Materials Selection in Framing
Is Steel Framing a Good Environmental Choice?

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April 24, 2007

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Introduction

Suppose that in designing a residential home, you have an objective of minimizing environmental impacts. Once decisions are made regarding house size and orientation on the site (both factors that have a significant impact on energy consumption and overall environmental impact over the life of the structure), one of the first issues to be resolved is selection of framing materials. A question that may arise is: Is it more environmentally responsible to use steel framing instead of wood framing?

A potential source of information for answering this question could be one of the Green Building Programs that offer information and guidance for making material choices. Virtually all such programs identify materials containing recycled content as environmentally preferable, and high percentages of post-consumer recycled content are viewed as even more preferable. Wood products that are third party certified as responsibly produced are also given preference in many green building programs.

Assume then, that as an environmentally conscious home builder or home buyer you have identified your framing options as either steel studs that contain more than 10 percent recycled content, or FSC[1] certified lumber. Using the checklists that characterize most green building programs today, and based on the fact that the steel contains recycled content and that the lumber is FSC certified, the two options would appear to be environmentally equivalent. In some green building programs the dilemma is resolved when the recycled content of the steel is above a 10 percent threshold, because then the steel framing is awarded an extra green point. In this case, an environmentally conscious consumer or a builder trying to follow the green building program would be led to select the steel framing – based solely on recycled content.

A bit more investigation, however, reveals substantial environmental differences between steel and wood framing systems. These differences raise serious questions about steel construction as an environmental strategy and challenge the appropriateness of incentives for steel products use that exist in many green building programs. Such differences point to the need for clear, informed thinking in materials selection, and highlight the dangers of using simplistic guidelines to define environmentally preferable products.

Wood or Steel – Essential Considerations

The Importance of Comparing Apples to Apples

In designing for minimal environmental impact and making materials selection it is critical to consider entire building systems. Different material selections will impact other

[1] Forest Stewardship Council, http://www.fsc.org

choices such as insulation needs, wiring plans, and fixture installation. It is rarely possible to simply substitute materials without having to adjust other factors as well.

For example, an exterior wall framed in steel is not thermally equivalent to an exterior wall framed in wood. As steel is about 400 times more conductive than wood, and a steel stud about 10 times more conductive than a wood stud through the depth of the stud, it is necessary to add layers of expanded polystyrene (EPS or XEPS) to the outside of a steel-framed structure to avoid thermal bridging and achieve thermal equivalence to wood framing. Thus, when selecting steel as framing, it is important to recognize that this decision is also a decision to sheath the structure in EPS; this is important, because the environmental impacts of manufacturing EPS are quite substantial.

There is another difference between FSC certified wood and steel products that goes to the heart of environmentally responsible consumption. The buyer of an FSC certified product is assured that the wood was harvested responsibly from a well-managed forest where the FSC standards are being met. Verification of compliance with the FSC standards assures that the local communities and workers are treated fairly, indigenous rights are protected, and areas of high historic and conservation value remain intact. Unfortunately, even though steel is often imported from developing countries much as wood is, a buyer of steel products has no such assurances. The absence of a third-party certification program for steel makes it impossible to accurately contrast the environmental and social impacts of steel versus wood framing.

Energy Impacts of Construction Materials

Implications of Greater Energy Use

Careful consideration of energy use is vitally important when seeking to minimize environmental impact. Energy generation from fossil fuels – far and away the leading source of energy in the U.S. – is linked to a wide array of impacts in extraction and combustion. Carbon dioxide, sulfur dioxide, nitrogen oxide, and methane are but a few of the emissions from fossil fuel combustion.

Embodied Energy Defined

The total quantity of energy consumed in raw material extraction, transportation, and processing through every step in manufacturing from primary to finished products, is referred to as *embodied energy*. It turns out that there are vast differences in energy consumption depending upon the building material or building system selected. Currently, the green building programs used in the U.S. do not make substantial use of embodied energy information when identifying environmentally preferable materials[2].

[2] Only two green building programs, the Green Globes Design and the NAHB Model Green Home Building Guide, both developed in cooperation with the Green Building Initiative, use environmental life cycle assessment data and protocols that include consideration of embodied energy, in identifying lowest impact in building design and materials selection. The LEED program is currently considering incorporation of life cycle assessment methodology in identification of environmentally preferred materials.

