Simplifying the Complicated Process of Wind Design for Roof Systems

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ABSTRACT

Wind design for roof systems is rather complicated, and with the latest version of ASCE 7, it has become that much more confusing. Different editions of building codes and, therefore, different versions of ASCE 7 are used in different parts of the country. The three versions that are currently in use are ASCE 7-05, 7-10, and 7-16. While each provides a method to determine the wind loads acting on a building, the specifics of each method vary. There are also groups (e.g., FM, NRCA) that provide methods to determine the wind loads acting on a roof. Once loads are determined, a roof system with a tested resistance greater than the loads is chosen for use. If it were only that simple!

The presentation will discuss the similarities and differences between the three versions of ASCE 7 and the roofing industry-developed methods to determine loads. The presenters will provide insights regarding the application of the traditional Factor of Safety in various design methods, as well as design enhancements for improved long-term performance. Lastly, the presentation will take a deep dive into the numerous listing services that provide wind-uplift-rated roof systems, such as FM, UL, and SPRI.

SPEAKERS

Joan P. Crowe holds a bachelor of science degree in architectural studies and a master of architecture degree from the University of Illinois Urbana-Champaign. In 1988, she began her career at Wiss, Janney, Elstner Associates, Inc. In 2000, Crowe joined the National Roofing Contractors Association (NRCA) working in the technical services section. In 2016, she joined GAF as manager of codes and regulatory compliance. Her responsibilities include monitoring building codes, standards, and regulations; providing technical assistance to the sales and marketing departments; and producing technical documents. Crowe is a licensed architect in Illinois and a member of the American Institute of Architects.

James R. Kirby is a building and roofing science architect with his firm. He has a master of architecture degree with a "structures" option. With over 25 years of experience in the roofing industry, covering low-slope, steep-slope, metal, SPF, vegetative, and rooftop photovoltaics, he understands the effects of heat, air, and moisture on a roof system. Kirby presents building and roofing science information to architects, consultants, and building owners, and he writes articles and blogs for building owners and facility managers and the roofing industry. He is a member of AIA, ASTM, ICC, MRCA, NRCA, IIBEC, and USGBC.

Simplifying the Complicated Process of Wind Design for Roof Systems

INTRODUCTION

Wind design for roof systems is rather complicated, and with the latest version of ASCE 7, *Minimum Design Loads For Buildings and Other Structures*, it has become that much more challenging for roof system designers and roofing contractors. Different editions of building codes and, therefore, different versions of ASCE 7 are being used in different parts of the country. The three versions that are currently in use are ASCE 7-05, 7-10, and 7-16. While each provides a method to determine the wind loads acting on a building, the specifics of each method vary. There are also non-code-related organizations (e.g., FM Approvals, NRCA[2]) that provide online calculators to determine the anticipated wind loads acting on a roof.

There are a number of factors that determine the design wind uplift loads for the field, perimeter, and corners of a roof. These factors generally include the building location, code in effect, building dimensions, risk category, exposure, topography, and occupancy/use. Earlier versions of ASCE 7, including the 2005 version, used allowable stress design- (ASD-) related values for its wind speed maps. However, the 2010 and 2016 versions have been revised to be based on strength (ultimate) design wind speed values.

The progression of ASCE 7 during the last two decades had added complexity to what was once a relatively straightforward calculation. The similarities and differences between the three versions of ASCE 7 provide for a better understanding of the complexity and must be understood for proper wind load determination. Since the 2010 version, the determination of a specific analysis method and use of certain design factors have become confusing and fraught with the potential for error (i.e., over- or under-design) for those that do not have a good understanding of ASCE 7. Hand calculations and roofing industry-developed tools are available for public use, but how does one choose the appropriate option?

Roof systems that have the tested capacity to resist calculated wind loads reside in approval listings, and recognizing how a safety factor is included is also critical to ensuring an appropriate roof system is selected and installed. Conceptually, the goal is to determine the design wind loads, then select the appropriate roof system with a tested resistance greater than the loads for use. If it were only that simple. In practice, due to the complexity of the analysis of uplift pressures and changes in wind speed maps, it's difficult to know if the industry is under- or over-designing wind loads and, consequently, roof system capacity.

It is important to note that this paper is not a wind design guide. It is not intended to supersede ASCE 7, model building codes, or any of the online calculators, etc. It is intended to provide information about the most common concepts and issues that may cause confusion for those determining wind loads acting on a building and/or selecting roof systems with the capacity to withstand the design wind loads.

This paper focuses on determining wind loads and has some information about selection of systems that have adequate capacity. Load determination is a key early design factor, but there are more wind design factors to consider.

