Understanding ES-1

Proper Specification and Implementation

By Mark S. Graham

Figure 1 – RE-3 test of a coping.

ANSI/SPRI/FM 4435/ES-1 (ES-1) provides a basis for laboratory testing of roof perimeter metal edge flashings (except gutters). It is also referenced as a requirement in the International Building Code (IBC) for metal fascia (gravel stop) and copings used with built-up, polymer-modified-bitumen and single-ply membrane roof systems.

Proper specification and implementation of ES-1 are important considerations in ensuring building code compliance and roof system performance in high winds.

The following is a brief overview of the IBC's ES-1 requirement, ES-1's test methods, and how to properly specify and implement ES-1 compliance.

IBC REQUIREMENT

In the IBC, 2018 Edition (IBC 2018), the following requirement applies to edge metal flashings:

> **1504.5 Edge securement for low-slope roofs.** Low-slope built-up, modified-bitumen and single-ply roof system metal edge securement, except gutters, shall be designed and installed for wind loads in accordance with Chapter 16 and tested for resistance in accordance with Test Methods RE-1, RE-2 and RE-3 of ANSI/SPRI ES-1, except basic design wind speed, V, shall be determined from Figures 1609.3(1) through 1609.3(8) as applicable.

IBC 2018's Chapter 35, "Reference Standards," indicates that the version of ES-1 that applies is ANSI/SPRI/FM 4435-11 (2011 Edition), *Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems*. SPRI has published an updated version of ES-1—ANSI/SPRI/FM 4435/ES-1-17 (2017 Edition), *Test Standard for Edge Systems Used with Low Slope Roofing Systems*—but it is not referenced in IBC 2018; it will be referenced in IBC 2021.

It is important to note only ES-1's Test Methods RE-1, RE-2, and RE-3 are referenced in and required by IBC 2018; ES-1 in its entirety is not. As a result, ES-1's Sections 1 through 10, Appendix A, Appendix C, and Commentary can be interpreted as not being applicable to IBC 2018.

IBC 2018's Section 1504.5 requirement for determining design wind loads in accordance with Chapter 16 using a basic design wind determined using IBC 2018's Figures 1609.3(1) through 1609.3(8) prescribes design wind loads be determined using ASCE 7-16's basic (ultimate) design wind speeds and ultimate design method.

IBC 2018's Chapter 16, "Structural Design," Section 1603, "Construction Documents," requires design wind loads be indicated in the project's construction documents. This requirement is as follows:

> **SECTION 1603**
> **CONSTRUCTION DOCUMENTS**
> **1603.1 General.** Construction documents shall show the size, section and relative locations of structural members with floor levels, column centers and offsets dimensioned. The design loads and other information pertinent to the structural design required by Sections 1603.1.1 through 1603.1.9 shall be indicated on the construction documents.

IBC 2018's Section 1603.1 enumerates the specific wind-load-related construction documents' requirements as follows:

> **1603.1.4 Wind design data.** The following information related to wind loads shall be shown, regardless of whether wind loads govern the design of the lateral force-resisting system of the structure:
> 1. Basic design wind speed, *V*, miles per hour and allowable stress design wind speed, V_{asd}, as determined in accordance with Section 1609.3.1
> 2. Risk category
> 3. Wind exposure. Applicable wind direction if more than one wind exposure is utilized
> 4. Applicable internal pressure coefficient
> 5. Design wind pressures to be used for exterior component and cladding materials not specifically designed by the registered design professional responsible for the design of the structure, psf (kN/m^2)

IBC 2018's Chapter 2, "Definitions," defines the term "construction documents" as follows:

> **CONSTRUCTION DOCUMENTS.** Written, graphic and pictorial documents prepared or assembled for describing the design, location and physical characteristics of the elements of a project necessary for obtaining a building permit.

ES-1 is not referenced as a requirement in the International Residential Code, 2018 Edition.

ES-1'S TEST METHODS

ES-1 is the U.S. national consensus standard for testing the wind resistance of roof perimeter metal edge flashings, including metal fascia (gravel stop) and copings used with low-slope membrane roof systems. ES-1 specifically defines the term "low slope" as being applicable to roofs having a slope of 2:12 or less.

