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TOTAL POST-FRAME BUILDING DESIGN

"THINGS SHOULD BE MADE AS SIMPLE AS POSSIBLE, BUT NOT SIMPLER."*—Albert Einstein*

As I grow older and our world becomes ever more complicated, I try to follow this maxim from Einstein. Maybe you're like me, struggling to simplify decisions and situations without oversimplifying them. Finding this balance when designing and constructing post-frame buildings is not a trivial process, especially when you consider the complexity of the following elements: proper material selection; the structural integrity of the building; geotechnical issues; building code compliance; local, state and federal permits; and zoning ordinances and building site planning requirements.

Despite modern post frame's development and history dating back to the 1930's and its unrivaled economy, strength and versatility as a building system, post frame is still not well known in many places. Post frame has made advances in commercial and residential applications in rural and suburban locations because, even if the building system is not well understood, owners still understand the bottom line! In agricultural settings, where the building system is more familiar and better understood, post frame is being used in ever larger buildings, as the size and value of stored agricultural equipment grows and as farmers increase the size of the livestock operations that the buildings house.

In this article, I hope to increase your awareness of the post-frame building system and to stress the importance of properly designing the entire building system (as opposed to constructing a building that uses one or two designed parts). I discuss three key post-frame features that make it different from other types of construction and provide a summary of key focus areas that are critical to consider in all post-frame construction projects. In the process, I also identify some building situations where extra attention is warranted and identify resources for additional information.

What Is Post-Frame Construction, and Why Is It Different?

Post-frame construction is simply a structural framing system that competes with other common framing systems, such as steel frame (metal or steel buildings, for short), concrete (either cast-in-place, precast or tilt-up), masonry (made with concrete masonry units, or CMUs) and other wood-frame construction (mostly stud-framed buildings, but also post-and-beam or other heavy timber construction). Post-frame buildings use a framing system different from that used in these other common building systems, but that system is often infused quite cleverly with features from other types of construction to gain a benefit in efficiency, fire-resistive characteristics or aesthetics. Also, with exterior finishes limited only by the availability of materials and one's imagination, you may be driving past post-frame buildings in many commercial settings every day and not be able to tell what structural framing system has been used.

As the name suggests, one of the identifying characteristics of the post-frame system is the post, used to frame the walls and serve as a column carrying vertical loads and to transmit (and even resist) horizontal loads placed on the building (from wind or earthquake) or bulk storage/soil loads when building walls also act as retaining walls. These columns or posts are typically composed of laminated dimensional wood assemblies (nailed, screwed, bolted together or manufactured as glulams), but they may also be solid sawn wood posts or made of steel, precast concrete or other innovative materials, depending on the design requirements and objectives for each project. For a comprehensive overview of post-frame construction with excellent photos and illustrations, read Chapter 1 of the *Post-Frame Building Design Manual*, second edition, to be published by the National Frame Building Association (in press).

Feature 1—Embedded Posts

The manner in which a post-frame building works to resist loads can be quite different from that of other types of construction, especially when the columns are embedded in the ground. Consider a stud-wall building supporting loads from a system of roof trusses and exposed to wind on the face of the wall. The wood stud can resist vertical loads from the roof and pass them into the foundation below and at the same time can transmit the horizontal wind load accumulated along the height of the stud into a roof diaphragm at the top and the foundation or floor system at the bottom. If the wind load is uniform along its height, the reaction at the top and bottom of the wall will each be presumed to be one-half of the total wind forces acting on the stud.

