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A Comparison Between Steel and Wood Residential Framing Systems

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A cost comparison study between wood and steel for residential framing in Florida was performed to show the cost effectiveness of each material. Advantages and disadvantages of steel and wood were reviewed as well as their sustainability from a life-cycle perspective. It was found that at the present time wood and steel walls were approximately similar in cost while the use of steel for roof framing is not cost competitive with conventional wood. Using steel for interior framing and wood for the exterior would be advisable at this time.

Key words: Residential Framing, Cost Comparison, Sustainability, Steel, Wood

Introduction

Wood frame construction has been the unchallenged norm for residential building for a very long time because of its satisfactory performance, availability, and relatively low cost. However, over the past few years, volatile wood prices, declining quality of framing lumber and environmental issues have raised serious concerns regarding the use of wood as a favorable option to residential construction.

The sharp fluctuations in the lumber prices is evident from the fact that the framing lumber composite price between October 1992 and February 1993 increased by nearly 100 percent, while the average weekly change in the framing lumber composite price varied in the year 1993, between $10 and $15 per 1,000 board feet, or about three times the rate of change experienced throughout the 1980s. The direct effect of the erratic cost of wood on the cost of a house is seen in Table 1. It shows how the framing lumber and structural panel costs increase with the lumber composite price. Due to such fluctuations in lumber costs, the need for assessing the alternatives to wood-frame construction becomes essential.

The need for alternative materials and methods for residential construction is intensely felt in Florida, particularly since concerns over termite and decay problems and high-speed winds discourage interests in wood framing. Recently, steel has emerged as a viable alternative to wood as it offers durable and hurricane resistant construction. With the various alternative systems available, steel framing has gained prominence primarily because it offers price stability and a simple piece-by-piece substitution for wood. This has enabled the builders to adjust to the new material without worrying about learning a whole different approach to framing. The hurricane resistant quality of a steel house has increased interest in steel amongst Floridians. However, it is not clear how the application of such alternative material compares with wood.

Table 1

Cost of Lumber in 2,000 Square Foot Home

Cost Per 1,000 Board Feet	Framing Lumber	Structural Panel	Lumber Costs Per House
$200	$3,488	$1,394	$4,882
300	5,232	2,091	7,323
400	6,976	2,788	9,764
500	8,720	3,486	12,206
600	10,464	4,183	14,647
700	12,208	4,880	17,088

Source: Nation's Building News, February 14, 1994.

This paper reports to result of a comparison study between wood and steel for residential framing. It includes a comparison of practical feasibility and in-place labor and material requirements of wood and steel framing for residential construction. By evaluating the two materials in terms of feasibility, quality and costs, the objective is to stimulate homeowners to investigate the material option more thoroughly.

Literature Review

A comparative study of in-place costs of wood and steel framing was performed by the Forest Products Laboratory for the U.S. Department of Agriculture in 1979. Primarily, the study investigated the residential market shares of wood and steel framing and then compared the in-placed costs of the two framing systems by dividing it into three major categories – flooring systems, load-bearing wall systems, and non-load-bearing partitions. These systems were analyzed in terms of material requirement, material costs, labor requirement and labor costs to calculate the total in-place costs for the two framing systems. The study concluded that both wood and steel flooring and load-bearing walls were approximately similar in cost while steel non-load-bearing partitions continued to enjoy a large price advantage.

An analysis of the sustainability of steel versus wood from a life-cycle perspective was conducted by Scientific Certification Systems, they evaluated the environmental burdens of the two systems. These burdens include the use of resources, energy consumed and pollution generated over each stage of a material's life cycle. By assessing the comparative severity of these environmental burdens, the relative degree of sustainability of the two materials to perform the same function is assessed. The study concludes that in the use of steel versus wood framing in residential construction in the U.S., steel appears to have clear advantages in the resource depletion and ecosystem depletion areas, while differences in energy use between wood and steel are insignificant.

Another study conducted by the Environmental Building News in 1994, again investigates steel and wood framing systems from a sustainability point of view. The study evaluates the two systems in terms of thermal performance, resource extraction and manufacturing process, and the advantages and disadvantages the two systems offer. The study concludes that the thermal performance of steel still remains to be resolved in a more environmentally favorable way. Also, substituting steel in conventional wood framing pattern is under-utilization of steel strength. On the other hand, the main area of concern for wood remains to be ecosystem depletion.