WIND DESIGN BASICS

Simply put, a roof assembly must be able to resist the design wind loads acting on the rooftop. The loads acting on a roof must be calculated in order to select a roof system that has the necessary capacity (i.e., wind uplift resistance). Therefore, step one is to determine the loads acting on the roof of a specific building.

$$\textbf{Resistance}_{roof} > \textbf{Loads}_{wind}$$

This paper will address low-slope roof systems (roofs with slopes <= 2:12) without parapets or with parapets that are less than 3 ft. in height.

DETERMINING THE LOADS ACTING ON A ROOF

In order to determine the wind loads acting on a roof, one needs to know the following about a building:

- Location
- Building code that is in effect at the building's location
- Height, length, and width
- Exposure category
- Use and occupancy
- Enclosure classification
- Topographic effects
- Ground elevation

There are a number of factors that determine the design wind uplift loads for the field, perimeter, and corners of a roof. These factors generally include the building location, code in effect, building dimensions, risk category, exposure, topography, and occupancy/use.

Location and Building Code in Effect

The location of the building tells us two things which must be determined in specific order. First, the location directs us to the specific version of the International Building Code (IBC) or the applicable building code that is in effect for the project. A call to the local building official's office is often the simplest way to determine which version of the IBC is being enforced, and whether there are any local amendments that are applicable for wind load determination. For example, if the 2006 or 2009 IBC is in effect, then ASCE 7-05 governs. If the 2012 or 2015 IBC is in effect, then ASCE 7-10 governs. If the 2018 IBC is in effect, then ASCE 7-16 governs.

Knowing which version of ASCE 7 applies will determine which wind maps, equations, and other factors are used. This paper will not dive deeply into the differences because most online calculators available for industry use have the variances embedded within the calculators. Users need to make sure any online calculator that is used references the correct version of ASCE 7.

Furthermore, there are two online tools that allow designers to look up design parameters, such as wind data, based on location. The ASCE 7 Hazard Tool (https://asce7hazardtool.online/) provides wind data for ASCE 7-10 and ASCE 7-16 wind data, and the Applied Technology Council's ATC Hazards by Location (https://hazards.atcouncil.org/#/) provides wind data for ASCE 7-05, ASCE 7-10, and ASCE 7-16.

Height, Length, and Width

Determining the height, length, and width of a building should be straightforward and a vast majority of buildings are predominately square or rectangular in shape. There are methods to determine the wind loads acting on a roof for non-rectangular or non-square buildings; however, that is outside the scope of this paper.

Exposure Category

Exposure category is based on the roughness of a building's nearby terrain. A terrain's surface roughness is determined from natural topography, vegetation, and the surrounding construction. The surface of the terrain (or body of water) adjacent to the building creates a drag on the wind and retards the air flow near the surface. This reduction in the flow of air is a function of the height of roughness elements above the terrain's surface and the amount of the terrain's roughness.

ASCE 7 uses three surface roughness category types—called B, C, and D—which, in turn, define three exposure category types, also called B, C, and D. The broad definitions of the surface roughness category types are:

- Surface Roughness B is defined as urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
- Surface Roughness C is defined as open terrain with scattered obstructions having heights generally less than 30 ft. This includes flat, open country and grasslands.
- Surface Roughness D is defined as flat, unobstructed area and water surfaces.

For the exact definitions, refer to the specific version of ASCE 7.

As previously mentioned, these surface roughness category types help define exposure categories B, C, and D. The definitions have changed slightly between editions, but the three types are generally defined as follows:

- Exposure B is applicable to buildings with a mean roof height of less than or equal to 30 ft. and where Surface Roughness B prevails in the upwind direction for a distance greater than 1,500 ft. For buildings with a mean roof height greater than 30 ft., Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 2,600 ft. or 20 times the height of the building, whichever is greater. See Figure 1.
- Exposure C is applicable for all cases where Exposures B and D do not apply. See *Figure 2*.
- Exposure D is applicable where Surface Roughness D prevails in the upwind direction for a distance greater than 5,000 ft. or 20 times the building height, whichever is greater. Exposure D also applies where the ground surface roughness immediately upwind of the site is B or C, and the site is within a

Figure 1 – Example of Exposure B: suburban residential area with mostly single-family dwellings and low-rise structures less than 30 ft. high. (Photo courtesy of American Society of Civil Engineers.)

Figure 2 – Example of Exposure C: open grassland with scattered obstructions having heights less than 30 ft. (Photo courtesy of American Society of Civil Engineers.)

