And the Winner is...

BY GEOFF WEISENBERGER

A framing system's environmental impact depends on more than just the choice of materials.

WHICH IS MORE ENVIRONMENTALLY FRIENDLY: concrete or steel?

This question is constantly being asked by sustainability-minded professionals in the design and construction world.

The answer is not as simple as counting up LEED credits or comparing sustainable attributes. It is not even as simple as determining which industry generates more greenhouse gasses (concrete) or which material has more embodied carbon per ton (steel).

As I mentioned in last month's Sustainability column ("The Fabrication Factor," July 2010 *MSC*) there is so much more to a material's environmental footprint than its initial production. Each material has its own supply chain and every link in the chain must be considered.

Adding to the complexity of "who's greener?" are two facts. The first is that one ton of concrete in a project is not equal to one ton of steel in a project, and the ratio varies from project to project. So while a ton-to-ton comparison may sound like a good, simple method for determining which material is more environmentally friendly, it really doesn't tell the full story. The second is that every structural steel-framed project contains a significant amount of concrete and every concrete-framed project contains a large amount of steel. So it is impossible to say that in a given project, structural steel's impact is X and concrete's comparable impact is Y.

There isn't—and likely never will be—a perfect way to quantify the life-cycle impacts of one construction material vs. another. However, comparing two similar buildings, framed with different materials, and evaluating the environmental impacts of both framing systems is a good step toward a more definitive answer—and also assists in identifying areas for improvement. And as a matter of fact, AISC has done just that, commissioning structural engineering consultant HDR Engineering and environmental consultant Five Winds International to perform such a study. The firms have recently completed a life-cycle analysis study for quantifying and comparing the environmental impacts of a steel-framed building and a concrete-framed building (for more on LCAs, see the February 2010 *MSC* Sustainability column, "The Whole Enchilada").

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The Study

HDR was commissioned to perform the study on two similar, existing buildings, one concrete and one steel. To get the most accurate results possible, the firm chose two buildings that were similar in use, in the same geographic location, and built within a few years of one another. However, as the projects varied in size, the life-cycle impact results were compared on a square-footage basis.

The two buildings chosen are both medical office buildings in Omaha, Neb. The steel building, the Methodist Women's Hospital Medical Office Building, is 151,910 sq. ft and five stories and is expected to be completed this year. It contains 1,211 tons of steel (this includes structural, rebar, bolts, decking, and studs) and 5,814 cubic yards of concrete in the structural system. The concrete building, the University of Nebraska Medical Center Durham Research Center, was completed in 2006. The eight-story facility is 280,000 sq. ft and contains 1,941 tons of steel and 15,650 cubic yards of concrete. The material take-offs, life-cycle inventory (LCI—a measure of the inputs and outputs of making a product or material) and LCA all were developed from the structural models of these two buildings.

The outputs of the steel production process were based on LCI data obtained from the World Steel Association's (worldsteel) ISO-compliant database of steel industry LCIs and adjusted for U.S. production methods. More comprehensive North American data for structural steel production, which is anticipated to show a lesser level of environmental impact, is currently being collected and the study will be updated with this actual data when it becomes available.

The study focused on the structural systems of both buildings and only included material production, fabrication, construction, and end-of-life deconstruction/landfill burden for the structural system; it did not include use and maintenance, exterior shell, or interior finishes, which were considered to be equivalent in both buildings.

Five Winds used its GaBi 4 LCI database and software to calculate the environmental inputs and outputs. Five environmental categories were measured:

- Global warming potential (kg CO_2 equivalent, the internationally recognized unit of measurement for this

area), which measures the effect of greenhouse gases. Each GHG has its own global warming potential, which indicates its heat-trapping ability relative to that of CO_2.
- Acidification potential (mol H+ equivalent), which measures emissions that cause acidifying effects to the environment.
- Eutrophication potential (kg nitrogen equivalent), which measures excessive nutrient inputs into water and land.
- Smog potential (kg nitrous oxide equivalent), which measures emissions of precursors that contribute to low-level smog.
- Non-renewable energy primary demand (megajoules), which measures the total amount of primary energy associated with a product. (Total primary energy demand was also measured.)

The Results

In all but one category, the structural steel building outperformed the concrete-framed building; the comparisons, expressed as percentages, are as follows:

- Global warming potential: 9% less equivalent CO_2 per sq. ft
- Acidification potential : 8% less mol H+ equivalents per sq. ft
- Eutrophication potential: 9% less kg N equivalent per sq. ft
- Smog potential: 14% less kg NO equivalent per sq. ft
- Non-renewable energy primary demand: 1% more MJ per sq. ft

The only category in which steel lagged concrete was energy demand, and only by one percentage point. The good news for structural steel in this case is that one of the main reasons for the lag—the relatively high amount of electricity used by the steel production process—is an area that can be addressed as the electrical power grid becomes more renewable lowering the non-renewable energy demand. As the grid becomes greener, so will the steelmaking process.

