Hurricane Hugo's Effects on Metal Edge Flashings

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ABSTRACT

This paper reviews current codes and design guidelines regarding wind performance of metal edge flashings, counterflashings, copings, gutters and nailers, and discusses selected case histories from Hurricane Hugo. It also offers conclusions and design recommendations. In preparing the paper, literature from Canada, England, West Germany and Japan was consulted on a somewhat limited basis in addition to literature from the United States.

INTRODUCTION

When Hurricane Hugo hit the coast of Charleston, S.C. in September 1989, it clearly showed the role that metal edge flashings play in a roof's wind performance. As with past wind events, many of the roofing failures associated with Hugo were directly related to inadequate securement of metal edge flashings or their nailers. Loss of copings and gutters, which became missiles, also contributed to roof damage. Their poor performance resulted in this re-evaluation.

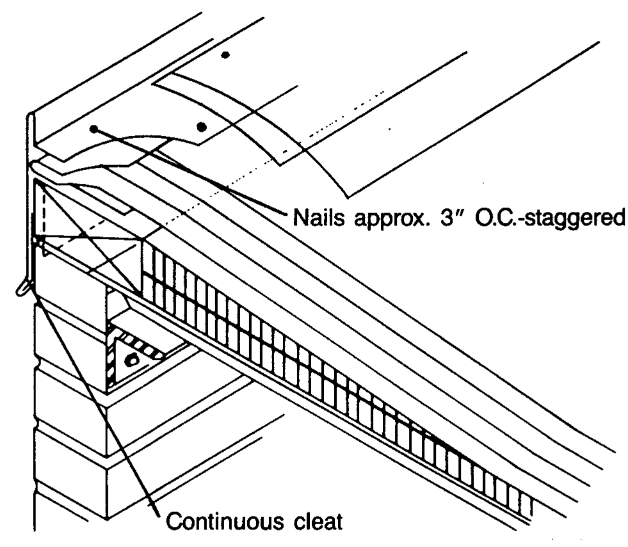
Hugo inflicted heavy damage in Puerto Rico and the Virgin Islands before heading to South Carolina, where it was a Category 4 when it struck the coast. (The Saffir/Simpson Potential Scale has five categories. Category 1 is minimal and Category 5 is catastrophic; Category 4 is extreme damage potential.) It continued to inflict significant damage as it traveled inland for a distance exceeding 200 miles (325 kilometers). A report from Texas Tech University's Institute for Disaster Research[1] characterizes the wind speeds and describes roof performance.

Wind's effects on metal components is not new information. It has long been widely recognized that the edge condition is vitally important. Baker,[2] Griffin,[3] Fricklas[4] and Factory Mutual (FM)[5] all acknowledge or report this fact. And at a major U.S. wind/roofing workshop held in 1989,[6] research regarding metal edge flashings ranked second out of 18 identified research needs. However, although Baker acknowledges the problem, he does not give guidance on avoiding it. Griffin's only advice is to use 18-gauge (1.2-millimeter) metal with a continuous cleat, which does not necessarily eliminate blow-offs. Fricklas refers to FM 1-49,[5] which does give significant design guidance but has many deficiencies. This paper will discuss FM 1-49 in depth. Manuals by NRCA,[7] the Canadian Roofing Contractors Association (CRCA),[8] the Alberta Roofing Contractors Association (ARCA)[9] and the Roofing Contractors Association of British Columbia (RCABC)[10] have limited or no information regarding securement of nailers and metal edge flashings, copings or gutters.

CODES AND GUIDELINES

ANSI A58.1[11] and the three U.S. model building codes present design methodology for calculating uplift loads on the roof system. However, the design procedure does not help determine loads on metal edge flashings, counterflashings, copings, gutters or the nailers to which these metal components are attached. Table 1 of FM 1-49 does give uplift loads and "outward force" on these components, but their correlation with ANSI A58.1 is unknown. *Thus, insignificant knowlege currently exists regarding component loading.*

