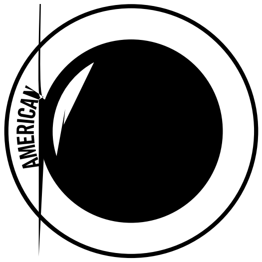

More than Recycled Content:

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 structur

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

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 ded

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.

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

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?

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 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.

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.

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.