A study conducted by National Association of Home Builders (NAHB) in 1994, focuses in finding alternatives framing materials to wood framing system due to high fluctuations in lumber prices. It includes an evaluation of the alternatives' practical feasibility and in-place labor and material requirements as compared to wood framing in comparable homes. In-place costs of the three alternative framing materials – foam-corestructural sandwich panels, light-gauge steel framing, and welded-wire sandwich panels – were determined and compared with conventional wood framing.

Results indicate that certain aspects of light-gauge steel are within the range that might be expected to be cost-effective with wood. The other alternatives, while offering structural advantages, presently do not appear to be cost competitive with wood.

Methodology

House Selection

A typical residential floor plan that represents the plans currently used in Florida is selected for the house to be used in this study. Two sets of survey data have been used in selection of the construction characteristics of this dwelling unit. They are:

1. The 1987-19993 Residential Data Summary developed by the Shimberg Center for Affordable Housing, and
2. Assessment of Damage to Single-Family Houses Caused by Hurricane Andrew developed by NAHB Research Center.

Table 2 and 3 show the summary characteristics of the houses in Florida according to aforementioned surveys. From Table 2, it is evident that, the average size of a house in Florida, ranges between 1400 SF to 1700 SF (24.1%), and incorporates 3-bedroom (60.4%). It is gathered from Table 3., that the other prominent characteristics include construction typically involving a single story structure (80%), and preferably with a gable roof (81%). Therefore, a feasible selection of a 1500 square foot, 3-bedroom, one-story gable house with slab-on-grade foundation is made.

Figure 1 shows the typical ground floor plan of the house chosen for the study. The study home measures 1470 square feet. All framing elements of the wood-framing house are designed to be fabricated in Southern Pine, Grade 2 lumber. While, all framing elements in steel house are designed to be fabricated in light-gauge steel. Wall studs in each case are spaced at 24 inches on center with load-bearing studs located directly in-line with pre-engineered roof trusses.

Table 2

Percent Application Preference for Intent Test

Interval Number	Time Interval	Case Count For Interval	Test Applied	% Test Applied	Test Not Applied	% Test Not Applied
1	1858-1867	1	0	0	1	100.0
2	1868-1877	1	0	0	1	100.0
3	1878-1887	3	2	67.0	1	33.0
4	1888-1897	11	9	81.0	2	18.0
5	1898-1907	22	10	45.0	12	48.0
6	1908-1917	25	13	52.0	12	48.0
7	1918-1927	7	3	43.0	4	57.0
8	1928-1937	4	3	75.0	1	25.0
9	1938-1947	8	3	38.0	5	62.0
10	1948-1957	10	7	70.0	3	30.0
11	1958-1967	12	4	33.0	8	67.0
12	1968-1977	20	4	20.0	16	80.0
13	1978-1987	33	9	27.0	24	73.0
14	1988-1991	18	3	17.0	15	83.0
	TOTALS	175	70	40.0	105	60.0

Table 3

Summary Description of Houses Surveyed in Florida

Home Characteristics	Area in SF	Percentages
	1	80
Number of Stories	1-1/2	2
	2	18
Roof Type	Gable	81
	Hip	13
	Comp. Shingle	40
Roofing Materials	Built-Up	8
	Flat Tile	15
	Clay Tile	3
Roof Sheathing Mat.	Plywood	89
	OSD	6
Wall Type	Block	96
	Wood	4
Foundation Type	Slab	100

