

# GETTING THE EDGE ON ROOF WIND DESIGN

By Gerard J. Teitsma, RRC, RRO, CDT

**W**hile there are many items to include in roof system selection and design, one of the most important is allowing for adequate wind resistance. Proper design takes into account the building location and specific building attributes such as height, deck construction, parapet or roof edge configuration, and even building use. With this information, a roof system designer can design the roof to meet anticipated roof uplift forces. However, unless considerable attention is paid to roof design details (more specifically, the edge of the roof), the roof system will still be vulnerable to blow-off. This paper will focus on edge details that can help complete the wind design.

United States model codes (and therefore state and municipal codes) provide directives to allow for anticipated wind loads. For example, the International Building Code (IBC) states that, "Buildings, structures, and parts thereof shall be designed to withstand the minimum loads described herein. Wind loads on every building shall be determined in accordance with Section 6 of ASCE-7."

This is not dissimilar to other requirements for which the



*Untested, insecure edge detail.*

building designer anticipates. Licensed professional designers rely heavily on one document for guidelines – ASCE 7-02. This document provides guidance for calculating loads on structures, including roofs.

At the heart of the ASCE 7-02 methodology for calculating wind forces on buildings is a simple formula that relates velocity pressure to air mass and velocity:

$$Q = 0.00256 V^2$$

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Since the constant 0.00256 contains the density of air, the only value needed to satisfy this equation is the velocity of the wind. For most locations, ASCE 7-98 provides basic design wind velocity. Some locations are omitted from the ASCE map because of local anomalies such as mountains. In these areas, the designer must obtain the basic wind speed from a local weather or code authority. The wind speed shown on the ASCE map is the wind speed recorded at 10 meters above ground and in an open area such as an airport. The basic wind is then adjusted for other types of terrain and for elevations other than 10 meters above ground level. ASCE 7-02 provides formulas and tables to make further modifications based on the importance of the building and on unusual topographical features such as a building on the edge of a cliff.

With all of this information in place, the velocity pressure (i.e., the pressure equivalent of air at the design velocity) can be identified. However, the effect of this velocity pressure on buildings is not easily calculated. Instead, wind tunnel tests have been performed on model buildings to evaluate the actual effect on the buildings. These wind tunnel tests have provided the basis to estimate forces on buildings resulting from various velocity pressures. From these studies, it is shown that wind can exert a force down on a roof (useful to the structural engineer) and an uplift force, useful to the roof designer as well as the structural engineer. Also, the uplift pressure can be increased by internal pressures. These internal pressures are a function of openings in the building – how many and facing in which direction. This relationship is shown by the equation:

$$p = q_h [(GC_p) - (GC_{pi})]$$

*where*

**p = wind uplift pressure**

**q<sub>h</sub> = velocity pressure**

**GC<sub>p</sub> = external pressure coefficient**

**GC<sub>pi</sub> = internal pressure coefficient**

It should be noted that external pressure coefficients are not uniform across the roof. At a given velocity pressure, uplift is greatest in the corner of the roof, second greatest along the perimeters, and least in the field of the roof. This should be the first hint as to the reason why the edge of the roof and its design are so important. The internal pressure coefficient (GC<sub>pi</sub>) is dependent on whether the building is a closed building, an open building, or a partially enclosed building. This internal pressure coefficient is assumed to act uniformly throughout the roof, perimeter, and field of roof alike.

From these considerations, the wind uplift pressure on a roof system is determined by the roof system designer. If the building is insured by an insurance company affiliated with Factory Mutual (FM) or if the roof designer wants to meet FM requirements in addition to local code, FM also provides wind calculation techniques. As of January 2002, this process has become easier for the designer because the FM calculation methods are now almost identical to ASCE 7-98. The major difference between FM and ASCE 7-98 is that FM treats all buildings as having an importance factor of 1.15. For this rea-

son, FM wind design will usually result in higher wind uplift design forces than ASCE 7-98.

With the uplift pressure known, where is the roof designer to obtain a specific roof system meeting his or her needs? Unlike the structural engineer who can choose a steel, wood, or aluminum beam of varying dimensions to bear a load, the roof designer can only choose a complete roof assembly that has been tested at various uplift pressures. Most frequently, designers select systems that have been recommended by roofing materials manufacturers and tested by Factory Mutual. Some roof systems have been tested by Underwriters Laboratories (UL). Uplift resistances for individual roof system components have not been tabulated and are not available for the designer to engineer a unique system. Fortunately, the designer has available many roof systems that have been tested by Factory Mutual and by testing organizations in high wind regions such as South Florida.