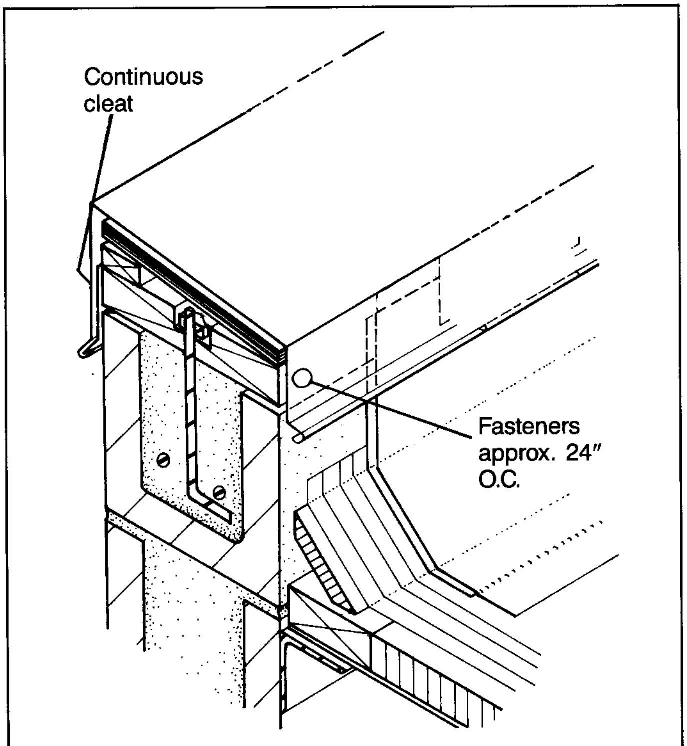
The **NRCA manual**[7] shows metal edge flashing and coping details (Figures 1 and 2) and a gauge selection guide (Figure 3). A 26 gauge (0.45 millimeter) steel cleat is permitted for a 6-inch (150-millimeter) vertical face, which is probably inadequate even under moderate wind loads. Also, the manual gives no criteria for cleat fastening. For the coping detail, the manual shows face fasteners for the inner leg, but gives no criteria for fasteners other than the 24-inch (600-millimeter) spacing, which may be too great for high wind loads.



Notes: Attach nailer to masonry wall. Refer to Factory Mutual Data Sheet 1-49.

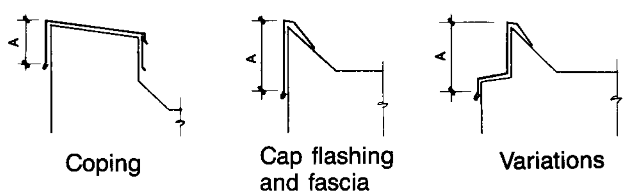
Refer to Built-Up-Roofing Detail Y for metal thickness and cleat requirement.

Figure 1 Light-metal roof edge (Source: The NRCA Roofing and Waterproofing Manual, *BUR Detail D).*



Notes: Refer to Built-Up-Roofing Detail Y for metal thickness and cleat

Figure 2 *Light-metal parapet cap (Source:* The NRCA Roofing and Waterproofing Manual, *BUR Detail J).*



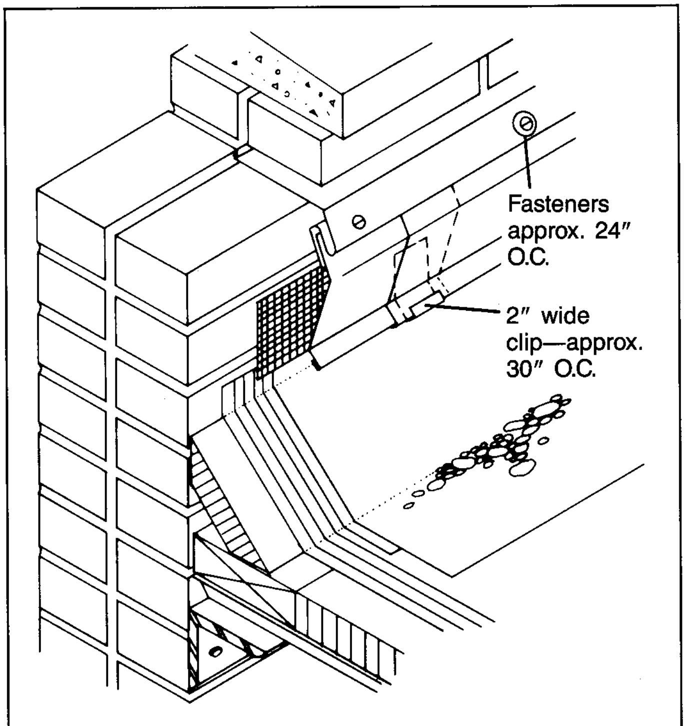
RECOMMENDED MINIMUM GAUGES FOR FASCIA SHOWN ABOVE

EXPOSED FACE WITHOUT BRAKES "A" DIMENSION	CLEAT REQUIRED	GALVANIZED IRON	COLD ROLLED COPPER
UP TO 4" FACE	NO	26 GA.	16 OZ.
4" TO 6" FACE	YES	26 GA.	16 OZ.
6" TO 8" FACE	YES	24 GA.	16 OZ.
8" TO 10" FACE	YES	22 GA.	20 OZ.
10" TO 15" FACE	YES	20 GA.	ADD BRAKES TO STIFFEN

