ANSI/SPRI RP-14 2016

Wind Design Standard For Vegetative Roofing Systems

Approved September 9, 2016

SINGLE PLY ROOFING INDUSTRY

Table of Contents

1.0 Introduction 2

2.0 Definitions 2

3.0 General Design Considerations and System Requirements 6

4.0 Design Options 8

5.0 Design Provisions 10

6.0 Determination of Vegetative System Roof Design 10

7.0 Maintenance 11

Commentary to SPRI RP-14 43

References 49

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This standard is for use by architects, engineers, roofing contractors, and owners of low slope roofing systems. SPRI, its members and employees do not warrant that this standards is proper and applicable under all conditions.

1.0 Introduction

This standard provides a method of designing wind uplift resistance of *vegetative roofing systems* utilizing adhered roofing membranes. It is intended to provide a minimum design and installation reference for those individuals who design, specify, and install *vegetative roofing systems*. It shall be used in conjunction with, or enhanced by, the installation specifications and requirements of the manufacturer of the specific products used in the *vegetative roofing system*. See Commentary C1.0.

2.0 Definitions

All words defined within this section are italicized throughout the standard.

The following definitions shall apply when designing a *Vegetative Roofing System*.

2.1 Vegetative Roofing System

An assembly of interacting components designed to waterproof a building's top surface that includes, by design, vegetation and related landscaping elements.

2.2 Ballast

The weight provided by stones, pavers or light-weight interlocking paver systems to provide uplift resistance for roofing systems that are not adhered or mechanically attached to the roof deck. The inorganic portion of *growth media* can be considered *ballast* if vegetation nominally covers the visible surface of the *growth media* or the *growth media* is protected by a system to prevent wind erosion. See Commentary 2.2.

2.3 Vegetation Coverage

2.3.1 Nominal Vegetation Coverage

No exposed *growth media* greater than a 4 in (102 mm) in diameter.

2.3.2 Unprotected Growth Media or Unprotected Modular Vegetative Roof Trays

Systems that do not have *nominal vegetation coverage*.

2.3.3 Protected Growth Media or Protected Modular Vegetative Roof Trays

Systems that have *nominal vegetation coverage* or a system to prevent *growth media* blow off.

2.4 Growth Media

An engineered formulation of inorganic and organic materials including but not limited to heat-expanded clays, slates, shales, aggregate, sand, perlite, vermiculite and organic material including but not limited to compost worm castings, coir and peat.

2.5 Basic Wind Speed

The *Basic Wind Speed* is the 3-second gust speed at 33 ft (10 m) above the ground in *Exposure C* as follows:

2.5.1 Risk Category II

Wind speeds correspond to approximately a 7% probability of exceedance in 50 years. See Attachment I-A.

2.5.2 Risk Category III and IV

Wind speeds correspond to approximately a 3% probability of exceedance in 50 years. See Attachment I-B.

2.5.3 Risk Category I

Wind speeds correspond to approximately a 15% probability of exceedance in 50 years. See Attachment I-C.

2.5.4 Risk Category IV

Wind speeds correspond to approximately a 1.6% probability of exceedance in 50 years. See Attachment I-C.

2.5.5 Wind speed conversion

The ultimate design *wind speeds* of Attachment I A, B, C, and D shall be converted to nominal design *wind speeds* V_{asd}, using the following equation:

$$V_{asd} = V_{ult}\sqrt{0.6}$$

where:

V_{asd} = nominal design *wind speed*

V_{ult} = ultimate design *wind speeds* determined from Attachment I A, B, C, and D

2.6 Roof Areas See Figure 1.

2.6.1 Corner

The space between intersecting walls forming an angle greater than 45 degrees but less than 135 degrees. See Commentary 2.6.1.

2.6.2 Corner Area

For roofs having height, h ≤ 60 ft (18 m), the *corner area* is defined as the *corner* roof section with sides equal to α (see below). See Commentary 2.6.2. For roofs having height, h > 60 ft (18 m), the *corner* zone is defined as the *corner* roof section with sides equal to 2 x **α** (see below).

α = 0.4h, but not less than either 4% of least horizontal dimension or 8.5 ft (2.9 m)

See Commentary 2.6.2.

2.6.3 Perimeter Area

Perimeter area is defined as the rectangular roof section parallel to the roof edge and connecting the *corner areas* with a width measurement equal to **α** (see above).

2.6.4 Field

The *field* of the roof is defined as that portion of the roof surface which is not included in the *corner* or the *perimeter area* as defined above.

2.7 Surface Roughness/Exposure Categories

A ground *surface roughness* within each 45-degree sector shall be determined for a distance upwind of the site as defined in Section 2.7.1, 2.72 or 2.7.3 for the purpose of assigning an exposure category.

2.7.1 Surface Roughness/Exposure B

Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

*Exposure B***:** For buildings with a mean roof height of less than or equal to 30 ft (9.1 m), *Exposure B* shall apply where the ground *surface roughness*, as defined by *Surface Roughness B*, prevails in the upwind direction for a distance greater than 1,500 ft (457 m). For buildings with a mean roof height greater than 30 ft (9.1 m), *Exposure B* shall apply where *Surface Roughness B* prevails in the upwind direction for a distance greater than 2,600 ft (792 m) or 20 times the height of the building, whichever is greater.

2.7.2 Surface Roughness/Exposure C

Open terrain with scattered obstructions having heights generally less than 30 ft (9.1 m). This category includes flat open country and grasslands. *Exposure C* shall apply for all cases where *Exposures B* or *D* do not apply. See Commentary C2.7.

2.7.3 Surface Roughness/Exposure D

Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice. *Exposure D* shall apply where the ground *surface roughness*, as defined by *Surface Roughness D*, prevails in the upwind direction for a distance greater than 5,000 ft (1,524 m) or 20 times the building height, whichever is greater. *Exposure D* shall also apply where the ground *surface roughness* immediately upwind of the site is B or C, and the site is within a distance of 600 ft (183 m) or 20 times the building height, whichever is greater, from an *Exposure D* condition as defined in the previous sentence. For a site located in the transition zone between *exposure categories*, the category resulting in the largest wind forces shall be used. See Section 5.3.

2.7.4 Exception

An intermediate exposure between the preceding categories is permitted in a transition zone provided that it is determined by a rational analysis method defined in the recognized literature.

2.8 Impervious Decks

A roof deck that will not allow air to pass through it. Some examples are poured in-place concrete, gypsum, and poured-in-place lightweight concrete. See Commentary C2.8.

2.9 Pervious Decks

A roof deck that allows air to move through it. Some examples are metal, cementitious wood fiber, oriented strand board, plywood and wood plank.

2.10 Occupancy Category

Occupancy category accounts for the degree of hazard to human life and damage to property. See Table 1.

2.11 Wind Borne Debris Regions

Areas within hurricane prone areas where impact protection is required for glazed openings.

2.12 Registered Design Professional

An individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of the state or jurisdiction in which the project is to be constructed.

Table 1

Classification of Buildings and Other Structures for Wind, Snow, and Earthquake Loads[1]

Nature of Occupancy	Category
Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: ▶ Agricultural facilities ▶ Certain temporary facilities ▶ Minor storage facilities	I
All buildings and other structures except those listed in Categories I, III, IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: ▶ Buildings and other structures where more than 300 people congregate in one area ▶ Buildings and other structures with elementary school, secondary school, or day care facilities with capacity greater than 150 ▶ Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities ▶ Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities ▶ Jails and detention facilities ▶ Power generating stations and other public utility facilities not included in Category IV ▶ Buildings and other structures containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released including, but not limited to: A. Petrochemical facilities B. Fuel storage facilities C. Manufacturing or storage facilities for hazardous chemicals D. Manufacturing or storage facilities for explosives	III
Buildings and other structures designated as essential facilities including, but not limited to: ▶ Hospitals and other health care facilities having surgery or emergency treatment facilities ▶ Fire, rescue and police stations and emergency vehicle garages ▶ Designated earthquake, hurricane, or other emergency shelters ▶ Communications centers and other facilities required for emergency response ▶ Power generating stations and other public utility facilities required in an emergency ▶ Ancillary structures (including, but not limited to communications towers, fuel storage tanks, cooling towers, electrical substation structures, fire water storage tanks or other structures housing or supporting water or other fire suppression material or equipment) required for operation of Category IV structures during an emergency ▶ Aviation control towers, air traffic control centers and emergency aircraft hangers ▶ Water storage facilities and pump structures required to maintain water pressure for fire suppression ▶ Buildings and other structures having critical national defense functions	IV

[1] The definitions above are based on those of ANSI/ASCE 7-2010. Examples of building types are retained from previous version of ASCE 7 for clarification.

3.0 General Design Considerations and System Requirements

All *vegetative roofing systems* shall comply with the following:

3.1 Roof Structure

The building owner shall consult with a *registered design professional* such as an architect, architectural engineer, civil engineer, or structural engineer to verify that the structure and deck will support the *vegetative roofing system* loads including the *ballast* load in combination with all other design loads.

3.2 Building Height

The building height shall be measured from ground level to the roof system surface at the roof edge. When more than one roof level is involved, each shall have its own design per Sections 4.0 and 5.0; or be designed to the criteria required for the most exposed or highest roof level. When building height exceeds 150 ft (46 m), the roof design shall be designed by a *registered design professional* using current wind engineering practices consistent with ASCE 7 and the design shall be approved by the authority having jurisdiction. See Commentary C3.2.

3.3 Slope

The Wind Design Standard for *Vegetative Roofing Systems* is limited to roof slope designs up to 1.5 in 12 (7 degrees) as measured at the top side of the roof membrane. For slopes greater than 1.5 in 12, a *registered design professional* experienced in vegetative roof wind design shall provide design requirements and the design shall be approved by the authority having jurisdiction.

3.4 Positive Pressure Building Systems

When HVAC equipment generates a positive pressure inside a building greater than 0.5 in (13 mm) of water the roof system shall be designed to resist the pressure by increasing the wind load requirements in accordance with Section 5.2.

3.5 Rooftop Projections

The *roof area* at the base of any rooftop projection that extends more than 2 ft (0.6 m) above the top of the parapet and has one side longer than 4 ft (1.2 m) shall be designed in accordance with Section 5.3.

3.6 Overhanging Eaves and Canopies

By their design, overhanging eaves and canopies are subject to greater uplift forces than the roof surface because of the impact of the air flow up the wall. Such conditions shall be designed in accordance with Section 5.4. See Figures 2 and 3.

3.7 Membrane Requirements

The membrane specified for use in the vegetative system shall meet the recognized industry minimum material requirements for the generic membrane type, and shall meet the specific requirements of its manufacturer. Membranes not having a consensus product standard shall meet the specific requirements of their manufacturer. Where the membrane is not impervious to root penetration, root barriers shall be necessary. See Commentary C3.7.

3.8 Membrane Perimeter and Angle Change Attachment

See Commentary C3.8.

3.8.1 At Roof Edge and Top of Parapet Wall

When the roofing system is terminated using a metal edge or coping flashing, the metal flashing shall be designed and installed in accordance with ANSI/SPRI/FM 4435/ES-1 *Wind Design Standard for Edge Systems Used With Low Slope Roofing Systems* except gutters. When the membrane or roof flashing is terminated on a parapet wall below the coping, the perimeter attachment used to terminate a roofing system shall be capable of withstanding the calculated load. For asphaltic and fully adhered single ply membranes, it is permitted to use alternative attachments that comply with manufacturer's drawings and specifications. Roofs terminated at gutters shall meet manufactures requirement for gutter edge securement.

3.8.2 For Angle Changes
All attachments of membranes at angle changes or system type changes in a roofing system shall be capable of withstanding the calculated load.

3.8.3 Parapet Height
The parapet height for *vegetative roofing systems* is the distance from the top of the *growth media* to the top of the parapet. When the lowest parapet height is outside of the defined *corner area* of the roof and is less than 70% of the height of the parapet within the defined *corner area*, then this lower parapet height shall be used for the design. When the lowest parapet is located outside the defined *corner area* of the roof and is equal to or greater than 70% of the height of the parapet within the defined *corner area*, then the minimum parapet height within the *corner* segment shall be used for the design. See example in Figure 4.

3.8.4 Metal Edge Flashing (Gravel Stop)
When an edge flashing is used at the building perimeter, the top edge of the flashing shall be higher than the top surface of the *ballast*, but not less than 2 in (50 mm) above the top surface of the *growth media*. Metal edge flashing shall be designed and installed in accordance with ANSI/SPRI/FM 4435/ES-1.

3.8.5 Transition
At the junction of loose-laid roof membranes with the adhered or mechanically attached membrane areas, a mechanical termination shall be provided. The termination shall resist the forces as calculated using ANSI/SPRI/FM 4435/ES-1.

3.9 Wind Erosion

When the *growth media* is not nominally covered with vegetation, provision for preventing wind erosion shall be installed in the *corner* and perimeter to prevent *growth media* from being wind-blown. See Commentary C3.9.

3.10 High Winds

When the *wind speed* exceeds 140 miles per hour (63 m/s) 3-second gust *wind speed* after all adjustments are applied, the roof design shall be designed by a *registered design professional* using current wind engineering practices consistent with ASCE 7 and the design shall be approved by the authority having jurisdiction.

3.11 Wind Borne Debris

Roofs installed in regions designated by ASCE 7, or the authority having jurisdiction, as *wind borne debris regions* shall be designed by a *registered design professional* using current wind engineering practices consistent with ASCE 7. The design shall be approved by the authority having jurisdiction. See Commentary C3.11.

3.12 Ballast Requirements

See Commentary C3.12. *Ballast* shall be in accordance with the manufacturer's specification and not less than the following:

3.12.1 #4 Ballast
For vegetative roofs when vegetation nominally covers the visible surface of the *growth media* or provisions have been made to prevent wind erosion from the surface, #4 *ballast* can consist of any of the following used independently or in combinations:

- *Growth media* spread at a minimum dry weight of 10 psf (49 kg/m^2) of inorganic material plus organic material;

  Interlocking contoured fit or strapped together trays containing *growth media* spread at minimum dry weight of 10 psf (49 kg/m^2) of inorganic material plus organic material;

- Independently set modular pre-planted or pre-grown vegetative roof trays containing 18 psf (88 kg/m^2) dry weight inorganic material plus organic material.

  Vegetation coverage or erosion protection is not required when the #4 *ballast* below is used.

- River bottom or coarse stone nominal 1-1/2 in (38 mm) of *ballast* gradation size #4, or alternatively, #3, #24, #2, or #1 as specified in ASTM D7655, *Standard Classification for Size of Aggregate Used as Ballast for Membrane Roof Systems* spread at a minimum weight of 10 psf (49 kg/m^2);
- Concrete pavers independently set (minimum 18 psf (88 kg/m^2));
- Interlocking, beveled, doweled, or contour-fit lightweight concrete pavers (minimum 10 psf (49 kg/m^2)).

3.12.2 #2 Ballast

For vegetative roofs when vegetation nominally covers the visible surface of the *growth media* or provisions have been made to prevent wind erosion from the surface, #2 *ballast* can consist of any of the following used independently or in combinations:

- *Growth media* spread at a minimum dry weight of 13 psf (64 kg/m^2) of inorganic material plus organic material;
- Interlocking contoured fit or strapped together trays containing *growth media* spread at minimum dry weight of 13 psf (64 kg/m^2) of inorganic material plus organic material;
- Independently set modular pre-planted or pre-grown vegetative roof trays containing 22 psf (104 kg/m^2) dry weight inorganic material plus organic material.

  Vegetation coverage or erosion protection is not required when the #2 *ballast* below is used:

- River bottom or course stone nominal 2-1/2 in (64 mm) of *ballast* gradation size #2, or alternatively, #1 as specified in ASTM D7655 *Standard Classification for Size of Aggregate Used as Ballast for Membrane Roof Systems* spread at a minimum weight of 13 psf; (64 kg/m^2);
- Concrete pavers independently set (minimum 22 psf (104 kg/m^2));
- Interlocking, beveled, doweled, or contour-fit lightweight concrete pavers (minimum 10 psf ;(49 kg/m^2)).

4.0 Design Options

The vegetative roof wind designs include, but are not limited to, the generic systems shown below. Other systems, when documented or demonstrated as equivalent with the provisions of this standard, shall be used when approved by the authority having jurisdiction. The designs listed in Sections 4.2 and 4.3 are the minimum specifications. See Commentary C4.0.

4.1 Roof Membrane Attachment

All roof membrane shall be fully adhered. The fully adhered roofing membrane shall withstand the uplift design pressure without the *ballast* in accordance with requirements of the authority having jurisdiction. See Commentary C4.1.

