

DOMINION TRUSS



A Structural System for 100-Year LEED-Compatible Wood Buildings

April 2008

Introduction

Wood-framed buildings can be more cost effective and more environmentally friendly for many applications currently dominated by 100% steel construction. Wood is rarely used for 100-year building applications. This paper presents a number of structural options using off-the-shelf components and well-tested methods to build a 100-year building that meets building and fire codes, using standard dimensional lumber.

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Wood v. Steel

Steel has the perception of strength and endurance. So when planning a 100-Year building, steel may seem to be the obvious choice. Steel-framed buildings have been marketed very effectively to the point that steel is today used for many applications where wood would be superior. Several of the marketing points often used by steel promoters are not factual. In this paper we will look at the advantages of hybrid construction, using steel and wood where each performs best.

Fire Resistance

Steel buildings are often promoted on the claim that steel doesn't burn. However, fire insurance premiums for steel buildings are not appreciably different than for wood framed buildings. Steel framing and trusses tend to fail rapidly in fires due to expansion and twisting that shears off the bolts at the connections. Most fires are started and fueled by the contents and furnishings of the building, not the structure.

Measured in time to failure, wood consistently performs better in fires, saving lives. Laminated wood columns are often still standing and even re-usable after building fires. The larger the wood member the slower it burns. Wood retains its strength longer than steel at high temperatures, even while it is burning.

Environmentally Friendly

Dimensional lumber is a renewable resource that requires only a fraction of the energy to produce that steel does. Even recycled steel uses far more energy to produce than wood. Wood is the most environmentally-friendly building material there is. It literally grows on trees. Using post-framed buildings with regionally grown lumber, several LEED points can be earned by the structural system.

Thermal Efficiency

Insulated post-frame wood buildings have 30-50% lower HVAC costs over the life of the building than a steel framed building with the same thickness of insulation. Since a smaller HVAC system will be required for the building there is a substantial upfront cost savings. The primary reason for this performance difference is that **steel is an excellent thermal conductor**, whereas wood is a thermal insulator.



Illustration 1: Condensation

A steel framed building has connection points from the foundation through the columns and trusses and to the roof and exterior wall membranes. This line of connection acts as a channel for heat gain or loss from the building and also causes moderate to severe condensation in both Summer and Winter in the humid climate of the Southeast. Condensation drips into the insulation and further reduces the thermal efficiency of steel framed buildings, as well as providing ideal conditions for mold to grow.

Wood is an insulator. Even wood buildings with a metal roof are more thermally efficient than steel framed buildings because the conditioned space is not connected to the roof and foundation by thermally conductive members.

While mold can grow on wood, the primary food source is dust, which is common in both steel and wood buildings. Condensation control is the most important factor to prevent mold growth.

Cost

Steel prices have been rising steadily for several years, while lumber prices have been falling for the past year. This situation has been caused by economic recession in the United States coupled with a weakening dollar. Steel is generally imported, whereas most dimensional lumber used

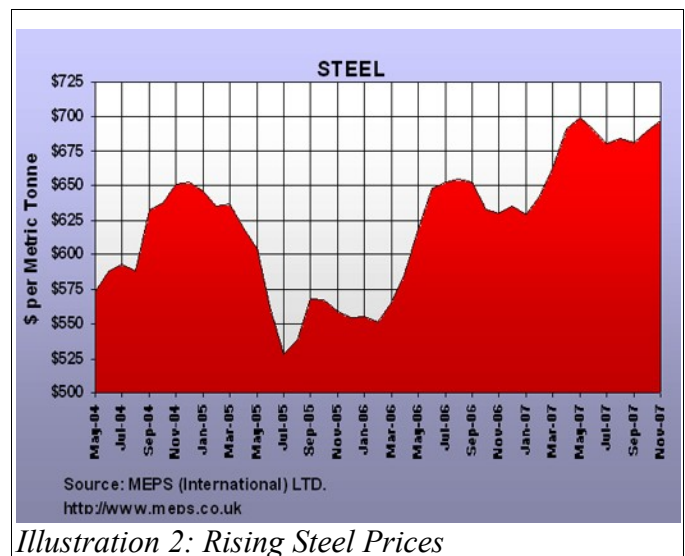


Illustration 2: Rising Steel Prices

in the United States is grown and manufactured locally. The recession in real estate has reduced demand for lumber, causing prices to fall.