Figure 3 – Example of Exposure D: a building at the shoreline (excluding shorelines in hurricane-prone regions) with wind flowing over open water for a distance of at least one mile. (Photo courtesy of American Society of Civil Engineers.)

distance of 600 ft. or 20 times the building height, whichever is greater, from an Exposure D condition. See *Figure 3*.

For the exact definitions, refer to the specific version of ASCE 7.

Use of Exposure B results in the lowest wind loads, while Exposure D results in the highest wind loads. While many buildings are considered Exposure B, it is conservative to use Exposure C.

Use and Occupancy

The use and occupancy of a building is used to determine the "Occupancy Category" in ASCE 7-05 or "Risk Category" in ASCE 7-10 and ASCE 7-16. They are effectively interchangeable terms; however, they are addressed differently. ASCE 7-05 uses Occupancy Category to determine the value to use for the Importance Factor. Importance Factor is a stand-alone factor in the velocity pressure calculations. ASCE 7-10 and 7-16 uses Risk Category and it is incorporated in the wind speed maps. In brief, the greater the importance of a building, the higher the Importance Factor or Risk Category, which results in higher uplift pressures.

For example, in ASCE 7-05, Importance Factor I uses values (0.87 or 0.77) that reduce uplift pressures, and in ASCE 7-10 and ASCE 7-16, Risk Category I's map has the lowest wind speeds. On the other hand, Importance Factors III or IV use a value (1.15) that increases uplift pressures, and Risk Categories III and IV's maps have the higher wind speeds. The following are general descriptions and building examples:

- Importance Factor/Risk Category I: Buildings that represent low risk to human life in the event of failure, such as barns and temporary and minor storage facilities
- Importance Factor/Risk Category II: Buildings that are not classified as I, III and IV, which include most residential, commercial, and industrial buildings
- Importance Factor/Risk Category III: Buildings that house a large number of persons in one place, such as theaters, lecture halls, elementary schools, prisons, and small healthcare facilities
- Importance Factor/Risk Category IV: Buildings and other structures designated as essential facilities, such as hospitals, police stations, fire stations, emergency communication centers, and buildings containing toxic or explosive substances where the quantity exceeds a certain threshold

Enclosure Classification

This factor essentially relates to the possibility that a building will become internally pressurized during a wind event. For ASCE 7-05 and ASCE 7-10, there are three classification types: Open, Partially Enclosed, and Enclosed. These classifications are defined as follows:

- **Open:** A building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8\ A_g$
  Where:
  A_o = total area of openings in a wall that receives positive external pressure (ft^2)
  A_g = the gross area of that wall in which A_o is identified (ft^2)
- **Partially Enclosed:** A building that complies with both of the following conditions:
  1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building enclosure (walls and roof) by more than 10 percent.
  2. The total area of openings in a wall that receives positive external pressure exceeds 4 ft^2 or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building enclosure does not exceed 20 percent.
- **Enclosed:** A building that does not comply with the requirements for open or partially enclosed buildings.

ASCE 7-16 amended these classification types by adding another type called "Partially Open" and also revised some of the definitions. They are as follows:

- **Enclosed:** A_o is less than the smaller of $0.01A_g$ or 4 ft^2 and $A_{oi}/A_{gi} \leq 0.2$
  Where:
  A_o = total area of openings in a wall that receives positive external pressure (ft^2)
  A_g = the gross area of that wall in which A_o is identified (ft^2)
  A_{oi} = sum of the areas of openings in the building enclosure (walls and roof) not including A_o, (ft^2)
  A_{gi} = sum of the gross surface areas of the building enclosure (walls and roof) not including A_g, (ft^2)
- **Partially Enclosed:** $A_o > 1.1A_{oi}$ and $A_o >$ the lesser of $0.01A_g$ or 4 ft^2 and $A_{oi}/A_{gi} \leq 0.2$
- **Partially Open:** A building that does not comply with Enclosed, Partially Enclosed, or Open
- **Open:** Each wall is at least 80 percent open.

An Enclosed building is not expected to be internally pressurized during a wind event. A Partially Enclosed building is expected to have doors or windows blown out; therefore, allowing the roof assembly to be positively pressurized from the underside in addition to the negative pressures from the topside.

A Partially Open building example is a parking garage through which the wind can easily pass but does not meet the definition for either an Open or a Partially Enclosed building. ASCE 7 treats buildings that are Partially Open or Enclosed as similar and assigns the same internal pressure coefficient value (0.18).