4.2 Ballasted Design Systems for Vegetative Roofing Systems

See Section 2.2 for definition of *Ballast*. The design systems listed below are based on Table 2. Any building not fitting the Table 2 Design Tables shall be treated as a Special Design Consideration and shall be reviewed by a *registered design professional* and approved by the authority having jurisdiction.

4.2.1 System 1

The installed membrane shall be ballasted with #4 *ballast*. See Section 3.12.1.

4.2.2 System 2

The installed membrane shall be ballasted as follows:

4.2.2.1 Corner Area

The installed membrane in the *corner area* shall be ballasted with #2 *ballast*. See Section 3.12.2 and Figure 1.

4.2.2.2 Perimeter

The installed membrane in the *perimeter area* shall be ballasted with #2 *ballast*. See Section 3.12.2 and Figure 1.

4.2.2.3 Field

In the *field* of the roof, the installed membrane shall be ballasted with #4 *ballast*. See Section 3.12.1. For areas designated as wind debris areas, #2 *ballast* shall be the minimum size-weight *ballast* used.

4.2.3 System 3

Install the system as follows:

4.2.3.1 Corner Area

In each *corner area*, the adhered roof system designed to withstand the uplift force in accordance with ASCE 7 or the local building code, shall be installed in accordance with the provisions for the *corner* location with no loose stone, *unprotected growth media or unprotected modular vegetative roof trays* placed on the membrane. See Figure 1 and Commentary C4.0.

When a protective covering is required in the *corner area*, install minimum 22 psf (104 kg/m^2) pavers, or other material approved by the authority having jurisdiction.

4.2.3.2 Perimeter

In the *perimeter area*, the adhered roof system designed to withstand the uplift force in accordance with ASCE 7 or the local building code, shall be installed in accordance with the provisions for the perimeter location with no loose stone, *growth media* or modular vegetative roof trays placed on the membrane.

When a protective covering is required in a perimeter area, install minimum 22 psf (104 kg/m^2) pavers or other material approved by the authority having jurisdiction.

4.2.3.3 Field

In the *field* of the roof, install #2 *ballast*. See Section 3.12.2.

4.3 Protected Vegetative Roofing Systems

(Systems where the insulation is installed over the waterproofing membrane) See Commentary C4.3 for description.

The protected membrane roof wind designs include, but are not limited to, the generic systems shown below. Other systems, which comply with the provision of this specification, shall be permitted when approved by the authority having jurisdiction.

4.3.1 System 1 and System 2

When the design criteria based on *wind speed*, building height, and parapet height and exposure, require a System 1 or System 2 design, the ballasting procedures for that respective system shall be according to Sections 4.2.1 and 4.2.2, respectively.

4.3.2 System 3

When the design criteria, based on *wind speed* and building height, parapet height and exposure require a System 3 design, a minimum 2 ft (0.6 m) parapet height See Section 3.8.3 for determining parapet height) is required and the installation procedures for System 3 as defined in Section 4.2.3 above shall be followed. In addition, the insulation that is installed over the fully adhered perimeter and *corner areas* shall be ballasted with 22 psf (104 kg/m^2) pavers (minimum) or other material approved by the authority having jurisdiction.

5.0 Design Provisions

5.1 Rooftop Projections

See Section 3.5 for description.

When rooftop projections rise 2 ft (0.6 m) or more above the parapet height and have at least one side greater than 4 ft (1.2 m) in length, the *roof area* shall be protected from wind erosion. See Commentary C3.9.

5.2 Overhangs, Eaves and Canopies

5.2.1 Impervious Decks

When a deck is *impervious*, overhang, eaves and canopy shall be defined as the following: Eaves and overhangs: The overhang or eave shall be considered the perimeter of the applicable design. See Figure 2. Canopies: The entire canopy area shall be designed as a *corner* section of the applicable design.

5.2.2 Pervious Decks

Because a fully adhered membrane roof system is used, the design shall follow the *impervious* deck design.

5.3 Exposure D

For buildings located in *Exposure D*, the roof design as identified in the Design Tables (See Table 2) shall be upgraded to a higher level of resistance to wind. Under *Exposure C* the roof top *wind speed* shall be increased by 20 mph (9 m/s) from the *basic wind speed* from the wind map. See section 2.7.3. Under these conditions a building roof located in a 90 mph (40 m/s) wind zone would be upgraded to 110 mph (49 m/s). Installation shall follow all of the requirements for the higher design wind.

5.4 Occupancy Category

ASCE 7 provides *wind speed* maps based on the *occupancy category* for the buildings being roofed. Find the *wind speed* from the appropriate map (Attachment I A-D) and install the appropriate system using the Design Table II A-G.

6.0 Determination of Vegetative System Roof Design

To determine the vegetative design for a given building, the following process shall be followed. See Commentary C6.0.

6.1 Based on the building location, the nominal design *wind speed* shall be determined following Section 2.5.4 and *Surface Roughness/Exposure* from Section 2.7.

6.1.1 The building height shall be determined by following Section 3.2 and the parapet height from Section 3.8.3.

6.1.2 Knowing the *wind speed*, building height, parapet height, *Risk Category* and *Surface Roughness/Exposure*, determine the System Design (1, 2 or 3) using the appropriate Design Table contained in Table 2.

6.1.3 Having determined the System from the Design Tables (Table 2), use Section 4.0, Design Options, to determine the ballasting requirements based on the type of roof system as described in Sections 4.1, 4.2 and 4.3.

6.1.4 Section 5.0, Design Provisions shall be reviewed to determine the necessary enhancements to the system's ballasting requirements. These provisions are the accumulative addition to the base design from the Design Table 2A-G.

7.0 Maintenance

Vegetative roof systems shall be maintained to provide vegetation that nominally covers the visible surface of the *growth media*. When wind scour occurs to an existing *vegetative roof system* and the scour is less than 50 ft^2 (4.6 m^2), the *growth media* and plants shall be replaced. For scour areas greater than 50 ft^2 (4.6 m^2), the vegetative roof design shall be upgraded a minimum of one system design level per Section 4.0. The requirement for maintenance shall be conveyed by the designer to the building owner, and it shall be the building owner's responsibility to maintain the *vegetative roofing system*.

Table 2

Design Tables[3]

A. From 2 inch high to less than 6.0 inch high parapet

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	110	115	125	125	140	140
15–30	110	115	120	125	140	140
30–45	100	110	110	125	140	140
45–60	No	No	105	125	130	140
60–75	No	No	100	120	130	130
75–90	No	No	No	No	No	No
90–105	No	No	No	No	No	No
105–120	No	No	No	No	No	No
120–135	No	No	No	No	No	No
135–150	No	No	No	No	No	No

B. For parapet heights from 6.0 to less than 12.0 inches

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	110	115	125	125	140	140
15–30	110	115	120	125	140	140
30–45	100	110	110	125	140	140
45–60	No	No	105	125	130	140
60–75	No	No	100	120	130	140
75–90	No	No	No	No	No	No
90–105	No	No	No	No	No	No
105–120	No	No	No	No	No	No
120–135	No	No	No	No	No	No
135–150	No	No	No	No	No	No

C. For parapet heights from 12.0 to less than 18.0 inches

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	110	115	125	125	140	140
15–30	110	115	120	125	140	140
30–45	100	115	115	125	140	140
45–60	No	100	105	125	140	140
60–75	No	100	100	120	130	140
75–90	No	No	100	120	120	130
90–105	No	No	100	110	120	120
105–120	No	No	95	110	110	120
120–135	No	No	No	110	110	120
135–150	No	No	No	105	110	120

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are “3 second gust” measured at 10 meters (33 feet).

Table 2

Design Tables[3]

D. For parapet heights from 18.0 to less than 24.0 inches

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	120	120	130	130	140	140
15–30	120	120	120	130	140	140
30–45	105	120	120	130	140	140
45–60	95	120	105	130	140	140
60–75	No	100	100	120	140	140
75–90	No	100	100	120	130	140
90–105	No	No	100	110	120	130
105–120	No	No	100	110	120	120
120–135	No	No	100	110	120	120
135–150	No	No	No	110	110	120

E. For parapet heights from 24.0 to less than 36.0 inches

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	120	120	130	130	140	140
15–30	120	120	130	130	140	140
30–45	105	120	120	130	140	140
45–60	95	120	110	130	140	140
60–75	No	100	100	130	140	140
75–90	No	100	100	120	140	140
90–105	No	No	100	110	130	140
105–120	No	No	100	110	130	140
120–135	No	No	100	110	130	140
135–150	No	No	100	110	120	140

F. For parapet heights from 36.0 to less than 72 inches

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	120	120	130	130	140	140
15–30	120	120	130	130	140	140
30–45	110	120	130	130	140	140
45–60	105	120	115	130	140	140
60–75	100	110	110	130	140	140
75–90	100	110	110	130	140	140
90–105	100	100	110	120	140	140
105–120	95	100	110	120	140	140
120–135	95	100	110	120	140	140
135–150	No	95	110	120	140	140

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are “3 second gust” measured at 10 meters (33 feet).

Table 2

Design Tables[3]

G. For parapet heights from 72 inches and above

Maximum Wind Speed (MPH)

Roof height feet	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–15	120	120	130	130	140	140
15–30	120	120	130	130	140	140
30–45	120	120	130	130	140	140
45–60	110	120	130	130	140	140
60–75	105	120	125	130	140	140
75–90	100	110	120	130	140	140
90–105	100	110	120	130	140	140
105–120	100	110	120	130	140	140
120–135	100	110	120	130	140	140
135–150	95	110	120	120	140	140

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are "3 second gust" measured at 10 meters (33 feet).

Table 2

Design Tables[3]

Metric

A. From 50 mm height to less than 150mm parapet height

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	50	52	56	56	63	68
5–9	50	52	54	56	63	68
9–14	45	50	50	56	63	68
14–18	No	No	52	56	59	68
18–23	No	No	45	54	59	68
23–27	No	No	No	No	No	59
27–32	No	No	No	No	No	No
32–37	No	No	No	No	No	No
37–41	No	No	No	No	No	No
41–46	No	No	No	No	No	No

B. For parapet heights from 150 mm to less than 300 mm

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	53	55	59	59	66	71
5–9	53	55	57	59	66	71
9–14	48	53	53	59	66	71
14–18	No	No	55	59	62	71
18–23	No	No	48	57	62	66
23–27	No	No	No	No	No	66
27–32	No	No	No	No	No	No
32–37	No	No	No	No	No	No
37–41	No	No	No	No	No	No
41–46	No	No	No	No	No	No

C. For parapet heights from 0.3 m to less than 0.45 m

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	50	52	56	56	68	68
5–9	50	52	54	56	68	68
9–14	45	52	52	56	68	68
14–18	No	No	47	56	63	68
18–23	No	No	45	54	59	63
23–27	No	No	45	54	54	59
27–32	No	No	45	50	54	54
32–37	No	No	43	50	50	54
37–41	No	No	No	50	50	54
41–46	No	No	No	47	50	54

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are “3 second gust” measured at 10 meters (33 feet).

Table 2

Design Tables[3]

D. For parapet heights from 0.45 m to less than 0.60 m

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	54	54	59	59	68	68
5–9	54	54	54	59	68	68
9–14	47	54	54	59	68	68
14–18	43	54	47	59	63	68
18–23	No	40	45	54	59	63
23–27	No	40	45	54	54	59
27–32	No	No	45	50	54	54
32–37	No	No	45	50	50	54
37–41	No	No	45	50	50	54
41–46	No	No	No	50	50	54

E. For parapet heights from 0.60 m to less than 1 m

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	54	54	59	59	68	68
5–9	54	54	59	59	68	68
9–14	47	54	54	59	68	68
14–18	43	54	50	59	68	68
18–23	No	45	45	59	63	68
23–27	No	45	45	54	63	68
27–32	No	No	45	50	59	68
32–37	No	No	45	50	59	68
37–41	No	No	45	50	59	68
41–46	No	No	45	50	54	63

F. For parapet heights from 1 m to less than 2 m

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	54	54	59	59	68	68
5–9	54	54	59	59	68	68
9–14	50	54	59	59	68	68
14–18	47	54	52	59	68	68
18–23	45	50	50	59	68	68
23–27	45	50	50	59	68	68
27–32	45	45	50	54	63	68
32–37	43	45	50	54	63	68
37–41	43	45	50	54	63	68
41–46	No	43	50	54	63	68

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are "3 second gust" measured at 10 meters (33 feet).

Table 2

Design Tables[3]

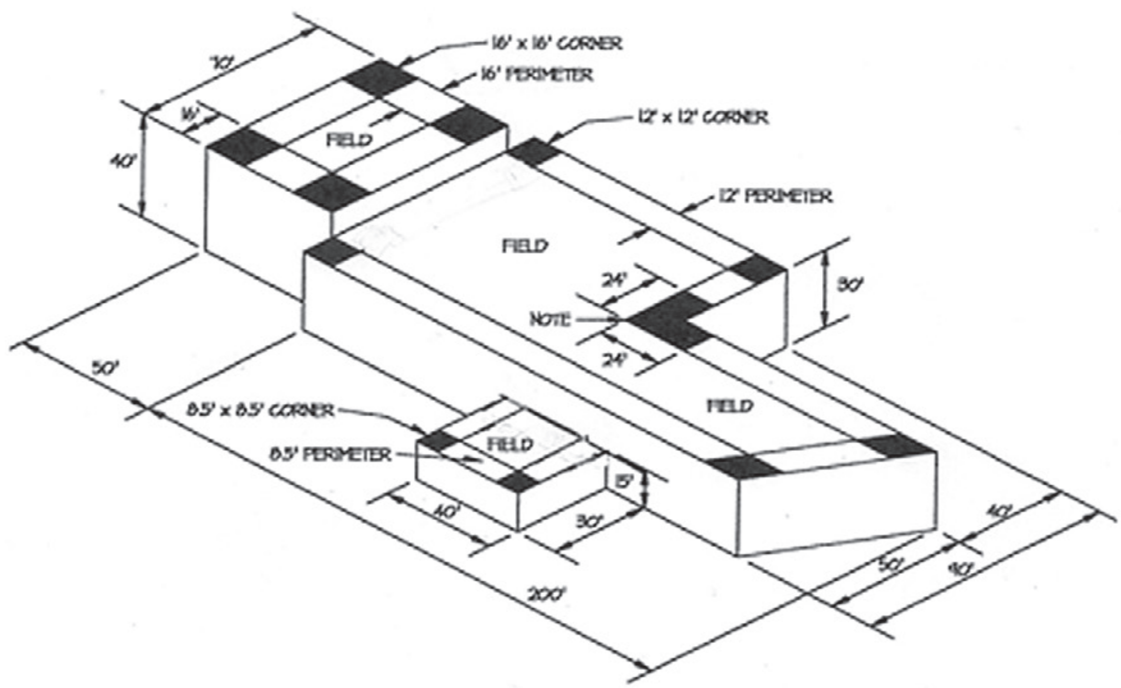
G. For parapet heights from 2 m and above

Maximum Allowable Wind Speed m/s

Roof height meters	System 1		System 2		System 3	
	Exposure C	Exposure B	Exposure C	Exposure B	Exposure C	Exposure B
0–5	54	54	59	59	68	68
5–9	54	54	59	59	68	68
9–14	54	54	59	59	68	68
14–18	50	54	59	59	68	68
18–23	47	54	56	59	68	68
23–27	45	50	54	59	68	68
27–32	45	50	54	59	68	68
32–37	45	50	54	59	63	68
37–41	45	50	54	59	63	68
41–46	43	50	54	54	63	68

[3] Wind speed reference see Section 2.5
Wind speeds in above tables are “3 second gust” measured at 10 meters (33 feet).

Figure 1
Roof Areas
Systems 2 and 3



Note: Reentrant corners are larger than other corners.

