Big Box Retail: Wood Saves Nearly $1 Million

Cost and environmental studies compare wood to steel

While many U.S. apartments are wood-frame, wood structure is far less common in stores and restaurants—even though it's permitted by code in numerous applications—and its use in the sub-category known as 'big box' retail is infrequent at best. To evaluate the opportunity, WoodWorks commissioned two studies, one cost comparison and one life cycle assessment (LCA), on the same big box project designed in steel vs. wood. This report summarizes the results of those studies and highlights opportunities for greater wood use in this segment of the construction market.

Among developers, architects and engineers, cost tends to be cited as the number one reason to specify wood as a structural material. For multi-unit residential buildings, for example, design teams often say that wood-frame construction allows them to achieve greater density at less cost, while meeting performance goals and allowing more budget for amenities. More recently, environmental considerations such as wood's relatively light carbon footprint have been getting a greater share of the attention, with some governments going so far as to call for the use of wood as a low-carbon alternative to other materials.[i]

In addition to the study highlights, this paper includes options for achieving the design requirements of big box stores (see page 8). These requirements include:

- Large, open floor plan with tall ceilings
- Minimal structure
- Interior space flexibility
- Adaptability—i.e., the ability to adapt to future needs through redesign

Although these requirements are often met with systems that include structural steel columns, open web joists and joist girders, and steel roof decking, they can also be achieved with wood framing—likely at less cost and with less impact on the environment.

Wood Design Outperforms Steel

COST

Nearly $1 million savings (22%), primarily:

- Structure cost savings – $425k
- Roof insulation savings – $400k

ENVIRONMENT

Better than steel in 5 out of 6 impact categories:

- Global warming potential
- Acidification Potential
- Eutrophication potential
- Smog potential
- Non-renewable energy use

Project Scope

Having received the drawings for a one-story, 54,800-sf steel-frame big box retail store in California (reference building), WoodWorks commissioned Parker Structural Engineering to design a comparable building using wood materials (proposed building). Both buildings are designed according to the 2010 *California Building Code* which is based on the *International Building Code* model code.

The two designs share the same geometry, structural layout, and column grid, including:

- Rectilinear building footprint
- Sloping roof deck on joists supported by a system of beams and perimeter load bearing walls ±23'-8" in height
- System of columns which support the beams, spaced at 30' – 45' by 30' – 64'
- Spread footings supporting the columns and strip footings supporting the perimeter walls
- A 400-sf equipment platform, slab-on-grade construction and no basement level

The buildings have the same gross floor area, floor plan and layout, functions, location, orientation and operating energy performance. For the LCA study, equivalent energy performance was established by proxy in lieu of performing an energy simulation for each building design. This was done by maintaining the same window-to-wall ratio and designing the proposed building envelope to be thermally equivalent to the reference building envelope. Table 1 provides a summary of the two designs.

WoodWorks then provided both sets of drawings to two firms. SSA Quantity Surveyors was asked to undertake a detailed cost comparison of the reference and proposed structures. Coldstream Consulting, a firm specializing in LCA of buildings, was asked to undertake a cradle-to-grave analysis of the material effects of structure, envelope and interior partition assemblies. Sixty years was selected for the service life because it is commonly used in North American LCA studies and is the minimum requirement for the LEED v.4 whole-building LCA credit.