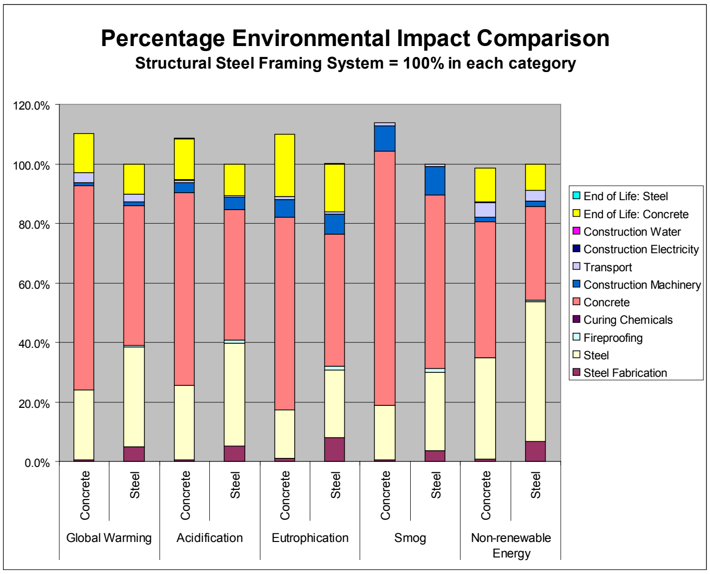
In nearly every category for both the concrete-framed and structural steel-framed buildings, the largest environmental impact on a per-sq.-ft basis resulted from the concrete production process. The steel production process was the second-largest contributor. The fact that this finding is independent of the framing system of the building is a direct consequence of the fact that there is a lot of steel in a concrete building and a lot of concrete in a steel building. By mass, the structural system including foundations for the concrete building was 6% steel and 94% concrete. For the steel building, it was only 10% steel and 90% concrete. The difference in relative masses between the steel and concrete structures was found to be quite small.

It should also be noted that a major environmental impact category, land resource use, was not included in this study because of the current lack of reliable, quantitative data relative to the impact. Land resource use would take into account the use of land and the long-term impacts of the use of land for activities such as quarrying, material extraction, mining, forestry, and manufacturing. As domestic structural steel is a highly recycled material (with an average recycled content of 93%), little if any land use impact results from the production of structural steel relative to other materials.

While the study did conclude that the steel-framed building had a lower environmental impact in four of the five categories, it should be noted that the differences in these categories did not reach a confidence threshold of a 15% difference to conclusively recommend one material over the other. Here's one way to think about it: this was one World Series, and steel won it four games to one—but they were all close games. In addition, keep in mind that no formal or definitive environmental claims can be made based on an LCA study until it is peer-reviewed and goes through the ISO 14040 process (a series of standards geared toward LCAs). It is anticipated that the study will be submitted for peer review once updated North American steel production data is entered into the worldsteel database.

Like any study, the results are only as good as the inputs and analysis. Data quality is judged by its precision, completeness, consistency, and representativeness. To cover these requirements and to ensure reliable results, firsthand industry data in combination with consistent, upstream LCA information from the GaBi 4 LCI database were used. This information has been used in LCA-models worldwide for several years in industrial and scientific applications for internally as well as critically reviewed studies. In the process of providing these datasets they have been cross-checked with other databases and values from industry and science. In other words, even though the results weren't "officially" conclusive per LCA standards, they were based on data and processes that are widely accepted to be accurate.

Data: HDR and Five Winds



The table above shows how 11 different activities and materials contribute to five different measures of environmental impact, for both concrete and steel buildings.

The Takeaway

Does all this mean that this and other LCAs are inconclusive or not beneficial? Hardly. A lot was learned.

Let's go back to the question the beginning of the article. Which material is more environmentally friendly? As the results in each category of the overall LCA are within 10%, and again didn't reach the confidence threshold of 15%, it might seem like a wash. But a better way of looking at these results is this: the choice of a structural framing system should not be made on the basis of the environmental impact of the materials alone. That, in and of itself, should be an extraordinarily beneficial revelation to project designers. It is not just the selection of materials that is important from a sustainable perspective, but also the optimization of design—which includes early involvement of a knowledgeable fabricator—combined with a structural steel framing system and BIM (building information modeling) that can result in a more sustainable project—one that uses material in a more efficient manner, which results in less labor, less cost, and less environmental impact.

As mentioned in last month's sustainability column, the study also revealed that the environmental impact of the fabrication process is 18%–20% of the total environmental impact of the structural steel. Remember that AISC's fabricator survey indicated that variation does exist between fabricators, which in turn indicates the potential for overall improvement in fabricator performance, particularly in the areas of energy consumption and waste reduction. Here's something else to consider: when only fabricators with above-average performance were included in the impact study, the improvement of steel over concrete exceeded the 15% confidence threshold.

Over the coming months and years there will be a growing number of additional LCA studies comparing the environmental impacts of construction materials. These studies will be performed by a variety of organizations and may show differing conclusions. The keys to evaluating any future studies (and this one) are the quality of the inventory data used to model the materials and the basis upon which the comparison is performed. This study provided an independent, comprehensive look at structural steel and concrete framing systems. While it wasn't a "big win" for steel in terms of the numbers, it was a big win for structural steel industry and designers in terms of its revelations. And it's an important step in the structural steel industry's continuing commitment to sustainable construction. **MSC**