	Low Roof	Main Roof	High roof
Roof Height	15 ft	30 ft	40 ft
40% of Building Height	6.0 ft	12 ft	16 ft
Corner Length	8.5 ft (a)	12 ft	16 ft
Perimeter Width	8.5 ft (a)	12 ft	16 ft

(a) 8.5 ft minimum controls

Figure 1
Roof Layout
Systems 2 and 3

Metric Dimensions

	Low Roof	Main Roof	High Roof
Roof height	4.6 m	9.0 m	12 m
40% of building height	2.0 m	3.6 m	5 m
Corner length	2.6 m (a)	3.6 m	5 m
Perimeter width	2.6 m (a)	3.6 m	5 m

(a) 2.6 m minimum controls

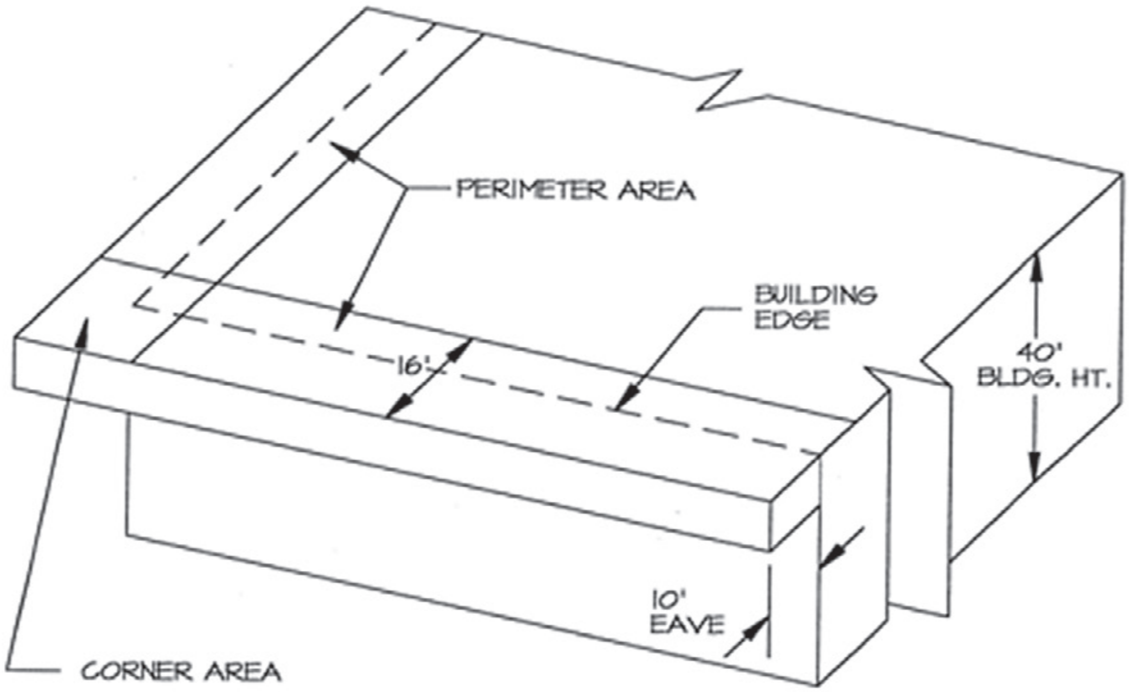
Other Dimensions

Description	IP	Metric
High Roof		
Corner	16 ft x 16 ft	5 m x 5 m
Perimeter	16 ft	5 m
Width	70 ft	21.3 m
Height	40 ft	12 m
Main Roof		
Corner	12 ft x 12 ft	3.6 m x 3.6 m
Perimeter	12 ft	3.6 m
Height	30 ft	9 m
Re-entrant Corner	24 ft x 24 ft	7.3 m x 7.3 m
Off set	40 ft	12 m
Width	90 ft	27.4 m
Length	200 ft	61 m
Low Roof		
Corner	8.5 ft x 8.5 ft	2.6 m
Perimeter	8.5 ft	2.6 m
Width	30 ft	9 m
Height	15 ft	4.6 m

Figure 2

Canopies and Overhanging Eaves
Impervious Decks

For Systems 2 and 3



Eave = 10 ft

Corner area = .4 × the building height
(or 8.5 ft (2.6 m) minimum)
16 ft for this example

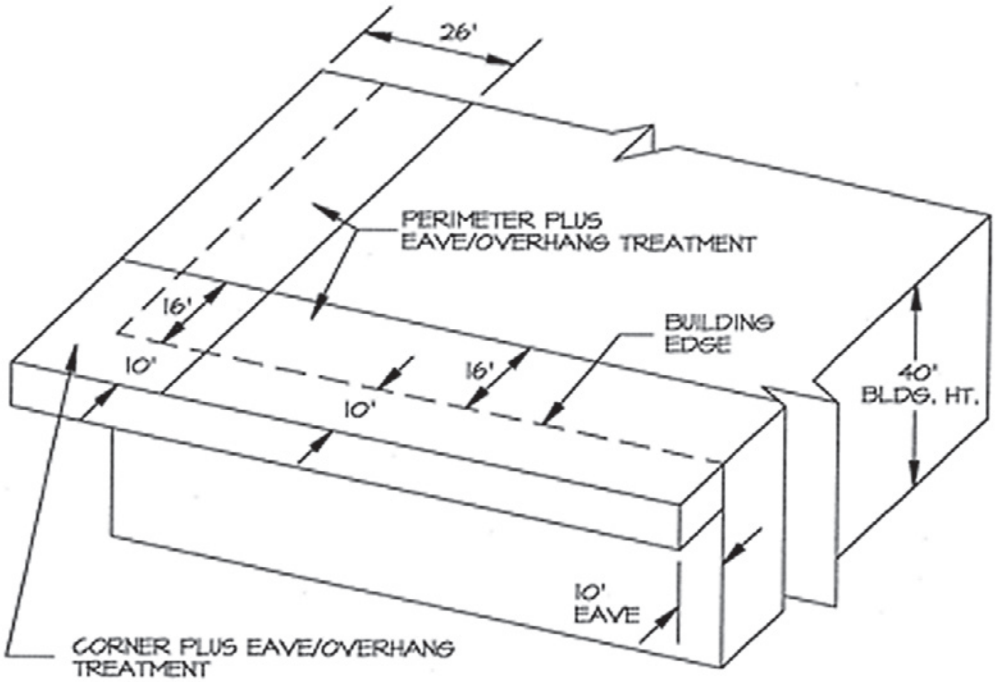
Perimeter area = .4 × the building height
(or 8.5 ft (2.6 m) minimum)
16 ft for this example

Description	IP	Metric
Building Height	40 ft	12 m
Eave	10 ft	3 m
Corner and Perimeter area	8.5 ft minimum	2.6 m
Corner and Perimeter area	16 ft for this example	5 m

Figure 3

Canopies and Overhanging Eaves Pervious Decks

For Systems 1, 2 and 3



Eave = 10 ft

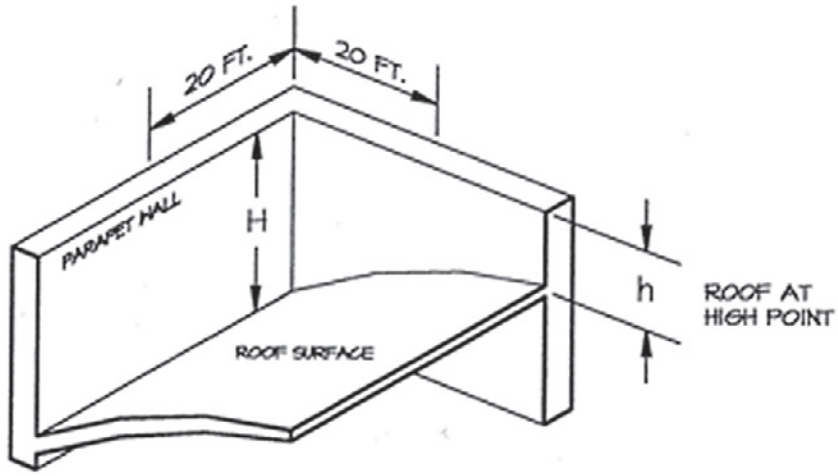
Corner area = .4 × the building height plus the overhang area
(or 8.5 ft (2.6 m) minimum)
26 ft for this example

Perimeter area = .4 × the building height plus the overhand are
(or 8.5 ft (2.6 m) minimum)
26 ft for this example

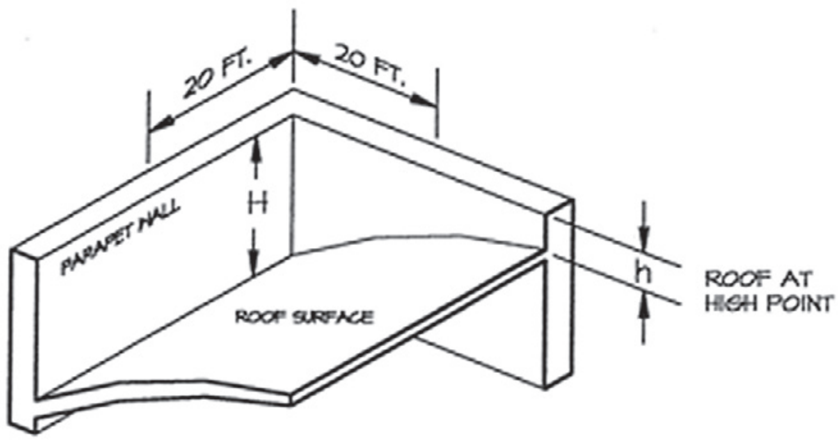
Description	IP	Metric
Building Height	40 ft	12 m
Eave	10 ft	3 m
Perimeter	16 ft	5 m
Corner and Perimeter area	8.5 ft minimum	2.6 m
Corner and Perimeter area	26 ft for this example	8 m

Figure 4

Parapet Height
Design Considerations



IF PARAPET h IS GREATER THAN OR EQUAL TO 70% OF CORNER HEIGHT H, THEN USE H FOR DESIGN



IF PARAPET h IS LESS THAN OR EQUAL TO 70% OF CORNER HEIGHT H, THEN USE h FOR DESIGN

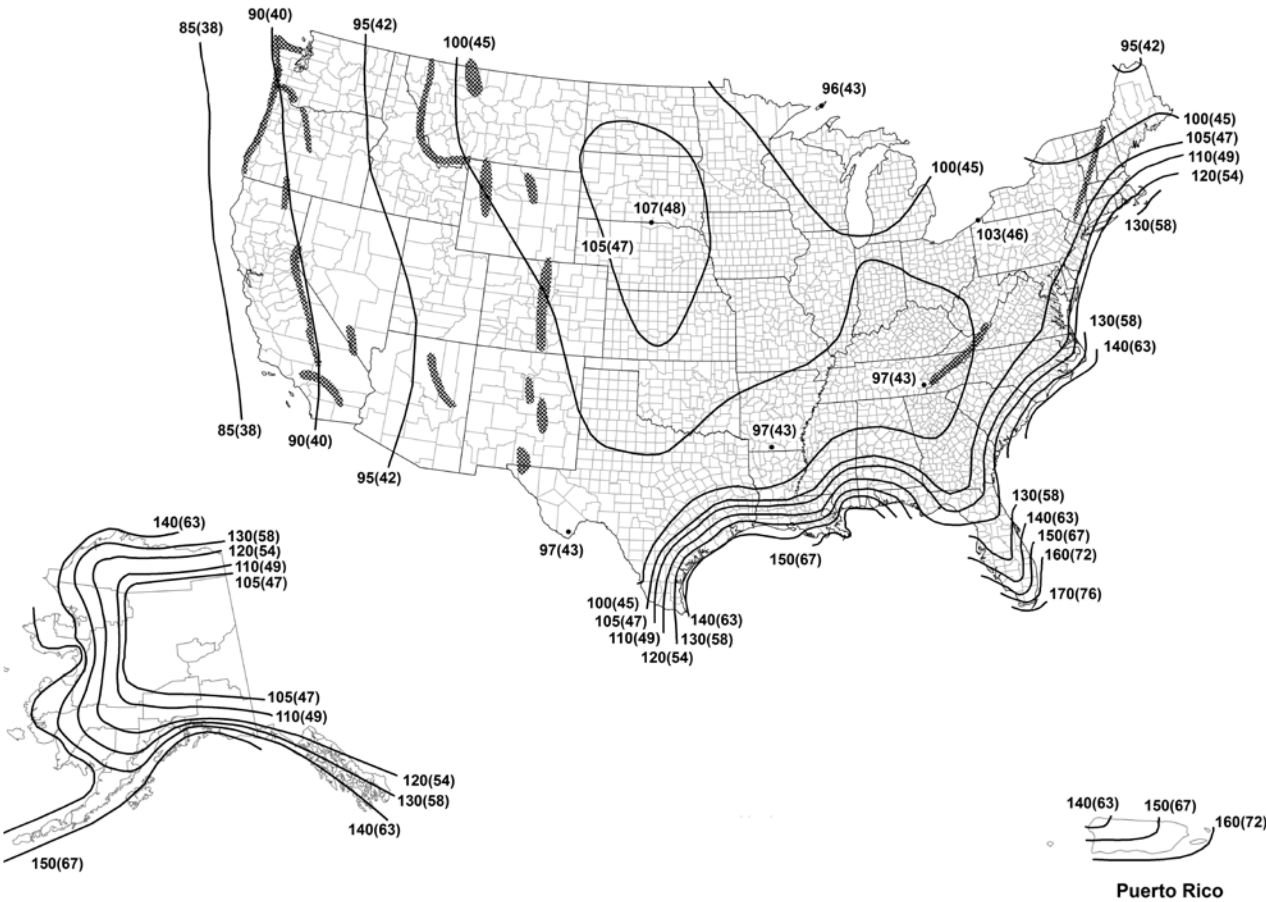
Metric Dimensions

Description	IP	Metric
Corner	20 ft	6 m

Attachment I

ASCE7-16 Figure 26.5-1A

Basic Wind Speeds for Risk Category I Buildings and Other Structures



Location	V (mph)	V (m/s)
Guam	180	(80)
Virgin Islands	150	(67)
American Samoa	150	(67)
Hawaii	See Figure 26.5-2A	

ANSI/SPRI RP-14 2016
Wind Design Standard For Vegetative Roofing Systems

Approved
September 9, 2016

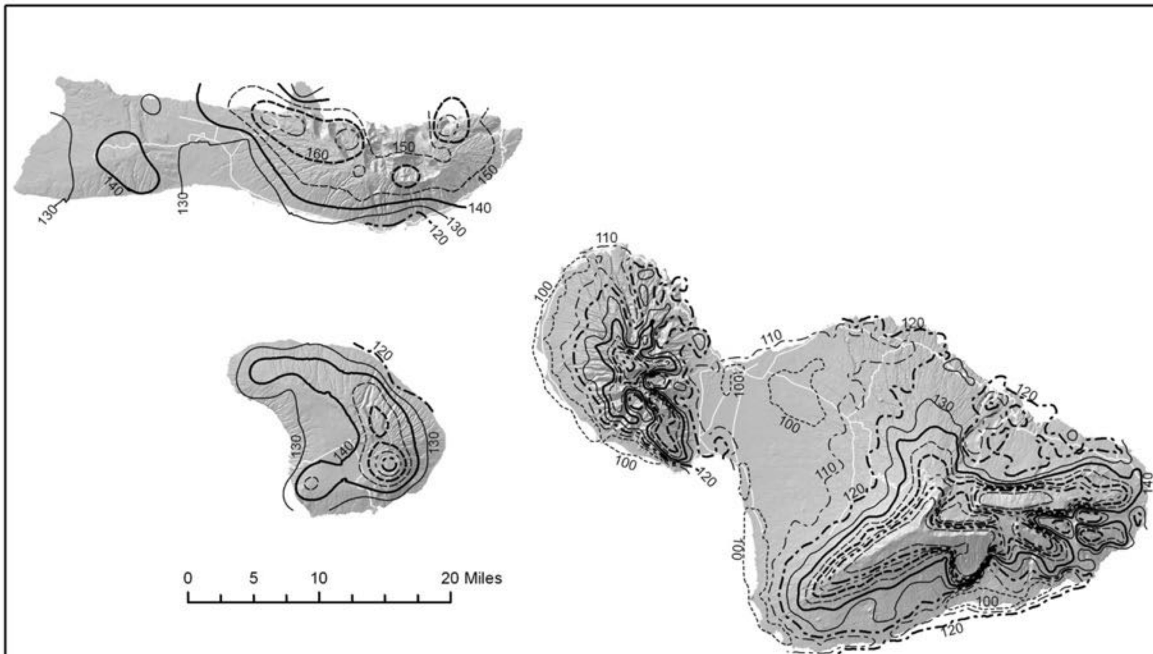
Notes: Dark shading indicates a Special Wind Region.

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas, and land boundaries outside the last contour shall use the last wind speed contour.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years).
6. Location-specific basic wind speeds shall be permitted to be determined using www.atcouncil.org/windspeed.