Assuming a Partially Enclosed building results in an increase of 33 percent in the field of the roof, over an Enclosed building with all other factors held equal, this is significant; and selecting an "Enclosed" building when it could become a "Partially Enclosed" building if doors and windows are blown out during a high-wind event could result in a roof system without the appropriate capacity to handle the anticipated higher loads.

Further discussion about the field, perimeter, and corner pressures as they relate to Enclosed versus Partially Enclosed follows later in the paper.

Research and experience have shown that wind speeds can increase significantly due to topographic effects. The wind speed increase is known as a wind speed-up effect. An abrupt change in the topography, such as escarpments, hills, or valleys can significantly affect wind speed.

Topographic Effects

Research and experience have shown that wind speeds can increase significantly due to topographic effects. The wind speed increase is known as a wind speed-up effect. An abrupt change in the topography, such as escarpments, hills, or valleys, can significantly affect wind speed. ASCE 7 addresses these speed-up effects by applying a multiplier to account for topography in the velocity pressure calculations.

While many of these factors seem straightforward, using a more conservative Exposure Category or Risk Factor, or even using a higher-than-code-required wind speed will result in greater wind uplift pressures, which leads to the selection of a roof system with greater capacity. What level of risk does your client want or expect from his or her roof system?

Basic Differences Among Versions of ASCE

There are some noteworthy differences among the three ASCE 7 editions, and they include the wind speed maps, roof zones, enclosure classifications, external pressure coefficients, and the equation to calculate velocity pressures.

Wind Speed Maps: Simply put, for the contiguous U.S., ASCE 7-05 has one wind speed map, and it is based on ASD. ASCE 7-10 has three wind maps, based on Risk Category I, Risk Category II, and Risk Categories III and IV, and they are based on Strength Design. ASCE 7-16 has four wind speed maps—one for each Risk Category—and they are also based on Strength Design.

Roof Zones: ASCE 7-05 and ASCE 7-10 have three roof zones: field, perimeter, and corner (see *Figure 4*). The dimensions of the zones are mostly determined by a building's length and width. ASCE 7-16

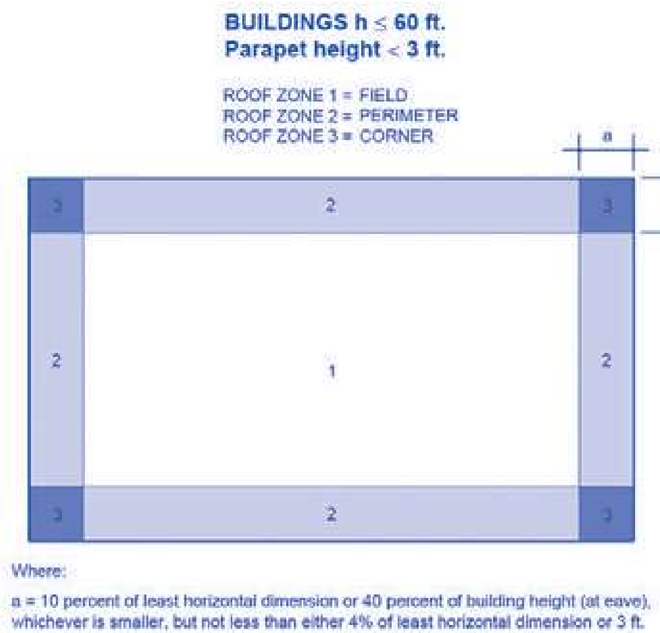

Figure 4 – ASCE 7-05 and ASCE 7-10 Roof Zone Layout.

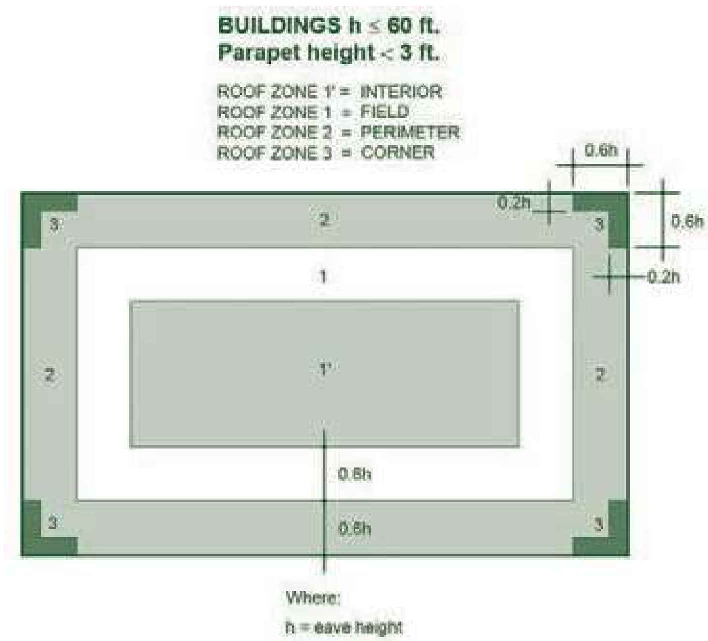

Figure 5 – Example of an ASCE 7-16 Roof Zone Layout showing all potential roof zones. Alternate roof zone layouts are possible with fewer zones.