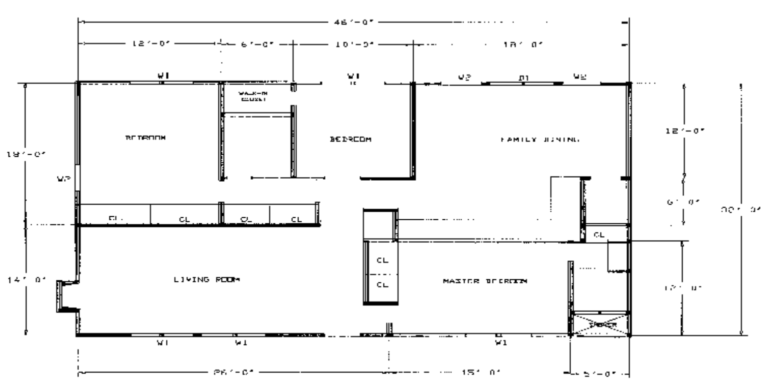

Figure 1. Typical House Plan for Study

The steel and the wood houses are generated using the typical study plan. The steel house is designed as the traditional stick construction, similar to the wooden counterpart, whereby there is one-for-one substitution of steel for wood. Both the houses are designed to withstand high velocity winds (110 mph), addressing the factor of destruction caused by the hurricane in the region of Florida.

The steel framing is designed in accordance with the "Minimum Design Load for Building and other Structure" provided by the American Society of Civil Engineers in ANSI/ASCE 7-93. Figure 2 shows the typical section through the steel-framed house. There is a roof overhang of 2-feet, with the slope of roof being 5 in 12. The shear walls represent the two adjacent exterior and interior plywood sheathing.

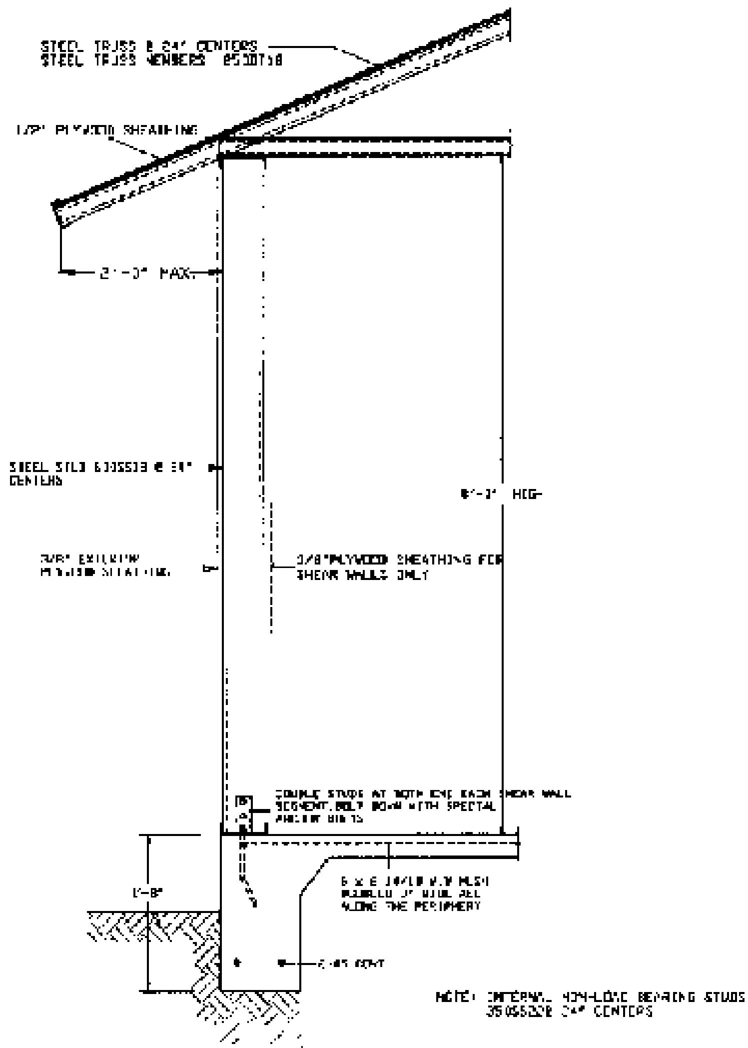

Figure 2. Typical Section through Steel Frame House

The design of a hurricane-resistant wood house is adopted from the details provided by John E. Meeks, P.A. Consulting Engineer through the Shimberg Center for Affordable Housing.

However, the appropriateness of the sections utilized for the wood stud walls and pre-engineered trusses to withstand winds with 110 mph velocity were checked. Figure 3. Shows the typical section of the wood-framed house.