Attachment I

ASCE7-16 Figure 26.5-2A

Basic Wind Speeds for Risk Category I Buildings and Other Structures: Hawaii



Effective Wind Speed Contour for the Islands of Maui, Molokai and Lanai (ASCE 7-2016) for MWFRS, Risk Category I

White line Major Road

Effective Wind Speed (mph)

- 100
- 110
- 120
- 130
- 140
- 150
- 160
- 170
- 180
- 200

N

ANSI/SPRI RP-14 2016

Wind Design Standard For Vegetative Roofing Systems

Approved
September 9, 2016

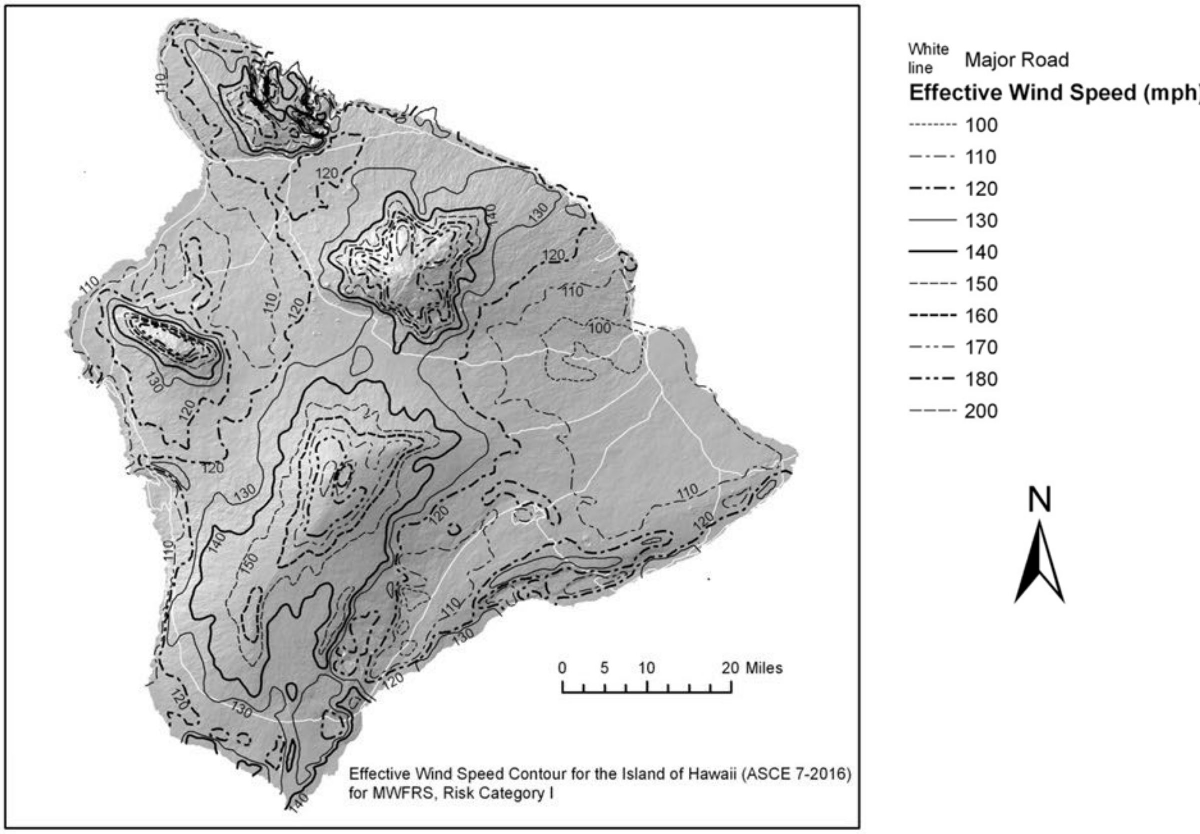
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years)

Attachment I

ASCE7-16 Figure 26.5-2A (continued)

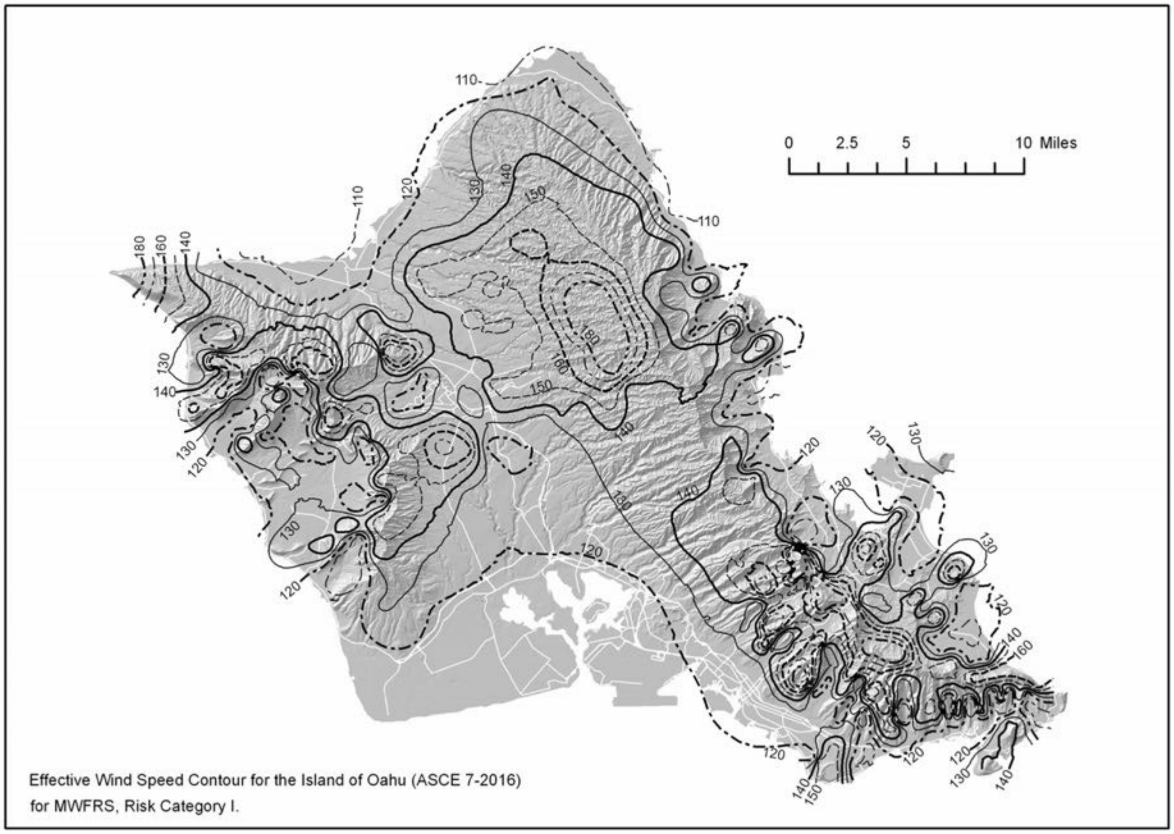
Basic Wind Speeds for Risk Category I Buildings and Other Structures: Hawaii



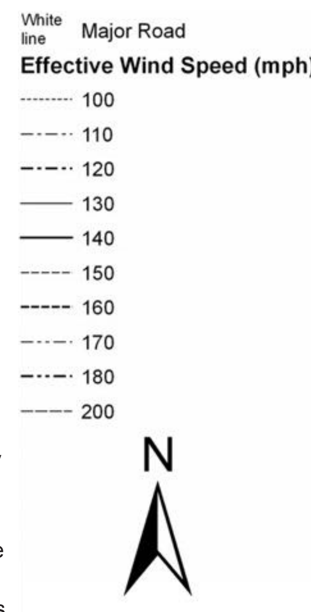
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years)

Attachment I
ASCE7-16 Figure 26.5-2A (continued)
Basic Wind Speeds for Risk Category I Buildings and Other Structures: Hawaii



Effective Wind Speed Contour for the Island of Oahu (ASCE 7-2016) for MWFRS, Risk Category I.



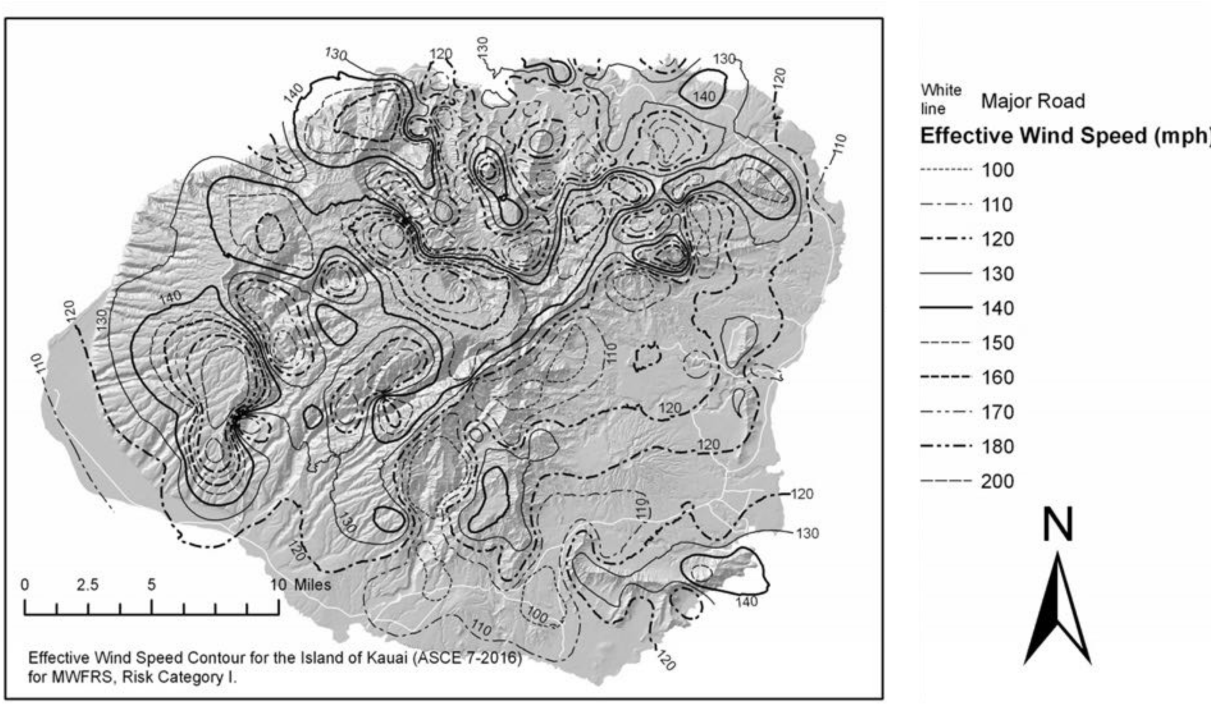
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years)

Attachment I

ASCE7-16 Figure 26.5-2A (continued)

Basic Wind Speeds for Risk Category I Buildings and Other Structures: Hawaii



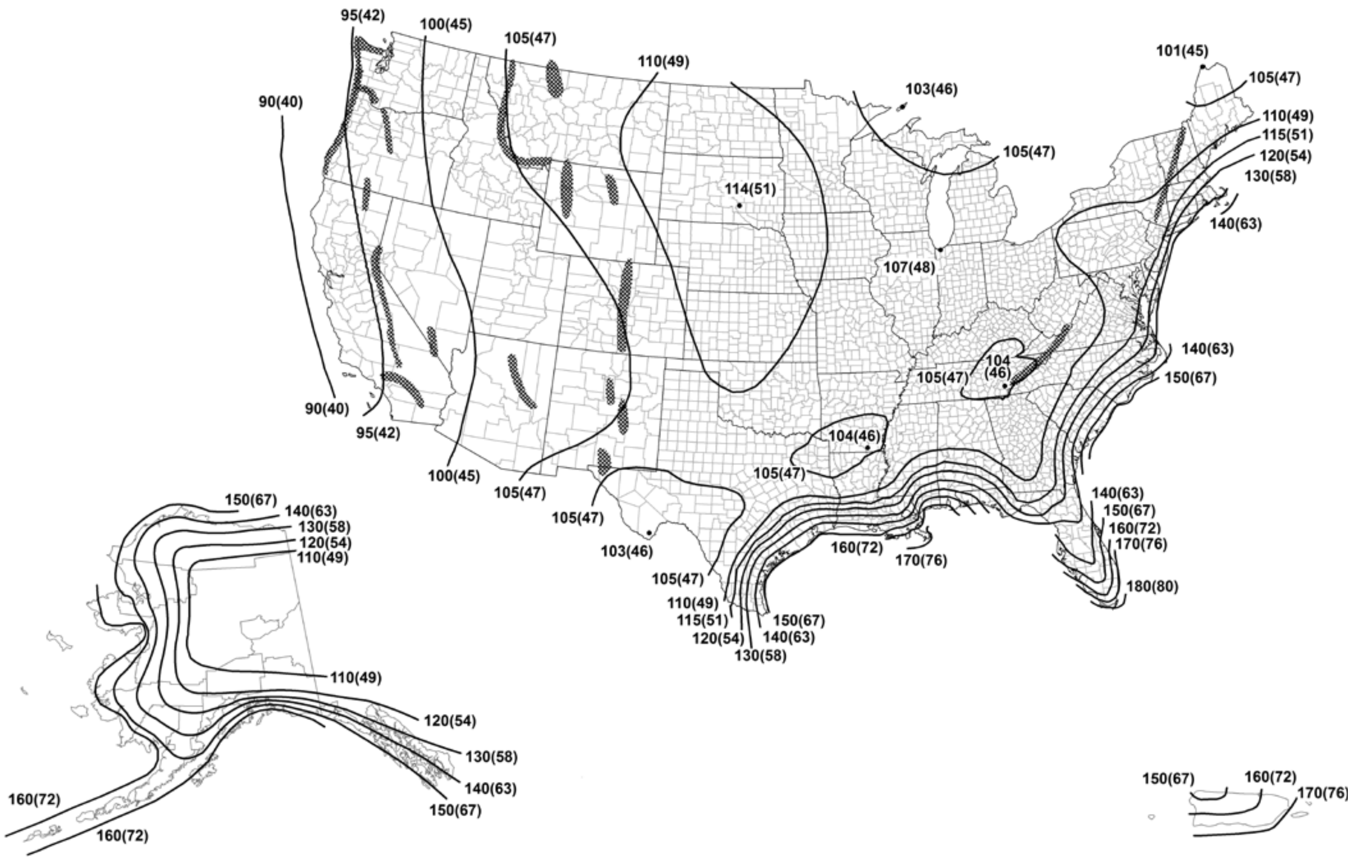
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years)

Attachment I

ASCE7-16 Figure 26.5-1B

Basic Wind Speeds for Risk Category II Buildings and Other Structures



Location	V (mph)	V (m/s)
Guam	195	(87)
Virgin Islands	165	(74)
American Samoa	160	(72)
Hawaii	See Figure 26.5-2B	

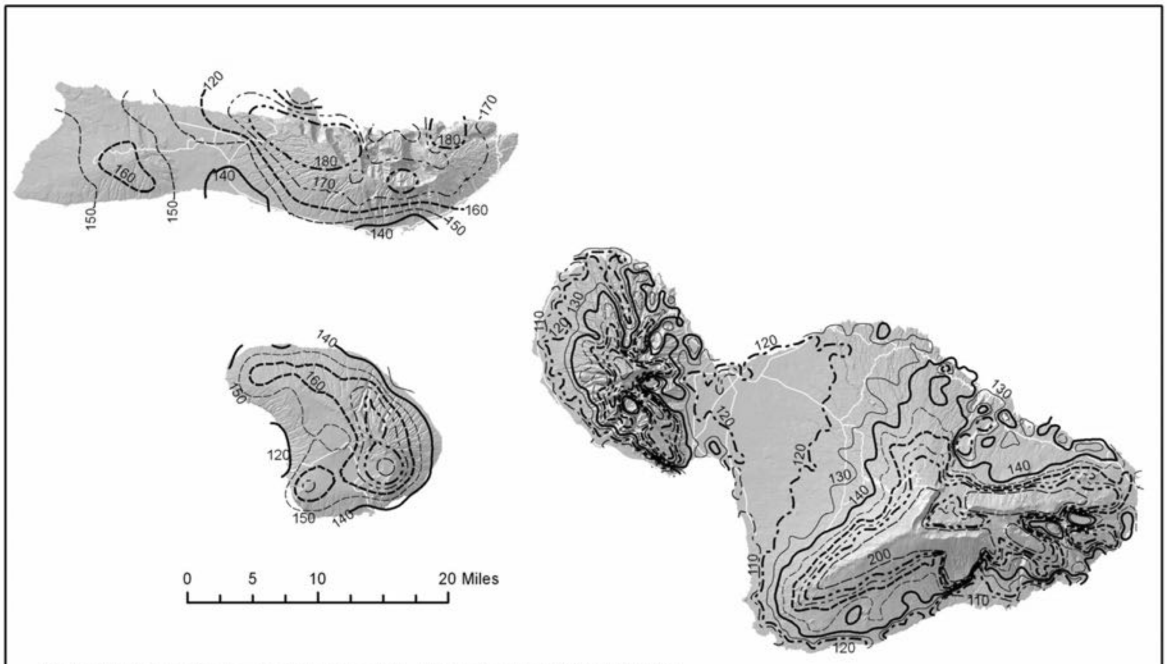
Notes: Dark shading indicates a Special Wind Region.