FM 4435

FM 4435, *Approval Standard for Edge Systems Used with Low Slope Roofing Systems*, is FM Approvals' in-house method for testing and evaluating the wind resistances of metal edge flashings. The current edition of FM 4435 was published in June 2013 and had an effective date of Dec. 31, 2014. The previous edition of FM 4435 was dated August 2004.

Unlike ANSI/SPRI/FM 4435/ES-1, FM 4435 is not a recognized consensus standard and not referenced in the IBC.

FM 4435 is referenced in FM Global's Property Loss Prevention Data Sheet 1-49, "Perimeter Flashings" (FM 1-49), as a recommendation for perimeter flashings on FM Global-insured buildings. FM 1-49 also references the construction details contained in *The NRCA Roofing Manual* under "Architectural Metal Flashing and Condensation and Air Leakage Control." FM 4435 has separate guidelines for testing, reporting of test results, quality assurance procedures for manufacturing, and product or package marking.

FM 4435 uses ANSI/SPRI/FM 4435/ES1-2011's RE-1, RE-2, and RE-3 test methods as the basis for its testing. However, instead of reporting test results as resistance pressures in pounds per square foot, FM 4435's results are reported using FM Approvals' classification designations (1-60, 1-75, 1-90, etc.). FM 4435's Table 1 is used to convert ANSI/SPRI/FM 4435/ES-1-2011's RE-1 test results into classification designations. FM 4435's Table 2 is used to convert ANSI/SPRI/FM 4435/ES-1-2011's RE-2 and RE-3 test results into classification designations. It appears FM 4435's tables include some mathematical rounding and use a safety factor of 2.0 for determining classification values.

FM 4435's manufacturing quality assurance procedures criteria require fabricators to establish and maintain a quality assurance program with specific process controls. FM Approvals also conducts periodic—usually one per year—surveillance audits to verify the established quality assurance program is being carried out.

FM 4435's marking criteria requires fabricators to apply an FM Approvals mark on the product or its packaging.

FM 4435 can be downloaded from FM Approvals' RoofNav website, www.roofnav.com. After login, it is located under the Reference Materials tab in the Approval Standards area.

Figure 2 – RE-2 test of a fascia detail.

ES-1's Appendix B, "Edge System Testing," provides three methods of testing metal edge flashing configurations. These methods are identified as RE-1, RE-2, and RE-3 and are described below.

Test Method RE-1, "Test Method for Dependently Terminated Roof Membrane Systems," tests metal edge flashings' abilities to restrain unadhered roof membranes at roof perimeters. This test is applicable to ballasted and mechanically attached single-ply membrane roof systems that do not include a peel stop within 12 inches of the roof edge. Adhered membranes, such as built-up and polymer-modified bitumen membranes, and other systems using alternative methods for perimeter attachment at roof edges, are exempt from RE-1 testing. RE-1 testing is typically conducted until failure occurs. Failure is defined as the membrane coming free from the edge termination or the termination coming free from its mount. Test results are stated in pounds (force) per linear foot.

Test Method RE-2, "Test Method for Dependently or Independently Terminated Edge Systems," tests resistances to horizontal (outward from the building face) loads from fascias and gravel stops. Testing is typically conducted to failure, which is determined as loss of securement of a metal roof edge component. Results are expressed in pounds (force) per square foot. See *Figure 2*.

Test Method RE-3, "Test for Copings," tests copings' resistances to separate front face pulls and back face pulls, while simultaneously applying loads to the copings' top surfaces. Testing is typically conducted to failure, which is determined as loss of securement of a metal roof edge component. Results are expressed in pounds (force) per square foot. See *Figures 1* and *3*.

The test load orientations for RE-1, RE-2, and RE-3 are shown in *Figure 4*.

In the National Roofing Contractors Association's (NRCA's) experience, disengagement of a hemmed drip edge from the cleat is a typical mode of failure in RE-2 and RE-3 testing.