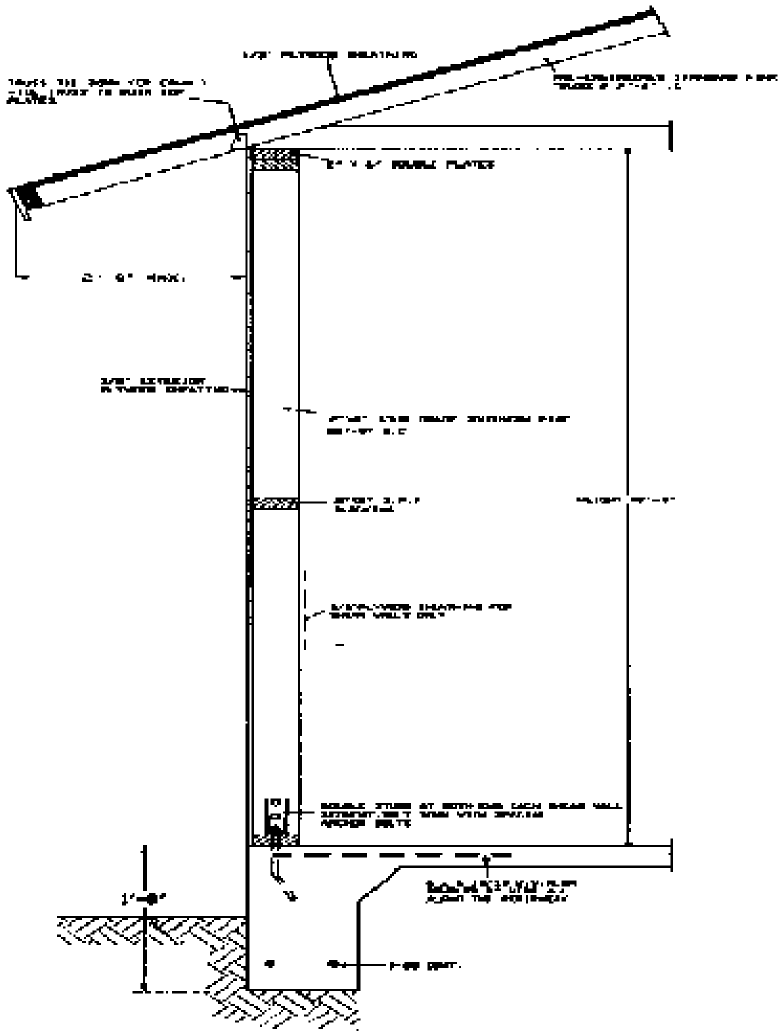

Figure 3. Typical Section through Wood Frame House

Common framing elements for steel and wood framed house involve:

1. Two adjacent external walls representing shear walls, incorporating 3/8" plywood sheathing on the interior face,
2. External wall sheathing consisting of 3/8" thick plywood,
3. Roof sheathing consisting of ½" thick plywood.

The finishes for the two houses are not considered in the study primarily because it will not affect the cost if they are similar. Moreover, only elements that affect the cost are considered.

Steel vs. Wood Cost Comparison

The cost of construction is calculated for both wood and steel framing systems. The cost includes, both, the cost of materials and the cost of labor. The cost of material is determined directly from the local lumber suppliers and steel manufacturers, while the cost of labor is calculated using 1995 Means Cost Data for Residential Construction. The material cost of the wood frame house is summarized in Table 4, and that of steel in Table 5.