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas, and land boundaries outside the last contour shall use the last wind speed contour.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).
6. Location-specific basic wind speeds shall be permitted to be determined using www.atcouncil.org/windspeed.

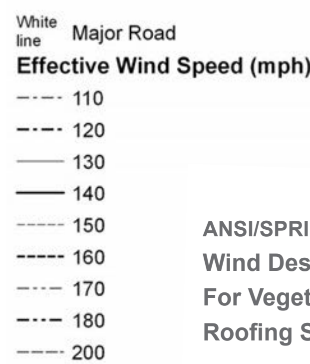
Attachment I

ASCE7-16 Figure 26.5-2B

Basic Wind Speeds for Risk Category II Buildings and Other Structures: Hawaii



Effective Wind Speed Contour for the Islands of Maui, Molokai and Lanai (ASCE 7-2016) for MWFRS, Risk Category II



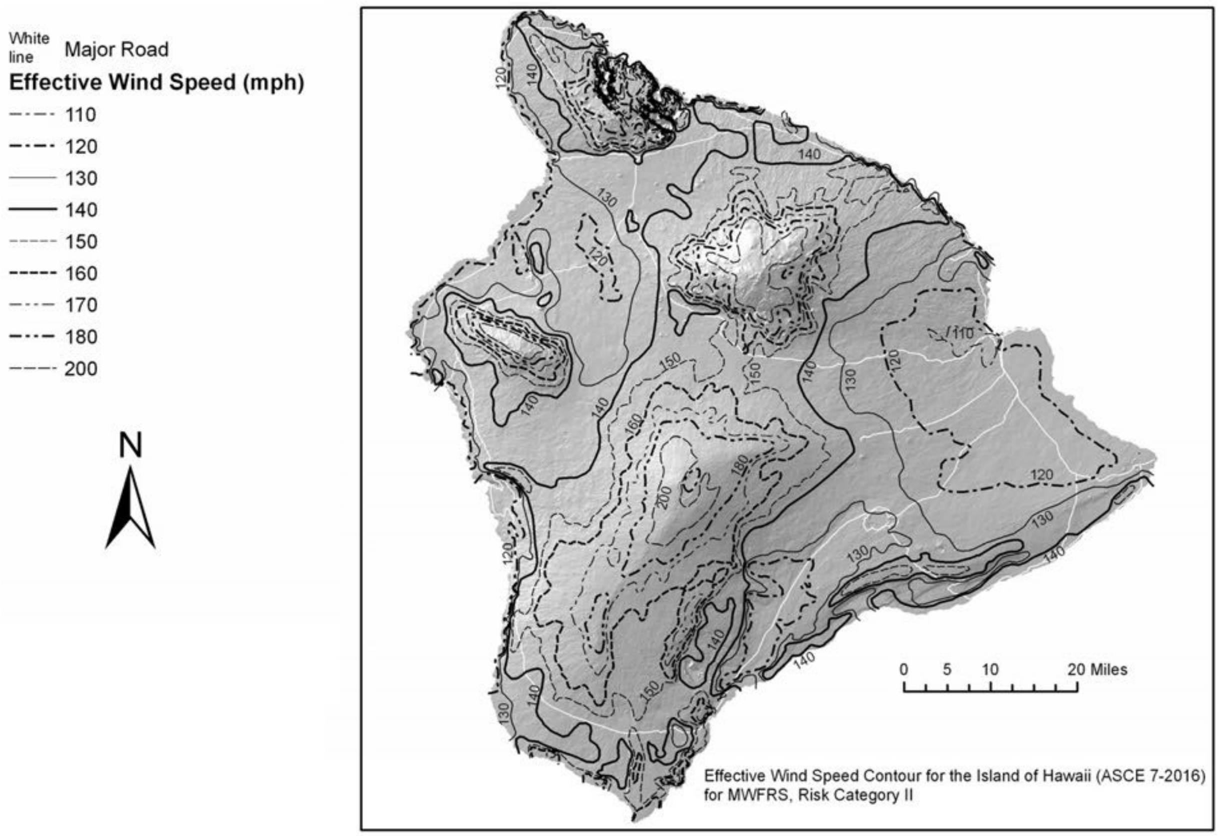
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).

Attachment I

ASCE7-16 Figure 26.5-2B (continued)

Basic Wind Speeds for Risk Category II Buildings and Other Structures: Hawaii



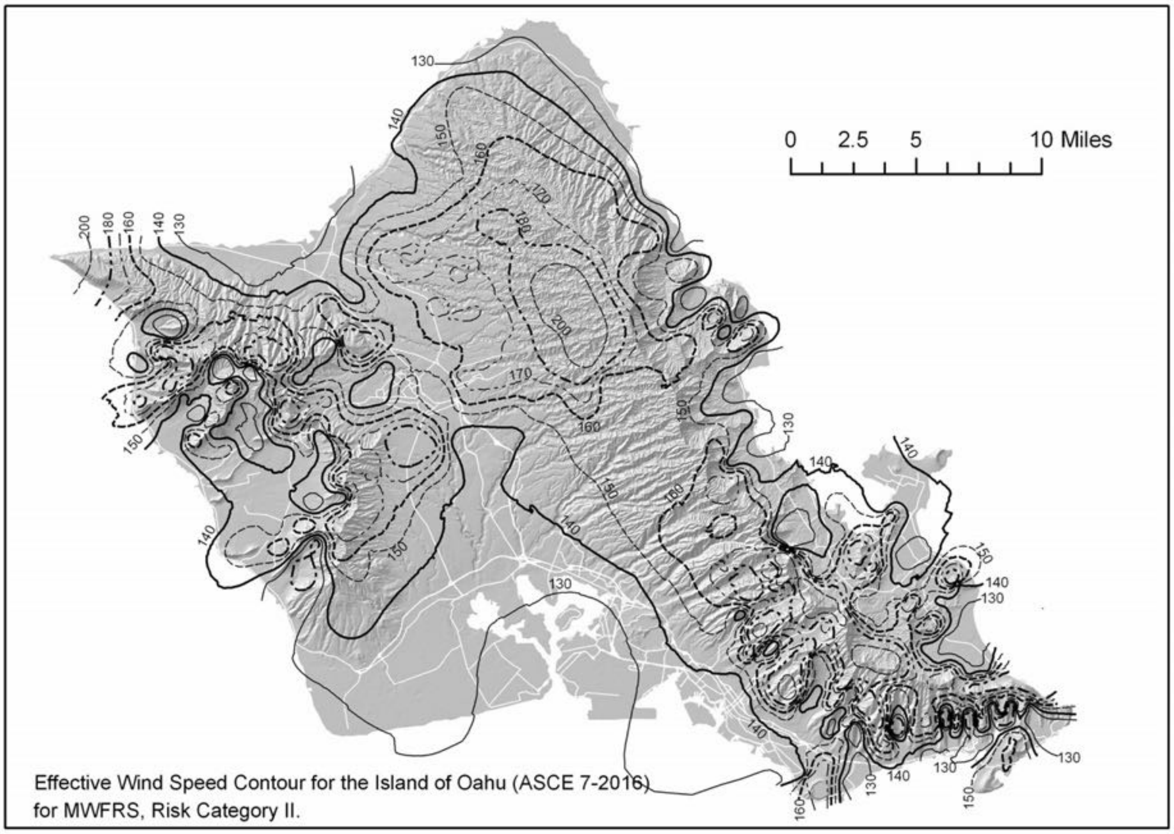
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).

Attachment I

ASCE7-16 Figure 26.5-2B (continued)

Basic Wind Speeds for Risk Category II Buildings and Other Structures: Hawaii



Effective Wind Speed Contour for the Island of Oahu (ASCE 7-2016) for MWFRS, Risk Category II.

White line Major Road

Effective Wind Speed(mph)

- 110
- 120
- 130
- 140
- 150
- 160
- 170
- 180
- 200

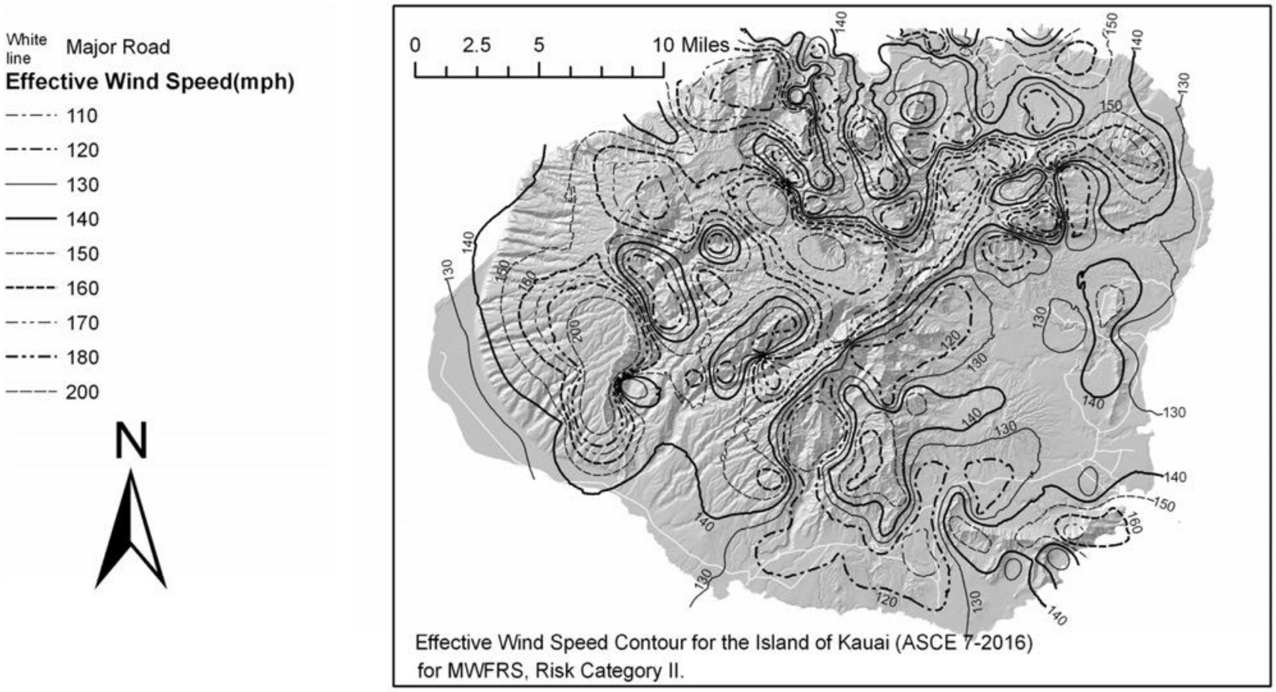
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).

Attachment I

ASCE7-16 Figure 26.5-2B (continued)

Basic Wind Speeds for Risk Category II Buildings and Other Structures: Hawaii

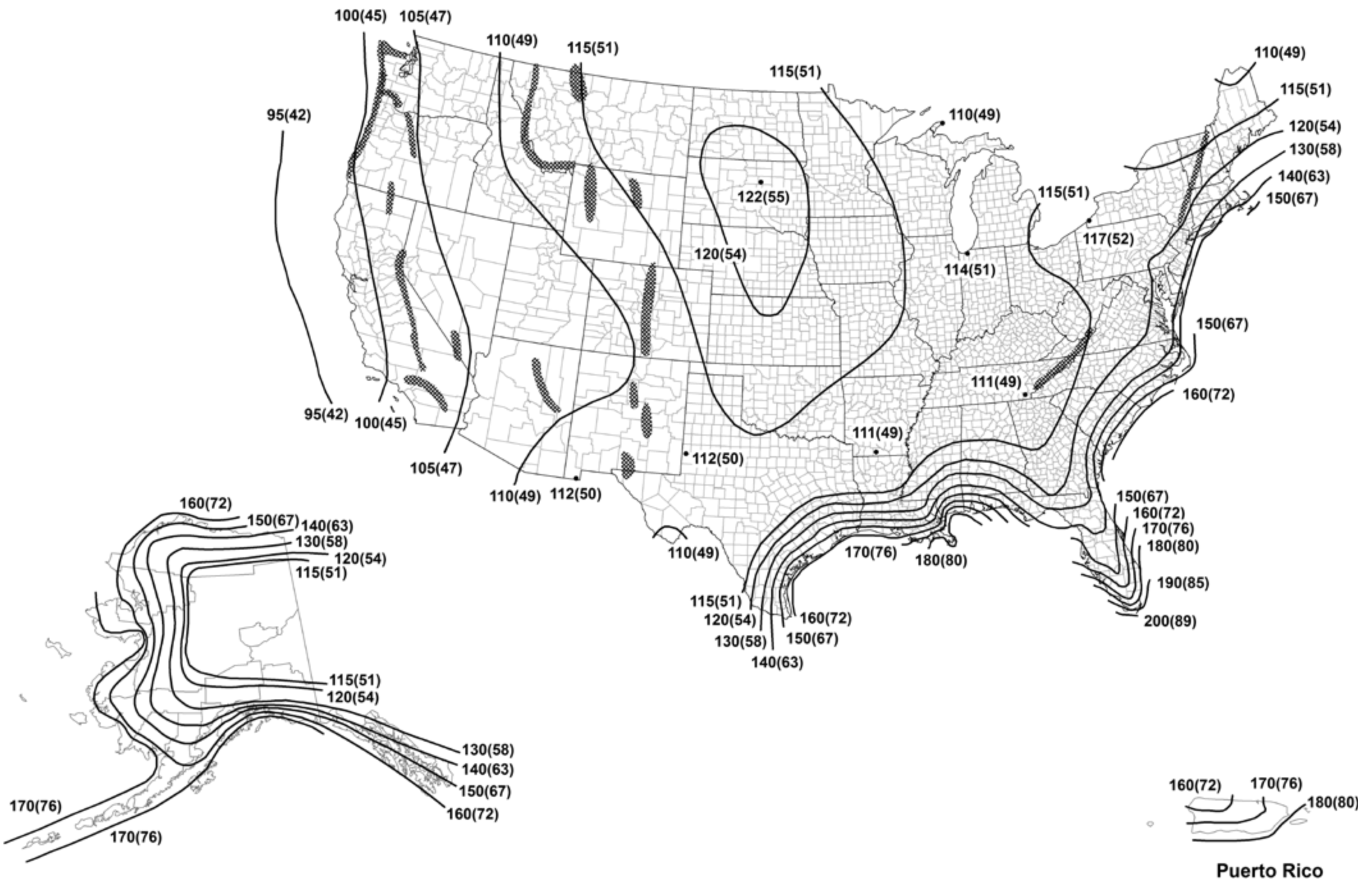


Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).

