DESIGN CONSIDERATIONS FOR POST-FRAME BUILDINGS IN HURRICANE REGIONS

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Post-frame buildings are some of the most cost-efficient, yet resilient, construction systems available today. In rural America, these buildings have been a fixture for decades, providing housing for livestock, space for farm equipment, equestrian facilities, and shop uses. More recently, post-frame buildings have been making their way into residential, business, and industrial districts as private homes, office buildings, warehouses, retail space, educational facilities, recreational structures, and places of worship. Many of these buildings are being constructed in hurricane-prone regions with extreme winds and impact loads from wind-borne debris. In such areas, cladding and all wind-resisting components of the structure are likely to be tested repeatedly during the life of the structure. Post-frame buildings are well-suited for these load conditions and are up to the challenge. Hurricane load conditions, however, are a real threat to any building and should not be underestimated. This article provides a simplified overview of general design considerations, reviews the components of wind-resisting systems, notes common design and installation oversights, and references wind-borne impact design requirements for buildings located in hurricane-prone regions.

The most recognized characteristic of any hurricane is the high wind speed. Wind speed is the base value for calculating wind loads on a building. The Minimum Design Loads and Associated Criteria for Buildings and Other Structures standard published by the American Society of Civil Engineers (ASCE/SEI 7) defines Hurricane-Prone Regions as coastal areas along the Atlantic Ocean and Gulf of Mexico where the basic wind speed for Risk Category II buildings is greater than 115 mph (Figure 1).

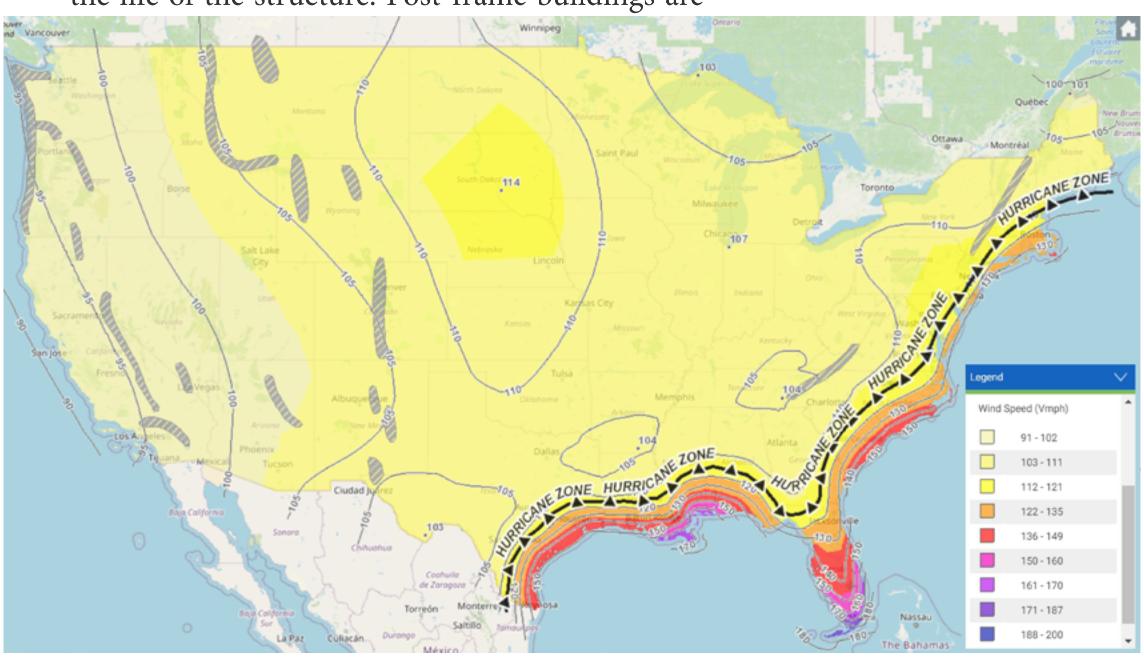

Figure 1: Hurricane Wind Load Map (image provided by ASCE 7 Online HAZARD TOOL: ASCE/SEI 7-16)

Less obvious is the relationship between the wind speed and the wind load effect on the building. Extreme wind speeds create even more extreme load effects on the building. A 10% increase in wind speed results in an approximately 20% increase in wind load on the building. A building located in a 180 mph area may be subjected to a wind load that is two and a half times greater than the wind load produced by 115 mph winds, while the increase in wind speed is only 57%. To put this in perspective, if the relationship between the wind speed and the wind load effect was linear, the wind speed in the latter example would be over 280 mph (2.5 times 115 mph). Additionally, the nature of hurricane winds leads to a potentially longer duration of exposure and from more directions than other sources of high wind.

