ASCE 7-16: Changes to Wind Calculations for Rooftop Solar

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Principal
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ASCE 7-16: Changes to Wind Calculations

Agenda

- Current Practice
- General changes to ASCE 7-16
- Solar-specific changes to ASCE
- Mitigations in SEAOC PV2 update

Calculation of Wind Pressure: ASCE 7-10 and ICC-ES AC 428

ICC EVALUATION SERVICE

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ACCEPTANCE CRITERIA FOR
MODULAR FRAMING SYSTEMS
USED TO SUPPORT PHOTOVOLTAIC (PV) PANELS

AC428

Approved November 2012

Previously approved June 2012, February 2011, October 2010

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes. (Some reports may also reference older code families such as the BOCA National Codes, the Standard Codes, and the Uniform Codes.) Section 104.11 of the International Building Code® reads as follows:

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.

New acceptance criteria will only have an "approved" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approved" date, or an "approved" date combined with a "compliance" date. The compliance date is the date by which relevant evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.

If this criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a change from the previous edition. A deletion indicator (→) is provided in the margin where any significant wording has been deleted.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

NOTE: The Preface for ICC-ES acceptance criteria was revised in July 2011 to reflect changes in policy.

Acceptance criteria are developed for use solely by ICC-ES for purpose of issuing ICC-ES evaluation reports.

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- Determine design wind speed and calculate design wind pressures using ASCE 7-10
- ICC Evaluation Services Acceptance Criteria AC 428: Acceptance Criteria for Modular Framing Systems Used To Support Photovoltaic (PV) Panels
- AC 428 is required to obtain an ICC-ES Evaluation Report; it is also useful as voluntary guidance
- AC 428 allows internal pressure set equal to zero (within constraints) in Components & Cladding method
- In future ASCE 7-16, there will be a calculation method specific to “flush mounted” PV systems on sloping “pitched” roofs

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ICC Acceptance Criteria AC 428

3.1.3.1 Wind Loads:

3.1.3.1.1 Flush-mounted System: All elements shall be designed for Component and Cladding (C&C) pressures defined within the applicable code (Chapters 26 and 30 of ASCE 7-10 for the 2012 IBC and Chapter 6 of ASCE 7-05 for the 2009 and 2006 IBC) using the Envelope Method prescribed in Chapter 30, Part I for the 2012 IBC and Method 2 (Analytical Procedure for Low-Rise Buildings and Building for Heights Less Than 60 feet) for the 2009 and 2006 IBC, except that the internal pressure coefficient, GC_{pi}, shall be equal to zero, and therefore the design wind pressure, p, shall be determined as follows:

Design Wind Pressure, $p = q_h(GC_p) \geq 10$ psf (479 Pa) for the 2009 and 2006 IBC; $p = q_h(GC_p) \geq 16$ psf (770 Pa) per Section 30.2.2 of ASCE 7-10 for the 2012 IBC

where:

q_h = velocity pressure determined at mean height of the row of PV panels in the array, h, and appropriate exposure category from ASCE 7.

- Components & Cladding method
- Internal pressure shall be set equal to zero
- Physical constraints are needed for method to be valid
- Pressure equalization is dependent on gaps between modules

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ASCE 7-10 with ICC-ES AC 428 Criteria

The following conditions shall be observed:

1. PV panels shall not be installed within 10 inches (254 mm) of a roof edge or ridge.

2. The distance between the roof or wall surface and the PV panel must be between 2 and 10 inches (51 and 254 mm).

3. A minimum gap of 0.25 inch (6.4 mm) must exist between PV panels and adjacent rows of panels.

Don't forget to consider:

- Roof edge zones, which are changing in ASCE 7-16
- Fire setbacks, which are changing (for the better) in 2018 IFC & IRC

Physical constraints of AC 428 wind method:

- Required 10 inch minimum distance from roof edge or ridge
- Height above roof between 2 inches and 10 inches
- Minimum gap of 0.25 inch between adjacent rows of panels
- In earlier version of AC 428, minimum gap was 0.75 inch