Presently, post-framed wood buildings cost substantially less than steel framed buildings of the same size, and may require less concrete in the foundation. By using hybrid construction we can use steel where its properties give the greatest advantage for the cost.

As mentioned above, steel framed buildings normally cost 50% to 100% more to heat and cool over the life of the building. Over 100 years, the HVAC costs will far exceed the initial cost of construction.

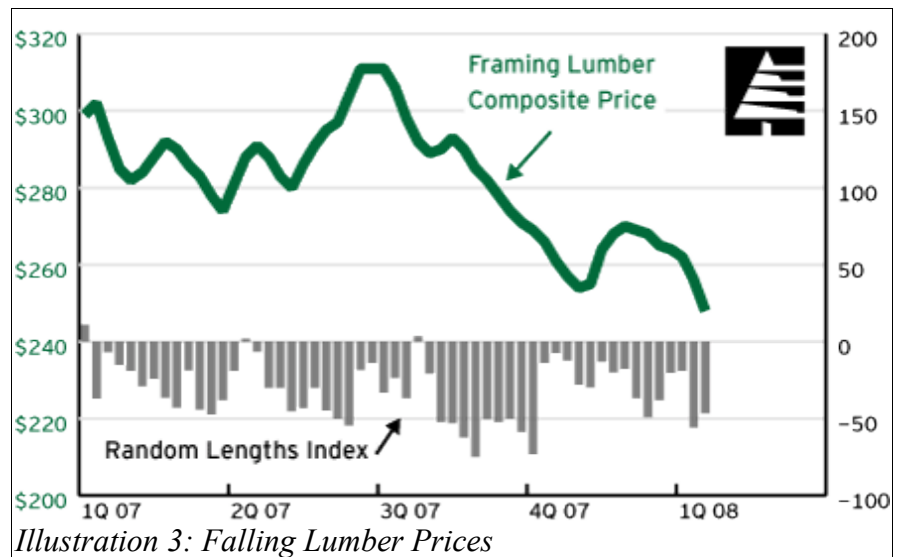
Durability

Steel buildings are perceived to last longer than wood. However, all building components deteriorate over time, especially in the presence of moisture. Wood rots. Steel rusts. Masonry gradually crumbles.

Steel's tendency to pull condensation out of the air promotes rust at the connection points and may shorten the life of the building.

The key to an enduring building of any material is proper design and maintenance of the roof and foundation.

“Give her a good hat and dry boots and she'll last.” -- Welsh Builder's Proverb



Wood that is kept dry will not rot. Wood that is properly separated from the soil by concrete will not get termites.

The lower cost of a wood framed building makes it possible to invest more into a high quality roof.

Strength

Though steel is much stronger than wood by volume, by weight wood's strength is comparable.

Rigid post-frame buildings may actually outperform traditional steel assemblies in some cases. In 1984 [Twin City Testing & Engineering Laboratories, Inc.](#) compared rack load capacities on different roof and wall panels. The wood-braced shear walls in the Reaves Building System outperformed the tie-rod braced and cable braced shear walls of typical metal buildings -- the key being the design of the assembly rather than the strength of individual parts.

Post-Frame Construction

“Post-Frame Construction” is a strong and inexpensive method that evolved from the “pole barn” of the 1930's. Post-frame buildings are sometimes called “post-and-beam buildings”. The design concept is simple and offers flexibility. The features of post-frame design include heavy posts, supporting columns and roof trusses. Depending on the spacing of the posts and trusses, wall girts and roof purlins may be required to attach and support wall and roof sheathing.