TABLE 1
Building Design Summary

<table>
<tr><th>ELEMENT</th><th>REFERENCE STEEL DESIGN</th><th>PROPOSED WOOD DESIGN</th></tr>
<tr><td rowspan="2">Foundations</td><td>• Spread footings: 3'x3'x2', 5'x5'x2', 6'x6'x3', 7'x7'x3' reinforced concrete
• Typical strip footing: 2'x2' reinforced concrete</td><td>• Spread footings: 2'x2'x2', 3'x3'x2', 4'x4'x2', 5'x5'x2', 6'x6'x3' reinforced concrete
• Typical strip footing: 1'-9"x2' reinforced concrete</td></tr>
<tr><td colspan="2">• Other strip footings: 2'-deep reinforced concrete (width varies)</td></tr>
<tr><td>Slab-on-grade</td><td colspan="2">• Sub-base: 7" crushed rock
• Typical slab-on-grade: 5" reinforced concrete, 15 mil vapor retarder
• Slab-on-grade at freezer/cooler: 4" reinforced concrete, 15 mil vapor retarder, 6" extruded polystyrene insulation, 5½" reinforced concrete
• Slab-on-grade at exterior truck ramp: 7" reinforced concrete, 15 mil vapor retarder</td></tr>
<tr><td rowspan="2">Floor construction</td><td>• 12"-deep light-gauge steel joists
• Structural steel beam</td><td>• 2x12 sawn lumber joists
• Glulam beam</td></tr>
<tr><td colspan="2">• ¾" plywood sheathing</td></tr>
<tr><td rowspan="2">Roof construction</td><td>• 1½" 18-gauge metal deck
• 18"–40"-deep open web steel joists @ ± 8'-6" o.c.
• 6"–8"-deep @16" o.c. light-gauge steel joists
• 36"–54"-deep girder trusses
• Misc. structural steel beams (W, C, MC, HSS shapes)
• 4"–9"-deep HSS columns</td><td>• 15/32" OSB sheathing
• 24"–54"-deep prefabricated wood trusses @24" o.c.
• 2x6, 2x8 @16" o.c. sawn lumber joists
• 13½"–36"-deep glulam beams
• Misc. wood beams (solid sawn lumber, glulam)
• 6x–14x-deep solid sawn lumber columns</td></tr>
<tr><td colspan="2">• Aluminum mesh, structural steel-framed canopies
• 1½" 18-gauge metal deck, HSS-framed entry towers</td></tr>
<tr><td rowspan="2">Exterior walls</td><td>• Walls supporting cladding: 6"-deep @16" o.c. light-gauge steel stud wall
• Structural walls: 8" reinforced concrete masonry unit wall, 6"-deep @16" o.c. light-gauge steel wall at north elevation
• Insulation: R-11 fiberglass batt (3½" thick) where noted on plans
• Interior: 6"-deep @16" o.c. light-gauge steel, 5/8" gypsum board where noted on plans</td><td>• Walls supporting cladding: 2x6 @16" o.c. sawn lumber stud wall
• Structural walls: 2x10 @16" o.c. sawn lumber stud wall (2-2x10 at wall sheathing edges) with 15/32" plywood sheathing, 8" reinforced concrete masonry unit wall at loading dock below slab-on-grade
• Insulation: R-13 fiberglass batt (3½" thick) where noted on plans
• Interior: 5/8" Type X gypsum board
• Solid sawn lumber lintels
• Holdowns</td></tr>
<tr><td colspan="2">• Cladding: 7/8" exterior cement plaster, thin brick veneer, slate tie veneer, ipe wood paneling</td></tr>
<tr><td>Lateral force-resisting systems</td><td>• Horizontal system: 1½" 18-gauge metal deck diaphragm
• Vertical system: 8" reinforced concrete masonry unit shear walls</td><td>• Horizontal system: 15/32" OSB sheathing diaphragm
• Vertical system: 2x10 sawn lumber shear walls with 15/32" plywood sheathing</td></tr>
<tr><td>Exterior windows</td><td colspan="2">• 1" insulated glazing with aluminum frames</td></tr>
<tr><td>Exterior doors</td><td colspan="2">• Insulated sectional overhead
• Hollow steel
• Automatic sliding entry</td></tr>
<tr><td rowspan="2">Roof coverings</td><td colspan="2">• 60 mil thermoplastic polyolefin (TPO) membrane, tapered extruded polystyrene insulation, ½" cover board, vapor retarder, ½" protection board</td></tr>
<tr><td>• R-22 extruded polystyrene insulation (4½" thick)</td><td>• R-22 fiberglass batt insulation (5½" thick, within roof trusses)
• Resilient channels, 5/8" Type X gypsum board</td></tr>
<tr><td rowspan="2">Partitions</td><td>• 3 5/8", 6"-deep @16" o.c. light-gauge steel stud walls</td><td>• 2x4, 2x6 @16" o.c. sawn lumber stud walls</td></tr>
<tr><td colspan="2">• 5/8" gypsum board each side
• R-11 fiberglass batt acoustic insulation where noted on plans</td></tr>
<tr><td>Interior doors</td><td colspan="2">• Solid core birch veneer
• Polyethylene clad
• Wood with glass</td></tr>
</table>

FIGURE 1

Total Building Cost Comparison

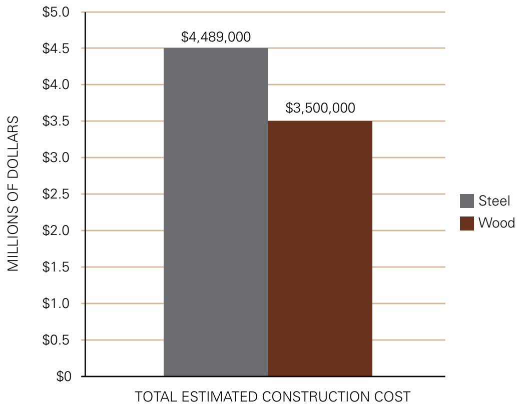


FIGURE 2

Total Cost Savings of Wood Building over Steel Building

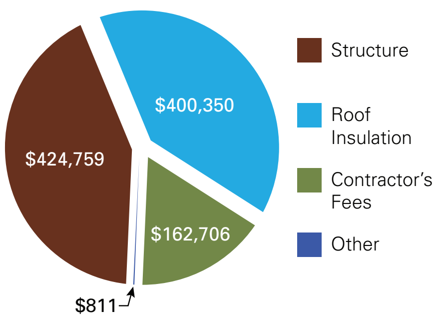
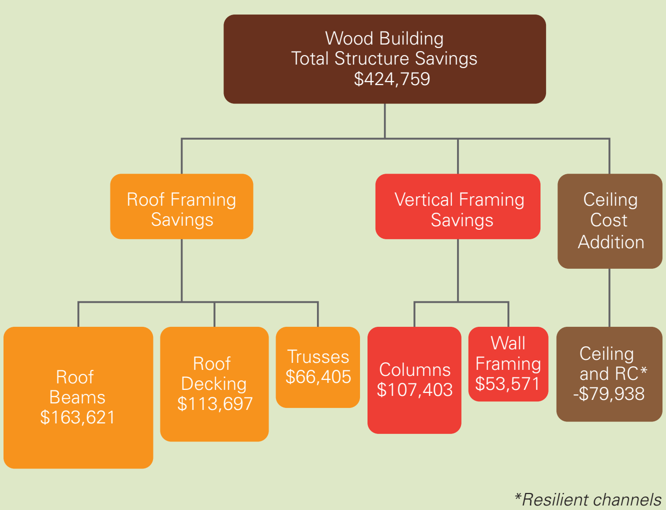


FIGURE 3

Structure Cost Savings of Wood Building over Steel Building



Cost Comparison: Wood vs. Steel

According to the comparison, the reference steel building design was estimated to cost $4,488,597, while the proposed wood building design was estimated to cost $3,499,971, resulting in a total cost savings of $988,626 for the wood design. The total building cost difference, equal to a 22% savings or $18 per square foot savings for the wood building, is illustrated in Figure 1.