Table 4

Wood Framing – Material Cost

Classification	Quantity	Unit	Cost/Unit $	Total Cost $	Comments
2x6 Section #2 Pine, 8 ft.	196	EA	3.79	743	Load bearing walls
2x4 Section #2 Pine, 8 ft.	216	EA	2.19	473	Non-load bearing walls
2x12 Section #2 Pine, 12 ft.	12	EA	17.79	213	Headers
32 ft Span fink truss	24	EA	55.00	1320	Prefabricated truss
2x4 Roof blocking, 2' long	29	EA	0.55	16	
3/8" CDX plywood	68	Sheet	12.39	843	Wall sheathing
½" CDX plywood	58	Sheet	14.09	817	Roof sheathing
Nails				200	
Misc. Hardware				250	
Subtotal				4875	
Sales Tax @ 6%				293	
Total Material Cost				5168	

Table 5

Steel Framing – Material Cost

Classification	Quantity	Unit	Cost/Unit $	Total Cost $	Comments
600SS18 Stud (Exterior)	936	LF	0.673	630	Load bearing walls
600SS18 Exterior Track	345	LF	0.673	232	
600SS18 Headers	90	LF	0.673	61	
350SS22 (Interior)	875	LF	0.326	285	Non-load bearing walls
350SS22 Interior Track	385	LF	0.326	126	
250DT18 for Trusses	24	EA	80.00	1920	On-site fabricated truss
3/8" CDX Plywood	68	Sheet	12.39	843	Wall Sheathing
½' CDX Plywood	58	Sheet	14.09	817	Rood Sheathing
Screws and hardware				600	
Subtotal				5514	
Sales Tax @ 6%				331	
Total Material Cost				5845	

The two houses are compared in terms of wall and roof framing including:

1. Wall Framing (External and Internal): Bottom plate, studs, top plate, header, internal shear-wall sheathing, external sheathing, and blocking.
2. Roof Framing: Pre-engineered wood trusses, on-site fabricated steel trusses, blocking between trusses, and roof sheathing.

As seen from Table 4 and 5, material cost for the steel house is about 12% higher than the lumber houses. However, as compared to the relatively stable price of steel, the constant fluctuations in lumbar prices may leave only a little edge for wood to be more cost effective in term of material cost.

Table 6 compares light gauge steel walls to conventional wood-framed walls and summarizes the unit costs for materials, labor, and equipment. Values are expressed in dollars per linear foot of an 8-foot high wall. The material costs for light-gauge steel walls are 3.5% less than for wood walls. This table reflects the price of lumber during May 1995. When comparing unit costs for new construction, an estimate reflecting the current costs will have to be made.

Table 6

Wall Framing Unit Costs

Wall Framing Unit Costs
Light Gauge Steel vs. Conventional Wood

	Material Costs $/LF*	Labor Costs $/LF	Equip. Costs $/LF	Total Costs $/LF
Light Gauge Steel Framing	7.93	4.66	0.29	12.88
Wood Framing	7.99	4.15	0.26	12.40

*External and internal walls plus external sheathing and internal sheathing at shear walls only.

Table 7 compares roof framing unit costs for the light-gauge steel and wood-framed houses. Values are expressed in dollars per square foot of the roof area. In the roof analysis, sheathing was included with the trusses.

Table 7

Roof Framing Unit Costs

Roof-Framing Unit Costs
Light Gauge Steel vs. Conventional Wood

	Material Costs $/SF of Roof	Labor Costs $/SF of Roof	Equip. Costs $/SF of Roof	Total Costs $/SF of Roof
Light Gauge Steel Roofing	1.79	0.86	0.15	2.80
Wood Roofing	1.43	0.67	0.18	2.28

Factors that contribute to a higher unit rate for light-gauge steel typically include more time spent on fastening together of the pieces. This is because screws simply take more time to install than nails. However, the new pneumatic fasteners and other products being developed will help bring the labor costs down.

Advantages and Disadvantages

The comparison between steel and wood is incomplete without understanding the inherent advantages and disadvantages offered by the two systems, since it immensely influences the choice between the two materials. The concerns of both, the homeowner and the builder, with respect to the two materials are addressed and appraised here.

A finished steel house does not look any different than a finished wood house. With this in mind, an impartial evaluation is made. Table 8, provides a comparison at a glance, between steel and wood, investigating matters of paramount importance to an owner. Amongst these, the consideration for insect resistance, hurricane and earthquake performance, and fire performance directly affect the homeowner's insurance rates. Factors like initial construction cost of the house, as well as the future maintenance cost, influence the choice of material. Understanding the pros and cons of the material will assist in making a wise investment, based on a correct judgment.

