



Roof Wind Load Design

By Karl A. Schaack, RRC, PE

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“Roof design” is a powerful concept that is often misunderstood, misrepresented, or applied incorrectly in today’s industry. When it comes to roof design, the big question is, “Who is responsible for the roof design, or who is the responsible party?”

BUILDING CODE

Determining wind uplift pressure resistance for roof assemblies is a requirement of the *International Building Code* (IBC)¹ that is applicable to most structures located in the United States. In the 2018 edition of IBC, important specifications are found in Chapter 16, Structural Design. Section 1609 defines the requirements for wind loads, and paragraph 1609.1.1 states, “Wind loads on every building or structure shall be determined in accordance with Chapters 26 to 30 of ASCE 7.” Additionally, IBC Section 1609.5 states, “Roof systems shall be designed and constructed in accordance with Sections 1609.5.1 through 1609.5.3, as applicable,” and Section 1609.5.1 specifies, “The roof deck shall be designed to withstand the wind pressures determined in accordance with ASCE 7.” ASCE 7 is the American Society of Civil Engineers’ *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.² Note that governing entities have adopted various versions of IBC and ASCE;

however, the same general principles remain constant.

In IBC Chapter 15, Roof Coverings, the performance requirements for roofing are outlined in Section 1504, Performance Requirements. Paragraph 1504.1 specifies, “Roof decks and roof coverings shall be designed for wind loads in accordance with Chapter 16 and Sections 1504.2, 1504.3, and 1504.4.” Section 1504.3, Wind Resistance of Non-ballasted Roofs, states,

Roof coverings installed on roofs in accordance with Section 1507 that are mechanically attached or adhered to the roof deck shall be designed to resist the design wind load pressures for components and cladding in accordance with Section 1609.5.2. The wind load on the roof covering shall be permitted to be determined using allowable stress design.

Paragraph 1504.3.1 states, “Other roof systems: Built-up, modified bitumen, fully adhered or mechanically attached single ply roof systems, metal panel roof systems applied to solid or closely fitted deck and other types of membrane roof coverings shall be tested in accordance with FM 4474, UL 580, or UL 1897.”

ANSI/FM 4474, *Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive or Negative Differential*

Pressures,³ is a national standard. As stated in the introduction,

This standard is intended to verify that the product as described will meet minimum specific stated conditions of performance, safety, and quality, useful in determining the potential suitability for end-use conditions of these products. It describes the minimum performance requirements of materials that are intended for use in roof assemblies by evaluating the ability of the materials, system components, and installation methods to withstand simulated wind uplift resistance.

The standard states the test requirements for evaluating the simulated wind uplift resistance of roof assemblies by using static positive or negative differential pressures. The standard applies to all components, including deck, insulation layers, and covering, as assembled in the roof system. Paragraph 2.1, Product Information, in Part 2, General Requirements, states, “Roof assemblies are usually comprised of a roof deck, insulation and roof covering. The complete assembly shall meet the requirements of this standard.” Section D-9, Results, paragraph D-9.2, states, “The uplift resistance rating shall be the highest level attained by the assembly that was held for the full 60 sec-

onds and continued to meet the Conditions of Acceptance.”

According to the scope of UL 580, *Standard for Tests for Uplift Resistance of Roof Assemblies*,⁴ the test method

is intended to determine the uplift resistance of roof assemblies consisting of the roof deck and roof covering materials.

1.2 The purpose of this test is to evaluate the comparative resistance of roof assemblies to positive and negative pressures.

1.3 The test evaluates the roof deck, its attachment to supports, and roof covering materials. It does not evaluate connections of the assembly to main structural supports (girders, columns, or other supports), structural integrity of secondary supports (purlins, joists, bulb tees, or the like), or deterioration of roofing materials.

In UL 1897, *Standard for Safety, Uplift Tests for Roof Covering Systems*,⁵ the scope states that the test method

is intended to provide uplift resistance data for the evaluation of the attachment of roof covering systems to roof decks by using differential air pressures....

1.2 The test evaluates the roof covering systems method of attachment, including all components such as base sheets, ply sheets, slip sheets, membranes, etc. and insulation, if used. Supporting roof decks are evaluated only with respect to span conditions and physical properties such as gauge, yield strength, grade, size, and/or species of lumber and related factors which affect fastener attachment or bond strength.

1.3 This test method provides a comparative measure of the uplift resistance for roofing systems by means of static differential pressure. The method does not necessarily simulate the actual dynamic uplift pressures encountered by roofing systems....

