Keeping Long-Span Roofing Weathertight

By Kenneth J. Guffey, PE

Post-frame construction is continuing to expand its footprint. Part of this expansion involves much larger structures than was common just a few years ago. Improved materials and expanded design knowledge have helped to increase the number and size of these larger structures. Post frame can now handle building widths well over 100' wide, and heights of 20' or more at the eave are possible. Even in this size range, post frame can provide a structure that meets even the strictest design criteria, at a cost that is very competitive relative to other types of construction.

One of the design considerations now getting increased attention is how to effectively use traditional, exposed-fastener metal roofing panels in these large structure applications. Multiple panels are needed to reach from eave to ridge, creating the need for panel endlaps. When all aspects of the roof system design and installation are not carefully considered, these large structures can develop weathertightness concerns at the roof panel endlaps and other areas. The building's contents, as well as the structure itself, can be damaged when moisture is allowed to get past the roof system and enter the building.

Leaking roof systems are not acceptable. Roof system "movement," for example, can overload panel endlaps and cause them to become compromised over time, resulting in moisture getting past these panel endlaps. There are several load cases that generate the forces known to cause roof system movement. Currently, there are only a few known effective solutions to prevent and repair post-frame panel endlaps and other areas that become compromised. Differences in building design and construction (i.e., truss roof system vs. post and beam roof system), differences in building materials (i.e., 100 percent aluminum vs. steel roofing), etc., make a universal solution difficult. However, with a better understanding of roof system movement, effective panel endlap designs and other solutions can be identified to allow the roof system to remain weathertight over its life span.

The focus of this article is the roof panel endlap, recognizing that other areas of the roof system can also experience damage (i.e., other shear transfer areas, etc.). More work needs to be done to understand roof system movement and the interaction between the various roof system components. Over the past several years, Rigidply Rafters Inc. has investigated numerous projects, has viewed their roof system weathertightness issues, and assisted with their solutions. Following is a review of these experiences.

WHAT IS HAPPENING?

1. Thermal expansion and contraction of the metal panels generate forces if resistance to this movement occurs. Any resistance forces generated need to be effectively handled, or alternatively the movement of the roof panels must be allowed. Roof panels can change in length significantly over their entire temperature exposure range. It is not uncommon for a steel roof panel to change in length at least ½" in 40' of panel length from the coldest to the warmest temperature exposure. Roof panels of 100 percent aluminum move at approximately twice the rate of steel.
2. Tall, wide and long post-frame structures can structurally tolerate more movement than conventional construction. This increased movement, however, can cause problems with building weathertightness. The post-frame structure resists the various loads as an assembled "unit." It is important to note that even when the roof system is not used as a structural diaphragm by the building design professional in the building design, it is still part of the structure and will take load unless the framing below is stiff and strong enough to prevent load from entering this roof system. In reality, the framing in a post-frame structure is rarely stiff enough to keep forces out of the roof system. Therefore, areas such as panel endlaps can become overloaded.

SYMPTOMS OF ENDLAP COMPROMISE

1. Leaking panel endlaps
2. Endlap and nearby fasteners backing out
3. Holes in the metal panels at the endlaps becoming elongated (both steel and aluminum)
4. Endlap fasteners shearing off just below the washer

