 ksi. The result was a reduction in the tonnage required for building construction. Today A913 Grade 65 steel (65 ksi) is produced domestically and is particularly appropriate for large columns and belt trusses.

A500 Grade B has been the standard grade for HSS for several decades with a minimum yield stress of 42 ksi for round sections and 46 ksi for square and rectangular sections. A500 Grade C is also available with a minimum yield stress of 46 ksi for round sections and 50 ksi for square and rectangular sections. In 2015 grade A1085 was approved and is becoming more available in the marketplace. A1085 has a minimum yield stress of 50 ksi for all shapes of HSS reducing the tonnage of material required in a typical project.

Coordination with the fabricator and local steel service centers to determine the most common shapes

While the environmental savings related to the selection of member sizes won't be apparent in a project's LCA, the selection of members that are stocked and readily available to fabricators in the project's geographic area will save transportation impacts, the need for special rollings and time in the overall project schedule.

Use of used material

Projects have been constructed in the United States using structural steel reclaimed from deconstructed buildings and industrial facilities. The environmental impacts related to the use of used steel is limited to the fabrication portion of the impacts listed earlier which represent about 12% of the impacts associated with domestically produced and fabricated structural steel. Used sections of a given size are not readily available in the United States from a consolidated source of supply so it is unlikely that all of the steel on a particular project at this time can be sourced from the used market. It is more likely that local scrap dealers or fabricators may be able to identify used or waste steel on the secondary market that would meet a subset of the sections required on the project.

If reclaimed steel is to be refabricated and used in a new structure the material must be tested according to the requirements of Appendix 5 of *The Specification for Structural Steel Buildings* (ANSI/AISC 360-16 – available for free download at www.aisc.org/specifications).

Minimization of material quantities

Other design decisions can significantly impact the environmental impacts associated with the structural steel framing system of a building. The challenge related to many of these design decisions is balancing a reduction in the quantity of structural steel being required for a project (and the corresponding reduction in environmental impacts) and the costs associated with fabrication. Less material does not always equate to less cost as some fabrication operations are more labor intense than other operations. Involving a structural steel fabricator in these discussions is a critical component of a successful design process balancing the competing demands of sustainability, cost and schedule.

The type of bracing system selected impacts both the cost of the project and the amount of material used. Bracing in vertical planes (between lines of columns) provides load paths to transfer horizontal forces to ground level and provide lateral stability. Several types of frames to handle a building's lateral loads can be used including moment frames, chevron bracing, X-bracing and specialty framing systems. Moment frame construction is typically a higher cost approach but will result in less material being used and a reduction in environmental impact.

The entire length of a beam or a column in a building is not subjected to the same level of load. At times a smaller section containing less material can be used if a plate is welded to the beam or column to handle the higher level of stress in a given region of the member. Caution must be taken when using this option even though the reduction in weight will reduce the environmental impacts, the additional welding operations will increase the labor and cost of the member that will needed to be evaluated on a cost-benefit basis.

Floor members can be cambered in anticipation of the deflection that will occur from the dead loads of the floor system. Cambering mechanically or by heating forces a deflection in the beam in the opposite direction of the deflection from the loading. In some cases the weight savings of as much as 25% can be accomplished. Cambering beams of less than 24 feet in length and cambering of less than ½ inch is not recommended.

Composite design where the strength of the floor system supplements the strength of the structural steel frame through the use of shear studs can be used to reduce material quantities.

Materials applied to the structural frame can be reduced through proper identification and specification further reducing the overall environmental impact of a structural steel frame on the building project. Designers often specify that all structural steel must be painted with a primer prior to erection. This is not necessary for members that will be enclosed inside the building envelope unless they will be subject to a corrosive atmosphere generated inside the building.

Recent tests conducted at Underwriter Laboratories and published as UL Design D982 indicate within certain limits the required thickness of fire protection for unrestrained floor assemblies is the same as for restrained floor assemblies. Recognizing this finding in building plans effectively halves the amount of fire protection material required for floor assemblies.

Further Resources

- The AISC Steel Solutions Center provides a wide range of technical information and support services for building teams including information on the sustainable attributes of structural steel. To learn more about structural steel and sustainability, the Steel Solutions Center can be reached at 1.866.ASK.AISC or solutions@aisc.org.

- Environmental Product Declarations for fabricated hot-rolled structural sections, fabricated steel plate and fabricated hollow structural sections can be found at www.aisc.org/epd.

- An annotated graphic of the cradle-to-cradle life cycle of structural steel can be downloaded at www.aisc.org/cradletocradle.

- Articles dealing with structural steel and sustainability as well as case studies of sustainable projects can be found at www.aisc.org/sustainability.

- But the best resource to minimize the environmental impacts for structural steel projects is a local structural steel fabricator who can discuss the optimization of the structural framing system. A list of structural steel fabricators, searchable by location, can be found at www.aisc.org/fabricator.

There's always a solution in steel.

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