added another zone, and it presents the potential to have four roof zones: interior, field, perimeter, and corner (see *Figure 5*). ASCE 7-16 also revised how the dimensions of the zones are sized; it is based on a building's height.

Enclosure Classifications: This was covered previously in section "Enclosure Classification." Essentially, ASCE 7-05 and ASCE 7-10 have three classification types: Open, Partially Enclosed, and Enclosed; while ASCE 7-16 added Partially Open and slightly modified the definitions. These classifications determine the values to use for the Internal Pressure Coefficient, GC_{pi}.

External Pressure Coefficients (GC_p): The values were significantly increased in ASCE 7-16. ASCE 7-05 and ASCE 7-10 use -1.0, -1.8, and -2.3 for field, perimeter, and corner zones, respectively. ASCE 7-16 uses -0.9, -1.7, -2.3, and -3.2 for interior, field, perimeter, and corner zones, respectively.

Velocity Pressure Equation: The equation to determine velocity pressure varies slightly between ASCE 7-05, ASCE 7-10, and ASCE 7-16. But first, it's important to recognize there are two basic steps used to determine design wind loads acting on a roof. The first step is to determine velocity pressure; the second step uses velocity pressure to determine wind loads for the interior (if applicable), field, perimeter, and corners of the roof. The following examples illustrate the differences between the velocity pressure equations from each edition.

ASCE 7-05 uses the following equation to determine velocity pressure (q_h):

$$q_h = 0.00256\,(K_z)(K_{zt})\,(K_d)\,(V^2)(I)$$

Where:

q_h = velocity pressure at mean roof height

K_z = exposure coefficient based on exposure and height (selected from a table)

K_{zt} = topography factor (likely 1.0 unless there is an abrupt elevation change on the windward side of the building)

K_d = wind directionality factor (components and cladding use 0.85)

V = basic wind speed for the location

I = Importance Factor (based on Occupancy Category)

ASCE 7-10 uses the following equation to determine velocity pressure (q_h):

$$q_h = 0.00256\,(K_z)(K_{zt})\,(K_d)\,(V^2)$$

The Importance Factor (I) was removed from the equation because the three wind maps in ASCE 7-10 take into account the Risk Category. Therefore, what was considered the "Importance Factor" is addressed by the wind speeds in each map.

ASCE 7-16 uses the following equation to determine velocity pressure (q_h):

$$q_h = 0.00256\,(K_z)(K_{zt})\,(K_d)\,(K_e)\,(V_2)$$

A ground elevation factor (K_e) was added to adjust for air density at higher elevations. It is permitted by ASCE 7-16 to be 1.0 for all locations. Using 1.0 is most conservative. As elevation increases, the air density decreases, as does the K_e factor. A K_e factor less than 1.0 will reduce the wind loads acting on a building.

DESIGN UPLIFT PRESSURES (LOADS)

After determining the velocity pressures, the next step is to calculate the design uplift pressures specific to the interior (if applicable), field, perimeter, and corner zones of a roof. Design uplift pressures on components and cladding elements (e.g., roof systems) on buildings with heights less than or equal to 60 ft. is determined by the following equation:

$$\text{Design uplift pressure} = q_h\,(GC_p - GC_{pi})$$

Where:

q_h = velocity pressure at mean roof height

GC_p = external pressure coefficient

GC_{pi} = internal pressure coefficient

The external pressure coefficient values are based on roof zones and the appropriate "effective wind area." Effective wind area is the tributary area for the element being considered, and 10 sq. ft. is typically used for roof systems. The internal pressure coefficient values are based on the building design (i.e., the enclosure classification).

The following are the uplift pressure equations that compare ASCE 7-05, ASCE 7-10, and ASCE 7-16.

ASCE 7-05 and ASCE 7-10

Field Uplift Pressure = q_h [-1.0 – (GC_{pi})]

Perimeter Uplift Pressure = q_h [-1.8 – (GC_{pi})]

Corner Uplift Pressure = q_h [-2.8 – (GC_{pi})]

The -1, -1.8, and -2.3 values in the equations are external pressure coefficients (GC_p). These are fixed values.