ES-1 specifically does not apply to gutters. A separate SPRI standard—ANSI/SPRI GT-1, *Test Standard for Gutter Systems*—provides a basis for testing the wind resistances of external metal gutters. ANSI/SPRI GT-1 is not referenced in IBC 2018 as a

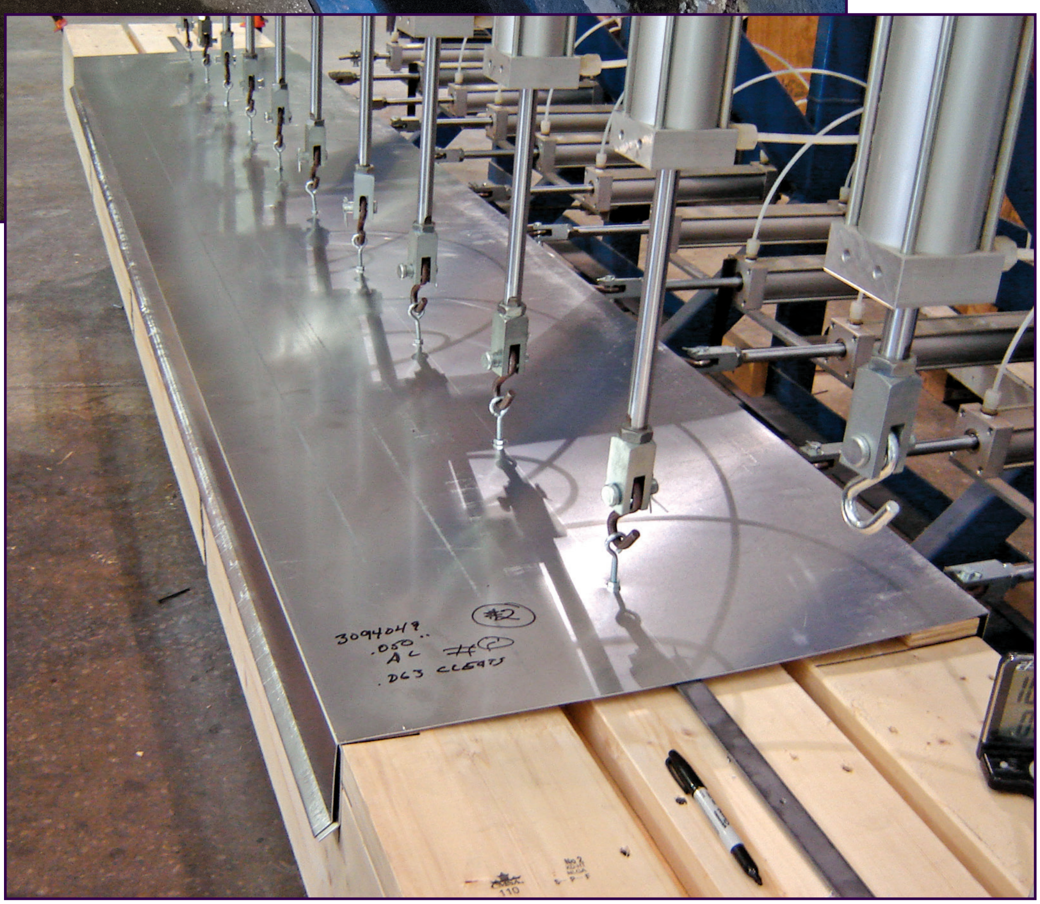

Figure 3 – RE-3 test of a coping.

requirement; it will be included in IBC 2021.

Also, ES-1 does not address weathertightness of metal edge flashings. SMACNA's *Architectural Sheet Metal Manual*, *The NRCA Roofing Manual*, and specific membrane system and metal edge system manufacturers can be consulted for their weathertightness guidelines.

SPECIFYING AND IMPLEMENTING

Properly specifying ES-1 consists of two essential steps: 1) determination and reporting of the design wind loads applicable to the specific roof perimeter edge condition (coping, fascia), and 2) selection of metal edge flashings with tested resistances based upon the design wind loads.