Hard costs associated with each building were limited primarily to structure and envelope. Stairs and elevators, interior finishes, fittings and equipment, electrical and mechanical were noted but not assigned values.

The largest cost savings were associated with the structure and roof insulation. The structure category included items such as roof framing (beams, trusses and decking) and vertical framing (columns and wall framing). A large number of items such as the slab-on-grade, roofing, wall finishes, and exterior windows and doors were identical for both buildings and are included in the *Other* category. See Figure 2 for a savings by category summary associated with the proposed wood building.

Structure cost savings associated with the wood design totaled approximately $425,000. In order from highest to lowest savings, they were concentrated in roof framing beams, roof decking, roof framing columns, primary roof framing such as trusses and joists and wall framing. Table 1 shows a comparison of the sub-components in each of these elements and Figure 3 depicts the allocation of savings in each structure category element associated with the proposed building.

It is interesting to note that the wood roof option required a direct-applied ceiling due to the use of batt insulation (as opposed to rigid insulation on top of the decking for the steel option), which consisted of one layer of 5/8" gypsum and resilient channels. While this added about $80,000 to the overall cost, the structure cost savings was still approximately $425,000.

Savings associated with roof insulation represented the largest single element savings (over $400,000), due to the cost difference between rigid insulation (steel design) and batt insulation (wood design). The rigid insulation was 4½" XPS (extruded polystyrene) and the batt insulation was 5½" fiberglass. Each insulation option provided a roof insulation R-value of 22.

Due to the lower hard costs associated with the wood design, a total additional savings of $162,706 was achieved in contractor's general requirements and contingencies. Two factors contributed to savings associated with contractor fees: the contractor's general requirements and fees (14% of hard cost totals) and the construction contingency (5% of total hard costs plus contractor's fees). This savings is included in the total building savings cited at the beginning of this section and illustrated in Figure 2.

Environmental Performance: Wood vs. Steel

Life cycle assessment is an internationally-recognized method for measuring the environmental impacts of materials, assemblies or buildings over their entire lives—from extraction or harvest of raw materials through manufacturing, transportation, installation, use, maintenance and disposal or recycling. It allows design professionals to compare different building designs based on their environmental impacts and make informed choices about the materials they use.

LCA is increasingly being used instead of a prescriptive approach to material selection, which assumes that certain prescribed practices (such as specifying products with recycled content) are better for the environment regardless of the product's manufacturing process or disposal. This shift is reflected in all of the major green building rating systems, codes and standards, including LEED v.4, Green Globes, the *International Green Construction Code, California Green Building Standards Code* and ASHRAE 189.1.

LCA studies consistently show that wood outperforms other materials in terms of embodied energy, air and water pollution, and carbon footprint.[ii]

Scope of Life Cycle Assessment

The LCA described in this paper was conducted in conformance with the Committee for European Standardization (CEN) standard EN 15978, which stipulates an LCA-based calculation and reporting method for whole buildings or building parts. While European in scope, many EN 15978 provisions are becoming the standard manner by which whole-building LCA work is conducted worldwide.

EN 15978 uses 22 environmental indicators to measure a structure's life cycle impacts. Five of these indicators were not in the scope of this project. For sake of clarity and conciseness, of the 17 indicators applicable to this study, the LCA comparison of the steel and wood buildings focused on the following six required for the LEED v.4 whole-building LCA credit:

1. Global warming potential
2. Ozone depletion potential
3. Acidification potential
4. Eutrophication potential
5. Smog potential
6. Non-renewable energy use

For more information on LCA, including definitions of common indicators and life cycle phases, visit the Athena Sustainable Materials Institute website: http://www.athenasmi.org/resources/about-lca/technical-details/.

Whole-building LCA typically draws on environmental product declarations (EPDs) and/or life cycle inventory (LCI) environmental data sources. Although EPDs have become a standard part of decision making elsewhere in the world, they are relatively new to North America, produced mainly by large manufacturers or industries committed to being leaders in environmental performance and used by leading design firms with the same objective. The wood industry has been at the forefront of this trend and EPDs are available for

Life Cycle Assessment: Why Wood Performs Well

Life cycle assessment studies consistently show that wood performs better than other materials in terms of embodied energy, air and water pollution, and greenhouse gas emissions.

One of the reasons for this is that wood products tend to require less energy to manufacture than other materials—and very little fossil fuel energy, since most of the energy used comes from converting residual bark and sawdust to electrical and thermal energy.[iii]

A comprehensive review of scientific literature examined research undertaken in Europe, North America and Australia pertaining to life cycle assessment of wood products.[iv] It applied LCA criteria in accordance with the International Organization for Standardization standard ISO 14040-42 and concluded (among other things) that:

- Fossil fuel consumption, potential contributions to the greenhouse effect, and the quantities of solid waste tend to be minor for wood products compared to competing products.
- Wood products that have been installed and are used in an appropriate way tend to have a favorable environmental profile compared to functionally equivalent products made out of other materials.

Increasingly, architects and engineers are utilizing LCA as an objective way to compare the environmental impacts of their material choices. This is due in part to the fact that information on LCA, including databases, tools and research, is growing. LCA is now also included in most green building rating systems.

many wood products (www.awc.org). However, this assessment did not use EPDs as a source of data since 1) EPDs are not widely available for competitive building products, and 2) there is, so far, a lack of consistency between EPDs in different product categories.