A stud wall is presumed to have no ability to resist tipping over in the absence of a valid diaphragm system at the top of the wall. Maybe you can picture diagonal braces used at construction sites to brace walls in place as soon as they are framed, but before the wood sheathing (diaphragm) is secured into place. In comparison, a post-frame building with embedded posts will also transmit horizontal loads to the foundation below and roof system above but will have some "built-in" resistance to tipping over because the post provides structural continuity at the foundation. One benefit of this is that more of the horizontal wind load is resisted directly into the foundation at the base of the column (about two-thirds of the load, instead of one-half for studwalls), where it is easier and cheaper to resist, while the remainder of the load (about one-third) is transmitted into the roof diaphragm, where it must be transferred into vertical diaphragms in the walls, called shearwalls, and then into the foundation system. (This is only a very loose estimation of the actual distribution of loads between the foundation and the roof diaphragm; it can vary from building to building, but I'm trying to keep things as simple as possible.)

Embedded posts are a common feature of post-frame construction but are not required. When used, however, they offer many benefits, including lower forces transmitted into the roof and wall diaphragms (as explained above), less excavation and site preparation work, less cast-in-place concrete required (sometimes eliminating it completely), more flexibility in construction sequence, a longer construction season in cold climates and improved speed of overall construction.

Challenges faced when using embedded posts include the use of proper preservative-treated wood for the embedded posts (as should be used for any wood application near or below the soil), obtaining the proper equipment to drill (auger) into the soil, placing a properly sized footing at the base to resist the required bearing (downward) and uplift forces and then getting the embedded posts in position accurately while performing proper backfilling procedures around the embedded posts. The structural analysis of the building also presents challenges to designers unfamiliar with post-frame construction because the embedded posts must be embedded to a depth sufficient to resist horizontal, bearing and uplift loads, and these capabilities vary depending on soil conditions at the site, geometry of the building, size of the post being used and the magnitude of loads that each post within the building must resist.

For more information, suggested resources include *PFBDM* Chapter 3 (structural overview of post frame) and Chapters 7 (on post design) and 8 (on post and pier foundation design) and also American Society of Agricultural and Biological Engineers publications *EP559.1 Design Requirements and Bending Properties for Mechanically-Laminated Wood Assemblies* (2010) and *EP486.2 Shallow Post and Pier Foundation Design* (2012).

Feature 2—Trusses Used at Intervals Greater Than 2 Feet

Although what is considered typical can vary by region, post-frame trusses are usually spaced at least 4 feet on center as compared to light frame conventional construction, where trusses at 2 feet on center are the norm. In post-frame buildings where the spacing between trusses matches the spacing between supporting posts, the spacing of trusses and posts is often matched up at 6 or 8 feet and even 10 to 12 feet in certain applications.

For the most part, this flexibility in truss spacing and the ability to still span large spaces for post-frame buildings has been made possible by the design and manufacturing of metal plate connected wood trusses. Often these are some of the first components designed for a post-frame project with a cost estimate given, and the design for these MPC trusses will be documented with truss drawings and calculations listing precisely what types of loads are included for the design and where the trusses will require bracing when they are installed in the building. These documents are often provided to the builder or the owner with an engineer's seal on them indicating that a licensed design professional has taken responsibility for the truss being designed in accordance with the Truss Plate Institute standard TPI-1 for the loads listed in the design and subject to the limitations stated in the documents.

This documentation with an engineer's seal can be misleading, especially if you try to oversimplify and ignore the limitations. A sealed truss document represents just *one* component in the building for which it is intended, and the limitations are pretty significant when you consider the number of things that the engineer for the truss does *not* take responsibility for. Instead, the document indicates a list of important tasks that are the responsibility of the building designer (which may be another licensed design professional, or the builder if one is not retained for the building design), including:

- Verification that the loads that the roof truss is designed for are correct;
- Verification that the resulting truss design is appropriate to meet the requirements for the intended building application;
- The design of continuous sheathing and/or lateral bracing systems;
- The connection of the truss to the building;
- Bracing, handling and erection to be performed with TPI and the Wood Truss Council of America component safety information and/or as described by the building designer.