Attachment I

ASCE7-16 Figure 26.5-1C
Basic Wind Speeds for Risk Category III Buildings and Other Structures

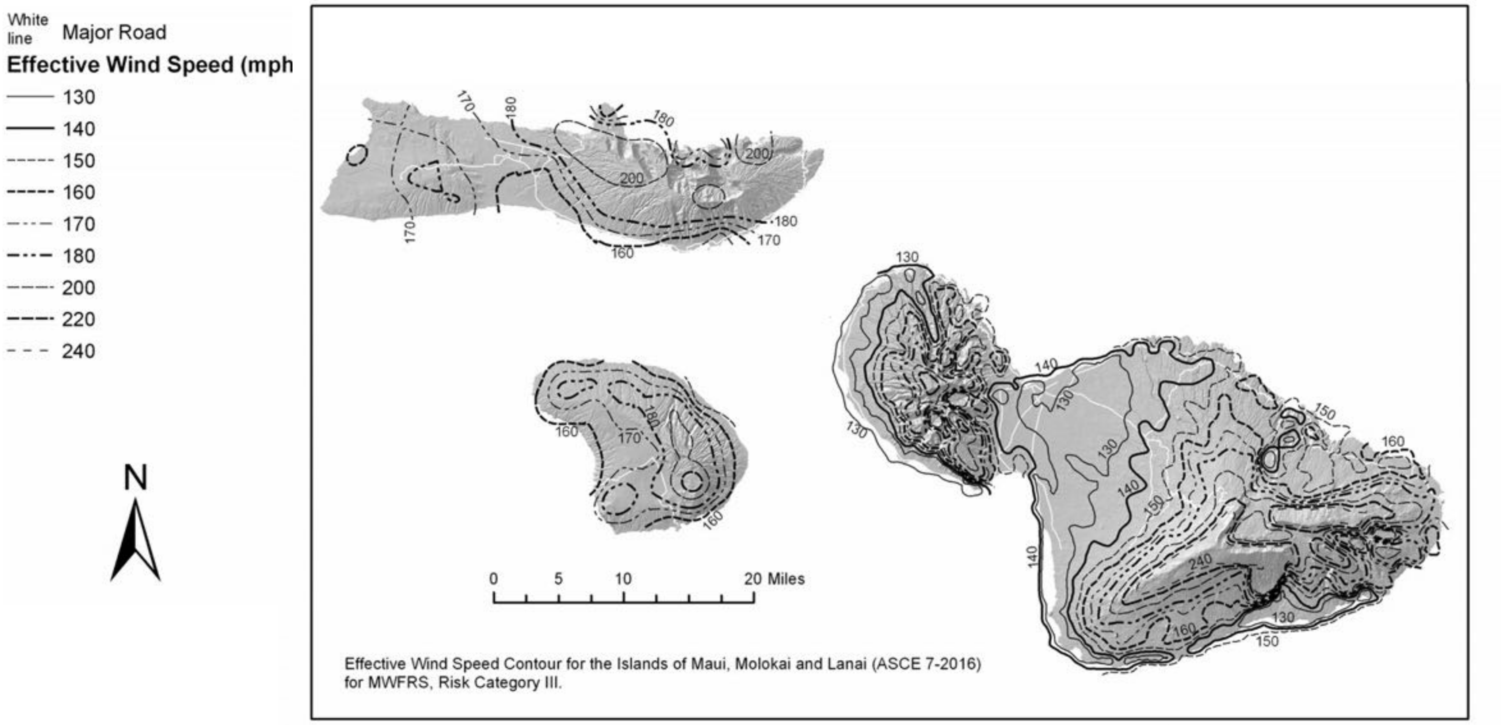


Location	V (mph)	V (m/s)
Guam	210	(94)
Virgin Islands	175	(78)
American Samoa	170	(76)
Hawaii	See Figure 26.5-2C	

Notes: Dark shading indicates a Special Wind Region.

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas, and land boundaries outside the last contour shall use the last wind speed contour.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1,700 years).
6. Location-specific basic wind speeds shall be permitted to be determined using www.atcouncil.org/windspeed.

Attachment I
ASCE7-16 Figure 26.5-2C
Basic Wind Speeds for Risk Category III Buildings and Other Structures: Hawaii



Approved
September 9, 2016

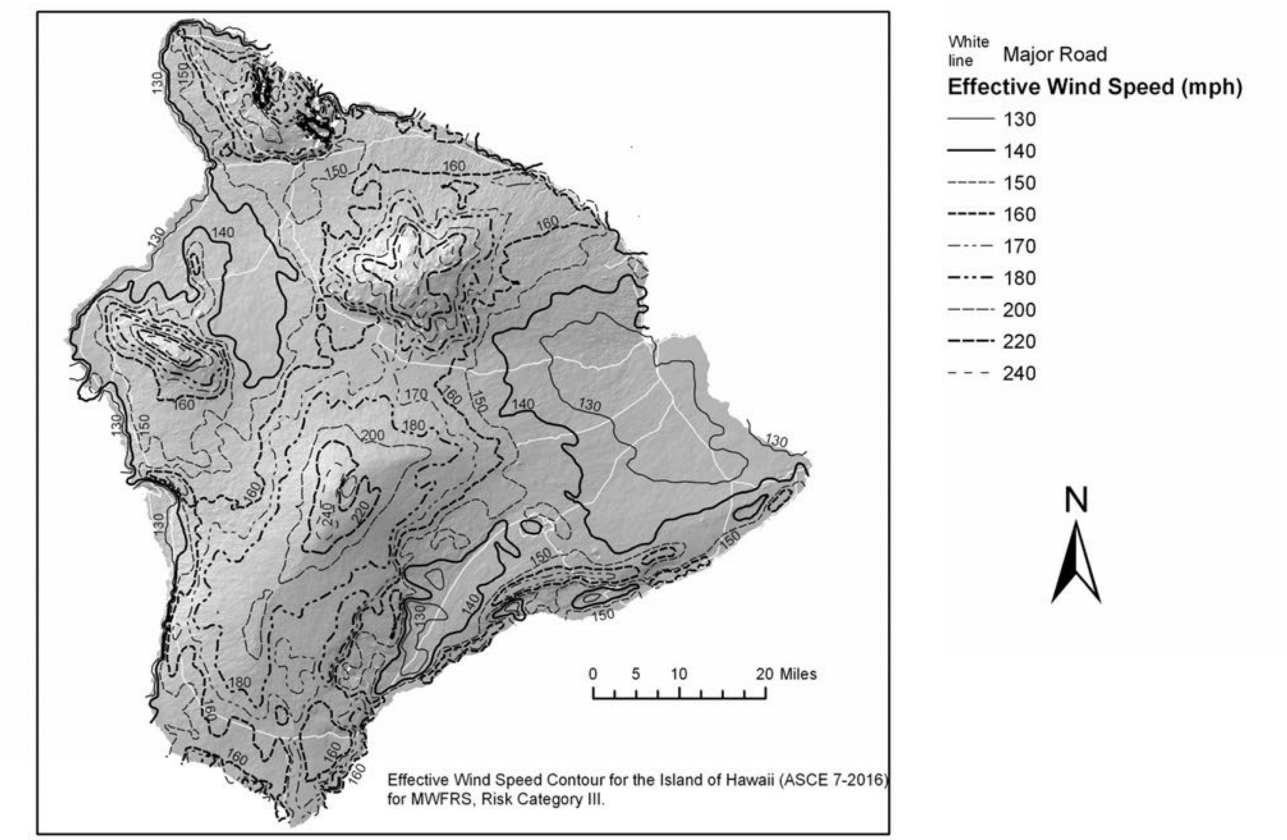
Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1,700 years).

Attachment I

ASCE7-16 Figure 26.5-2C (continued)

Basic Wind Speeds for Risk Category III Buildings and Other Structures: Hawaii



ANSI/SPRI RP-14 2016

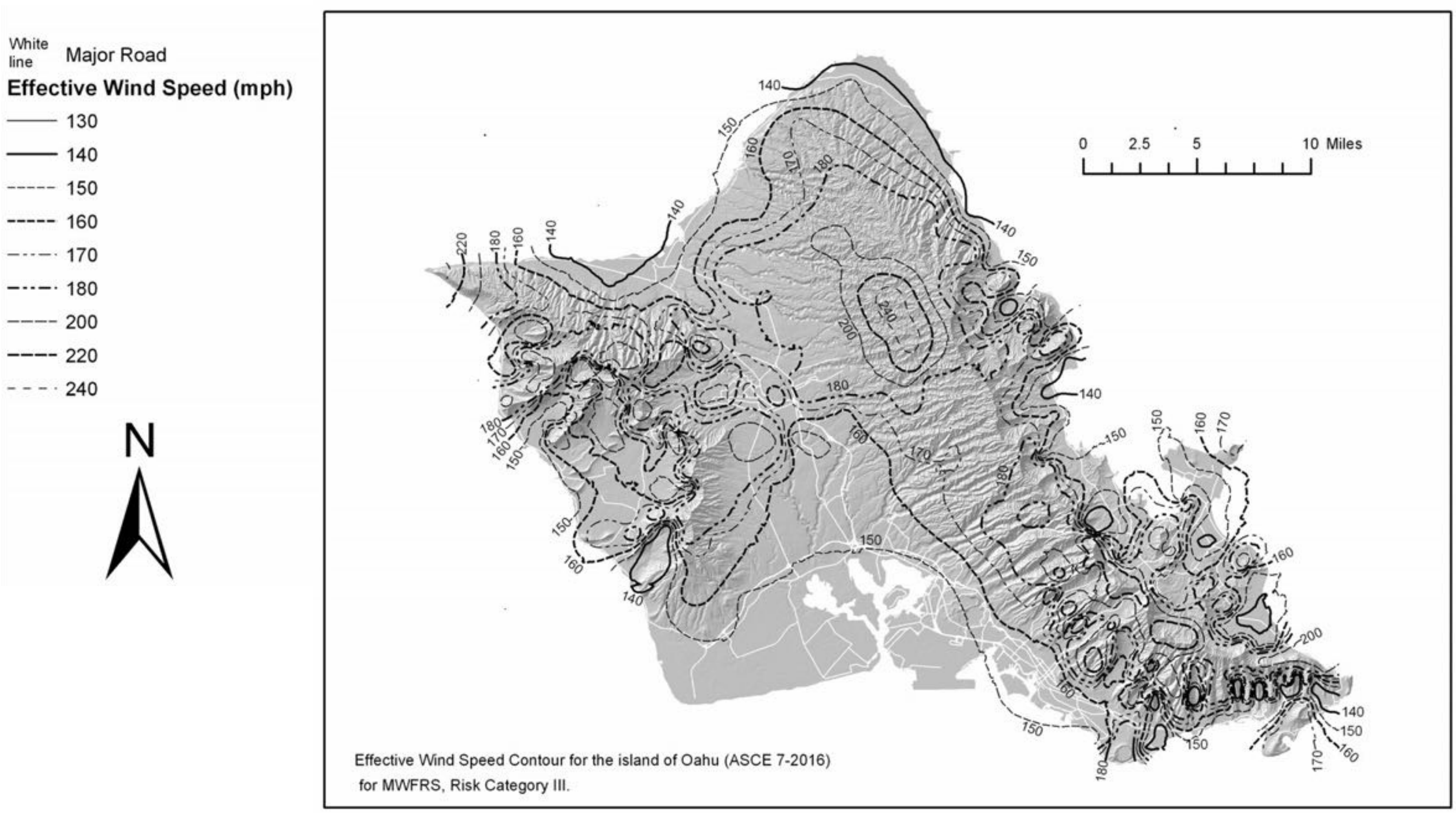
Wind Design Standard For Vegetative Roofing Systems

Approved September 9, 2016

Notes:

1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C. Metric conversion: 1 mph = 0.45 m/s.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1,700 years).

Attachment I
ASCE7-16 Figure 26.5-2C (continued)
Basic Wind Speeds for Risk Category III Buildings and Other Structures: Hawaii



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2. Linear interpolation between contours is permitted.
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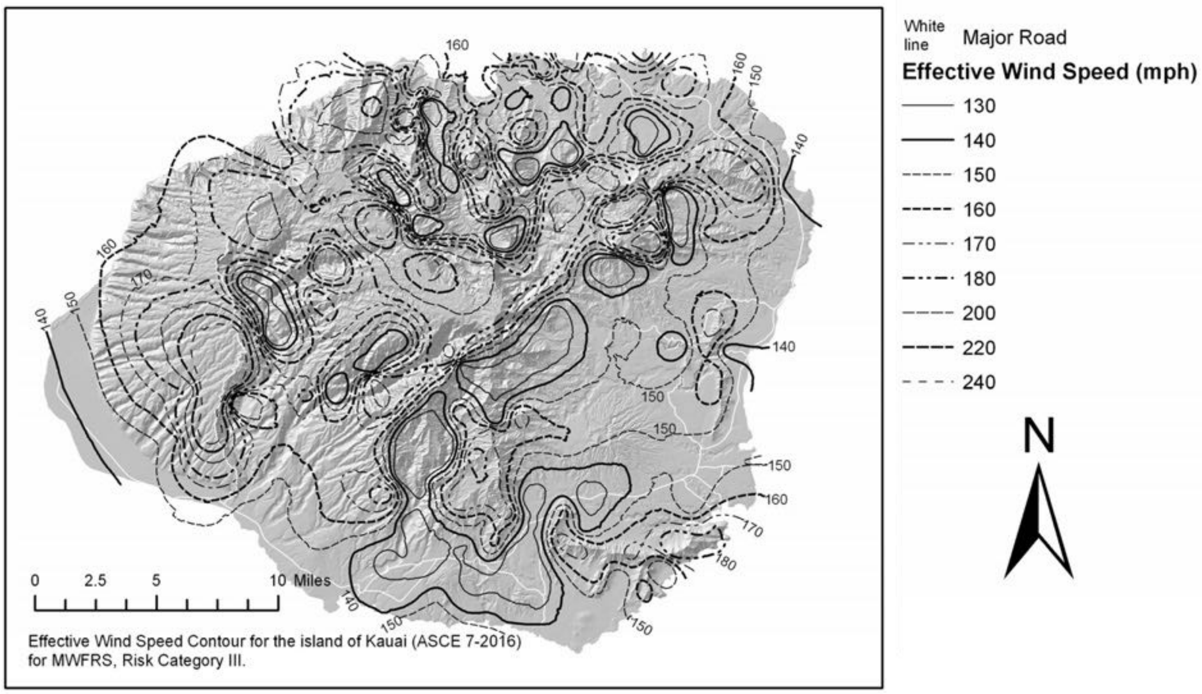
Attachment I
ASCE7-16 Figure 26.5-2C (continued)
Basic Wind Speeds for Risk Category III Buildings and Other Structures: Hawaii



ANSI/SPRI RP-14 2016

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3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
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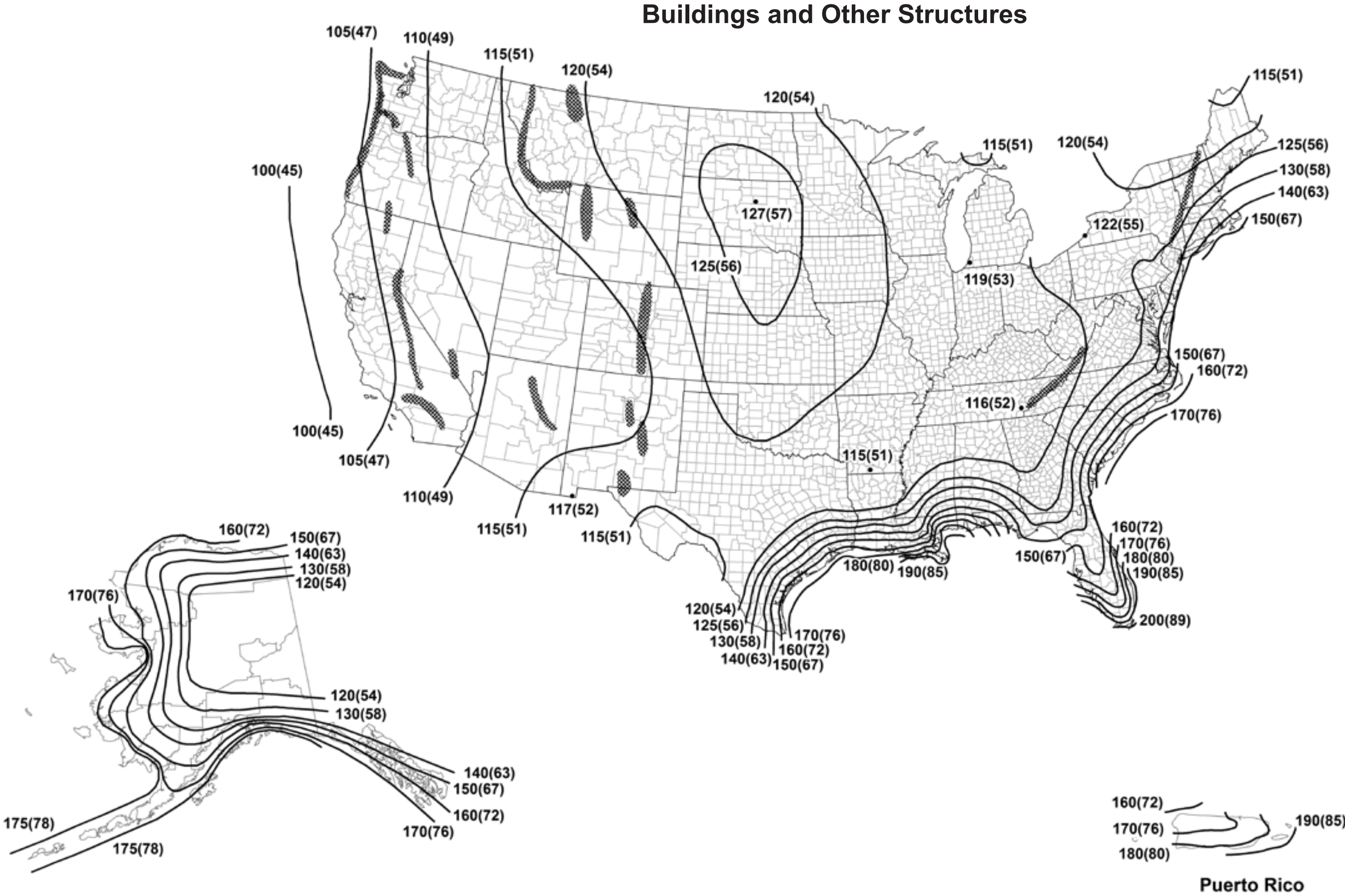
Attachment I