The assessment drew on the following three LCI data sources:

- The Athena LCI Database (http://www.athenasmi.org/our-software-data/lca-databases/)
- The US LCI Database (http://www.nrel.gov/lci/)
- The Ecoinvent LCI Database (http://www.ecoinvent.ch/)

This study considered the following elements (as shown in Table 1): foundations, slab-on-grade, floor construction, roof construction, exterior walls, exterior windows, exterior doors and roof coverings. This group of elements broadly includes structure, envelope and interior partition materials, which corresponds to the current modeling capacity of the *Athena Impact Estimator* LCA software and is compliant with the requirements of the LEED v.4 whole-building LCA credit.

Notable assessment omissions include:

- Non-structural fasteners, clips, etc.
- Surface treatments (e.g., weatherproofing, fire-retarding coatings)
- Adhesives and sealants
- Soffit, drain covers, vents, roof hatches, etc.
- Temporary works used during construction and demolition/deconstruction phases (e.g., shoring, formwork)
- Freezer and cooler box, including walls and doors
- Soil treatments

Figure 4 shows the life cycle stages included in the analysis. Defined in "modules" (e.g., A1, A2, A3, etc.), the results are calculated in two ways, one that includes modules A, B and C and another that also includes D (steel and concrete recycling, wood combustion, biogenic carbon sequestration of landfilled wood products). The four grey modules were not included in the study for various reasons. For example, operating energy and water use were assumed to be the same for each building type and omitted from the scope. Additionally, these building aspects are not required for attaining the LEED v.4 whole-building LCA credit.

LCA Results

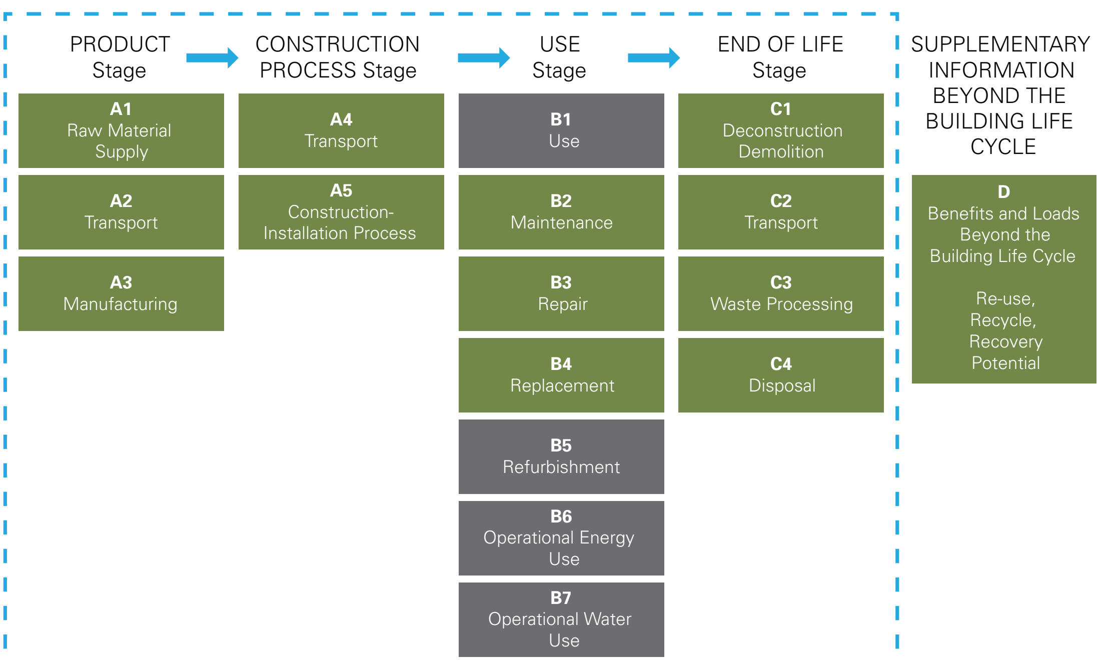
The proposed wood building uses less mass of materials than the reference steel building and performs better against five of the six environmental indicators.

In addition to manufacturing processes, transportation and other factors, the amount of materials used in a building has an impact on its LCA results. The total mass of materials used by the steel and wood building designs are 6,924 and 5,923 metric tonnes, respectively, a 14% reduction for the proposed building. Relative to the steel building, the wood building uses 66% less steel products, 26% less concrete products, 1,125% more wood products and 36% more gypsum products. Differences between *Fossil Fuel Derived* and *Other* products can be primarily attributed to the choice of roof insulation—i.e., extruded polystyrene vs. fiberglass batt.

Figure 5 shows a comparison of material use over the 60-year reference study period, including construction waste and materials used for maintenance, repair and replacement activities.

FIGURE 4

Life Cycle Stages[vi] (Green boxes included in this analysis)



Highlights from the LCA Report

Impacts of the proposed wood building are lower than the steel building impacts for all indicators except ozone depletion potential, where the proposed building results were 5% higher. (See Figures 6 and 7.)

Raw Materials through Demolition/Disposal:

- Global warming potential: wood building saves 642 tonnes of carbon dioxide equivalent (CO_2e)
- Non-renewable energy use: wood building saves 9,116 gigajoules (GJ)
- Raw material supply and manufacturing: wood building has an average of 30% less impact across all indicators
- End of life transport: wood building has 11% less impact across all indicators

Adding the recovery/re-use/recycle stage has minor effects on the overall comparison between the wood and steel buildings. As with the analysis excluding this stage, the wood building outperforms the steel building overall and for all indicators except ozone depletion potential, where the proposed building results were slightly higher.