Constructing a post-frame building that will safely and predictably withstand hurricane loads cannot be done without an analysis-based design. It is true that many non-engineered post-frame buildings withstood the test of time. The strength and safety of such buildings, however, is an unknown quantity. Building "by ear" is not advisable especially for buildings located in hurricane regions. Fortunately, the design procedures are the same and are governed by the same design standards as post-frame buildings located elsewhere in the country. ASCE/SEI 7 provides separate provisions for wind pressures on components and cladding (C&C) and wind pressures on the main wind force resisting system (MWFRS). Each component and connection in the building's envelope, including the cladding material, roof purlins or rafters, and wall girts should be sized and detailed to withstand the calculated local C&C wind pressures. The nearest members and connections of the MWFRS (columns, trusses) must be designed to receive the localized C&C loads from the cladding members and safely transfer them into the larger MWFRS systems until they are absorbed entirely and no longer control the design. It is important to consider the edge and corner zones as defined in ASCE/SEI 7 and not skip any steps. Wind-related failures in buildings often start with corner and edge surfaces peeling away from the building. Installing additional intermediate purlins and girts and extra fasteners in these areas may be necessary.

Collectively, the MWFRS pressures on the building surfaces create a net lateral load on the building. The lateral force resisting system (LFRS) of the post-frame building, typically comprised of embedded columns, roof trusses, the roof diaphragm, and shear walls (endwalls and sidewalls), is responsible for providing a continuous path of load resistance between the load source, the wind, and the source of load resistance, the earth. Each component of the LFRS, especially the roof diaphragm, requires careful detailing to ensure that a continuous load path is provided. The design and detailing of splices in the diaphragm chords are often omitted. Figure 2 shows a diaphragm concept where the roof is separated into two smaller diaphragms, each having two diaphragm chords. Other concepts may use more or all roof purlins as diaphragm chords or use one large diaphragm with structural ridge cap capable of transferring shear forces between the two smaller diaphragms. Some of the other commonly overlooked areas include blocking

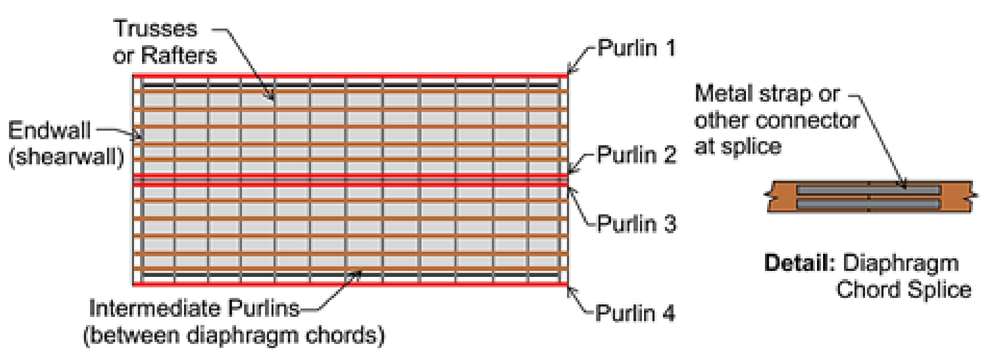

Figure 2: Roof diaphragm with some purlins as chords

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between roof purlins at the endwalls (Figure 3),

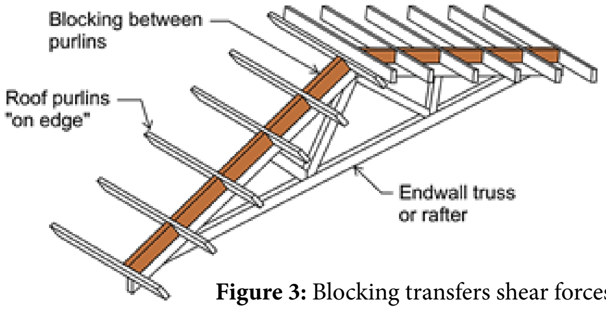

Figure 3: Blocking transfers shear forces.

