Two Story Post-Frame Buildings

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Post-frame construction has several characteristics that make it a great choice for all types of applications, whether it is commercial, residential, or agricultural. The goal of any building project is to design a building that meets all of the owners needs in the most efficient way possible. A multi-story building is often an appealing solution for projects since it adds usable space without increasing the overall footprint of the building. An often-overlooked feature of post-frame construction is the ability to easily incorporate a second story into the building. While there are items that need to be taken into consideration early in the design process, a two-story post-frame building can achieve the same desired results as other construction methods.

The International Building Code (IBC), which applies to commercial buildings, does have specific requirements related to multi-story buildings. Chapter 5 & 6 of the IBC provides the design constraints based upon the occupancy/use group classification and construction types, which are the primary factors in determining most of the other building code requirements found in later chapters. The types of construction are based upon whether the primary structural components of a building are combustible or non-combustible or offer a fire resistance rating. Typical post-frame construction is classified as wood frame construction with no level of fire rated protection on the primary components. This is known as Type VB. The other sub-category for type V construction is VA. VA construction provides a 1-hour fire resistant rating to the primary structural components. Ways to achieve a 1-hour rated assembly for wood construction can be done per a UL tested assembly or per a calculated method in Section 722 of the IBC. An additional resource for the calculated fire resistance rating of exposed wood members and wood decking is chapter 16 of the ANSI/AF&PA National Design Specification for Wood Construction (NDS). Generally, the fire resistance of a wood frame assembly is equal to the sum of the time assigned to the membrane on the fire exposed side, the time assigned to the framing members, and the time assigned for additional items such as insulation (IBC section 722.6.2.1). UL designs U528 and V304 are examples of a post-frame 1-hour wall assembly. Since type VB construction can limit buildings to a single story for several commercial uses, VA is the alternative option for using wood/combustible materials and being permitted to have an additional story.

If a full second story is not feasible with the building code requirements, a mezzanine may still be an option. While the structural framing of a mezzanine is similar to framing for a second floor, the building code looks at these two spaces differently and has different requirements. By definition, a mezzanine is an intermediate level between the floor and ceiling of any story. A mezzanine is limited in size to 1/3 of the area of the space below that it is open to. A mezzanine is also required to be open, not enclosed. As always, the building code does allow exceptions, most of which are dependent upon occupant load and egress. A story is that portion of a building included between the upper surface of a floor and the upper surface of the floor or roof next above.
A second floor system is designed to satisfy the strength and deflection requirements of the International Building Code (IBC). In post-frame buildings, the second floor framing consists generally of dimensional lumber or manufactured joists (I-joists, floor trusses), dimensional lumber, glulam, laminated veneer lumber (LVL) or steel girders, and dimensional lumber or LVL ledgers. The girders are supported by wood or steel columns on a thickened concrete slab, spread footings below the slab, or a round shallow post foundation. The design of wood framing and connections is governed by the National Design Specification for Wood Construction (NDS). The design of steel and concrete components is governed by the Specification for Structural Steel Buildings (ANSI/AISC 360) and Building Code Requirements for Structural Concrete (ACI 318), respectively.

The loading on the floor framing is determined by the intended use of the space. For example, the live load for office use is 50 psf. Structural design is more challenging for warehouses that use the second floor area for warehouse-type storage. The IBC separates warehouse storage loads into “heavy” and “light” categories with minimum live loading of 250 psf and 125 psf, respectively (see also additional requirement for concentrated point loads).

The outside perimeter of the second floor framing can be supported by the side and end wall columns. The most common detail for this type of support includes a single or doubled ledger board fastened to the wood columns with nails or structural screws. A support below the ledger may be required if the ledger cannot fit the required quantity of fasteners. The floor joists are attached to the ledger board with joist hangers.

The designer should also consider the effects of the second floor system on the lateral force resisting system of the building. The effects may be negligible, positive or negative. If the floor system is a small mezzanine near the end of a building, the effects are likely negligible. However, if the floor system takes up all or most of the building footprint, the effects on the lateral force resisting system are likely significant. The floor system in the latter case is a diaphragm located somewhere between the main floor below and the ceiling or roof above. In a typical post-frame building, without a second floor system, approximately 50% to 63% of wind pressures on the sidewalls are taken down into the foundation, while the remaining 50% to 37% are taken up into the roof diaphragm. The roof diaphragm collects lateral wind loads from the sidewall columns and transfers the loads into the endwalls according to the stiffness relationship of all the involved components. This process is discussed in Diaphragm Design of Metal-Clad, Wood-Frame Rectangular Buildings (ASAE EP484) and referenced in the IBC. When a large second floor system is introduced, approximately 25% of wind pressures on the sidewalls are transferred down into the foundation, while approximately 75% is transferred up into the floor and roof diaphragms (see Figure 1-1 & 1-2). A large second floor system may increase the lateral stiffness of the building and thereby reduce lateral deflections due to wind and seismic loading. In the process of stiffening
the building, however, the shear loads in the endwall may increase by 100 or more percent. To ensure that the endwalls are not overloaded, it is not recommended that the effects of the second floor system are ignored, even when the roof diaphragm and all other components of the lateral force resisting system are sufficiently stiff and strong and do not require help from the second floor diaphragm.