Post frame buildings have been found to be surprisingly strong and highly resistant to lateral live loads (wind, earthquake, etc.) because the wood frame and metal membrane act together in a “diaphragm effect”. The building will deflect slightly under high live loads but returns to its original shape when the live load is removed.

Originally post-frame construction employed cylindrical “poles” made from single a single pressure-treated log, however it is now more common to use laminated columns made from standard dimensional lumber. Advantages of using laminated columns include lower cost, flexibility in design, and a square surface that makes it easier to anchor girts and other structural members. It is also possible to make laminated columns where only the bottom eight feet are pressure treated – greatly reducing the cost.

Depending on the design and purpose of the building, post-frame construction may require substantially less concrete in the foundation system.

Post-frame buildings can be built up to four stories in height by using laminated columns. Though taller buildings are structurally possible, fire codes generally prohibit tall wood buildings.

In order to achieve a 100-Year wood building with post-frame construction the design must ensure no wood is in contact with the soil. Since the strength of traditional post-frame comes from the post's ability to transfer bending moment from lateral loads (racking) to the foundation, any modification that elevates the posts off the foundation will still have to achieve this.

There are three common solutions to this problem. First, the racking problem can be solved by raising the posts off the soil on engineered precast concrete piers with integrated steel attachment points designed to transmit bending moment. There are commercial engineered products available to achieve this, as discussed in the next section.

The second method is to use a rigid building frame, such as the Reaves System, to eliminate bending moment at the point where the posts connect to the foundation. A rigid frame building requires post-to foundation-connections that resist uplift and lateral load, but not bending moment. This can easily be achieved with brackets. Rigid frame systems can be used with a wide variety of foundation types.

The third solution is to use Type 3B construction where the exterior wall is made of block masonry with a two hour fire rating. In this case horizontal wind loads are transferred to the ground by the

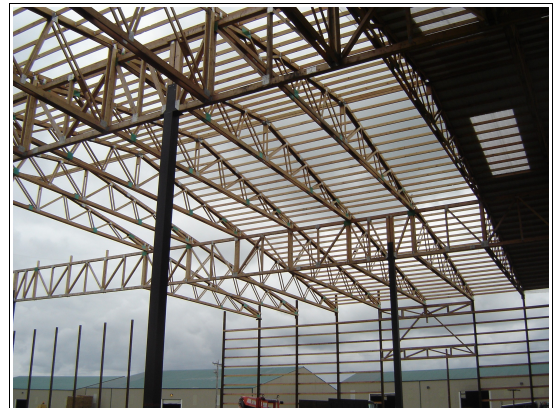


Illustration 4: Post Frame

masonry wall. In Type 3B construction wood columns and trusses can be used without fire retardant.

Foundation Piers or Stem Wall

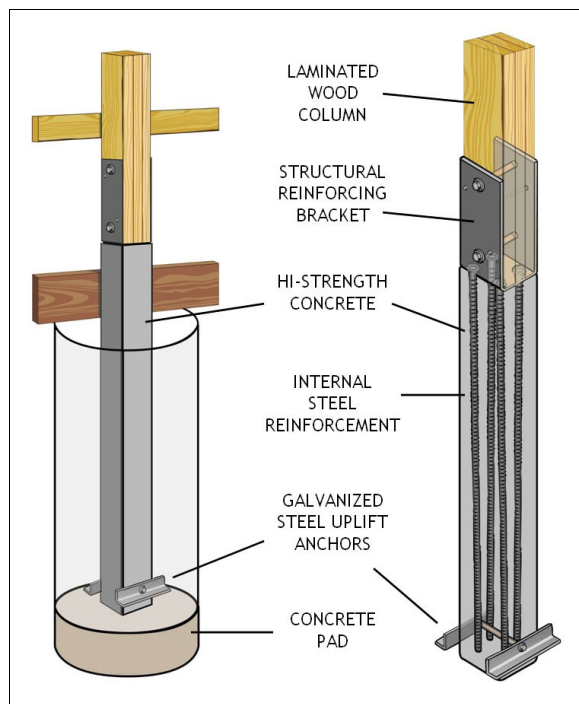
Traditionally, pressure-treated wood posts have been set four to six feet in the soil. Obviously, wood in contact with the soil will eventually rot, greatly limiting the life of the building. This has been the primary limitation of post-frame construction until recently.