shear transfer across a continuous horizontal strip of non-structural translucent wall panels (Figure 4), design and detailing of collector members and

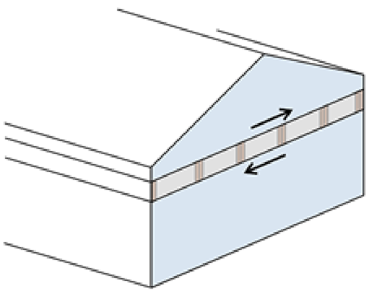

Figure 4: Shear Transfer complication at translucent panels

connections in buildings with shear walls or braced frames that are distantly spaced in the same wall (Figure 5), design of the skirt board and connections to transfer shear forces from the sheathing in the wall into the columns (Figure 6), and design complications related to the use of knee braces in the primary frames between columns and trusses.

Equally important are the building's components and connections resisting wind uplift forces, from roof sheathing, purlins, trusses/rafters, to columns and foundations. The secondary members and components are as important as the primary members. A local failure of the secondary members and components may create openings in the building's envelope potentially tripling the internal building pressures (GCpi of 0.55 vs 0.18) leading to progressive failures. The secondary roof components are also part of the lateral force resisting system: once the envelope is compromised, so is the building's ability to resist lateral loads.

Wind-borne debris is a major design consideration. ASCE/SEI 7 provisions stipulate that glazed openings must be impact-resistant or protected by impact-resistant covering in buildings located in areas with basic wind speeds of 140 mph or greater. This requirement also applies to buildings located within 1 mile of the coastal mean high water, where the basic wind speed is 130 mph or greater. If glazing is not impact-resistant or protected by an impact-resistant system, the glazing area should be treated as an opening - potentially changing the envelope enclosure classification from an "enclosed building" to a "partially-enclosed building". State and local codes may also require the wall and roof assemblies to be impact-resistant. The 2020 Florida Building Code (2020 FBC), for example, provides a list of approved wall and roof assemblies and requires testing for all other assemblies. Some wall and roof assemblies may require thicker gauge corrugated metal panels installed over plywood or OSB panels to achieve the required impact rating.

The continued expansion of post-frame construction is a welcome trend that should be embraced responsibly. Design and installation oversights may have high consequences. This is especially true for buildings located in hurricane-prone regions with high occupancy loads

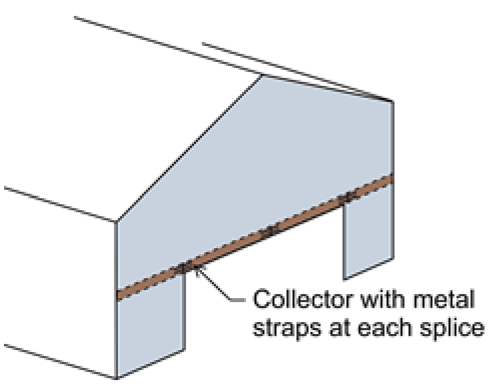

Figure 5: Collector members within shear walls

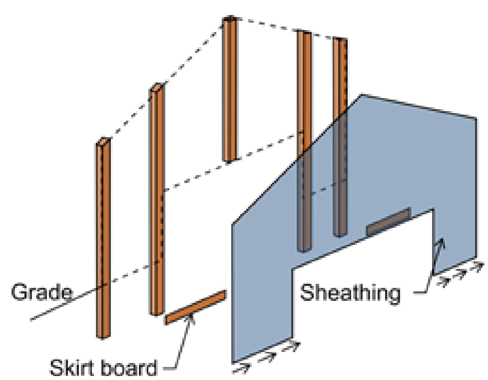

Figure 6: Multiple elements transfer lateral loads

or in densely-populated districts. In response, the post-frame industry combined the wealth of traditional construction practices, the standard engineering mechanics, and the empirical data to create post-frame-specific engineering standards and later the Post-Frame Building Design Manual (PFBDM, NFBA), the Non-Diaphragm Post-Frame Building Design Guide (NDPFBDG, NFBA), and other technical resources. Today, the post-frame industry can offer the familiar framing methods of traditional post-frame construction backed by modern engineering practices to produce post-frame buildings that can withstand the worst of the hurricane loads safely and predictably.

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This article was subjected to a peer review process conducted by the NFBA Editorial Committee, which consists of at least 10 members from engineering and academic organizations throughout the United States who are each knowledgeable about Post-Frame construction.