Note: When using the above table, other items should be considered, such as fastening pattern. For instance, if the metal can only be fastened at 10-foot intervals, a heavier gauge metal would be required. All cleats will be continuous and of same material of equal or greater thickness than the fascia metal used.

Figure 3 *For metal fascia exposed to view (Source:* The NRCA Roofing and Waterproofing Manual, *BUR Detail Y).*

The manual also shows metal counterflashings (Figure 4), with 2-inch (50-millimeter) clips at 30 inches (750 millimeters), which may also be too great for high winds. This detail also allows elimination of the clips when the vertical leg is 6 inches (150 millimeters) or less, which could lead to problems in high wind areas.



Notes: Clips at the bottom of the flashing are not necessary on flashings of 6" or less.

Figure 4 *Base flashing for wall-supported deck (Source:* The NRCA Roofing and Waterproofing Manual, *BUR Detail F).*

The **CRCA manual**[8] shows an interesting metal edge flashing (Figure 5). Rather than using a cleat, as is commonly done in the United States, the lower edge of the flashing is broken horizontally and nailed. This loads the fasteners in shear, thus eliminating the complex interaction between the cleat and flashing. Fasteners are specified to penetrate a minimum of 1 inch (25 millimeters) and to be spaced at 24 inches (600 millimeters). The manual also specifies a 24-gauge (0.56-millimeter) steel and gives data on other types of metal.

The design of this detail is probably suitable for high wind loads, even with these minimal dimensions. Although the manual shows copings, it does not give specific criteria for attachment.

The **ARCA manual**[9] does not show cleats for metal edge flashings, counterflashings or copings. For metal edge flashings, the manual specifies face fasteners at 4 feet (1.2 meters), which is too great except for low wind loads. The manual also specifies coping fasteners at 4-foot (1.2-meter) spacings. Lower legs of counterflashings are not required to be fastened.

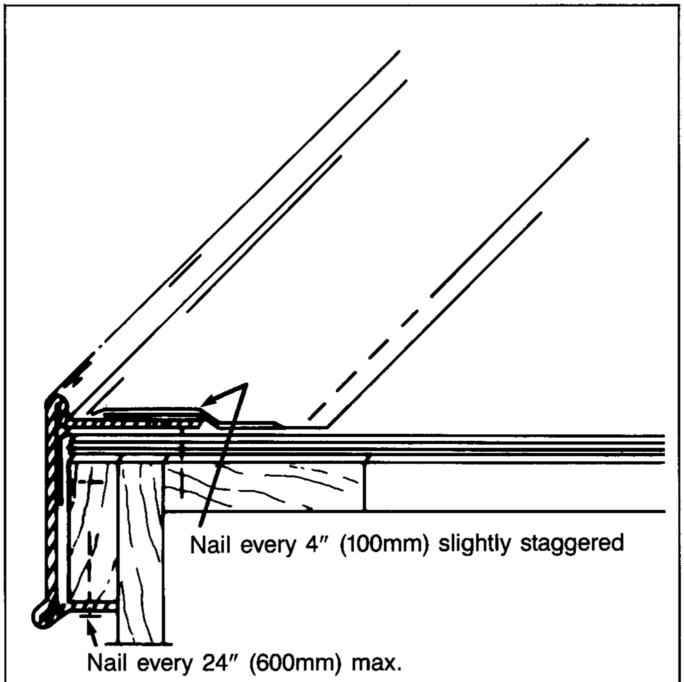


Figure 5 Metal gravel stop-sloped edge, slopes 1:12 to 1:4 (Source: CRCA Roofing Specifications Manual, *Detail FL504).*

Architectural Graphic Standards (AGS)[12] and the ARCA manuals have charts for sizing metal gauges. But neither chart differentiates between high and low wind loading conditions. This criticism also applies to the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) manual.[13]

AGS does not give criteria on cleat gauge with respect to the flashing or coping gauge, as FM 1-49 and SMACNA do. AGS does not give criteria on cleat fastening. For copings, it shows cleats on each coping leg, which is difficult for the applicator to execute and sometimes results in poor cleat/coping interlock. AGS does show clips for counterflashings, but the spacing is at 4 feet (1.2 meters), which is probably excessive for high wind loads.