5. Endlap fastener washers tearing and separating
6. Wood framing deterioration under the endlap area

COMMON OBSERVATIONS WITH ENDLAP COMPROMISE

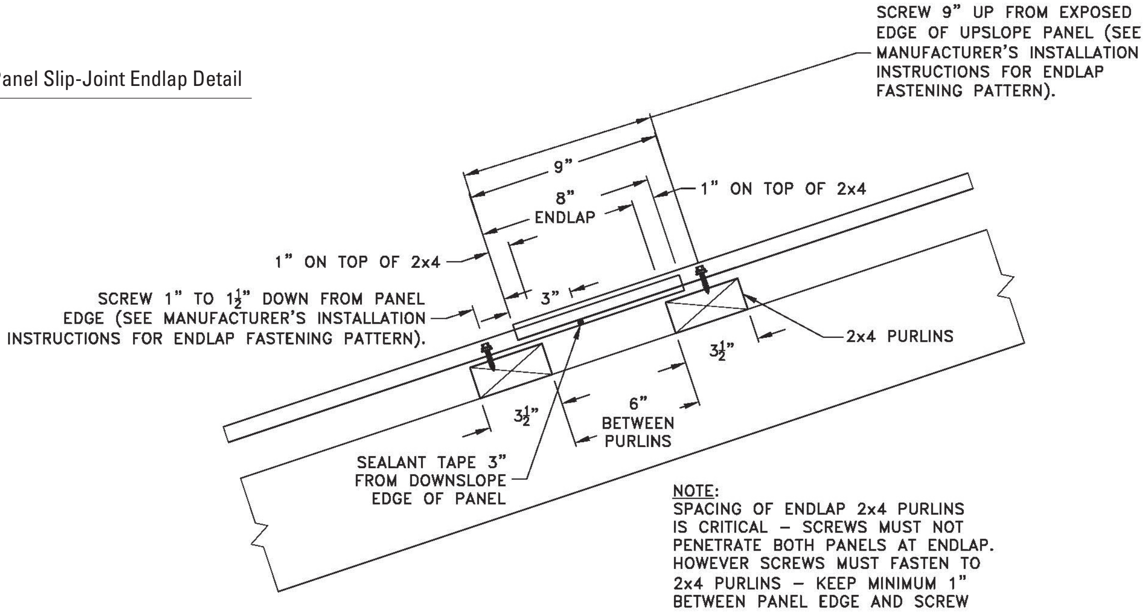
1. Individual roof panel lengths in applications requiring endlaps tend to be 24' or less for steel, and 16'8" or less for aluminum. Individual panel lengths longer than these values have a significantly higher frequency of endlap issues. Reducing individual panel lengths below these values does help to reduce endlap issues and has historically been the industry's suggestion. However, reducing individual panel lengths has not proven effective on these more recent, much larger structures.
2. Roof systems with more than one endlap in an eave to ridge panel run (i.e. three or more panels) have more issues than an application with a single endlap in an eave to ridge panel run (i.e., two-piece roof). Applications with a single panel and no endlaps have few issues, provided the panel length is below 36' for steel and 20' for aluminum.
3. Endlap issues tend to be more significant at weaker, more flexible areas of the roof system. Post-frame structures by design have variations in building flexibility/stiffness within the structure. The stronger and stiffer roof areas seem to resist movement better, and force the issue to weaker, less stiff areas. Roof system movement combined with panel expansion and contraction often overload panel endlaps on larger structures. The contribution of each, however, is currently very difficult to determine.
4. With problem endlaps, the top or upslope panel at the endlap is the most likely to experience endlap fastener hole elongation over time. Fastener washers at these endlaps are typically also damaged due to the panel movement under the washer. In some cases, fasteners have fractured. Even if roof system movement from weather-related building design loads is minimized through stronger and stiffer framing, roof system metal panels expand and contract at very different rates than the wood framing underneath.
5. With problem endlaps, the endlap fasteners often are observed to be backing out. Butyl endlap sealant tape is commonly omitted at panel endlaps in post-frame structures. Water and dirt siphon upslope between the endlap panels, creating a visible stain and "dirt line." If the moisture reaches the shank of the endlap fasteners between the panels, it enters the building, causing the wood around the fastener shank to become wet and weakened, and this moisture eventually causes the wood to deteriorate. This moisture issue reduces the endlap fastener's structural capacity, promoting fastener backout. Butyl endlap sealant tape needs to be installed in panel endlaps. We can't just worry about handling the forces involved with the endlap—we must keep the endlap dry.
6. 1½" long roof panel fasteners have fewer issues than 1" long roof panel screws in larger structures. Larger diameter screws also have fewer issues. Increasing the amount of fasteners at and around the panel endlap has been helpful in more effectively handling the forces at the panel endlap. It is common to use the double fastener endlap pattern not just at the panel endlap, but also at least in the adjacent upslope and downslope purlins. Panel endlaps and adjacent purlins that utilize the "beefed up" double fastener pattern have fewer issues, particularly in two-piece roof applications (i.e., only one panel endlap in an eave to ridge panel run).
7. Fasteners applied to the top of roofing panel ribs have fewer issues than fasteners applied through the flat of the panel. Fasteners applied to the top of the panel ribs effectively create a gap between the fastener/panel intersection point and the wood purlin underneath—typically this gap is ¾" or the height of the panel rib. This gap allows the fastener shank to flex to some degree without damaging the wood purlin or the panel. However, there is a limit to how much movement can be handled with this connection design.
8. Southern Yellow Pine (SYP) purlins have an open cell structure vs. Spruce-Pine-Fir (SPF) purlins. Fasteners tend to back out of SYP much easier than SPF due to SYP's open cell structure allowing moisture to move quickly and frequently in and out of the wood. These wood purlin moisture content changes encourage fastener backout.
9. The south side of a structure has more endlap issues than the north side. Those slopes that see the sun first warm up faster each day. The faster the temperature rise, the faster the roof panels expand. This rate of expansion makes a difference and causes more issues than slower rates of expansion and contraction. Expansion and contraction related endlap issues are not just from the annual changes in temperature, but are also from the more frequent daily changes in temperature.
10. Insulation applied directly under the roof panels elevate the actual roof panel temperature during those more intense summer days. This further increases the expansion/contraction panel length changes in the roof panels. The net result is more movement at the panel endlaps.

COMMENTARY

Roof panel fasteners connect the roof panels to the wood framing underneath, and therefore transfer forces into and out of the roof panels of the post-frame structure. Roof panels in most post-frame structures try to "help" the structure carry various loads. These light-gauge roof systems have limits to their structural capacity. This is particularly true of the fastener connection between the roof panels and the wood purlins.

More work is needed to understand these higher, wider and longer post-frame structures relative to their roof panel system behavior, and to further explore potential solutions to issues that develop. Preliminary work and observations indicate that effective solutions can be developed and will vary depending on a variety of building parameters.

Figure 1. Roof Panel Slip-Joint Endlap Detail



Keeping in mind that panel endlap issues are often caused by a combination of different loads/forces, solutions must consider all these potential forces and not just panel expansion and contraction. For example, areas of a roof system can be strengthened such that movement is relocated to areas better able to handle this movement (i.e. beefing up panel endlap fastening patterns). In other cases, movement is simply too great and must be reduced through a stronger and stiffer frame design. In yet other situations, particularly very long eave to ridge distances, the roof panels must *not* be connected in any way to any adjacent roof panel. This "slip joint" approach, as illustrated in **Figure 1**, is becoming more common because it is very effective in solving the endlap weathertightness issue. However, careful consideration must be given to the structural implications of "un-connecting" roof panels from each other, particularly due to the fact that many post-frame structures depend heavily on the roof system diaphragm for at least some structural support.

Contact your building design professional and your roof panel manufacturer to collectively establish an effective approach to connecting your roof panel system to your structure, and to establish a reliable approach to handling your panel endlap design. Taller, wider and longer post-frame structures offer many benefits to their owners, and are here to stay. Our industry needs to realize that post-frame structures are not temporary structures, but are in fact structures that the building owner expects to utilize for many years, in applications with high expectations for performance, appearance, and weathertightness. FBN

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