The design wind loads occurring on roof perimeter metal edge flashing configurations typically consist of a combination of uplift loads acting upon the roof system and horizontal loads acting on the buildings' vertical surfaces (wall cladding). For example, ES-1 prescribes a combination of vertical (uplift) and horizontal loads acting on a parapet coping. Using IBC 2018's criteria, these vertical design loads are defined by ASCE 7-16's Zone 2 and Zone 3, and the horizontal design loads are defined by ASCE 7-16's Zone 4 and Zone 5. For fascia (gravel stop) with an exposed horizontal component (flange) less than 4 inches, ES-1 prescribes a horizontal load acting on the front face of the fascia. Using IBC 2018's criteria, this horizontal design load is defined by ASCE 7-16's Zones 4 and 5.

As described previously, design loads specific to the project are required by the code to be provided in the construction documents.

Specific metal edge flashings should be specified that have tested resistance loads equal to or greater than the applicable design wind loads. Individual metal edge system manufacturers can be consulted for their ES-1 test information. Also, NRCA has conducted ES-1 testing of a number of shop-fabricated metal edge shapes described in the construction details in *The NRCA Roofing Manual*. NRCA's ES-1 information is accessible on NRCA's website at www.nrca.net. It is located under the Resources drop-down menu in the Technical, then Guidelines and Resources areas, by selecting Shop-fabricated Edge Metal Testing.

When a single metal edge flashing configuration occurs continually along the entire length of a roof area perimeter edge, multiple design wind load combinations (Zones 2 and 3 vertical loads, and Zones 4 and 5 horizontal loads) may apply. Consequently, the designer should consider selecting a metal edge flashing with a tested resistance load equal to or greater than the highest applicable design wind loads. At this situation, the highest design wind

Specific metal edge flashings should be specified that have tested resistance loads equal to or greater than the applicable design wind loads.