The **SMACNA manual** gauge sizing chart is very complex. It also permits a 5-inch uncleated vertical face for metal edge flashings. (The NRCA manual permits a 4-inch uncleated face.) These uncleated conditions may present problems in high-wind areas. The manual does not give fastener criteria, other than for spacing. *This is the only document reviewed that gives the angle of the cleat break* (30 degrees from the vertical). The cleat's broken leg is dimensioned at one-half inch (13 millimeters), which is probably inadequate in moderate and high winds. Some of the details show cleats on each side of the coping. However, other details show the preferable method of cleating one face and face fastening the other. As with the NRCA manual, this manual shows the coping face fasteners spaced at 24 inches (600 millimeters).

For counterflashings, the manual states that "clips can be specified for the lower edge," but guidance on spacing and fastener loads is not given. Rake and eave metal for shingle roofs is shown to be fastened only along the horizontal flange (as in the NRCA manual). The SMACNA manual gives a fastener spacing of 18 inches (450 millimeters). In high-wind areas, this is probably inadequate.

FM 1-49[5] was the most comprehensive guide reviewed. While it has several minor deficiencies, its major one is that it only covers low and moderate wind loadings. This guide has an easy-to-use gauge selection chart. It also has several recommendations regarding nailers: one-half-inch (13-millimeter) diameter bolts at 4-foot (1.2-meter) spacings are specified, except at 8 feet (2.4 meters) from corners, where bolts should be spaced at 2 feet (600 millimeters) on center. For steel decks, the manual gives alternatives for using screws in lieu of bolts for nailer attachment. The manual also specifies 1½-inch-(38-millimeter)-thick nailers as a minimum. Recommendations for nailing a top nailer to a bottom bolted nailer are given—two rows at 24 inches (600 millimeters), except at 8 feet (2.4 meters) from corners, where nails should be spaced at 12 inches (300 millimeters).

Withdrawal resistance of 100 pounds (45 kilograms) is specified. (Although not indicated, this is assumed to be an ultimate load rather than a working load.) The manual specifies continuous cleats to be fastened with annular threaded nails that penetrate the nailer a minimum of 1¼ inches (32 millimeters). The manual also gives options for screws. These cleat fasteners are specified to be spaced at 24 inches (600 millimeters) or 16 inches (400 millimeters), depending upon wind loads. Additional fasteners near corners are not specified. The effect of thermal movement on metal edge flashings prompted the recommendation of the thickest cleat to be 24 gauge, which may be inadequate. However, FM should recognize that if thermal movement concerns prove to be valid, the use of slotted fastener holes could permit heavier cleats.

The manual specifies fastening the lower leg of metal counterflashings at 36 inches (900 millimeters), with fasteners having a minimum pullout of 200 pounds (91 kilograms). FM 1-49 shows several details, but only one of them dimensions the broken leg that receives the cleat (Figure 6). A three-quarter-inch dimension is given, which is not common, but may be appropriate in moderate and high wind areas. A critical aspect of the cleat/flashing or coping interlock is deformation under load. Likewise, a critical aspect of this deformation is the location of the cleat fastener, which is not dimensioned. To exacerbate the lack of dimensioning, the details typically show the fasteners near the top of the cleat rather than near the cleat break (Figures 6 and 7). Another critical aspect of the cleat interlock is that the flashing or coping should have maximum engagement of the cleat. Yet Figure 7 shows the flashing only engaging about half of the cleat leg.

FM 1-49 does give some limited information regarding gutter securement, but it fails to point out that the gutter can impose a concentrated continuous edge load on the nailers or deck. Although this additional edge load can be large, particularly for wide gutters, designers often overlook it.