Even with all this work and the selection of an appropriate system, the roof may fail during a high wind event due to poor edge design or other factors in the field of the roof. The roof may fail due to a metal edge that became dislodged, allowing the wind to peel the roof back. It is possible that the wood blocking at a perimeter will let go, allowing wind under the membrane to initiate a blow off. Galvanic corrosion can cause sheet metal or fastener failure, leading to a loose edge detail. Perhaps the perimeter is not sealed properly and the high positive pressure on the outside of the wall is allowed to pressurize the roof system, leading to failure. Perhaps rooftop equipment is not properly anchored, allowing dislodgement during a high wind event. This could allow air under the membrane at that point or could tear holes in the roof membrane as sheet metal tumbles across the roof. Blow off may also be initiated by holes in the deck, allowing localized pressure under the membrane. All of these aforementioned defects could cause a roof to fail in high winds, even though the system was tested for the uplift pressures experienced and easily passed the test.

Where can a designer turn to obtain support with these edge and field of roof details? There are several sources for information and assistance. Following is a list of some of these sources and a summary of the assistance they can provide:

1. [Sheet Metal & Air Conditioning Contractors National Assoc. \(SMACNA\)](#)



*Delamination in the field of the roof may be the result of defects other than the edge.*

PO Box 221230  
Chantilly, VA 22022-1230  
703-803-2980 [www.smacna.com](http://www.smacna.com)

#### **Architectural Sheet Metal Manual**

SMACNA has provided detail assistance to architects and specifiers for many years. The association provides standard sheet metal roof edge, coping, counterflashing, gutter, and other miscellaneous details. Its details are time proven. They are designed to be secure although there are no performance numbers to match job site requirements. SMACNA provides guidance on sheet metal gauges, cleat gauge and engagement, fastener placement, and more. The gutter design section provides information on resisting gutter wind uplift that can initiate air entry under the roof membrane. SMACNA also provides information on galvanic corrosion. Additional information on this topic is provided by the National Roofing Contractors Association.

2. [National Roofing Contractors Association \(NRCA\)](#)

O'Hare International Center  
10255 West Higgins Road, Suite 600  
Rosemont, IL 60018-5607  
847-299-9070 [www.nrca.net](http://www.nrca.net)

#### **Roofing and Waterproofing Manual**

The NRCA *Roofing and Waterproofing Manual* provides a wealth of information on many topics, including edge details. Details are available for most perimeter configurations with information on suitable metal, fastener types, and frequency. Like SMACNA, these details are tried and



*Proper edge design is critical.*

proven with considerable roofing contractor input. NRCA recognizes that the information and details provided are good but general in nature. The uplift resistance in psf or lbs/lin. ft. for each of the guide details is not known. For the special situation where high wind forces are expected, NRCA provides the following caution:

“Consideration must be given to wind zone and local conditions for the selection of metal gauge, profile, and fastening schedule. Severe conditions or code and regulatory bodies may require more conservative designs. When using the above (NRCA) table, additional items should be considered, such as fastening pattern.”

Excellent information is provided to the designer on the potential for galvanic corrosion. Especially useful are the tables providing information on the appropriate fasteners to use with various metals to avoid incompatibility.

3. [Factory Mutual Global](http://www.fmglobal.org)  
1151 Boston-Providence Turnpike  
Norwood, MA 02063  
617-762-3772 [www.fmglobal.org](http://www.fmglobal.org)

**Loss Prevention Data Sheet 1-49: Perimeter Flashing**

This document recognizes the potential loss to the insurer for wind blow off of roof systems caused by inadequate perimeter flashings. Factory Mutual states in this Data Sheet, “The majority of roof failures resulting from windstorms involve improperly designed or constructed perimeter flash-

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ings.” To reduce liability in this area, FM provides specific guidelines for perimeter flashing details.

The document is unique in at least two ways. First, up until the issuance of ANSI/SPRI ES-1, this had been the only guidance to flashing design to meet specific wind uplift forces for a particular building. The guidance provided starts with wind uplift forces determined using FM Data Sheet 1-28. For roof exposures requiring 1-60 or 1-90 wind uplift tested assemblies, FM 1-49 provides guidance for maximum dimensions of flashing elements for various types and gauges of sheet metal. For exposures having velocity pressures greater than 45 psf (requiring roof systems rated higher than 1-90), FM provides uplift and outward forces on flashings in psf but does not provide specific design guidance or testing methods.

The second area of uniqueness associated with the 1-49 Data Sheet is the guidance it provides for attachment of perimeter wood nailers. This document provides specific bolt diameters, frequency, and fastening patterns for wood nailers and wood cant strips. The SMACNA and NRCA designs assume secure attachment of the nailers. The ANSI/SPRI ES-1 document, described next, also assumes the nailers are sufficient-



*Wind damage can be very expensive.*



*Workers prepare for reroofing after extensive wind damage.*

ly attached. This is not always the case, and roof systems do blow off due to poor design or construction of perimeter structural members. Therefore, FM 1-49 is a necessary design and specifying tool for the perimeter flashing system designer.