1.4 The purpose of this test method is to provide data regarding the securement of the roofing system to the roof deck based upon a short-term static load.

ASCE 7² is used to determine the design pressures for the subject roof assembly (roof covering, insulation, and roof deck). This pro-

cess provides methods for determining the wind uplift pressures for field, perimeter, and corner wind zones on the roof. The calculations are used to determine the ultimate design pressures for the respective zones. The designer then applies factors to the ultimate design pressures to determine the allowable design pressures. The allowable design pressures are the values that are commonly presented by roof material manufacturers, but they could also present the ultimate design pressure. As noted, ASCE provides the procedure for calculating

the pressures for each of the respective zones.

ASCE 7 does not mention or note the common practice of using roof system attachment requirements for the field of the roof and then using prescriptive enhancements for the respective roof system to determine installation requirements for the perimeter and corner zones. This practice is commonly used for roof systems approved by FM Global and incorporates mechanical fasteners or adhesives applied in ribbon fashion. Therefore, it is the author's opinion that any roof system or systems pro-

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vided for a building should meet or exceed the calculated design pressures, which may involve the use of three different attachment methods and three different roof assemblies.

For example, for a building with calculated elevated wind uplift pressures, a two-ply modified bitumen roof membrane applied over cover board and polyisocyanurate insulation board on a fluted steel deck may be acceptable to adhere the membrane to the cover board that is adhered to the base layers. However, because wind uplift pressures are higher in perimeter or corner zones, the attachment of the tested assembly may require simultaneous attachment of the cover board and the underlying insulation layers, or simultaneous attachment of a polyester-reinforced base ply in conjunction with underlying cover board and insulation layers to meet the calculated wind uplift pressures.

In FM Global Property Loss Prevention Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*,⁶ FM Global provides commentary regarding roof system attachments in paragraph 3.1.6, Wind uplift. Prescriptive enhancements for Zones 2 and 3 may be used for relatively low wind-pressure designs where the needed wind rating in Zone 1 is 90 lb/ft² (4.3 kPa) or less. The standard also has parameters for permitting prescriptive enhancement, including the following:

- The rows of roof cover fasteners should run perpendicular to the steel deck ribs, and the deck should be designed to resist the design wind pressure applied at the roof cover fastener row spacing.

- The Zone 2 and 3 enhancements should be extrapolations based on Zone 1 and not Zone 1'.
- In situations where buildings are located in a nontropical, cyclone-prone region where the design wind speed does not exceed 90 mph (40 m/s) and the roof height does not exceed 75 ft (23 m) in Surface Roughness Exposure B or C. For partially enclosed buildings in Surface Roughness Exposure D, the roof height is limited to 30 ft (9 m).

FM Global also states that prescriptive enhancements have limitations as increasing fastener density or decreasing fastener spacing may become impractical and can yield diminishing returns on wind uplift resistance.

SAFETY FACTOR

It is up to the designer to determine whether a safety factor is to be applied to the calculated ultimate design wind uplift pressures. IBC and ASCE 7 do not provide explicit guidance or criteria related to the application of safety factors to calculated wind uplift pressures. However, the most current ASCE 7 versions (ASCE 7-2010 and ASCE 7-2016) are based on the load- and resistance-factor design (LRFD) method (compared with the allowable stress design methodology in ASCE 7-2005). LRFD, which is commonly referred to as ultimate stress design, includes two safety provisions: one on the load side (wind speed) and the other on the strength or resistance side. The importance factor from the earlier versions of ASCE 7

has been eliminated, and the current ASCE versions include factored wind speeds. Because of the unreliability in structural design theories, the nominal strength (resistance of the structure/component) is multiplied by a strength reduction factor. The strength reduction factor used to convert the ultimate design pressures to allowable design pressures is 0.6. An additional safety factor such as 2.0 should be applied to account for the uncertainties in the constructed roof system and weathering.

Guidance documents from FM Global, ASTM International,⁷ the National Roofing Contractors Association (NRCA),⁸ and the American National Standards Institute/Single Ply Roofing Industry (ANSI/SPRI)^{9,10} all recommend applying a safety factor when determining wind uplift. ASTM D6630, *Standard Guide for Low Slope Insulated Roof Membrane Assembly Performance*,⁷ paragraph 7.3.7 states, "Wind uplift forces should be determined according to ASCE-7. Roof system wind uplift resistance shall have a minimum 2.0 factor of safety."