I can understand why some building owners may see an engineer's stamp and signature on the truss drawing and wrongly conclude that engineering has been performed on their entire building, but that assumption is an obvious oversimplification that we do not condone through promotional efforts or in any representations made in our offers to provide services. An engineered truss component does *not* make an engineered building and should never be represented as such. Total post-frame building design implies that not just one system but all components and systems have been designed to work together.

The obvious benefit of using trusses at larger spacing is a significant reduction in both the total materials used in the building and the cost and time required to construct the building. Also, though perhaps less obvious, the increased spans between trusses typically use dimensional lumber (2x4, 2x6, or larger) purlins to support the roof cladding, but these purlins running perpendicular to the trusses serve as the ideal supporting system for steel cladding with through-fasteners. This symbiotic system of secondary framing and cladding attachment comes into play not just for roof cladding on purlins and trusses but also for wall cladding on wall girts and posts. This identifying feature of typical post-frame construction is discussed more in the next section.

Post-frame truss systems involve challenges as well, including the need to verify that the truss design assumptions reflect actual construction (proper live loads, dead loads and bracing locations) and that the bracing and connections are designed by a qualified building designer. The Building Component Safety Information (BCSI) guidelines, produced by TPI and Structural Building Components Association, include one topic intended specifically for trusses used in post-frame buildings, “B10–Post Frame Truss Installation & Temporary Restraint/Bracing.” Only by properly installing these engineered trusses into a well-designed building system and treating them properly can we ensure that they will be able to achieve the load capacities they were designed for.

Suggested resources for additional information about properly using trusses in post-frame buildings include *PFBDM* (in press) and two TPI publications: *ANSI/TPI 1-2007: National Design Standard for Metal Plate Connected Wood Truss Construction* (2007) and *TPI/SBCA Building Component Safety Information (BCSI)* (2013).

Feature 3—Metal-Clad Wood-Frame Diaphragms

Metal-clad, wood-framed diaphragms are created when light-gauge, roll-formed steel panels are fastened with nails or screws to the wood framing (purlins in the roof and girts in the walls) and are the most common exterior finish used in post-frame buildings. Defining and predicting the allowable strength and stiffness characteristics of MCWF diaphragms was one of the major technical efforts required in the second half of the last century, when post-frame construction moved from its agricultural roots to become a recognized building system fit for commercial and residential applications in which more research would be needed to justify the building system’s capabilities, similar to the type of information and research available for competing building systems.

The steel panels used in post-frame buildings are often used in lighter gauges (thinner base metal thicknesses, such as 26, 28 or 29) than other types of construction. Yet because of the large area of these panels in the roof and walls, these thin steel panels fastened frequently in a prescribed pattern to the wood framing create a structural diaphragm that can resist and transmit significant forces.

The analysis of the load carried by MCWF diaphragms may not be as straightforward in post-frame construction when embedded posts are used because the horizontal loads are resisted between the two systems (MCWF diaphragms and the post frames themselves), depending on a relatively complex comparison and analysis of the building and the relative stiffness of the two systems. Several modeling and analysis procedures have been developed to analyze post-frame buildings using diaphragms for lateral resistance capabilities, which may be the biggest underlying factor for the cost and strength efficiencies available in modern post-frame construction.

Chapter 5 of the new *PFBDM* is devoted to diaphragm design and gives multiple references for additional research, but I would call attention to two ASABE publications: *EP484.2 Diaphragm Design of Metal-Clad, Wood-Frame Rectangular Buildings* (2012), which is adopted in the International Building Code, and *EP558.1 Load Tests for Metal-Clad Wood-Frame Diaphragms* (2014).

Interdependence

Understanding these three distinctive features of post frame should help you distinguish it from other building systems and—more importantly—make you keenly aware of the importance of having the entire building system designed to form an integral building system.