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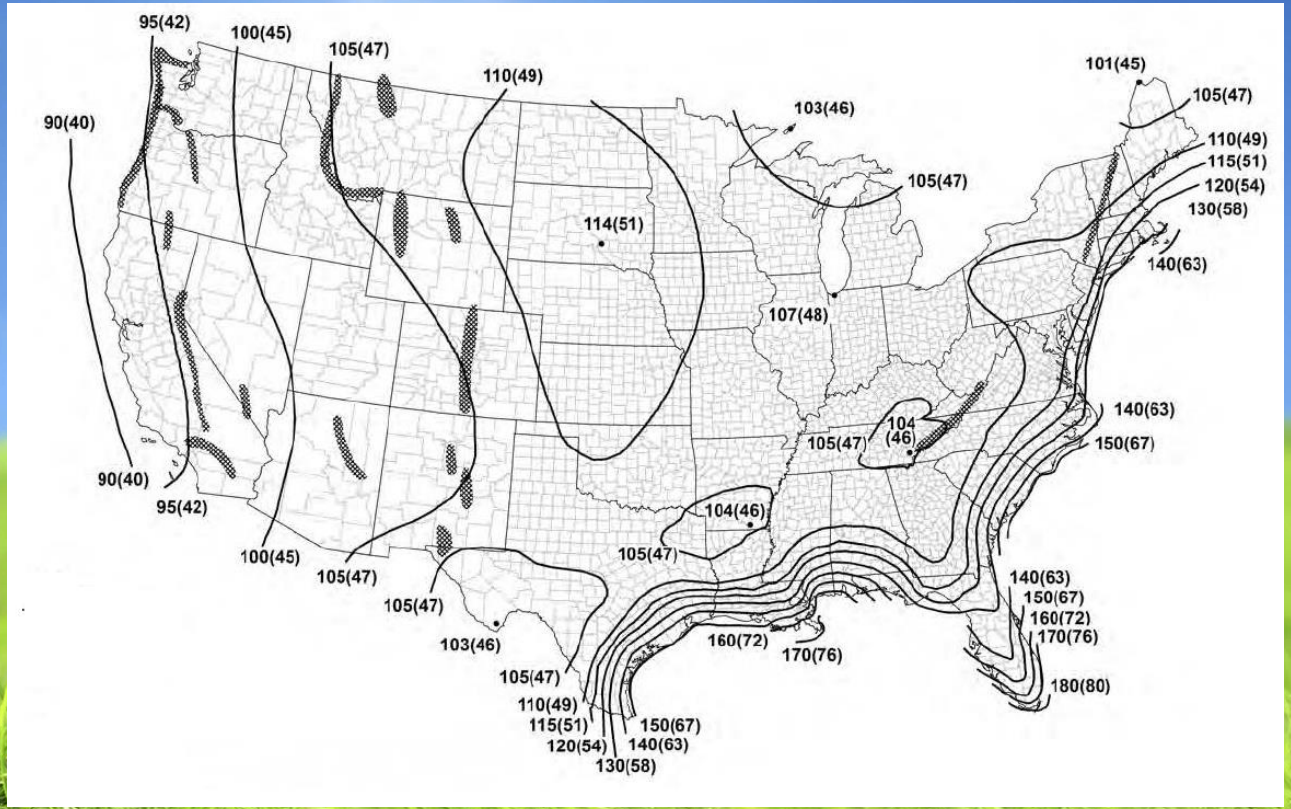
ASCE 7-16 Wind Speed Maps Revised (again)



- Risk Category II
- Mean Recurrence Interval (MRI) 700 years)
- ASCE 7-16 wind speed maps show contour lines in Western states