FIGURE 5

Life Cycle Product Use Mass Comparison by Building Product Type

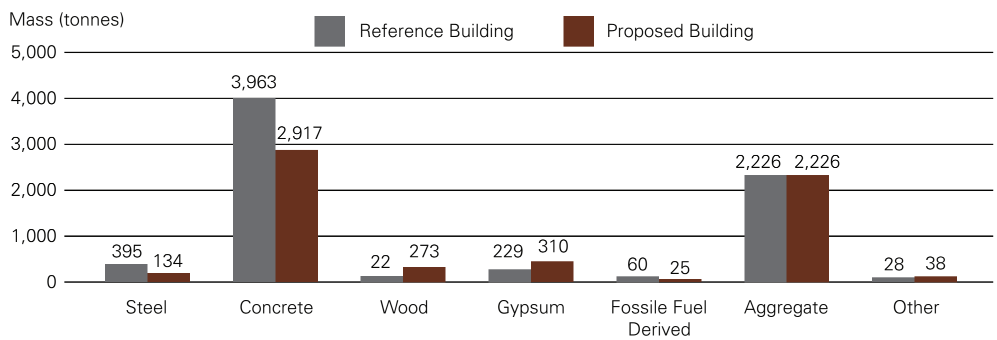


FIGURE 6

LCA Results Comparison (Normalized) – Raw Materials through Demolition/Disposal

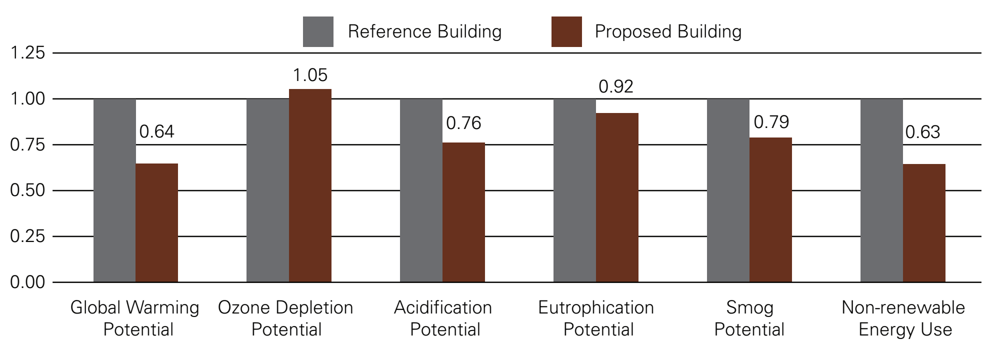
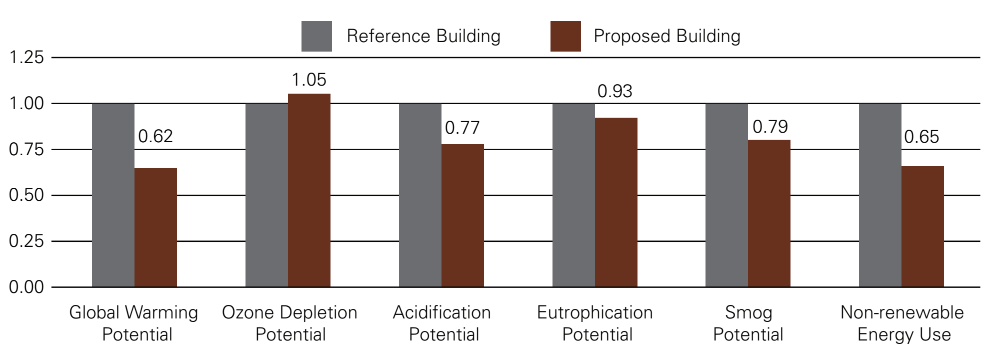


FIGURE 7

LCA Results – Raw Materials through Recovery/Re-use/Recycle



Opportunities for 'Big Box' Wood Design

Due to longstanding practices in big box building design, wood framing is seldom used for the structural systems. However, as these cost and LCA comparisons illustrate, there are tangible benefits to using wood-frame construction in large commercial structures such as grocery stores, home improvement stores, wholesale warehouses, shopping malls, restaurants and department stores. Also due to these longstanding practices, many designers don't realize the extent to which building codes allow wood framing in retail structures.

The design flexibilities provided by wood framing—which include everything from conventionally framed wall, floor and roof construction, to mass timber columns, beams and lateral framing systems, to metal plate-connected long-span trusses—offer near endless possibilities in terms of building size, shape and configuration.

As noted, the vast majority of big box stores have requirements that include large open floor plans, tall ceilings, minimal structure, interior space flexibility and the ability to adapt to future needs through redesign.

Although these requirements are often met with systems that include structural steel columns, open web joists and joist girders, and steel roof decking, they can also be achieved with wood framing—likely at less cost and with less impact on the environment.

The majority of retail buildings fall under the *International Building Code* (IBC) occupancy classification of mercantile (M). With the installation of an automatic sprinkler system (required for Group M occupancies with a fire area greater than 12,000 sf per IBC Section 903.2.7), significant building sizes are permitted for buildings of Types III, IV and V construction. These construction types may utilize wood framing for all framing components (Types III and IV may utilize fire retardant-treated wood for exterior walls). Additionally, one- and two-story buildings of mercantile occupancy may be unlimited in area for any construction type when an automatic sprinkler system is installed and the building is surrounded and adjoined by public ways or yards 60' wide or greater (IBC Sections 507.3 and 507.4). Table 2 provides a summary of allowable mercantile occupancy building sizes for Types III, IV and V construction. The proposed building is Type VA construction, fully sprinklered.