Post-frame buildings are so efficient because they are highly interdependent structures in which the individual systems function together to become more than the sum of the parts. Think of the embedded posts being laterally supported by an MCWF diaphragm in the roof, supported by properly braced long-span trusses, a design that transmits loads into the walls of the building and down through the MCWF shearwalls of the building and into the foundation (again, this could be an embedded post load path). The benefit of the building system efficiency comes at the cost of understanding and taking care of these interdependent relationships throughout the process of conceiving, designing, procuring, constructing and maintaining these buildings, but I believe this care is well worth the cost—for each individual building and for the entire post-frame industry.

Because of the interdependent nature of post-frame systems, it is difficult to develop a checklist of critical issues or to develop a prescriptive method on how to design and construct high-quality post-frame buildings that could be used by someone not experienced with post frame. Reliable and efficient prescriptive methods have not yet been developed for post-frame construction because it would require some compromise or balance among three factors: simplicity of use (Einstein again!), structural reliability and efficiency of the constructed building. These three factors are not easily resolved to the point where everyone would be satisfied with the results for all building situations. Without this prescriptive method, accurately and efficiently using the post-frame system may be difficult for the uninitiated, but post-frame buildings designed by competent designers and builders are able to achieve very high levels of structural reliability and economic efficiency.

For building systems where the total building system is not analyzed or reviewed by a competent designer, it is difficult to state what the structural reliability of the building is likely to be as it faces design wind, snow or earthquake loads, or even how the building will respond to gravity loads of its own weight, or the combination of two or more of these loads.

The Insurance Industry and Post-Frame Construction

In a presentation at NFBA's Frame Building Expo in March 2014, Ryan Michalek, PE, a professional engineer from Nationwide Insurance, identified the three most common failures in post-frame construction based on Nationwide's database of claims made. But he admitted that these documented failures were *all* from buildings constructed without the involvement of a licensed professional engineer.

For these reasons, insurance industry workers are finding it difficult to assign and analyze risk in the cases of individual post-frame buildings when a professional engineer was not involved. As a response, at least two insurance companies (including Nationwide) have initiated incentive programs for post-frame buildings; the building owners will receive lower insurance premiums if the building is designed before construction by a licensed professional engineer and if the engineer's certified plans are available during and after construction to verify compliance with the engineered design. This trend is likely to continue as more owners become aware of this option and insurance companies find their way to implement and refine these programs for the benefit of the insurance companies and their customers.

The top three failures identified by Michalek were (1) improper or missing bracing installed in the truss systems (discussed above); (2) inadequate connections between the roof purlins and the truss system (this is a critical connection for the adequate performance of the trusses and for the proper functioning of the MCWF roof diaphragm); and (3) failure to properly account for the appropriate amount of snow load on the trusses, specifically unbalanced snow loads and snow drift loads created at steps in the roof line.

What is really interesting about these three failures is that all have something to do with the roof truss system, but none would be solved by obtaining an engineered truss component.

1. The building designer, not the truss designer, is responsible for designing the permanent truss bracing systems. (See Feature 2 above.)

2. The building designer is responsible for purlin design and adequate connections, including the purlins into the truss. This connection serves as a critical uplift and shear resistance component and also serves as part of the lateral bracing of the roof truss. (See Features 2 and 3 above.)

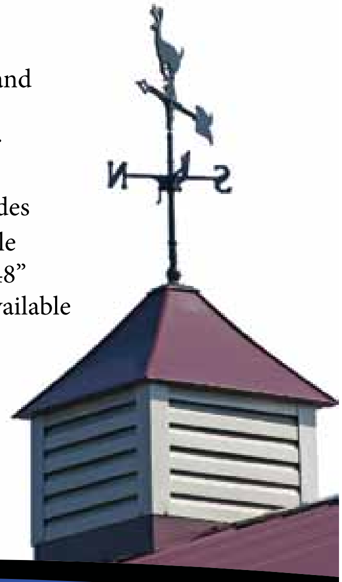
3. The building designer, not the truss designer, is responsible for determining the appropriate design loads for the truss, including snow load conditions. Many times a truss designer can generate snow loads based upon his or her experience, but the limitations of the truss design standard remove any responsibility from the designer for ensuring that those snow loads are adequate. The best solution is to ensure that the building designer uses at least the minimum design loads for the building indicated by the American Society of Civil Engineers standard known as ASCE 7, which includes provisions for calculating design snow, wind and earthquake loads throughout the United States. (See Feature 2 above).