Energy and Related Differences Between Wood and Steel Framing Systems

Comparisons of embodied energy in steel and wood framing systems show significant differences. Framing interior non-load bearing walls or partitions using steel studs requires almost exactly ***twice as much energy*** as framing the same walls using wood. For exterior walls, in which the gauge of the steel must be adjusted to resist loads, embodied energy associated with steel framing is ***three to four times*** that of wood. Emissions to air and water are also dramatically different for the two wall framing systems, with effluents and emissions of specific materials and pollutants being between 1.6 and 41 times higher for steel manufacturing than for wood. (Table 1).

Table 1
Comparative Effluents in Manufacturing Steel vs. Wood-Framed Interior Wall[2,3]

Emission/Effluent	Wood Wall	Steel Wall	Difference
CO_2 (kg)	305	965	3.2x
CO (g)	2,450	11,800	4.8x
SO_X (g)	400	3,700	9.3x
NO_X (g)	1,150	1,800	1.6x
Particulates (g)	100	335	3.4x
VOCs (g)	390	1,800	4.6x
Methane (g)	4	45	11.1x
Suspended solids (g)	12,180	495,640	41.0x
Non-ferrous metals (mg)	62	2,532	41.0x
Cyanide (mg)	99	4,051	41.0x
Phenols (mg)	17,715	725,994	41.0x
Ammonia (mg)	1,310	53,665	41.0x
Halogenated organics (mg)	507	20,758	41.0x
Oil and grease (mg)	1,421	58,222	41.0x
Sulfides (mg)	13	507	39.0x

[2] The walls examined here are 3 meters (10 feet) x 30 meters (100 feet), and are framed in non-structural steel studs (galvanized) and wood studs, both of nominal 2 x 4 cross-section.
[3] Source: Meil, J. (1994).

In addition to the differences depicted in Table 1, the production of steel walls requires the use of 23x more water than wood production.

The only characteristic of the construction process that favors steel is in solid waste generated at the jobsite. For the wall described in Table 1, approximately 120 kg (264 pounds) of wood waste is typically generated as compared to 95 kg (209 pounds) of steel waste. Assuming that steel recycling opportunities are commonly available, the waste generated from steel construction can be further minimized.

The numbers shown in Table 1 are for interior, non-load bearing walls. Because of the greater steel cross-section required to resist loads, the embodied energy and emissions associated with exterior, load-bearing wall structures are much higher than for interior walls or partitions. This is also true for steel used for floor or roof assemblies. Thus, impacts related to combustion of fossil fuels for energy production are greatly magnified in exterior walls as compared to interior partitions. Moreover, because the exterior wall defines the thermal envelope, in comparing alternatives it is important to consider thermally equivalent assemblies. As noted earlier, the conductivity of steel requires that insulation be added to the outside of the framing to prevent thermal bridging. This material, typically expanded polystyrene (EPS), has a very high embodied energy, often equal to 50 percent or more of the embodied energy of the steel itself.

When finished structures, that tend to use many common elements for sheathing, siding, and trim, are compared, the magnitude of difference in environmental impacts of framing members is partially hidden. Nonetheless, differences are non-trivial. A recent detailed analysis of typical home construction in Minneapolis, that extensively used environmental life cycle assessment of components, showed significant differences in key environmental measures with steel again having significantly higher impacts than wood in all categories except for solid waste (Table 2).

Table 2
Environmental Performance Indices for Above-Grade Wall Designs and for Floor and Roof Assemblies for a Home Built to Minneapolis Code Standards[4]

Environmental Performance Index	Above-Grade Exterior Walls[5]			Floor[8] and Roof Assemblies		
	Wood[6]	Steel[7]	Diff.	Wood	Steel	Diff.
Embodied Energy (Gj)	250	296	18%	109	182	67%
Global warming potential (kg CO_2)	13,009	17,262	33%	3,763	9,650	157%
Air emission index (index scale)	3,820	4,222	11%	981	1,813	85%
Water emission index (index scale)	3	29	867%	17	70	312%
Solid waste (kg)	3,496	3,181	- 9%	13,766	13,641	-0.9%

4 Source: Perez-Garcia et al. (2005).
5 All walls with $^{7}/_{16}$-inch plywood sheathing and vinyl siding.
6 2 x 6 kiln-dried SPF
7 20-gauge, 2x6, galvanized studs containing average recycled content for steel framing produced in North America.
8 Floor joists are 2x10 for both steel and wood, with the steel of 18-gauge.