The value of the internal pressure coefficient, GC_{pi}, is based on the enclosure classification.

- 0.0 is used for an Open building
- 0.18 is used for an Enclosed building
- 0.55 is used for a Partially Enclosed building

For ASCE 7-10, these resultant field, perimeter, and corner pressures can be multiplied by 0.60 to adjust them to ASD pressures. This paper is not going to attempt a structural engineering discussion about the difference between ASD and Strength Design loads. However, the appropriateness of using ASD values with roofing systems and the adjustment of the Strength Design to ASD values are addressed in the 2018 edition IBC and the 2016 edition of ASCE 7.

The 2018 edition of IBC allows the use of ASD values in Section 1504.3:

> **1504.3 Wind resistance of nonballasted roofs.** 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 ASD.

The rationale for applying a 0.6 multiplier to Strength Design values in order to adjust to ASD can be found in the Commentary of ASCE 7-16, Section C26.5.1-Basic Wind Speed:

> Building envelope products that have been tested to air pressure standards (such as ASTM E330, CSA A123.21, or other standards that incorporate a safety factor) are typically rated for an ASD wind pressure (0.6W) rather than a strength design pressure (1.0W) or wind speed. In order to properly select products tested and rated in this manner, the C&C pressures determined from Chapter 30 should be adjusted for the ASD load factor of 0.6W.

Ultimately, the decision to use ASD pressures for the field, perimeter, and corners is an engineering judgment call that should be made by the structural engineer and/or designer or record. The decision to use ASD pressures should not be taken lightly, as it results in a reduction and, ultimately, in the selection of a roof system that has lower wind uplift capacity.

ASCE 7-16

For ASCE 7-16, the equation to calculate design uplift pressures on components and cladding elements of buildings with heights less than or equal to 60 ft. is the same; however, there is an additional roof zone.

Interior Uplift Pressure = q_h [-0.9 – (GC_{pi})]

Field Uplift Pressure = q_h [-1.7 – (GC_{pi})]

Perimeter Uplift Pressure = q_h [-2.3 – (GC_{pi})]

Corner Uplift Pressure = q_h [-3.2 – (GC_{pi})]

Where:
q_h = velocity pressure at mean roof height
GC_{pi} = internal pressure coefficient

The -0.9, -1.7, -2.3, and -3.2 values in the equations are external pressure coefficients (GC_p). Again, these are fixed values.

The value of the internal pressure coefficient, GC_{pi}, is based on the enclosure classification.

- 0.0 is used for an Open building
- 0.18 is used for an Enclosed and Partially Open building
- 0.55 is used for a Partially Enclosed building

For additional information regarding the changes to the 2005, 2010, and 2016 editions of ASCE 7, refer to the following articles by Thomas L. Smith published in *Professional Roofing* magazine: "ASCE 7 Update" (June 2008); "Mapping the 2010 Wind Changes" (August 2010); and "How Do I Load Thee?" (October 2017).

CALCULATING WIND LOADS ACTING ON ROOFS

There are a number of methods that can be used to calculate the wind loads acting on a roof. The most commonly used methods include:

- Hand calculations per ASCE 7 (or IBC Chapter 16)
- RoofNav (from FM Approvals)
- Roof Wind Designer (from the National Roofing Contractors Association [NRCA], Midwest Roofing Contractors Association [MRCA], and North East Roofing Contractors Association [NERCA]
- WD-1 and RP-4 (from SPRI)

Hand Calculations

Hand calculation allows the designer of record and/or the structural engineer to make the assumptions based on the owner's level of risk, and it is often a more exact method for determining the interior, field, perimeter, and corner pressures. Hand calculations follow the step-by-step procedures established in ASCE-7.

Once uplift pressures are determined, the designer of record and/or the structural engineer need to determine if the Strength Design pressures or the ASD pressures should be used. The next step is to apply a safety factor.

Loads x Safety Factor = < Capacity of the roof system

Additional information about safety factors is found later in this paper.

Online Calculators

Most, if not all, online calculators have some assumptions embedded, and often, these assumptions are not changeable. Some of them use ranges for certain factors (e.g., height) that can result in higher loads and, therefore, reduce the choices by the designer. However, if you are using an online calculator, make sure the applicable version of ASCE 7 is selected, and understand the embedded assumptions. Let's look at some examples.