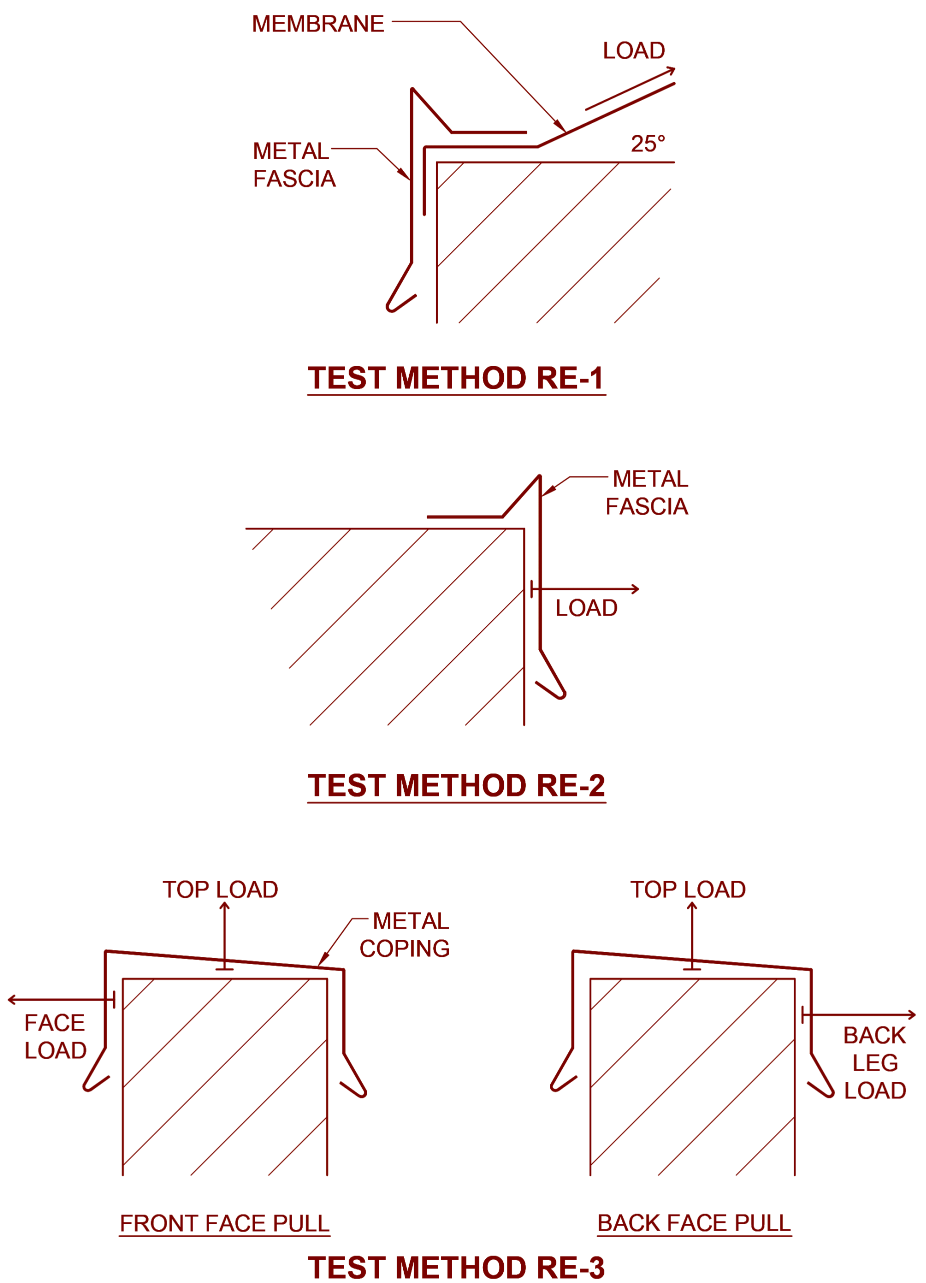

Figure 4 – Illustration of load combination applicable to ES-1's Test Methods RE-1, RE-2, and RE-3.

loads occur at Zone 3 (vertical load) and Zone 5 (horizontal load).

Also, although not specifically required by IBC 2018, designers should consider applying an appropriate safety factor to their metal edge system designs to account for normally anticipated variations in wind loads, edge metal materials and fabrication, field installation, and substrates.

ES-1 prescribes a safety factor of 2.0 be added to its design wind load determination method; however, ES-1's design wind load determination method and safety factor recommendations are not incorporated into IBC 2018.

AISI S100, *North American Specification for the Design of Cold-Formed Structural Steel Members*, which is referenced in IBC 2018, prescribes use of a safety factor of 1.67 for light-gauge steel in bending. Similarly, ADM1, *Aluminum Design Manual*, which is also referenced in IBC 2018, prescribes use of a safety factor of 1.67 for thin-gauge aluminum. Both of these standards—and their 1.67 safety factor—are often used for the design of structural metal panel roof systems.

In FM 4435, *Approval Standard for Edge Systems Used with Low Slope Roofing*, FM Approvals applies a safety factor of 2.0 to its tested resistance values. This application of a safety factor effectively reduces FM Approvals' allowable resistance values to 50 percent of their tested values. This approach is similar to that used in FM Approvals' wind uplift resistance classifications for roof systems (1-60, 1-75, 1-90, etc.).

ES-1 can be downloaded from SPRI's website, www.spri.org.

IBC 2018 can be purchased by accessing the International Code Council's (ICC's) website, www.iccsafe.org.

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Dune Museum is Subterranean Gallery

The UCCA Dune Art Museum is carved into sand dunes along the northeast coast in Qinhuangdao, China. Designed by Beijing-based OPEN Architecture, the 10,000 ft.^{2} museum is almost buried in the sand. Three terraces open to expansive sea views.

Originally envisioned as a space for art and dining adjacent to luxury homes and shops, the concept morphed midway into an art museum.

Photos by Wu Qingshan.

The existing dune was excavated and the structure was erected with steel columns encased in concrete, with steel micro-piles transferring the vertical load to bedrock beneath the brick walls. The atrium walls are 18 in. thick. To prevent condensation, engineers devised thermally broken connections between the new steel elements and the existing masonry walls. The sand-covered roof helps to keep the interior cool in the summer.

The museum also tracks the sky: two of its skylights orient to the sun at the summer and winter solstices, while others are designed to capture daylight or cast it on the walls.

— *Architectural Record* and *Designboom*