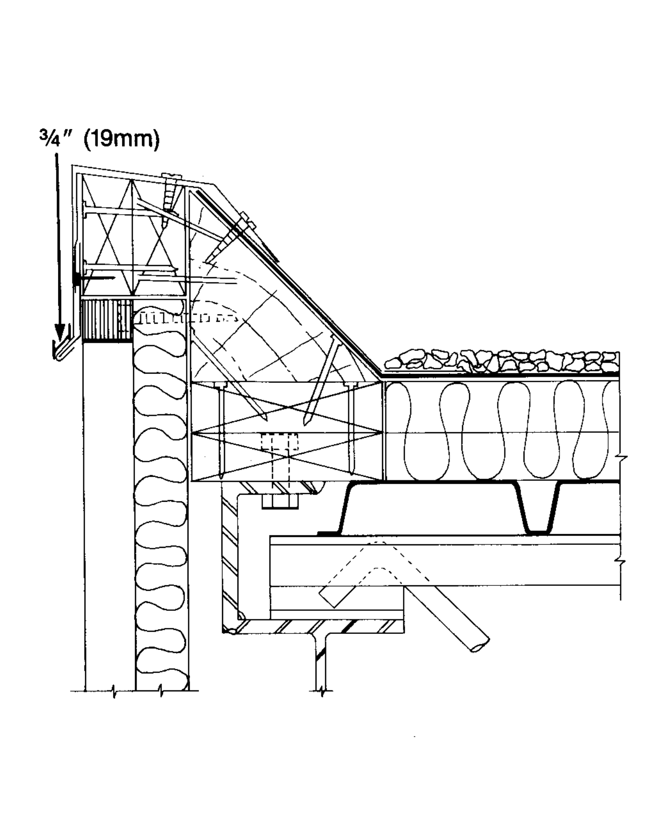


Figure 6 Perimeter flashing (Source: FM Loss Prevention Data 1-49, *Fig. 10).*

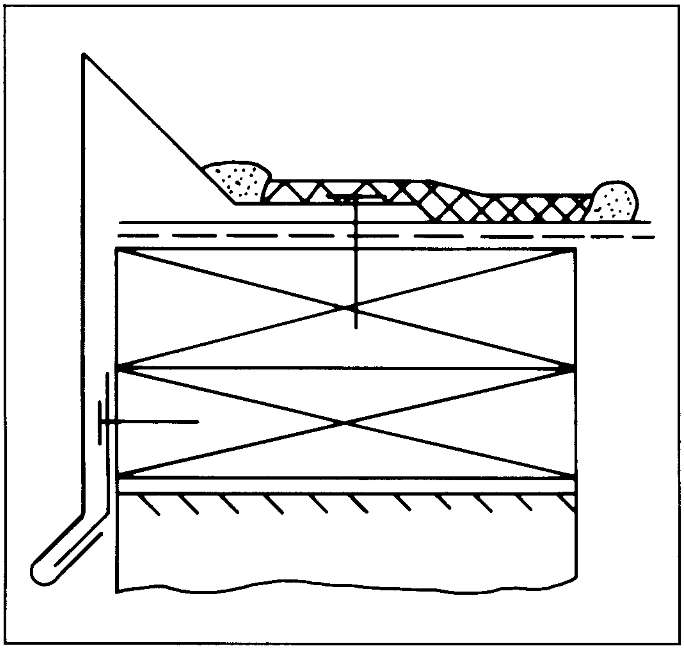


Figure 7 Membrane stopped at edge (Source: FM Loss Prevention Data 1-49, *Fig. 14).*

HUGO CASE HISTORIES

Photo 1 shows a metal edge flashing that disengaged from the continuous cleat and lifted up. On other portions of the building, the wind lifted and peeled the flashing and membrane. The flashing had a 7-inch (175-millimeter) vertical face. The flashing and cleat were 24-gauge (0.56-millimeter) stainless steel. The cleat was 2 inches (50 millimeters) high and had a three-quareter-inch (19-millimeter) break leg. The cleat was sealed to the wall. Cleat fasteners were located near the top of the cleat and were spaced 12 inches (300 millimeters) on center. Although the cleat and flashing were stiff, and the cleat had a long break leg, deformation of the flashing and cleat caused failure. Cleat fasteners closer to the break may have prevented failure. Although in this instance, an even longer cleat break leg may have been needed in addition to the fasteners' being located closer to the break.