RoofNav

FM Approvals offers RoofNav, a tool that can be used to determine wind uplift pressures. To access the tool, go to roofnav.com and click on the Ratings Calculator. As stated on the RoofNav website:

> The Ratings Calculator outputs six values: Wind Uplift ratings and actual pressures for the roof Field, Perimeter, and Corners. In order to obtain these values, you must complete every field in this section with a valid entry, and then click the Calculate button in the Calculate Wind Uplift section.

The ratings are used to determine what FM Approved assemblies can be used in a given roof area. In many cases, there are two options for enhancing roof systems for the perimeter and corners:

- Determine the field of roof rating and select an assembly meeting that criteria, followed by prescriptive enhancements for the perimeter and corners in accordance with the applicable FM Global Property Loss Prevention Data Sheets (LPDSs).
- Determine the field, perimeter, and corner ratings and select an assembly meeting the criteria for each roof area.

RoofNav uses its own wind speed maps and is based on the wind design procedures found in FM Global's LPDS 1-28, "Wind Design." The procedures in this data sheet use much of the terminology and concepts from ASCE 7, so it is often assumed they are identical wind design procedures. However, LPDS 1-28 has tables where you look up uplift design pressures and adjust them, if needed, for a specific project. Consequently, it should not be presumed you will get the same results as ASCE 7; loads may be higher or lower.

RoofNav asks for the terrain (e.g., Exposure Category), wind speed, windborne debris risk, and roof area dimensions. RoofNav provides wind pressures for the field, perimeter, and corners. A safety factor of 2.0 is used, and the Wind Uplift Ratings are provided based on the factored loads for the field, perimeters, and corners.

Additionally, RoofNav references LPDS 1-29, "Roof Deck Securement and Above–Deck Roof Components." This data sheet provides FM-specific requirements that will affect/drive the overall roof design, such as prescriptive enhancements for increasing fastener spacings in perimeter and corner zones, and the use of intermediate securement for mechanically attached single-ply membrane roof systems.

Using the RoofNav results, you can then find FM approved roof assemblies with the appropriate wind rating (i.e., 1-60, 1-90, etc.) using the "Assembly Search" feature in RoofNav. These rated roof assemblies are tested by FM Approvals using FM Approval Standards 4450, *Approval Standard for Class 1 Insulated Steel Deck Roofs*; FM 4470, *Approval Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Assemblies for Use in Class 1 and Noncombustible Roof Deck Construction*; and FM 4474, *American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*. Also keep in mind that FM approved roof assemblies may be used as validation for uplift resistance capacity to illustrate compliance with building code.

The RoofNav Ratings Calculator should be used when the building is insured by FM Global or when required by the project specifications. But keep in mind that RoofNav may or may not result in a roof system that strictly meets the requirements of the building code that is in effect for the project location. The design wind loads are still required to be determined using the version of ASCE 7 referenced in the building code.

Roof Wind Designer

Roof Wind Designer is an online tool that can be used to determine wind loads. To access the tool, go to RoofWindDesigner.com. As stated on the Roof Wind Designer website:

> Roof Wind Designer is intended to provide users with an easy-to-use means for determining roof systems' design wind loads for many commonly encountered building types that are subject to building code compliance.

Roof Wind Designer allows the user to select which version of ASCE 7 to use, and it then provides a set of instructions for the specific ASCE 7 version. Roof Wind Designer asks for a roof description, building configuration, exposure, occupancy or risk category, basic wind speed, and roof type.

Roof Wind Designer is limited to the "simplified" method or approach provided in the three editions of ASCE 7 to determine design wind loads. The simplified method is limited to buildings less than 60 ft. in height, and an "Enclosed" building configuration. The basic wind speed is auto-generated based on the project's county and occupancy or risk category, if applicable. Roof Wind Designer determines Strength Design loads and also adjusts them to ASD loads by using a 0.6 factor. Then, based on deck and covering type, Roof Wind Designer applies a safety factor. For example, membrane roofs over steel decks have a safety factor of 2.0 applied. This result is the minimum recommended design uplift-resistance capacity. Selection of a roof system that has the appropriate capacity is the responsibility of the designer of record.

WD-1 and RP-4

SPRI has two documents that can be used to help design and select roof systems based on wind uplift design pressures. The first is ANSI/SPRI WD-1, *Wind Design Standard Practice for Roofing Assemblies*. The second is ANSI/SPRI RP-4, *Wind Design Standard for Ballasted Single-ply Roofing Systems*. To access these documents, go to www.spri.org and search "Standards."

As stated in WD-1's Introduction:

> This Wind Design Standard Practice provides general building design considerations as well as a methodology for selecting an appropriate roofing system assembly to meet the rooftop design wind uplift pressures that are calculated in accordance with the current version of the International Building Code

> (IBC). This Standard Practice is appropriate for non-ballasted Built-Up, Modified Bitumen, and Single-Ply roofing system assemblies installed over any type of roof deck.