Another difference that has substantial influence on the environmental impact of a material is the source of energy used in its manufacture. It has long been the case that the North American steel industry is fueled almost entirely by fossil fuels, namely coal and natural gas. In contrast, the lumber industries of the U.S. and Canada use scraps of bark and what was once waste wood to produce their own energy in large industrial boilers and co-generating equipment. As a result, the lumber industry is 50 to 60 percent energy self-sufficient overall. From an environmental point of view the difference is both significant and important, since energy generation from wood and other biomass is carbon neutral and less polluting than energy generation from fossil fuels. This fuel source difference explains why the global warming potential values shown in Table 2 are much larger than the relative differences in embodied energy at 33% versus 18%, respectively.

Summarizing the Environmental Performance of Steel Framing

Proponents of steel framing often point out that energy consumption for heating, cooling, lighting, and general household operation through the life of a structure is many times greater than energy embodied in the construction materials. Those promoting steel sometimes also argue that because construction differences are relatively small compared to use of operational energy, construction differences become, in effect, insignificant. It is an interesting argument. This argument becomes less convincing, however, when the impact of construction differences are expressed in commonly understood terms. For instance, if from this point forward every new home built in the U.S. that would normally be framed in wood were instead framed in steel, the difference in energy consumption would be roughly equivalent to continuously operating a fleet of 950,000 SUVs, each driving 20,000 miles each year.

There are valid uses for steel framing, such as in large, many-story multifamily structures and in high-hazard termite zones. In these instances, steel's durability as an inorganic material and steel's structural attributes provide important benefits. However, the preponderance of evidence illustrates that it is inappropriate to characterize steel as a environmentally preferable material in instances where wood, and especially PEFC/SFI or FSC certified wood, is available as an alternative.

If the steel industry can develop technologies to significantly reduce embodied energy in their products, address the thermal bridging problem in framing in a manner that uses far less energy than is required today, and develop steel certification programs similar to those used for wood, promotion of their products for use in green buildings will have much greater traction. For now, though, environmental performance of steel building systems appears to be lacking when compared to readily available alternatives.

Tools for Improving Environmental Performance – The Next Level

The use of simplistic guidelines is not a sufficient basis for identifying environmentally preferable materials. Too often, a checklist approach over-simplifies the alternatives and leads to material selections based on single attributes (e.g recycled content) and overlooks the preponderance of evidence that relates to a more complete analysis of the environmental impacts of a given materials.

Fortunately, there is no need to wait for a better system for identifying environmentally preferable building materials. That system exists today in the form of a scientific, life cycle analysis-based, architect and builder-friendly, computer simulation model that can be used to analyze alternative building designs and materials selection. The system – the *Environmental Impact Estimator* (http://www.athenasmi.ca/tools/index.html), was developed by and is available through the Athena Sustainable Materials Institute (http://www.athenasmi.ca/index.html).

In the Athena *Environmental Impact Estimator* preset building assembly dialogues are used to quickly create a conceptual building design. This design is then evaluated using an extensive database of life cycle assessment data. The data takes into account materials manufacturing, including resource extraction and recycled content; related transportation; on-site construction; regional variation in energy use, transportation and other factors; building type and assumed lifespan; maintenance, repair and replacement effects; demolition and disposal, and operating energy emissions and pre-combustion effects. The design is instantaneously assessed, with findings presented in the form of values indicating:

- Embodied primary energy use
- Global warming potential
- Sold waste generation
- Emissions to air
- Emissions to water
- Natural resource use

The system allows the user to change the design and/or substitute materials and to then make side-by-side comparisons for any or all of the measures listed above. Similar projects with different floor areas can also be compared on a unit floor area basis. This tool offers a powerful and consistent way to compare environmental impacts for specific materials and alternative designs. In terms of moving green building analysis to the next level, the future is *now*!

The Bottom Line

Although promoted as an environmentally preferable material, and classified as such in several green building programs, the production and use of steel framing results in a number of adverse environmental impacts that greatly exceed the impacts of available renewable alternatives such as wood. Even when considering steel framing that contains recycled content as high as 35 percent, considerable energy is consumed in the production process and places steel products near the top of any embodied energy ranking of construction materials. The high conductivity of steel and associated need for energy-intensive insulation adds to the environmental burden of steel-framed structures. Finally, high energy intensity and manufacturing processes unique to steel translate to very high levels of emissions to air and water and global warming potentials. The bottom line of this analysis is that it is rarely appropriate to characterize steel as the more environmentally benign material when compared to wood. Additionally, the take home message is that evaluating the impacts of a material and comparing alternatives needs to be a thoughtful and holistic process that does not rely on individual attributes. The use of existing and readily available life cycle assessment data offers the opportunity to efficiently accomplish this more thoughtful analysis.

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This Dovetail Report is made possible through the generous support of the Surdna Foundation and additional individual donors.

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