ASCE7-16 Figure 26.5-1D

Basic Wind Speeds for Risk Category IV Buildings and Other Structures



Location	V (mph)	V (m/s)
Guam	180	(80)
Virgin Islands	150	(67)
American Samoa	150	(67)
Hawaii	See Figure 26.5-2D	

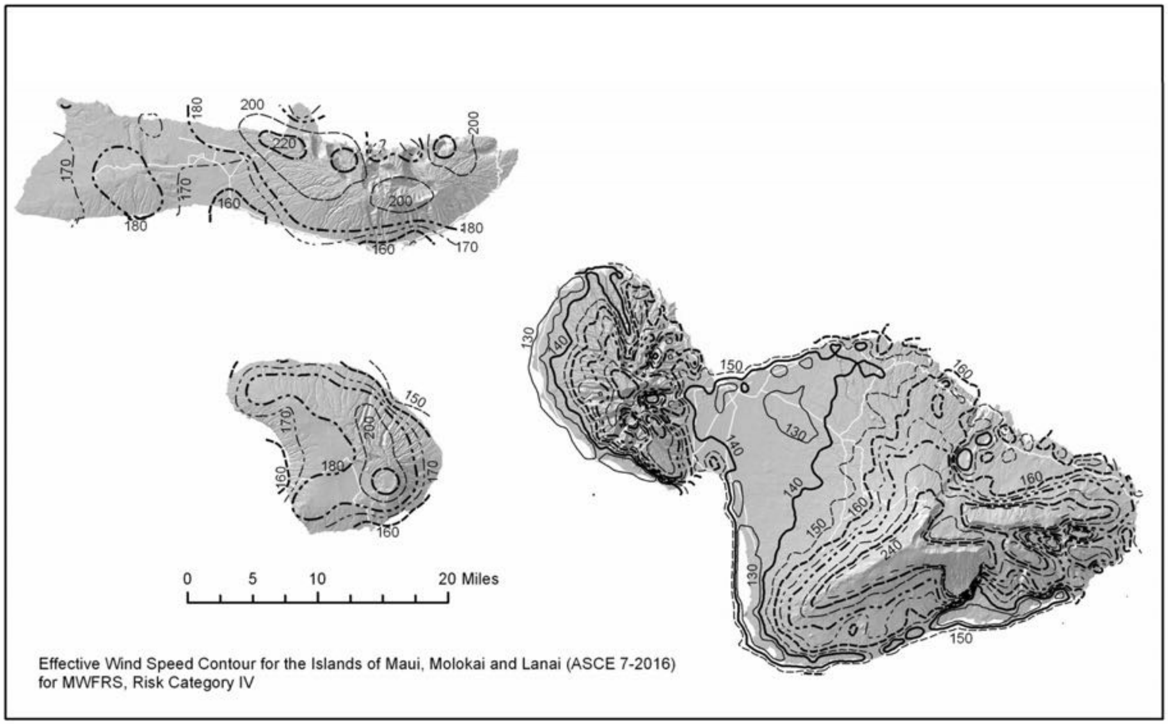
Notes: Dark shading indicates a Special Wind Region.

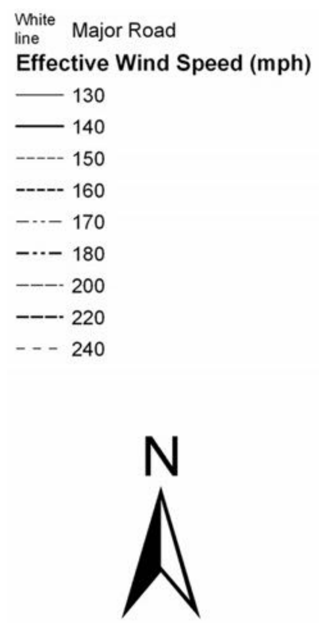
1. Values are nominal design 3-s gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure Category C.
2. Linear interpolation is permitted between contours. Point values are provided to aid with interpolation.
3. Islands, coastal areas, and land boundaries outside the last contour shall use the last wind speed contour.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 1.6% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00033, MRI = 3,000 years).
6. Location-specific basic wind speeds shall be permitted to be determined using www.atcouncil.org/windspeed.

Attachment I

ASCE7-16 Figure 26.5-2D

Basic Wind Speeds for Risk Category IV Buildings and Other Structures: Hawaii





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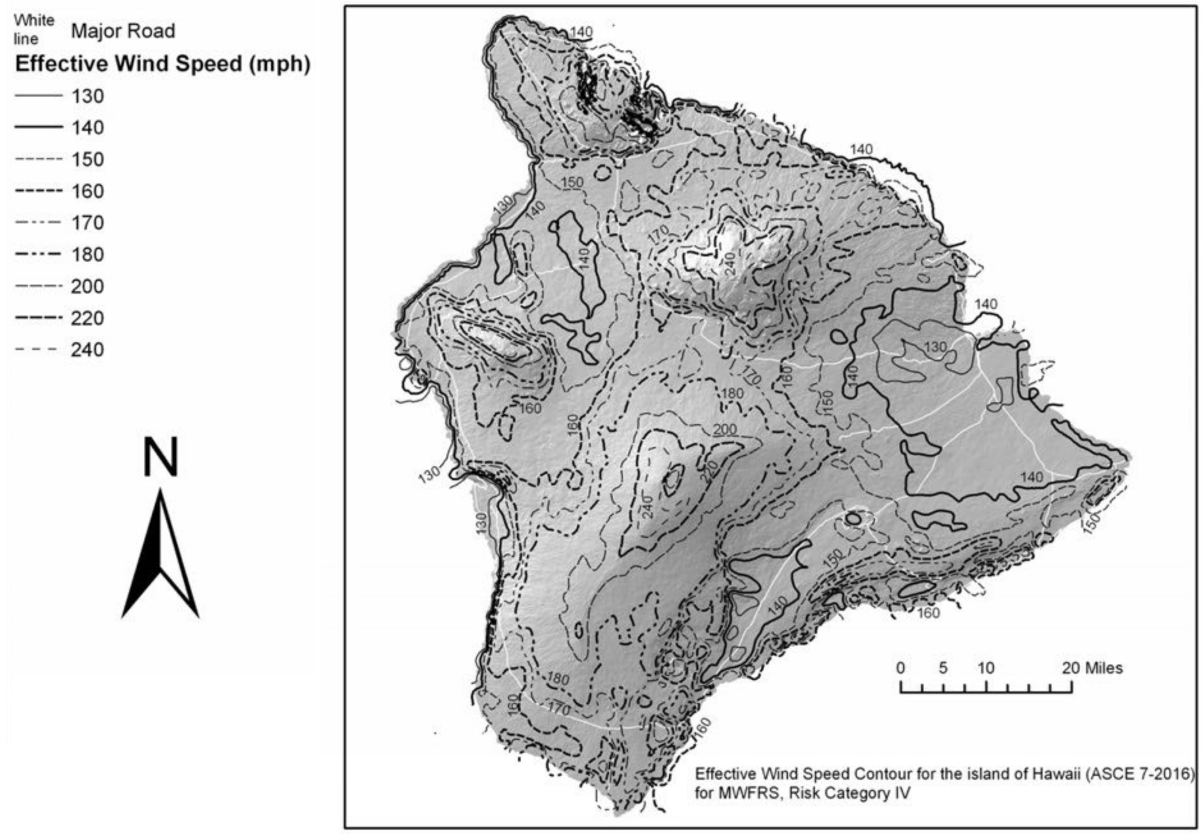
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 1.7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000333, MRI = 3,000 years).

Attachment I

ASCE7-16 Figure 26.5-2D (continued)

Basic Wind Speeds for Risk Category IV Buildings and Other Structures: Hawaii



Notes:

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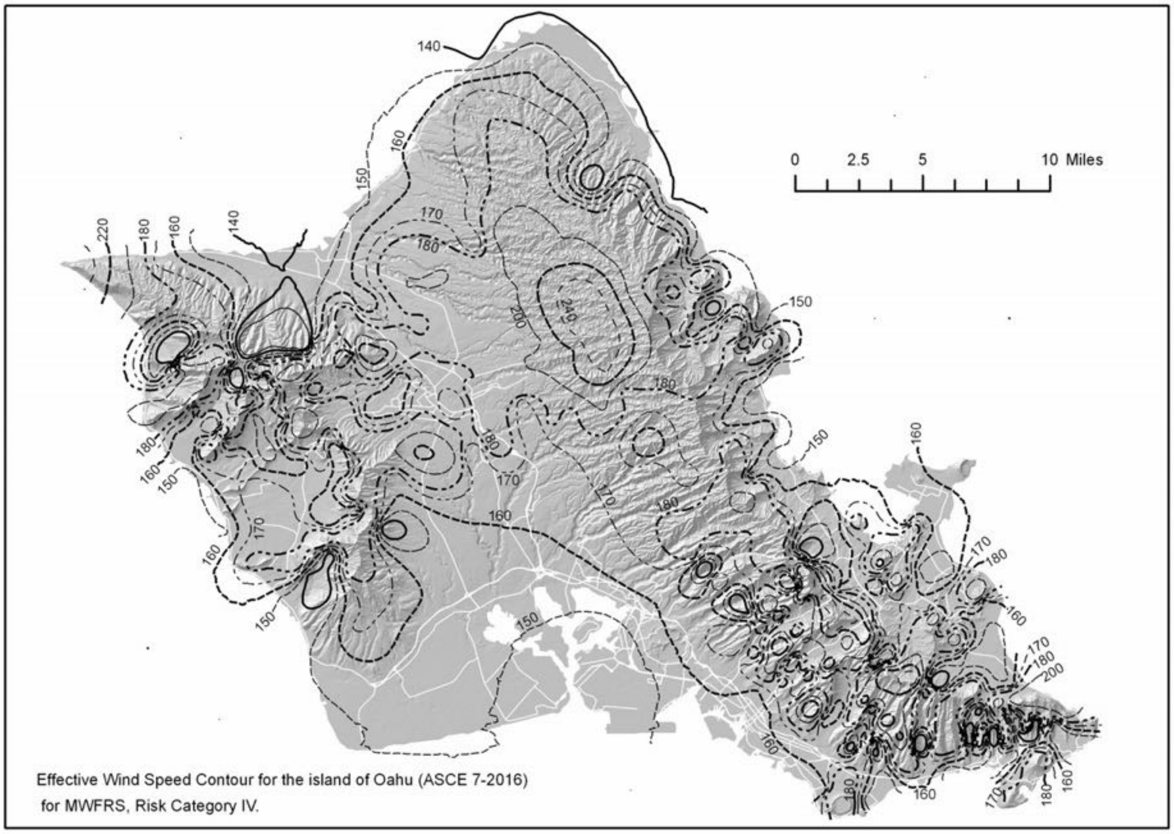
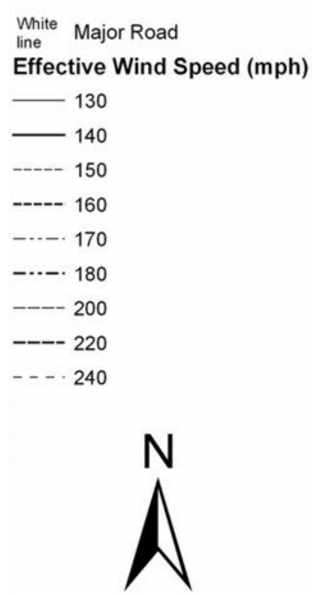
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
5. Ocean promontories and local escarpments shall be examined for unusual wind conditions.
6. Wind speeds correspond to approximately a 1.7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000333, MRI = 3,000 years).

Attachment I
ASCE7-16 Figure 26.5-2D (continued)
Basic Wind Speeds for Risk Category IV Buildings and Other Structures: Hawaii





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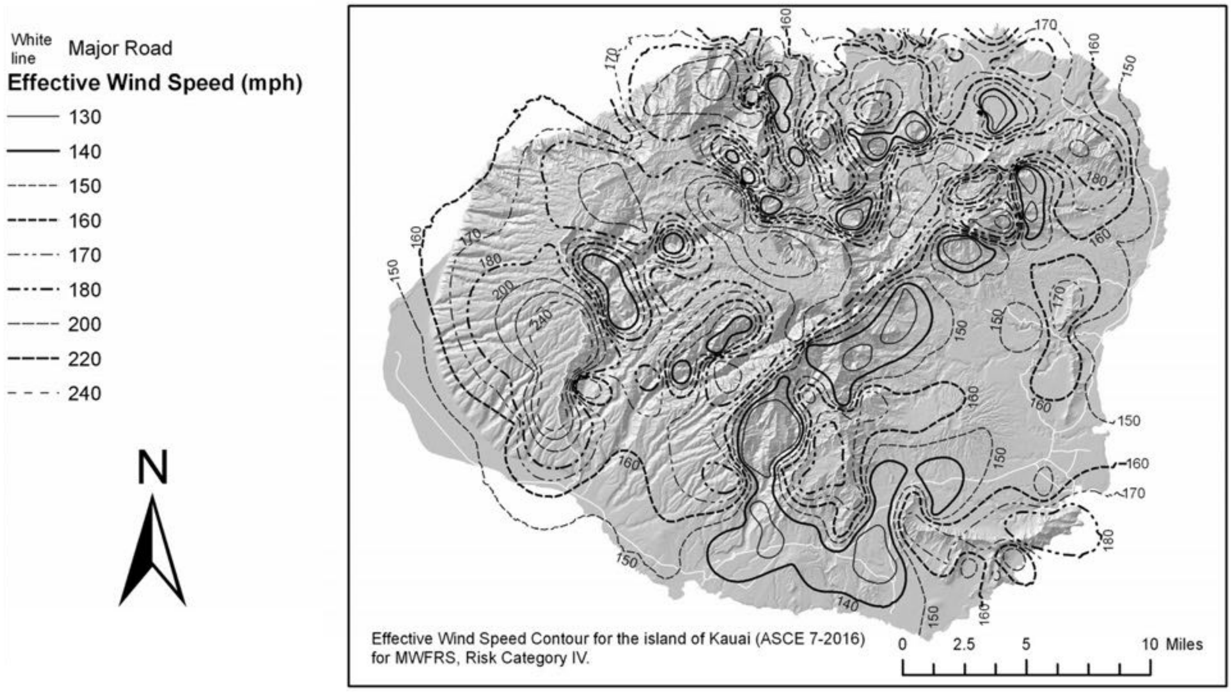
Attachment I

ASCE7-16 Figure 26.5-2D (continued)

Basic Wind Speeds for Risk Category IV Buildings and Other Structures: Hawaii



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4. It is permitted to use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.
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6. Wind speeds correspond to approximately a 1.7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000333, MRI = 3,000 years).

Commentary to SPRI RP-14

This Commentary consists of explanatory and supplementary material designed to assist designers and local building code committees and regulatory authorities in applying the requirements of the preceding standard.

The Commentary is intended to create an understanding of the requirements through brief explanations of the reasoning employed in arriving at them.

The sections of this Commentary are numbered to correspond to the sections of the RP-14 standard to which they refer. Since it is not necessary to have supplementary material for every section in the standard, there are gaps in the numbering of the Commentary.

All metric conversions within the standard are "soft metric" within the tolerances of the inch pounds dimensions.

Metric engineering lengths: mm = millimeter, m = meter

Wind speed = m/s meters per second

Weight = kg/m^2

Pressure = Pa = Pascal

All conversions are based upon the 2009 ASHRAE Book of Fundamentals.

C1.0 Introduction

Green roofs, also known as vegetative roofs, eco-roofs, and rooftop gardens fall into two main categories -intensive, primarily defined as having more than 6 inches (0.15 m) of growing medium, greater loading capacity requirements, and greater plant diversity, and extensive, defined as having less than 6 inches (0.15 m) of growing media, less loading capacity requirements and fewer options for plants.

These systems are considered to be roof gardens or landscaped roofs or part of a roof garden or landscaped roof. Vegetative roofs are complex systems consisting of many parts critical to the functioning of the system. A few of the components generally found in these systems include, but are not limited to: insulation, waterproofing membrane, protection mats/boards, root barrier, drainage layer, filter fabric, *growth media*, and vegetations. A vegetative roof may consist of more than just *growth media* and vegetation with such things as walkways, water features, stone decoration, and benches included. Requirements between manufacturers vary, and some items may be optional.