Gravity Framing Systems

Specific occupancy and use requirements for the proposed and reference buildings included 16' ceilings (minimum above finish floor), 23' exterior walls, a monoslope roof (¼" per foot) capable of supporting HVAC equipment, a loading dock, multiple exterior aesthetic features such as parapets, canopies and an entrance tower, and a small mezzanine for storage, mechanical and other miscellaneous use. Below is a discussion of the wood structural framing members, systems and details utilized in the proposed building that facilitated the cost and environmental savings.

In the proposed building, a roof framing grid of approximately 45'x45' consisting of glue-laminated (glulam) beams and solid sawn columns was utilized to achieve an open floor plan with minimal columns for space disruption. Glulam beams span 30' to 46' and support an average of 40' to 56' of roof width. They range in size from 8¾"x24" – 8¾"x36" and utilize cantilever connections and hinge hangers to speed construction and minimize on-site connection difficulty (see Figure 8). The grids used in the reference building and proposed building were identical.

The proposed building design utilized prefabricated, metal plate-connected parallel chord roof trusses at 24" on center (o.c.) spanning 30' to 64', with depths of 24" to 54" in the main area of the building. Trusses were decked with 15/32" sheathing and hung from the glulam beams using prefabricated hangers supporting the truss bottom chords. The design also provided the flexibility to bear the truss top chords on top of the glulam beams if that option proved more cost effective. The glulam elevations were set to be flush bottom with the deepest adjacent truss bottom chord in order to simplify ceiling installation (see

TABLE 2

Group M NFPA 13-Compliant Sprinklered Buildings – Maximum Floor Area[a,b]

# of stories	% frontage	Maximum floor area per story (sf)				
		IIIA	IIIB	IV	VA	VB
1	0-25	74,000	50,000	82,000	56,000	36,000
	50	78,620	53,120	87,120	59,500	38,250
	100	87,870	59,370	97,370	66,500	42,750
	100 (60')[c]	UL	UL	UL	UL	UL

UL = Unlimited; Source: 2012 Code Conforming Wood Design, American Wood Council

a. Frontage based on open space widths of 30' or more
b. Interpolation permitted
c. Sprinklered Group M buildings of one or two stories may be unlimited in area if the frontage width is at least 60' in accordance with IBC Sections 507.3 and 507.4.

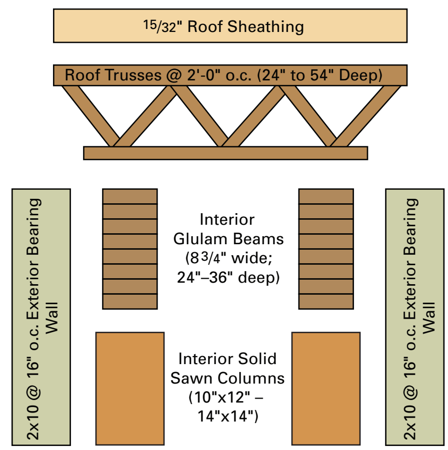
Figure 9). The column and beam elevations varied across the building (highest at the front of the building, lowest at the back) to provide the required roof slope.

Solid sawn columns, approximately 18' to 23' tall, were specified using two options: exposed, larger columns (14"x14") utilizing mass timber's inherent fire-resistance characteristics, and smaller columns (12"x12") sized only for structural loads and protected with two layers of gypsum board to provide fire protection. This provides the architect and owner with greater design flexibility and allows an option of exposing the mass timber columns to create a desirable aesthetic uncommon in big box stores. The glulam members utilized in the proposed building design are Douglas-Fir-Larch with a 24F-V8 combination. Figure 10 provides a summary of the typical gravity framing system.

The proposed wood building design specified load-bearing exterior stud walls. In order to support roof loads while also creating a parapet without kickers, the exterior wall framing detail (Figure 11) specified 2x10 at 16" o.c. balloon-framed studs, with 6x12 ledgers