Concluding Thoughts and Comments

Although, as I've shown, a checklist is too simple and won't magically solve design challenges or misunderstandings in post-frame construction, I can offer some guidelines for post-frame building design:

- Have construction plans and calculations developed by a licensed engineer familiar with post-frame design for every building required by law and also for any building where it would be desirable to avoid a failure in the building. Especially consider doing so when one or more of these conditions exist in the building project:

  - The truss-bearing height above finished floor is more than 14 feet.
  - The building width is more than 50 feet.
  - The building has a length-to-span (length-to-width) ratio larger than 2:1.
  - One wall has numerous large openings, a condition that severely reduces the capacity of the MCWF shearwall on that wall.
  - The building has non-embedded columns (the building will transmit more load through the structural diaphragms and shearwalls than an embedded post building would).
  - The building has a roof shape or site features that could affect accumulation of snow on the roof and create complex force analysis and difficult connection requirements.
  - The building lacks a structural diaphragm (e.g., when the owner wants to use standing seam without a wood structural diaphragm or wants to use polycarbonate roofing).
  - The building is open-sided (as in a pavilion) or partially open (the load transfer path and/or wind pressurization forces can be significant).
- Ensure that structural loads are well defined and communicated on the construction plans and contract documents so the owner, builder and designer clearly know what the use and load requirements for the building should be. An important part of this process is identifying the building's risk category, which establishes appropriate safety factors for the building. Unoccupied minor storage buildings could be designed for lower loads than a high-occupancy assembly building at the same site because the impacts of a loss are significantly different.
- Use appropriate materials for each application, especially properly preservative-treated wood in areas exposed to earth, bulk storage materials or moisture (including high-humidity environments where wood moisture exceeds 19 percent).
- Pay attention to proper truss installation, specifically truss restraints and truss bracing for top chord, bottom chord and webs.
- Consider load transfer at openings carefully. Headers and girders are often



used in post frame for creating openings larger than the common post spacing. The forces accumulated and resisted at these openings need to be handled carefully.

- Carefully consider roof and shearwall design details in combination with the frame resistance. Possibly analyze them in a bracketed format, one that is calculated slightly conservatively for the roof diaphragm and the other that is slightly conservative for the post-frame forces. This method would avoid error introduced into the design by not having the load-sharing assumptions between the two systems exactly right.

- Use high-quality construction drawings. These will show more than building elevations and a floor plan. Clear details of the critical connections should be shown, as well as material specifications, so that no ambiguity about design assumptions exists that would necessitate calling the building designer in for interpretation.

- Remember that the design and construction of the building are highly interdependent. I've found that the best designs (the strongest, most efficient and easiest to construct) are achieved by working with the builder rather than dictating the design from the engineering office for the builder to follow. I should note here that my favorite builders to work for are those who take responsibility for their own building quality, are active in regional and national post-frame industry activities such as NFBA functions and educational events and are also NFBA Accredited Builders. The builders, suppliers and other engineers that I've met at NFBA events really care about delivering a superior product and service to the end customer, and they collectively embody the interdependent attitude of "T.E.A.M.": Together, Everyone Achieves More.

I've mentioned the NFBA's new *Post-Frame Building Design Manual* throughout this article because I believe this second edition will help move the industry forward in technical and educational efforts and growth efforts for decades to come. Also, NFBA members have a treasure trove of information available to them at www.nfba.org (click on the Technical Resources link in the "Members Only" section, and find links to past Research and Technology articles published in *Frame Building News*, like this one). **FBN**

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