The state of the art has improved to use prefabricated concrete piers or stem walls with steel connection brackets for the base of the posts. This elevates the post base well above the ground level and eliminates the necessity to use pressure-treated wood in the posts. By removing the wood posts from contact with the soil, the life of the building can be extended to 100 years or more.

The use of concrete piers greatly reduces the expense typically associated with concrete footers. However, the stem wall option, which uses more concrete, may be preferred for 100-year buildings (shown below).



Illustration 5: Perma-Column Precast Piers



[Perma-Column Inc.](#) is one supplier of pre-cast piers with integrated engineered attachment points, as well as an engineered bracket called “Sturdi-Wall Plus” that allows columns to be anchored to a concrete stem wall, using “wet set” installation.

The wood column is attached to a steel "U" connection bracket with 1/2" thru-bolts or 1/4" lag bolts depending on application and preference.

The Perma-Column is made of 10,000 p.s.i. pre-cast concrete. This is not the standard 3,000-4,000 p.s.i. concrete typically found in foundations.

Perma-Column Inc's Sturdi-Wall Plus brackets are designed to resist shear, uplift, and bending moment in accordance with code requirements. The brackets come in a wide range of sizes and shapes for various post dimensions.

Sturdi-Wall Plus must be installed in “wet set” in order for the rebar to concrete bond to develop correctly and create a connection that allows for bending moment transfer from the column to the steel bracket and into the concrete wall or foundation.

Since the bracket capacities are based on strong-axis bending of the column it is important that the supported structure be designed to resist lateral loads through diaphragm action of roof and shear walls or other bracing means.

It is also important that the concrete wall or foundation that the Sturdi-Wall brackets are cast into is designed to resist the uplift, shear, and moment that is transferred through the Sturdi-Wall Plus bracket into the concrete wall or foundation. Complete design calculations for the Sturdi-Wall Plus Brackets are available from that company.

Rigid Frame Systems

Rigid frame buildings, such as the Reaves Building System¹, extend the truss system to include the posts so that the connection point from post to roof truss is rigid instead of acting like a hinge. The rigid connection resists racking from lateral loads. This kind of structure converts bending moment into a downward and lateral force at the post connections to the foundation.

The key component of the Reaves system is a three-ply column with a partial truss angle at the top. The center ply is absent from the elbow. The roof truss fits in the space, becoming the center ply, and is nailed or bolted to the two plies on either side, making it integral with the column.

Fire Resistant Girders & Trusses

Fire marshals have increasingly been requiring fire ratings for interstitial spaces in roof and floor trusses. In order to meet this requirement there are two general options: active fire suppression systems, and intumescent paint.

Active fire suppression systems are expensive and generally only used when required by law.

Even though intumescent paint is also costly, a wood truss system with intumescent paint is less expensive than a steel truss system. A steel truss system still needs to be painted, and the total labor cost is substantially higher for installing steel truss systems.



Illustration 6: Sturdi Wall Plus Bracket



Illustration 7: Reaves System Post Elbows

¹ http://www.reavesbuildings.com/wood_supporting_steel/

[Fire Free Coatings](#) manufactures an intumescent paint called “FF88” that is UL approved for 1 and 2 hour firewall assemblies. FF88 can be applied to wood roof and floor trusses on site in order to obtain fire marshal approval for commercial retail, multifamily residential, and industrial structures.

For multistory buildings, it is important to block the vertical passages between columns with girts in order to prevent the chimney effect in a fire.