WD-1 includes a generalized discussion about the methodology used to calculate wind uplift design pressures, determining uplift resistance of a roofing system, and the use of a safety factor. It is important to note that WD-1 is not referenced in building codes.

As stated in RP-4's Introduction:

> This standard provides a method of designing wind uplift resistance of ballasted single-ply roofing systems. It is intended as a design and installation reference for those individuals who design, specify, and install ballasted single-ply roofing systems.

RP-4 uses the three wind speed maps from ASCE 7-10, and RP-4 is referenced in IBC 2015 and IBC 2018 as an accepted standard for the design of ballasted roof systems.

DETERMINING RESISTANCE

The primary method for determining a roof system's wind uplift resistance (also known as capacity) is through physical testing. The test methods to determine wind resistance are listed in the IBC Section 1504, Performance Requirements.

In the 2003 and 2006 IBC, for wind resistance of nonballasted roofs, the code states that built-up, modified-bitumen, fully adhered or mechanically attached single-ply, through-fastened metal panel roof systems, and other types of membrane roof coverings shall be tested in accordance with FM 4450; FM 4470; UL 580, *Standard for Tests for Uplift Resistance of Roof Assemblies*; or UL 1897, *Standard for Uplift Tests for Roof Covering Systems*.

In the 2009, 2012, 2015, and 2018 versions of the IBC, for wind resistance of nonballasted roofs, the code states that built-up, modified-bitumen, fully adhered or mechanically attached single-ply roof systems, metal panel roof systems applied to a 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.

These tests are run by approved testing agencies. FM Approvals, Underwriters Laboratory, Intertek, NEMO, PRI, and others can perform testing—according to the code-approved test methods—that can be used to determine a roof system's capacity.

It is important that the testing method used to determine the capacity of a roof system is listed in the applicable building code.

APPROVAL LISTINGS

The tested roof systems are found in approval listings. Approval listings are maintained by various entities, such as government agencies, testing laboratories, and even a trade association. Example of government agencies with approval listings include Florida Department of Business and Professional Regulation, Miami Dade County, and the Texas Department of Insurance. Testing laboratories that have listings of rated roofing assemblies include Underwriters Laboratories and FM Approvals. And lastly, SPRI sponsors the Directory of Roofing Assemblies (DORA), which is an online database of tested assemblies.

UNDERSTAND SAFETY FACTORS

Accepted engineering practice provides for applying a reasonable "safety factor" to design uplift pressures when using the ASD method. The roofing industry traditionally follows ASTM D6630, *Standard Guide for Low Slope Insulated Roof Membrane Assembly Performance*, and the scope is as follows:

> This guide lists test methods intended to establish a minimum level of performance for insulated roof assemblies, and lists pertinent design guidelines and installation method in a unified manner. Material tests and evaluations are included, with and without roof insulation.

Relevant to wind design, Subsection 7.3.7, in Section 7.3, "Roof System Design" in ASTM D6630 states:

> Wind uplift forces should be determined according to ASCE-7. Roof system wind uplift resistance shall be a minimum 2.0 factor of safety. For ballasted single-ply roofs, use ANSI/SPRI for determining their wind uplift resistance.

Consequently, this recognized consensus standard establishes a minimum 2.0 safety factor to be appropriate for determining wind uplift resistances of roof systems.

STEP-BY-STEP SUMMARY

- Know the applicable building code for the project.
  - This determines which version of ASCE 7 to use.
  - This provides the code-approved test methods used to determine a roof system's capacity.
- Determine wind uplift pressures for interior (if applicable), field, perimeter, and corner zones according to the correct version of ASCE 7 by using the appropriate wind speed, exposure, risk factor, and enclosure category that fits the level of overall risk desired by the building owner, designer of record, and/or the structural engineer. Use Strength Design or ASD values—again, based on the level of risk desired by the building owner, designer of record, and/or the structural engineer.
- Ensure that an appropriate safety factor is included on either the load side or the resistance side. Select a roof system with a tested capacity that meets or exceeds the design wind loads. Use approval listings to select the appropriate roof system.

CONCLUSIONS

- Don't mix and match methods; for instance, don't use the wrong wind map with the online application that you are using.
- Utilize solid engineering judgment to determine if Strength Design or ASD is appropriate to determine uplift pressures.
- Select roof systems that have capacity greater than the loads acting on the building.
- Select roof systems that have been tested in accordance with code-approved test methods by accredited testing laboratories.