RP-14 is a minimum standard and may be enhanced by designer or manufacture requirements.

A *vegetative roofing system* may cover the whole roof or share a portion of the surface with a conventional roofing system. They are versatile systems with many strong attributes including storm water management, reduced heat island effect, and aesthetics to name a few.

When large shrubs and trees are used attention should be given to ensure adequate anchorage and structural support.

While the standard is intended as a reference for designers and installers, the design responsibility rests with the "designer of record."

C2.1 Vegetative roofing systems

A *vegetative roofing system* consists of vegetation, *growth media*, drainage system, and waterproofing over a roof deck. Where the membrane is not impervious to root penetration, root barriers shall be necessary. The system can be considered to be a roof garden or landscaped roof.

Several wind performance tests on *vegetative roofing systems* have been conducted. They have shown that the systems are very stable when vegetation is present or when a soil tackifier or erosion mat is included in non-vegetative areas. See References #24, 29 and 30.

There are several types of vegetative roofs that are generically described in Section 4.

C2.2 Ballast

The *ballast* used in roofing systems is made up of a number of types. For the *growth media*, the designs that follow in the document consider the exposed media is the worst case scenario therefore the wind erosion mats and soil tackifiers are used to cover the exposed media to prevent wind scour. However, when the plants cover the media, the media gets the benefit of the windbreak provided by the plants and the holding power of the root system in the zone around the plants. Combinations of large aggregate or stones and *growth media* can also be considered as part of the *ballast* weight when they are protected by vegetation.

Ballast is any object having weight that is used to hold or steady an object. In ballasted roofing systems, the most common *ballast* used is stone. However, materials such as concrete pavers, lightweight concrete pavers, rubber pavers, and weighted insulation panels are often used to *ballast* roofing systems. With the advent of vegetative roofs, *growth media* and pre-constructed vegetative modular trays also act as *ballast*. These *ballast* systems have been organized into categories based on their ability to resist the forces of the wind.

Ballast can also provide drainage options.

C2.5 Basic Wind Speed

The wind speed used in this document is from ASCE 7. When the current code in the area of the building being constructed is not ASCE 7, but an older ASCE wind map, the commonly used conversion is; fastest mile plus 20 mph (8.9 m/s) is approximately equal to the 3-second gust speed. When more detail is needed, consult ASCE 7.

Ballasted roofs are not recommended where the *basic wind speed* is greater than 140 mph (63 m/s). However they can be designed using Reference 1, consultation with a wind design engineer, or wind tunnel studies of the specific building and system.

- Special Wind Regions (mountains or valleys): Refer to Section C6.5.4.1 of the ASCE 7 Commentary.
- The intensifying effects of topography (hills or escarpments) are to be accounted for. Information on speed up over hills and escarpments can be found in ASCE 7 *Minimum Design Loads for Buildings and Other Structures*; Section 6.5.7. ASCE 7 provides data for wind pressure increase, but does not give specific advice for wind speed tables as are used in this document. Consult a wind engineer to determine the roof top wind speed. The increase in wind speed due to hills is the K_{zt} factor from the above ASCE reference. (i.e. multiply the wind speed by K_{zt} and use this new wind speed as the design wind speed.) A conservative approach is to add the height of the hill to the height of the building. Hills less than 60 ft (18 m) above the surrounding terrain in Ground Roughness A & B and 15 ft (4.6 m) above the surrounding terrain in Ground Roughness C & D, need not be considered

  Wind Borne Debris Regions: ASCE 7 defines these regions as areas within hurricane regions located:

  1. within one mile of the coastal high water line where the *basic wind speed* is equal or greater than 110 mph (49 m/s) and in Hawaii; or
  2. in areas where the *basic wind speed* is equal to or greater than 120 mph (54 m/s). This document requires the use of #2 *Ballast* only, in these areas. For vegetative roofs used in this area, consideration shall be taken to minimize woody vegetation that could become wind borne debris. Trees, palms, woody bushes could have limbs break off in the wind leading to building damage.

     The “authority having jurisdiction” is the only source for approval of designs not covered in this document. ASCE 7 gives guidance on how non-standard conditions should be evaluated. (See Reference 1, or conduct wind tunnel studies in accordance with ASCE 7 for information to determine requirements for designs or systems not covered).

C2.6.1 **Corners are not always square.** They are formed by the intersection of two walls. This document is using the definition of the angle formed by the two walls as being between 45 and 135 degrees to signify a *corner*. The designer may choose to include angles outside this range as a *corner*.

C2.6.2 & 2.6.3 **The corners and perimeters** used in this document are 0.4 times the building height, which is greater than the 0.1 times the building height in ASCE 7. This 0.4 factor adds a significant conservative factor for taller buildings. This is particularly true for tall narrow buildings where a 90 ft (27 m) high roof designed to this standard would require a 36 ft (11 m) wide perimeter.

C2.7 **Exposure Categories/Surface Roughness**

A roof being designed in a city center may be either too tall to benefit from the protection of adjacent buildings, or is low enough to be affected by wind channeling between them. Wind profiles are much more complex in city centers, and therefore not necessarily subject to the more rational directionality as studied in the wind tunnels. Choosing Exposure Category C reduces the wind speeds at which the system is safely installed. Because of the effects on ballasted roof systems performance if *ballast* disruption were to occur, city centers and individual tall buildings should be evaluated to determine if a more stringent wind exposure category should be used in the design. ASCE 7 has photos that show the various categories in its commentary C6.5.6

C2.8 **Impervious Deck**

The first thing that comes to mind when thinking about materials such as poured concrete and gypsum is that they are impervious to the flow of air. However, in deck constructions there are from time to time penetrations that are cut through these decks that air can pass through. There are also constructions where the expansion joint is located at the deck-wall junction or the wall construction itself (stud or cavity wall construction) can let air in under the roof system. The designer should investigate to assure the “impervious construction” is truly that. All penetrations (new or existing) are to be sealed to prevent the system from pressurization. Unless proper detailing is considered the system is to be treated as pervious. (See Reference 7 for detailing)

C3.2 **Building Height**

Vegetative roofs with heights greater than 150 ft (46 m) can be designed using Reference 1, consultation with a wind design engineer, or wind tunnel studies of the specific building and system.

C3.7 **Membrane Requirements**

Membranes not having a consensus Product Standard should meet the specific requirements of their manufacturers.

EPDM	ASTM D-4637
PVC	ASTM D-4434
TPO	ASTM D-6878
KEE	ASTM D-6754
SBS MB	ASTM D-6164, 6163, 6162
APP	ASTM D-6222, 6223, 6509
BUR	As defined by the standards referenced in the International Building Code Fully Adhered Hot-Applied Reinforced Waterproofing System ASTM D 6622

Certain membranes contain plasticizers that may be extracted from the membrane. They may require a slip-sheet between the membrane and some insulations and *growth media*.

C3.8 **Membrane Perimeter and Angle Change Attachment**

This standard addresses the basic requirements for membrane termination. For more details on the design of edging and attachment of nailers, see ANSI/SPRI/FM 4435/ES-1 *Wind Design Standard for Edge Systems Used with Low Slope Roofing Systems.*

Perimeter Attachment

Some wall constructions allow pressure from the interior of the building to flow up wall cavities, bypassing the deck and entering the space between the roof covering and roof deck. This can be mitigated by following Reference 7 or consulting the manufacturer for expert design.

Exterior through wall scuppers, if not sealed on the exterior, can allow air on the windward side of the parapet wall to pressurize the space under the roof covering.

Parapets

The use of parapets will improve the wind performance of the roofing system. The designer, whenever possible, should use a parapet design that will improve the roof system's ability to resist the wind. When parapets are less than 1 ft (0.3 m), vegetative systems are limited to 75 ft (23 m). The improvement in wind resistance is a function of parapet height. See tables for response.

C3.9 Wind Erosion

There are several ways to prevent wind erosion of *growth media*. The most common approach is to use a wind erosion mat. When the vegetation does not nominally cover the *growth media* a wind erosion mat or erosion soil conditioner or tackifier is to be installed over the roof to prevent *growth media* from being wind blown. The mat shall be anchored in place using techniques that provide pull out resistance capable of withstanding the calculated load as tested according to Attachment I with consideration for the porosity of the mat. Wind erosion mats can be attached to the deck or held by a paver at the perimeter of the vegetation. Mats can use soil staples or other devices to hold them in place. Wind erosion can also be prevented by the installation of pavers in place of *growth media* or wind screens. Pre-cultivated mats have also been shown to hold the *growth media* in place.

The requirements for soil stabilizers or tackifiers will vary with the soil used and the wind loads. Products should be tested for the soil conditions on the roof being installed. Most are not designed for prolonged exposure. When pre-cultivated mats are not used, wind erosion control should be used until the minimum establishment period of the vegetation is reached, as determined by the green roof design professional. An established root system can help prevent wind erosion.

C3.11 **In wind borne debris regions** consideration shall be taken to minimize woody vegetation that could become wind borne debris.

C3.12 *Ballast* is any object having weight that is used to hold or steady an object. In ballasted roofing systems, the most common *ballast* used is stone. However, materials such as concrete pavers, lightweight concrete pavers, rubber pavers, and weighted insulation panels are often used to *ballast* roofing systems. With the advent of vegetative roofs, *growth media* and pre-constructed vegetative modular tray also act as *ballast*. These *ballast* systems have been organized into categories based on their ability to resist the forces of the wind.

Ballast Weight: The minimum *ballast* weight is based on the wind design requirements of the system. Structural design should consider that the installed system will have variation of weight across the surface and with the amount of water retention in the system. Additional structural capacity should always be considered.

You may be able to have a lower weight based on tray pressure equalization when there is a ¼ in gap between the tray and the membrane using current wind engineering practices consistent with ASCE 7.

The dry weight of the *growth media* can be determined using ASTM E2399.

Combinations

Combinations of any of the types of *ballast* can be used on any roof, and combinations of stone and *growth media* etc. can be used to achieve the *ballast* weight required.

All stone *ballast* comes with some **fines** mixed in. ASTM standard D-448 allows up to 5 percent fines. This may lead to problems at drains, scuppers, etc. due to build-up of these fines. If the source of stone is including too many fines, it may be advisable to have it “double washed”. The research basis for the stone *ballast* was model stone that approximated the gradations of ASTM D-448. This included fines and the largest sizes in the simulated gradation. The average size of the stone was deemed to be the controlling factor in wind performance.

Vegetative Roofing Systems also bring the problem of root growth that may work their way into the drain leading to clogging problems. On *Vegetative Roofing Systems* using less than 4 inches (100 mm) of *growth media* depth, stone *ballast* should be placed around the drain extending out a minimum of 1 ft (0.3 m) (a clear space around drains is required but stones are optional for modular tray systems). For systems with greater than 4 inches (100 mm) depth of *growth media*, a perforated drain box wrapped with a filter fabric is to be installed over the drain to keep the *growth media* and as an aide to keep the plant roots out of the drain. The drain box should have a cover. Drains should be inspected twice a year to make sure they are clean.

Air/drainage layers are often incorporated. When these layers contain inorganic matter, such as stone the weight of the inorganic matter can be considered part of the *ballast* weight.

C4.0 Design Options

The Design Options of Section 4, which also references the Design Tables in Table 2, are built on the wind tunnel work done by Kind and Wardlaw and supported by extensive field investigations (see references). The base used as the design criteria from the wind tunnel work was Critical Wind Speed VC2, the gust wind speed above which scouring of stones would continue more or less indefinitely but not blow off the roof if the wind speed were maintained.

The *corners* and *perimeter areas* are where the greatest effects of the disrupted airflow over the building will occur. The worst case scenario is the wind coming onto a *corner* at a 45° angle. These situations generate wind vortices along the roof edges causing low-pressure areas over the roof system as well as wind turbulence that can scour *ballast* and balloon the membrane. Typically, scour occurs first. To prevent *ballast* movement, enhanced design provisions are required in some cases for these areas.

The terminology “documented as demonstrated as equivalent with the provisions of the standard” means that a proprietary system has been evaluated through one or all of the following methods:

- Wind tunnel testing conducted in accordance with ASCE 7;
- In a Full Scale Test conducted by a *registered design professional*; and/or.
- Field Documented Studies

The results would show performance levels that meet the locations design requirements.

Test methods typically used to evaluate roof systems for their ability to resist uplift forces are ANSI/FM4474 *American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*, and Underwriters Laboratories ANSI/UL1897 *Uplift Tests for Roof Covering Systems*. Both testing facilities publish the results for the specific roof systems tested. Contact them for additional information.

C4.3 Protected Vegetative Roofing System

A protected *vegetative roof system* consists of vegetation, *ballast* as defined in 2.2, a fabric that is pervious to air and water, insulation, membrane and substrate materials installed over a structural deck capable of supporting the system. The waterproofing membrane is fully bonded directly to the roof deck.

In protected Vegetative Roof designs, the insulation is placed above the roofing membrane. When working with this design, the designer needs to account for the potential rafting of the insulation as it might float. A diffusion open fabric or similar material shall be installed above the insulation.

The water-and-air pervious fabric is used for four purposes: (i) provide temporary UV protection for foam plastic insulation, (ii) prevent gravel fines from working down between the insulation joints to the membrane which could potentially cause damage to the membrane, (iii) prevent clogging of the drainage layer, and (iv) to control insulation board rafting in a floatation situation. Rafting is when insulation board, which may be floating due to heavy rainfall or a slow draining roof, moves out of place.

For information on air retarders, see References 7 and 10. Although all systems may benefit from well-installed air retarders, this standard is based on having no deliberately installed air retarders for all systems with 10-lbs/sq. ft or more of *ballast* weight. For systems less than10-lbs/sq. ft, air retarders are required, but this standard assumes the air retarder is imperfect.

Several options exist for increased interconnectivity and securement of the perimeters. Heavy weight *ballast* is a non-proprietary way of achieving this requirement.

System 3 design can be achieved by consulting References 6, 7, 8, and 9 or manufacturer's proprietary designs.

C6.0 Determination of Ballasted System Roof Design

When a building does not fit the criteria of this document the designer should refer to Reference 1 and ASCE 7.

C7.0 Maintenance

Vegetative roofing systems shall be maintained to provide vegetation that nominally covers the visible surface of the *growth media*. When wind scour occurs to an existing v*egetative roof system* and the scour is less than 50 square ft (4.6 m^2), the *growth media* and plants shall be replaced. For scour areas greater than 50 square ft (4.6 m^2), the vegetative roof design shall be upgraded a minimum of one system design level per Section 4.0. Maintenance shall be the responsibility of the building owner.

Vegetative roofs should always be inspected after a wind event and at least 2 times per year to make sure the vegetation and *growth media* are in place, drains are open, and do any weeding necessary to maintain the performance and desired look of the system. The system needs to be maintained to promote the growth of the vegetation for the loss of the vegetation will have major impact on the wind and water retention performance and fire properties of the system, let alone the aesthetics of the system. Items like watering and fertilizing are important functions to support the vegetation. For more information on the care and maintenance of *vegetative roof systems*, see Reference 22, Guideline for the Planning, Execution and Upkeep of Green-Roof Sites. The requirements for maintenance must be clearly spelled out to the owner of the roof, and the maintenance is a responsibility of the building owner.

References

1. Kind, R.J. and Wardlaw, R.L., "Design of Rooftops Against Gravel Blow-Off", National Research Council of Canada, Report No. 15544, September 1976.

2. Kind, R.J. and Wardlaw, R.L., "The Development of a Procedure for the Design of Rooftops Against Gravel Blow-off and Scour in High Winds," Proceedings of the Symposium on Roofing Technology, 1977, pp. 112.

3. Gillenwater, R.J., "Wind Design Guide For Ballasted Roofing Systems", Proceedings of the Second International Symposium on Roofing Technology, 1985, pp. 219.

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5. Schneider, K.G. Jr., "A Study of the Behavior of Loose-Laid, Ballasted Single-Ply Roofing Systems Subjected to Violent Winds," Proceedings of the Second Inter- national Symposium on Roofing Technology, 1985, pp. 243.

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    [1.] With permission from ASCE: the wind speed map shown as Attachment I is an element of the ANSI/ASCE 7 document, "Minimum Design Loads for Buildings and Other Structures", an American National Standards Institute Standard, copyrighted by the American Society of Civil Engineers. Copies of this standard may be purchased from the American Society of Civil Engineers at 1801 Alexander Bell Drive, Reston, VA 20191.

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