Figure 1-1: Wind pressure diagram in a single story post-frame building

Figure 1-2: Wind pressure diagram in a two-story post-frame building
The following are two design examples of post-frame buildings that included a second floor or mezzanine. Since the focus of this article is on two-story post-frame buildings, the design examples selected showcase a variety of options that can be used to frame a second floor while still working in conjunction with typical post-frame methods.

Design examples-

**Example 1: 60’x120’x22’ Middlesex County Fair building-** The post-frame building was built in 2013 by Tri-State Buildings, LLC of Stevens, PA. The building is used by the Middlesex County Fair Association to store antique farm equipment. The building was designed under the 2009 IBC as an S-2 use using VB construction. There is a large u-shaped mezzanine in the building. The floor framing consists of TJI floor joists supported by glulam beams and steel columns. The framing is also tied into the sidewall of the building and is supported by glulam columns found in that wall. (photos courtesy of Tri-State Buildings, LLC)

The structural design of this building utilized wall and roof diaphragms to resist lateral loading based on the procedures described in the ASAE EP484 Diaphragm Design of Metal Clad, Wood Frame Rectangular Buildings. Steel roof panels were fastened to 2x4 roof purlins that were attached to the roof trusses. Roof trusses and roof rafters were installed 4’ on center and were designed to bear on 2x12 headers which span between the 8’ on center wood glulam posts. Steel siding was installed on 2x4 wall girts which were fastened to the wood posts. Design of the wood members and their connections was completed according to the National Design Specification (NDS) for Wood Construction as published by the American Wood Council. The second floor framing consisted of wood I-joists that were supported by wood glulam beams. The second floor glulam beams were supported by glulam posts within the perimeter walls and steel columns at interior areas. In this case the client preferred steel columns to minimize their size but wood glulam columns were also an option. The second floor added an additional structural benefit to the design by increasing overall building stiffness. In this building the second floor was designed for a substantial commercial storage load of 125 psf live load and 15 psf dead load. The main wood post-frame portion of this building utilized embedded post foundations with concrete collars around the post for lateral and uplift resistance. The embedded post foundations were designed according to ASAE EP486 Shallow Post and Pier Foundation Design.
Example 1 Figure 1: Glulam beams with steel columns to support floor framing
Example 1 Figure 2: TJ floor joist installation
Example 1 Figure 3: Finished mezzanine/2nd floor
Example 1 Figure 4: View from mezzanine/2nd floor level
Example 1 Figure 5: View of glulam beams tied into building sidewall
Example 1 Figure 6: Exterior of building
Example 1 Figure 7: Exterior of building
Example 1 Figure 8: Second Floor plan
Example 1 Figure 9: Second Floor Framing Plan
Example 1 Figure 10: Section through 2nd floor framing
Cross Section D/3

Example 1 Figure 11: Section Detail of sidewall support post for 2nd floor beam
Example 2: 67’x78’x14’ Post-Frame Building for Attaboyz Archery Center located in Marysville, OH. This unique post-frame building is an archery facility that contains an indoor archery range as well as a bow shop and retail area. There is a second floor area that contains a few offices and a break room. The building was constructed by Kennedy Construction in 2018 (photos courtesy of Kennedy Construction and Attaboyz Archery).

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Example 2 Figure 1: Exterior of the Building
Example 2 Figure 2: Framing of the building shell
Example 2 Figure 3: Aerial view of building during construction
Example 2 Figure 4: Interior framing of 2nd floor area
Example 2 Figure 5: Finished interior view of retail area w/ 2nd floor
Example 2 Figure 6: Plan view of 2\textsuperscript{nd} floor area
Example 2 Figure 7: Framing Plan
Example 2 Figure 8: Cross Section through building
Example 2 Figure 9: Partial Section through 2nd floor area