Table 8

Comparison Between Steel and Wood at a Glance

Issue of Concern	Steel	Wood
Dimensional Property and stability	Consistent quality, exact dimensions. Steel does not rot, shrink or warp	Inconsistent quality. Wood shrinks, warps which causes movement
Price	Volatile wood prices make steel more predictable. Steel is competitively priced and prices are stable.	Erratic price and quality. Low material costs (at times).
Indoor air quality	Steel is inert, wood releases terpene and treated wood contains toxins.	Untreated wood causes no problem to people.
Thermal efficiency	Steel's thermal performance is poor, but can be resolved by adding exterior insulation or other modification.	Wood is naturally low in conductivity. It insulates well.
Insect resistance	Steel is not attractive to insects.	Wood attracts termites. Preservative-treated wood is safe and effective.
Recycling or Disposal	Steel is recyclable. Magnetically separated easily.	Treated wood is not biodegradable. Non-treated wood is biodegradable. Wood may be salvaged and reused.
Hurricane and Earthquake Performance	Steel can be engineered to sustain high speed wind and seismic loads. Lighter weight of structure reduces damage.	Wood can also be designed to take greater loads, but it makes the structure very heavy.
Fire Performance	Steel does not burn. However, steel losses its strength at high temperatures.	Wood is easily combustible.
Building Codes	Steel framing codes are not standardized.	Wood codes are well established.
Construction Waste	Members are available in a variety of pre-cut, custom and standard shapes and sizes, minimizing construction waste.	The wastage of wood ranges from about 10-20% as compared to steel which is about 1-3%, which can be sold as scrap and recycled.

Environmental Impact and Sustainability Issues

Every form of development has an environmental impact. All basic materials have finite reserves and their extraction result in the release of pollutants into air and water. Energy is also needed to process the materials into useful products. However, by assessing the comparative severity of these environmental burdens, it is possible to obtain important insights into the relative degree of sustainability of various material options used to perform the same function.

Wood is renewable, but that does not mean it is automatically more sustainable than steel. While it is possible to replant trees after cutting, there is no guarantee that replanted trees will grow to the same size or the same quality, or that trees can be continuously re-grown on the same land base. Thus, while it is a fact that trees can be renewed to some degree after a given harvest, such processes would have to be repeatable indefinitely to claim full sustainability.

On the other hand, all steel products can be recycled without degradation or loss of properties. The steel industry has invested a lot of money in environmental and efficiency improvements in the last decade. Energy use and pollution are now way down. However, in spite of improvements, environmental impacts are still significant.

To assess the sustainability as well as the environmental impacts caused by these two materials, it is essential to evaluate these two materials against several environmentally sensitive issues.

From a life-cycle perspective, the measurable factors that characterize the sustainability of a resource include:

- the rate of *resource depletion*
- *extended material use* or recycling
- the direct *energy* required in manufacturing
- *Resource Depletion: Wood vs. Steel*

Wood

It has been estimated that each year, more than 40 million acres of forestlands are lost forever worldwide. Drought and forest fires have totally destroyed several million acres of forest in the U.S. alone resulting in no wood resources and no ecosystems left at all.

Aside from these natural events, the U.S. government has negotiated by mandating that 12 million acres be to be locked up as critical habitat for the spotted owl. Even more discouraging for the wood industry is that fact that, 88% of all national forests in the U.S. not set aside by law are tied up in federal court by environmentalists who wish to make these areas unavailable for timber extraction.

All combined, these factors have substantially reduced the total reserve base of the entire western region of the U.S. resulting in a drop of 29% of the production of lumber. Western softwood lumber production has fallen from nearly 24 billion board feet in the later 1980’s to the current production level of 17 billion board feet, and is expected to fall even further in the future.

Currently, the wood that is being extracted is from smaller diameter trees, about 7-inch diameter logs as compared to the 40-inch diameter trees that were harvested 50 years ago. The small diameter trees contain a significant percentage of sapwood requiring more kiln drying, and which yields a greater percentage of low grades of lumber, as compared to the greater diameter lumber which was dry, structurally sound, without knots, and with exceedingly good yields. Also, log-diameter affects the rate of utilization because for a given quantity of lumber, more smaller diameter trees will be required as compared to a fewer bigger diameter trees. Thus, more trees will have to be harvested in case of smaller diameter trees removing a higher proportion of forest cover.