NRCA's *Wind Design Guide*⁸ indicates that it is reasonable to ensure that a roof system's wind-resistance capacity is greater than design loads because engineering and wind design practices call for safety factors to be applied to roof systems' design wind loads. Safety factors for building materials, components, and systems typically vary in magnitude based on a number of factors, but for roofs, the variability can be in material strength of roof system components, in construction quality, and in the chance that actual wind speeds exceed the design wind speed. Therefore, for low-slope membrane roof systems, a minimum safety factor of 1.5 up to 2.0 is recommended by NRCA and is based on ASTM D6630.

The SPRI Wind Design Calculator¹¹ is used to calculate the roof edge design pressure. As noted on the web page for the calculator:

The calculator is based on ASCE 7, as prescribed by IBC Chapter 16, and can be used to calculate the design loads that edge metal systems must be tested to resist. The calculator requires four inputs: 1. Project location (zip code), 2. Building height, 3. Exposure, 4. Importance Classification (Risk Category).

The calculator results are for corner zones of an enclosed building and include a safety factor of 2.0.

The author also recommends applying a safety factor because the allowable capacity

Selecting a roof assembly that meets requirements of the local building code can be a challenge, particularly when the existing roof deck is not part of an assembly that has been verified through testing to meet calculated wind uplift pressures.



Figure 1. Pull test being performed in accordance with ANSI/SPRI FX-1 2021 version.⁹

of most building structural elements such as fasteners are designed with safety factors. The application of a safety factor to calculated pressures is considered a prudent approach for the following reasons:

- When roof systems are subjected to applicable laboratory testing for determination of uplift resistance capabilities, the last successful test pressure prior to system failure is the maximum design pressure rating assigned to that system.
- Roof systems are assembled and tested in laboratory settings and conditions, but they are installed in harsh and less than desirable field conditions, commonly by improperly prepared and inadequately trained labor forces.
- Multiple factors affecting the materials, handling, storage, and installation could adversely affect system performance. For this reason, FM Global specifies that FM 1-52, *Field Verification of Roof Wind Uplift Resistance of Roofing Assemblies*,¹² should be performed at 1.25 times the calculated allowable design wind uplift pressures.

Additionally, roof assembly listings in the Florida Building Code Product Approvals, Miami-Dade County Product Control Approvals, and Texas Department of Insurance Product Evaluation Index include safety factors in the published wind ratings.

EXISTING CONSTRUCTION

Roof replacement performed on existing buildings involves considerations and concerns that do not apply to new construction. Selecting a roof assembly that meets requirements of the local building code can be a challenge, partic-

ularly when the existing roof deck is not part of an assembly that has been verified through testing to meet calculated wind uplift pressures.

Traditional attachment of new roofing assemblies to existing roof decks such as lightweight insulating concrete fill over metal form deck (commonly less than 22-gauge) or fiber cement deck panels to achieve high wind uplift pressures can become difficult. When encountering these types of decks, a prudent approach would include performing pull tests (Fig. 1), in accordance

with ANSI/SPRI FX-1,⁹ of proposed traditional base sheet fasteners attached to the lightweight insulating concrete or fiber cement panel, or screw-type fasteners installed to the metal form deck, or another type of fastener into the fiber cement panel.

Another option could include performing bonded tests, in accordance with ANSI/SPRI IA-1,¹⁰ of rigid board insulation adhered to the substrate with proposed bonding adhesive (at various ribbon spacings or coverages) (Fig. 2). Upon obtaining test results, a proposed attachment method can be determined to meet calculated wind uplift pressures. The proposed new roof system would then be considered an “engineered” assembly in lieu of a tested assembly to meet the required building code criteria.

In addition, when the attachment method for a tested assembly can only meet the wind uplift requirements for the field zone, calculations can be