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4. American National Standards Institute (ANSI)  
1430 Broadway  
New York, NY 10018  
202-354-3300 [www.ansi.org](http://www.ansi.org)

and

5. Sheet Membrane and Component Suppliers to the Commercial Roofing Industry (SPRI)  
200 Reservoir Street, Suite 309A  
Needham, MA 02194  
781-647-7026 [www.spri.org](http://www.spri.org)

**ANSI/SPRI ES-1-98: Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems**

This is a relatively new document that provides a methodology for calculating upward and outward forces on metal edge and coping details. It also provides specific testing procedures to evaluate the performance of nearly all envisioned edge details – testing procedures that had not existed in the past.

The calculation methodology used by the ANSI/SPRI ES-1-98 standard is closely tied to those detailed in *ASCE-7-98: Minimum Design Loads for Buildings and Other Structures*. In fact, the ANSI/SPRI documents follow the same wind map, exposure categories, velocity pressures, and velocity pressure coefficients as the ASCE-7 document. The only simplification is that the ANSI/SPRI perimeter flashing calculations assume no unusual topographical features and that all buildings are classified with an Importance Factor = 1.0.

For buildings on an isolated hill or cliff, or buildings deemed more or less important than “normal” buildings, the roof edge designer can use the same multipliers as provided in the ASCE-7 document. However, this should rarely be needed.

The testing methods outlined in ANSI/SPRI ES-1-98 are test methods RE-1, RE-2, and RE-3. Respectively, they provide the test methods to evaluate the resistance of sheet membrane pull out at metal edges, the outward force resistance of fascia edge details, and the upward, inward, and outward force resistance of wall coping systems. The test methods detail attachment to the flashing element, sample size, rate of load application, and identification of end of test. These tests are being conducted by independent testing labs and by individual flashing manufacturers (overseen by an independent professional engineer).

Initially, the ES-1 tests were promoted only by manufacturers of roofing edge systems. However, specifying edge systems using the ES-1 criteria is truly a non-restrictive specification, as any flashing design can be evaluated using this standard. Even roofing contractor-fabricated edge systems that have been evaluated by NRCA and contractors authorized by NRCA to produce the tested designs may qualify under an ES-1 specification.

So where is the system designer to turn to “get the edge” on roof design for wind resistance? First of all, to meet the building code, the designer should use ASCE-7-98 or the code stipulated alternative to evaluate wind uplift forces on the roof membrane. If the building is Factory Mutual insured, the *FM Loss Prevention Data Sheet 1-28* should also be utilized to evaluate uplift forces. With uplift forces determined, the designer should look for a tested roof assembly appropriate for the calculated forces. Normally, this means choosing a system tested by Factory Mutual Research Corporation or by Underwriters Laboratory.

For the edge system design, it will take a combination of SMACNA, NRCA, FM 1-49, and ANSI/SPRI ES-1-98 to properly detail and specify the roof edge. Increasingly, specifiers will use the ANSI/SPRI ES-1-98 criteria to obtain performance numbers to match calculated wind pressures on metal edge details. This will become more and more common as the new International Building Code (IBC) provisions become local code. These new provisions require edge designs according to the ANSI/SPRI ES-1 Standard. ■

## REFERENCES

American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-95, New York, NY: ASCE, 1998.

Factory Mutual Research Corporation, *Factory Mutual Property Loss Prevention Data Sheet 1-49 – Perimeter Flashing*, Norwood, MA: 1998.

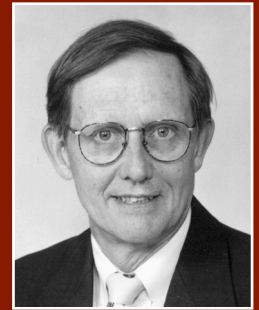
Sheet Metal, Air Conditioning Contractors National Association, *Architectural Sheet Metal Manual*, Fifth Edition.

Single-Ply Roofing Institute, *ANSI/SPRI ES-1-98 – American National Standard for Edge Systems Used with Low Slope Roofing Systems*, Needham, MA: SPRI, 1998.

*Underwriters Laboratories Roofing Materials and Systems Directory*, updated annually.

## ABOUT THE AUTHOR

**Gerry Teitsma, RRC, RRO, CDT**, is Director of Educational Services for the Roof Consultants Institute. Teitsma spent 17 years with Dow Chemical, where he was responsible for the development of the IRMA Roof System. He later owned his own roof consulting firm and was employed with the the Roofing Industry Educational Institute (RIEI). He is also a registered Consultant Document Technologist and a member of ASHRAE and CSI.



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