Glu-lam columns perform better in fire than nail-laminated columns. (The less-than-airtight bond between the members of the nail-lam column result in it burning like three 2x8's instead of one 6x8.)

Hybrid Construction

It is possible to make the best use of steel and wood in a structure while avoiding the disadvantages of both.

In a building with large open spaces, steel girders resting on wood columns can be used to support wood trusses. By using wood at the connection to the foundation, roof and walls, steel's thermal conductivity problem is avoided. Likewise, the problem of steel shearing off support bolts in a fire is minimized by connecting steel to wood.



Illustration 8: Metwood Steel Beams

[Metwood](#) is a Virginia company that manufactures special steel girders and chase hole reinforcements for wood trusses and I-beams. Their design for rolled steel beams has holes cut in the sides in such a way that the single-piece beam has the structure, shape, and strength of a truss. These can be used in a post-frame building as girders to support large spans of wood trusses, or to support concrete floors.

Structural Insulated Panels (SIPs)

Structural insulated panels are composed of expanded polystyrene (EPS) or polyurethane foam sandwiched between two thin layers of OSB or cement board.

SIPs act like I-beams with the EPS foam serving as the web and the outer layers as the bearing chords.

SIPs can be useful for rapidly sheathing a post-frame building and providing required lateral reinforcement to the post-frame structure.

Advantages of using SIPs include, greatly reduced labor cost (50%+) and

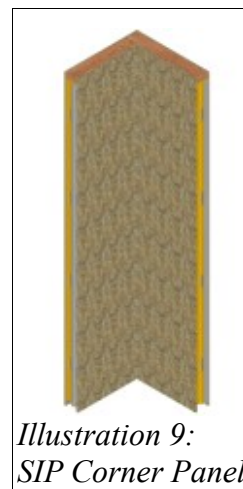


Illustration 9: SIP Corner Panel

uniform uninterrupted insulation. SIPs can also be laid on widely spaced trusses to support the roof membrane. This design brings the attic into the conditioned envelope of the building, simplifying the roof, support and insulation system.

For building applications with higher fire code requirements, cement-board polyurethane SIPs are ideal. They can provide the fire-resistant interior and exterior wall surface, requiring only paint or stucco for the finish. Alternately, OSB SIPs can be painted with an intumescent paint such as FF88.

Due to their strength, SIP's are ideal as a roof deck for supporting a green roof system.

Some SIPs are made with EPS, others with polyurethane foam. The advantages of polyurethane are higher strength, substantially higher R value per inch, and fire resistance. The disadvantage of polyurethane is that it can off-gas formaldehyde. EPS is highly inflammable, but as a very simple plastic, it does not produce toxic gases when it burns.

SIPs are manufactured in flat wall sections, as well as corner panels. Window and door openings can be precut at the factory. Electrical chases and electrical boxes are usually included in the panels.

Roof Membrane

Post-frame buildings normally use sheet metal roof and siding. The metal panels act together with the wooden frame as a diaphragm to resist lateral loads.

A number of LEED points can be earned by using a vegetated roof. Most green roof designers prefer to use a metal sheath beneath the membrane layer. This allows leaks in the membrane to be detected with a device that measures electric fields.

More roofing options are available if SIPs are used to support the membrane, as the SIP replaces the structural function performed by the sheet metal.

Siding

Post-frame buildings can be sided with any of the commonly available systems. For attractive look and low cost, [Moderra Components](#) makes an excellent mortarless masonry system that can be quickly installed.

The Moderra blocks are made of textured concrete and look like brick or cinderblock, though they are only two inches thick. Each block has a tenon that slides into a channel on the adjacent blocks. The blocks are secured to the framing system with screws and metal brackets.

Conclusion

Using post-frame construction with state of the art components, wood and steel can be combined to make a 100-Year LEED compatible building at comparable or lower cost than traditional steel framed buildings.

For public structures, schools, churches, and multifamily housing, post-frame construction offers a cost effective and aesthetically attractive building system that is environmentally sound.