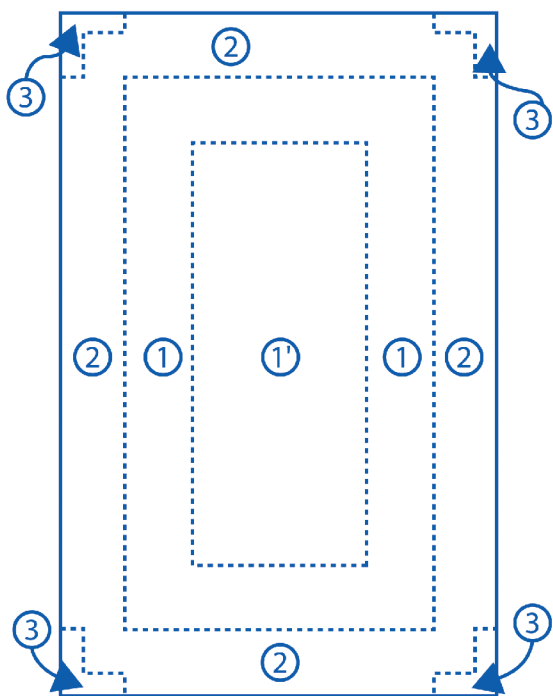
performed to determine the allowable load per fastener for the field. Then, one can calculate the prescriptive enhancements for the number of fasteners required to meet the required design pressures. Again, these types of systems would be considered “engineered” systems.

DESIGN RESPONSIBILITY

On new construction projects, the lead designer (such as a project architect) is the entity typically responsible for roof design. Typically, the project architect has a relationship with a structural engineer, who is either an employee of the design firm or a consultant on the design team. The engineer provides design criteria for the building that include wind loads on the structure. The wind design criteria are often included within “general notes” or building code analysis or information sheet, or it may be depicted on an individual sheet within the structural drawings. The criteria may be displayed in a table form, or a tabulation of wind pressures may be combined with a dia-



Figure 2. A worker performs a bonded test of rigid board insulation adhered to the substrate in accordance with ANSI/SPRI IA-1 2021 version.¹⁰



Buildings with least horizontal dimension greater than $2.4 h$

Figure 3. An example of a diagrammatic depiction of a building denoting the respective designated zones of roofs for roof pressures.

grammatic depiction of a building denoting the respective designated zones of roofs and walls together (Fig. 3), along with the assumptions/criteria (building classification, risk category, and so on).

The tabulation also typically presents various pressures at multiple tributary areas or effective wind areas of 10, 20, 50, or 100 ft² (Table 1). However, roof design is traditionally associated with or discussed in terms of 10 ft².

Project documents often request that the contractor submit design criteria supplied by the manufacturer in accordance with ASCE 7. However, manufacturers explicitly state that they are not design professionals and only provide “design” information as a courtesy to the contractor for project purposes. When roofing contractors provide services directly to building owners and provide the roof system selection, components, and methods of attachment, the contractor then assumes the responsibility as the “designer.”

Historically (and even in current times), designers often default to specifying the roof system to meet “FM 1-90”³ or “UL 90”⁴ requirements. Although the criteria outlined by FM Global to meet FM 1-90 requirements for a specific system may be suitable for the respective project, manufacturers have compiled listings

of roof systems that have been tested by other third-party entities that can meet specific project and code requirements. It is important to note that FM 1-90, which provides criteria for the field wind zone, may not actually be applicable for all wind zones of the respective building, as discussed previously.

The author has participated in multiple submittal review processes for new construction projects in which it was discovered that roofing system submittals that had been approved by project design personnel did not meet the actual specified design requirements. Additionally, the author has also encountered projects where design professionals did not require that the specified new roof system be a roof assembly that had been tested in accordance with FM 4474³ and that had met IBC requirements. Additionally, experience has shown that even when roof system components have been selected by design professionals to meet project design parameters, it is possible that those components were not included in a system that had been tested and thus may not meet the required building code criteria.

SUMMARY

As the industry improves its understanding of wind loads and as the various governing entities update the applicable codes, it can seem like the criteria and requirements for determining wind uplift pressures for roof systems are a constantly moving target, with changes occurring almost as often as shifts in the direction of the wind. These changes pose challenges to the designer, manufacturer, and contractor, who are all obligated to keep track of code updates and other guidance so they can provide high-performing roofs and achieve resilient buildings for the current and future market. When the construction scenario is a new structure or a renovation/replacement project, the wind uplift design requirements for the new roof should be provided/approved by a design professional. 