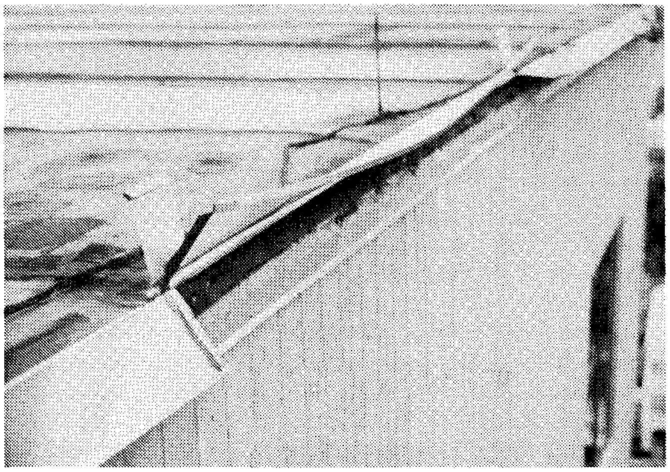


Photo 1 *Metal edge flashing disengaged from continuous cleat and lifted up.*

Photo 2 shows a nailer that was inadequately secured to a brick wall. A good cleat/flashing interlock (Photo 3) prevented peeling of the flashing and membrane.

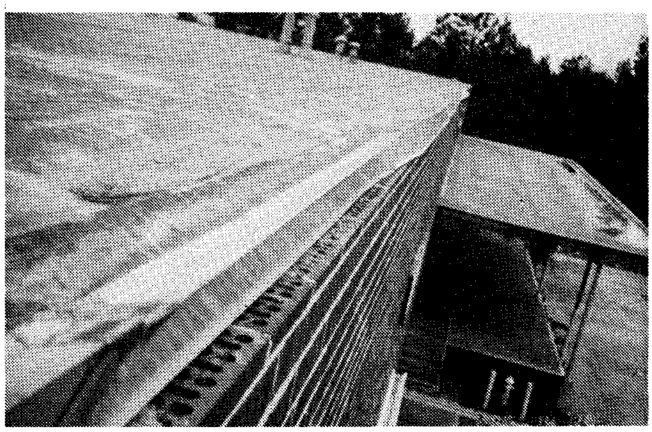


Photo 2 *Wood nailer inadequately attached to brick wall. See Photo 3.*

Photo 3 Good cleat attachment and cleat/metal edge flashing interlock prevented the metal edge flashing and membrane from lifting and peeling.

Photo 4 shows a preformed coping attached with clips that were adhered to EPDM. The EPDM was adhered to the concrete and brick parapet. Coping sections were 10 feet (3 meters) long, and two clips were installed per section. The adhesive connection was inadequate.

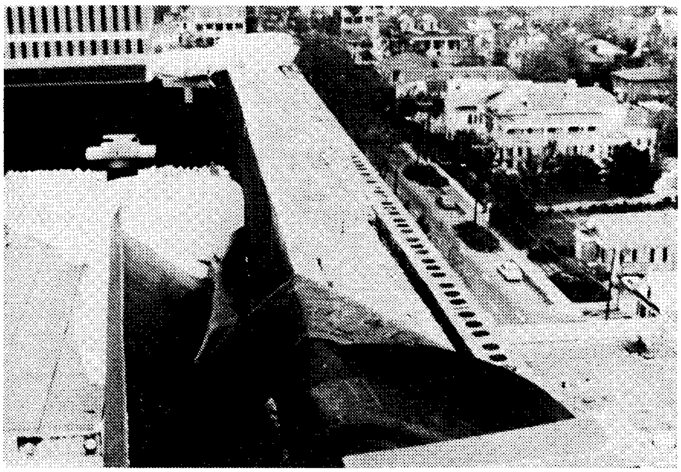


Photo 4 Preformed coping clips were adhered to EPDM, which was adhered to the concrete and brick parapet. Several sections of coping were blown off.

Photo 5 shows a metal edge flashing attached to a nailer that was 1½ inches (38 millimeters) thick. The nailer was fastened to a bottom nailer bolted to the wall. The top nailer was fastened with 10 penny nails spaced an average of 9 inches (225 millimeters) on center. This gives a calculated working load resistance of 90 pounds per lineal foot (124 kilograms per meter). Initial failure probably began several feet (meters) from the location where steel decking blew off. A secondary (progressive) failure was likely to be nailer lifting and peeling.

Photo 5 Metal edge flashing attached to a nailer, which was nailed to a bottom nailer that was bolted to the wall. The nails attaching the top nailer had a calculated working load capacity of 90 pounds per lineal foot (124 kilograms per meter).

Photo 6 shows a parapet with only a few sections of coping remaining. Most coping sections were blown off. Very inadequate attachment (two nails at each end of each section) caused the failure.