Steel

All raw materials used in manufacturing steel are in plentiful supply. Iron is one of the most abundant minerals on earth. Iron is one of the most abundant minerals on earth. Its reserves are stable and do not face hazards of fire, drought or disease like wood.

Mining practices have improved dramatically, and also, much new steel is recycled from scrap. Furthermore, products made from high-strength steel require significantly less steel per product than regular steel to perform the same function. For example, it takes 380 pounds less steel per car than it did just five years ago.

It is estimated that the amount of steel that would be required to build every new residential house in the U.S. over one year would be around 8 million tons, compared to the total annual output of 88 million tons. Therefore, the need of the residential market can be met without constructing new steel mills or adding capacity to existing mills. However, the raw materials used to make steel include iron ore, limestone, coal and zinc, all of which are non-renewable substances mined from the earth.

Extended Material Use or Recycling

Wood

In the U.S., wood used in residential construction has not found any widespread secondary use. Although, it could be possibly used in engineered wood products, the diminishing grades of wood reduce this extended use critically. This drop in grade is primarily due to the harvesting of much younger trees and the reliance on sapwood rather than dry heartwood. Wood is biodegradable, but most residential wood is treated with toxins and will be required to be handled as hazardous waste.

Steel

Steel has a proven track record of material extension through recycling. In fact, for a given amount of iron ore extracted and used, the steel produced can be continuously reclaimed and recycled without significant losses or degradation. This makes steel much closer to being a sustainable resource than wood. Magnetic separation makes steel the easiest and most economical material to remove from the solid waste stream and contamination is not an issue.

Direct Energy Requirement in Manufacturing

Wood

The manufacture of wood products requires much less process-energy input than steel. Most of the energy in wood is stored solar energy produced by photosynthesis. As the wood grows, it converts carbon dioxide to oxygen, during the process of photosynthesis, storing the carbon even in its manufactured state. The use of wood results in much lower CO_2 emissions than other materials because of the low amount of fossil-fuel energy used in the manufacture of wood materials.

Engineered wood products are provided viable alternatives to solid lumber for some applications. By using fast-growing and underutilized species, they avoid many of the forestry concerns of solid wood products, and they tend to be more stable and uniform in quality then new lumber. However, the manufacturing processes for these products have environmental drawbacks such as increased processing energy and use of fossil-fuel-derived binders. Also, engineered products are still too expensive to replace most lumber in a standard house.

Steel

Steel is one of the most energy intensive industrial materials, generating pollution and waste from all stages of the process, including coking coal, purifying iron, and galvanizing. The process of smelting does galvanization of steel. Wastewaters from zinc smelting facilities can contain a number of heavy metals including cadmium, toxic organic and chlorinated compounds.

The steel industry in the U.S. has made tremendous strides in improving its environmental performance over the past two decades. According to data from Scientific Certification Systems (SCS), since the early 1980s CO_2 emissions have dropped by more than 28%, and SO_2 emissions, responsible for acid rain by 95%.

Conclusions

The rapid escalation of lumber cost over the past few years has increased the cost of wood framing and improved the prospect for steel in the residential market. The results of this study showed that at the present time wood and steel walls are approximately similar in cost while use of steel for roof framing is not cost competitive with conventional wood. A factor that contributes to a higher unit labor cost for steel is the time spent on fastening together of the pieces. This is because screws simply take more time to install than nails.

Steel is over 400 times more conductive of heat than wood, thus wherever steel spans from the inside to the outside of the building envelope, it causes severe thermal bridging. In areas with significant heating or cooling loads, using steel for interior framing and wood for the exterior would be advisable. Steel-framed houses tend to be over designed due to simple wood-to-steel conversions, switching stick-to-stick, rather than truly designed to take advantage of its greater strength and uniformity. Steel should be used in a system that requires for fewer framing members, spaced farther apart.

On the issue of sustainability, steel appears to have clear advantages in the resource depletion, while differences in energy use between wood and steel are insignificant if design modifications due to steel's high strength are included in life cycle calculations.

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