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Roof pressure (gross)					
Zone	0–10 ft ²	20 ft ²	50 ft ²	More than 100 ft ²	More than 500 ft ²
1	+20, -49	+19, -48	+17, -46	+16, -45	+16, -45
2	+20, -82	+19, -74	+17, -62	+16, -53	+16, -53
3	+20, -124	+19, -100	+17, -75	+16, -53	+16, -53
Wall pressure					
Zone	0–10 ft ²	20 ft ²	50 ft ²	More than 100 ft ²	More than 500 ft ²
4	+45, -49	+43, -47	+41, -44	+39, -42	+34, -36
5	+45, -60	+43, -58	+41, -51	+39, -47	+34, -36
Parapet pressure (cladding)					
Zone	0–10 ft ²	20 ft ²	50 ft ²	More than 100 ft ²	More than 500 ft ²
4	+36, -42	+36, -49	+34, -37	+32, -35	+27, -31
5	+36, -53	+36, -49	+34, -44	+32, -40	+27, -31
Parapet pressure (studs)					
Zone	0–10 ft ²	20 ft ²	50 ft ²	More than 100 ft ²	More than 500 ft ²
4	±114	±100	±89	±78	±73
5	±156	±132	±101	±78	±73

Table 1. An example of a tabulation of wind pressures (lb/ft²) shown on project drawings

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Karl A. Schaack,
RRC, PE

Karl A. Schaack is president of Price Consulting Inc., located in Houston, Texas. Price Consulting is a professional engineering consulting firm that has specialized in building enclosure technology, including roofing, waterproofing, and exterior wall construction and cladding, for more than 25 years. Since 1983, Schaack has been employed in the consulting industry, with emphasis on building enclosure technology. He performs condition assessments, prepares design documents, performs constructability reviews, performs material and system testing, and performs quality assurance monitoring. He is a registered professional engineer in Texas and North Carolina.

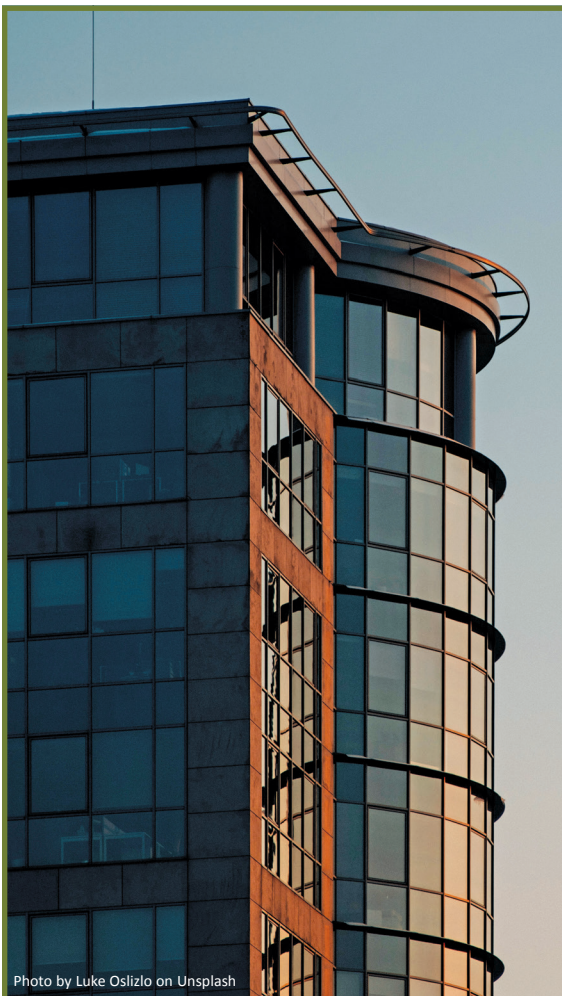


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SPECIAL INTEREST

CRRC Debuts Exterior Wall Rating Program

After more than two years of development, the Cool Roof Rating Council (CRRC), of which IIBEC is a member, has launched an energy efficiency ratings program for exterior wall materials. The Wall Rating Program, which debuted in January 2022, provides consumers with information about a product's solar reflectance and thermal emittance. A CRRC Rated Wall Product Directory, which can be accessed online at no cost, displays the product ratings.

A CRRC board advisory committee composed of 27 people across 21 organizations evaluates aspects of the program, such as testing and weathering protocols suited for exterior paint, coatings, vinyl siding, metal panels, and other wall claddings, the organization said. Building enclosure consultant and IIBEC member Steven C. Drennan, who serves as an IIBEC liaison to the CRRC, said, "I have had the honor of representing IIBEC for the last two-and-a-half years as a voting member on the board advisory committee in both a technical role and various other committee functions. This program is the next step in combating the urban heat island effect, and IIBEC has been on the forefront championing this effort."

CRRC executive director Jeff Steuben said, "The development of this program would not have been possible without the hard work of all the volunteers who served on our wall committees and the generous contributions of the program's founding members."

Source: Cool Roof Rating Council