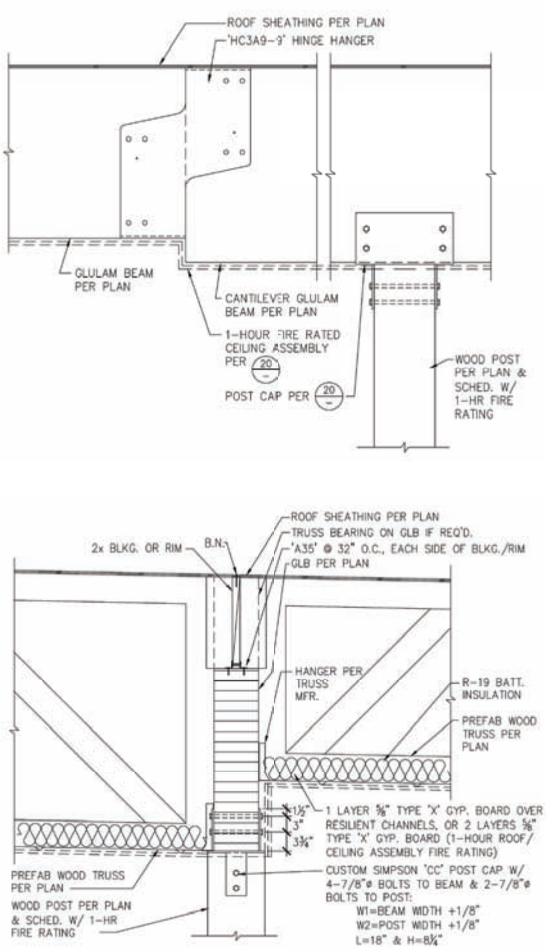
FIGURE 10

Typical Gravity Framing System



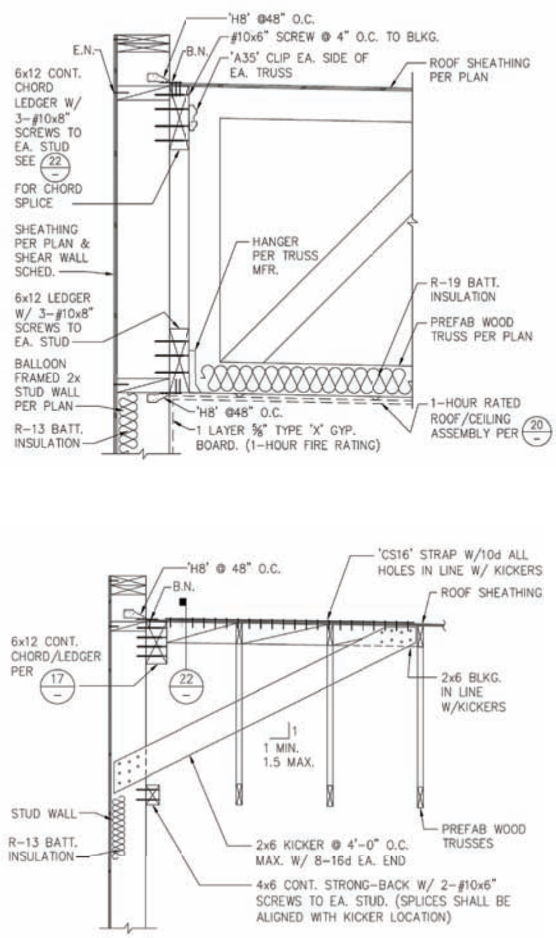
FIGURES 8 AND 9

Glulam Beam and Roof Truss Connection Details



FIGURES 11 AND 12

Exterior Wall Roof Support Details



attached to the inside face of studs aligned with the supported truss top and bottom chords. A combination of truss bottom chord hangers, hurricane clips and holdowns were used to attach the trusses to both the ledgers and exterior wall for roof load support and out-of-plane load resistance and anchorage. At locations where the roof trusses span parallel to the exterior walls, a 6x12 ledger in line with the truss top chords is attached to the inside face of studs to transfer roof diaphragm forces. A 4x6 ledger in line with the truss bottom chords is attached to the inside face of studs to support the end of the ceiling, while 2x6 kickers brace the wall studs at the ceiling elevation in order to maintain consistent wall stud unbraced lengths and design spans (see Figure 12).

Alternative Roof Framing Options:

A variety of wood framing options exist for roofs of large, open retail spaces.

To achieve the required open floor plan, roof member spans of 30' to 50' are common. If using closely spaced members, prefabricated metal plate-connected wood trusses spaced at 16" to 32" are effective. With these framing member spacings, wood structural panels are commonly used as the decking material, with typical thicknesses ranging from 15/32" to 7/8". In lieu of the glulam girders specified, multi-ply metal plate-connected truss girders are an option.

Roof framing: Glulam girders and purlins, solid sawn lumber sub-purlins, and wood structural panel sheathing

Photo: SBE Builders

Another option is to use glulam purlins at 8' to 12' o.c. with solid sawn timber decking (e.g., 2x, 3x, or 4x tongue and groove) or mass timber panels (e.g., nail laminated timber or cross laminated timber) spanning between the purlins. Alternatively, in lieu of heavy/mass timber decking, 2x sub-purlin framing members spanning between the glulam purlins could be utilized, with a wood structural panel decking on top. This last option is often utilized in panelized roof construction for warehouses or other large, open structures.

Alternatives to the solid sawn columns utilized in the proposed building include glulam columns, engineered wood columns (e.g., parallel strand lumber), or built-up columns composed of multiple plies of solid sawn lumber.

Alternative Wall Framing Options:

In order to achieve the tall exterior walls required to provide tall ceilings, tall wall studs are necessary. However, designers have a choice of two main design routes.

The exterior walls can be load bearing, supporting the roof loads in addition to out-of-plane wind and seismic loads acting on the wall.

Alternatively, a series of beams and columns could be installed just inboard of the exterior walls, supporting the roof loads and making the exterior walls curtain walls, designed only for out-of-plane wind and seismic loads. Per Tables 601 and 602 of the IBC, this option can potentially be used to lower fire-resistance rating requirements of exterior walls, depending on fire separation distance, construction type and occupancy. Although this option requires additional framing for perimeter beams and columns, it may also reduce required stud sizes.

If using load bearing exterior walls in lieu of hanging the trusses from ledgers on the interior face of studs (as was the case for the proposed building) another option would be to frame the studs to the underside of the truss bottom or top chords and bear the trusses on the exterior walls. This would reduce the required stud lengths; however, depending on the required parapet height, kickers may be required to brace the top of the parapet walls.

Lateral Framing Systems

As large roofs and open floor plans make interior lateral force-resisting systems (LFRS) unfeasible, significant lateral forces tend to be concentrated along a retail building's exterior walls. Vertical LFRS (shear walls) and horizontal LFRS (diaphragms) must therefore be designed to account for these concentrations of load. This design challenge exists regardless of the material used for framing.

Wood-frame construction is effective when designed as a lateral force-resisting system. This is largely due to wood's ability to sustain significantly higher loads for short durations of time—as is the case in high wind and seismic events—as well as the redundant load paths typically created by wood framing members and connections.