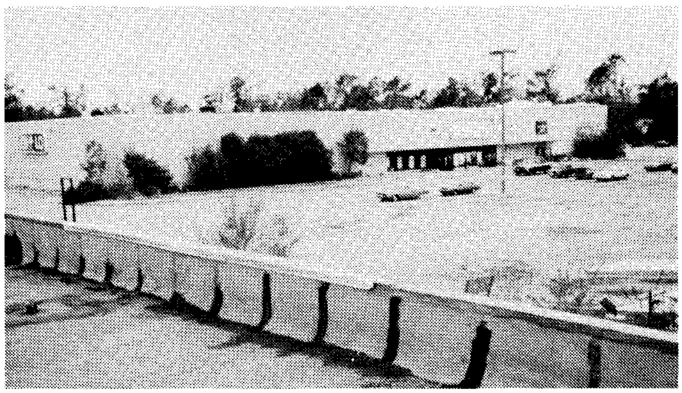


Photo 6 Ten foot long (3 meter) sections of 0.023-inch (60 millimeter) aluminum coping were attached with only two nails at each end. The coping had 2½-inch (62 millimeter) vertical legs. Most of the coping sections blew off.

CONCLUSIONS

Metal edge flashing, coping, counterflashing, and gutter performance is highly dependant upon design attention, yet these components seldom receive it. Lack of clear, concise and thorough design guides exacerbate lack of design attention.

RECOMMENDATIONS

A design methodology, including localized effects near corners, is needed to determine outward acting loads on components. An additional need is a standard practice to determine uplift on components. In the interim, FM 1-49 should be consulted for outward loads. Also, in the interim, the design uplift on components and nailers should be determined by:

- Calculating the uplift in accordance with ANSI A58.1 (or the local building code).
- Determining the width of the coping or metal edge flashing and multiplying by the uplift.
- Increasing the load by 100 percent.

Also recommended is an understanding of the deformation and interaction of cleats and flashing. This understanding is needed to determine metal thickness and lengths of coping break legs. Perhaps full-scale measurements at Texas Tech University's facility[14] can be used to provide this information as well as the information needed to determine the outward loads.

Other recommendations include a standardized laboratory test methodology to evaluate component performance and a comprehensive component design guide.

The following are interim design recommendations.

- Because metal should not be directly attached to concrete or masonry, nailers should be used to attach metal components. They should be bolted to concrete, masonry, cement woodfiber and lightweight concrete. Nailers may be bolted or screwed to steel or wood. They may be nailed to wood, provided a sufficient number and length of nails are used. In all cases, nailer fasteners should be designed to meet the design uplift. With bolted connections, at least three-quarters inch (19 millimeters) of wood should be left below the washer.
- For metal edge flashings and copings, the outer leg should be continuously cleated, face fasteners should be used or a detail similar to Figure 5 should be employed. For steel, cleats should be a minimum of 22 gage (0.80 millimeters), or thicker for very high wind loads, and have a minimum break leg length of three-quarters inch (19 millimet- ers). For very high loads, a break leg length of 1 inch (25 millimeters) should be considered. The break angle should be 30 degrees, as SMACNA recommends. Fasteners loaded in withdrawal should be annular or screw-shank nails or screws with a minimum penetration of 1¼ inches (32 millimeters). Spacing should meet the outward load, but no greater than 18 inches (450 millimeters). For a distance of 16 feet (4.8 meters) from the corner, the fastener spacing should be decreased by one half. Fasteners should be located about one-half inch (13 millimeters) above the cleat break.

  For shingle and tile flashings, an uncleated or fastened face may be acceptable for low or moderate wind loads, but the face dimension should not exceed 3 inches (75 millimeters).

  For heavy extruded sections, face fastening or cleats may not be needed. Adhesive should not be used to connect these components.
- Counterflashings often see little outward load. However, if they occur near a roof edge, they can be lifted and peeled out of their receiver. Depending upon loading conditions, continuous cleats or closely spaced clips may be needed, particularly near the roof edge.
- Gutters exert an additional continuous concentrated load on the nailers or deck, depending upon attachment details. The designer should allow for this added load. The gutter itself should be designed to resist the design uplift load.
- If the roof system incorporates an air retarder, the continuity of the retarder should be maintained at the roof perimeter. Smith[15] briefly reports on this aspect of component design.

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