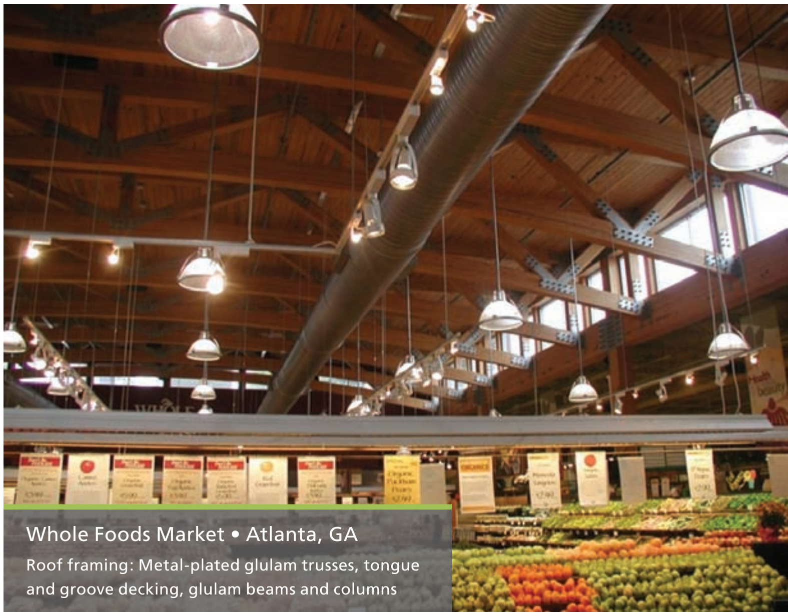
A wood-frame diaphragm's capacity is a function of the wood structural panel edge fastener size and spacing, among other factors. Tight sheathing panel edge nail spacing, in addition to the installation of blocking at all panel edges, can provide high diaphragm capacities. The proposed building design utilized both of these techniques to achieve an open floor plan without the need for interior lateral force-resisting elements. To make efficient use of materials, nail spacing was also varied throughout the building to meet varying diaphragm and shear wall load requirements.

Shear walls are vertical walls with in-plane shear stiffness which resist lateral forces as a cantilever unit. The steel-frame building in this comparison utilized masonry perimeter walls as shear walls while the wood-frame building utilized wood structural panel shear walls. With big box stores, there are often large sections of solid exterior wall due to the placement of shelving, racking, coolers, etc. along the perimeter. As such, the relative magnitudes of load applied to each section of wall can be low.

Several characteristics of light wood framing directly translate to lower seismic forces. Most notable is the fact that wood-frame walls are significantly lighter than masonry walls. The steel reference building in this case study utilized fully grouted 8" masonry walls, which have an average weight of 81 psf, while the wood-frame building utilized 2x10 Douglas-Fir-Larch #2 wood studs at 16" o.c., which have an average weight of 13 psf.[vi] A building's seismic forces are directly tied to its mass, meaning that the seismic forces contributed by exterior masonry walls were over six times greater than those of the wood-frame walls. Seismic forces on a building are also directly tied to the code-specified Seismic Response Coefficient (R). As the R term is in the denominator of the seismic force equation, a larger R value results in lower seismic forces. The steel-frame building utilized a seismic lateral force-resisting system of "special reinforced masonry shear walls" (R = 5) while the wood-frame building utilized "light-frame walls sheathed with wood structural panels rated for seismic resistance" (R = 6.5, per Table 12.2-1 of ASCE 7). This increase in R value translates to a 23% reduction in seismic base shear for the wood-frame building.

Roof Insulation

As noted above, the largest single cost savings associated with changing the framing system from steel to wood resulted from the roof insulation. While the reference building used extruded polystyrene insulation on top of the decking, the proposed building used fiberglass batt insulation between the roof framing. This provided a savings of more than $7 per sf. The depth of wood roof framing and wall framing associated with big box stores, due to roof spans and wall heights, are typically more than adequate to house batt insulation, even in colder climates where more insulation may be required. Where more insulation is required, the increased cost of insulation would still be offset by significant savings associated with the wood structure as well as increased energy efficiency.



Whole Foods Market • Atlanta, GA
Roof framing: Metal-plated glulam trusses, tongue and groove decking, glulam beams and columns

Conclusion

Although big box retail buildings are typically framed with structural steel, masonry and concrete, significant cost savings and environmental impact reductions can be realized through the use of wood framing. As this paper illustrates, wood was able to meet all of the same performance criteria as steel for a 54,800-sf big box store in California while saving nearly $1 million, using 14% less total mass of materials and performing better overall and in five out of six LCA environmental impact categories. For these reasons, designers are encouraged to consider wood framing as an alternative to traditional building materials for big box stores and retail building projects.

WoodWorks-The Wood Products council is available to provide project assistance at no cost related to the use of wood in retail buildings—or any non-residential or multi-family building in the U.S. Email the project assistance help desk at help@woodworks.org or visit the WoodWorks website to contact a regional member of WoodWorks' technical staff: www.woodworks.org/project-assistance.

i *Evaluating the Carbon Footprint of Wood Buildings,* Architectural Record CEU, includes examples of governments with policies that recognize the benefits of wood products. http://www.rethinkwood.com/sites/default/files/Evaluating-Carbon-Footprint-CEU.pdf

ii Links to LCA studies, tools and other resources can be found at: http://www.woodworks.org/why-wood/life-cycle-assessment-lca/life-cycle-assessment-lca-resources/

iii *A Synthesis of Research on Wood Products and Greenhouse Gas Impacts,* FPInnovations, 2010

iv Werner, F. and Richter, K., *Wooden building products in comparative LCA: A literature review;* International Journal of Life Cycle Assessment, 12(7):470-479, 2007, Werner F. and Richter K.

v An explanation of each life cycle stage is provided on the Athena Sustainable Materials Institute website: http://www.athenasmi.org/resources/about-lca/technical-details/

vi *ASCE 7-10: Minimum Design Loads for Buildings and Other Structures,* Table C3-1