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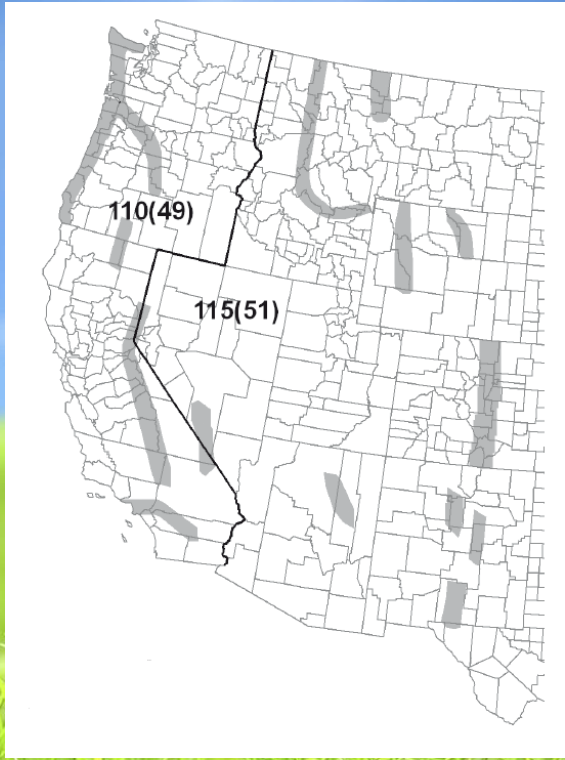
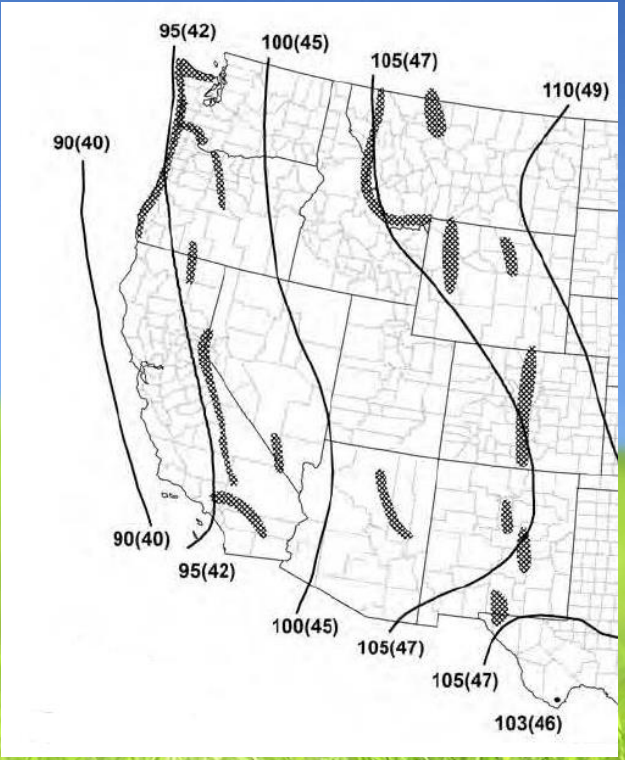
Compare ASCE 7-10 and ASCE 7-16 Maps



ASCE 7-10 Risk Category II



ASCE 7-16 Risk Category II

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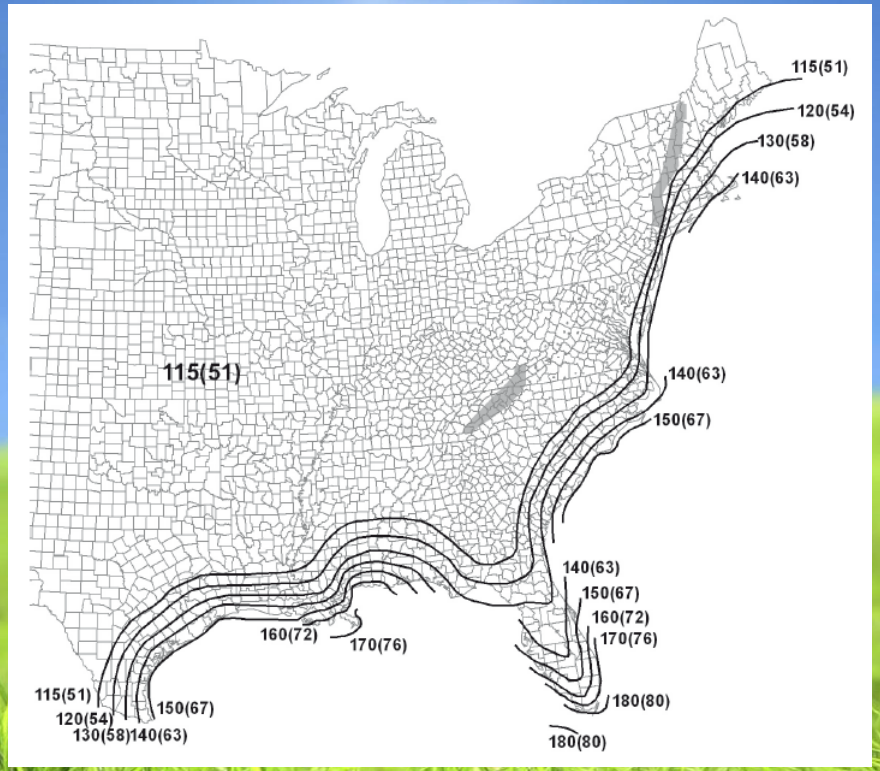
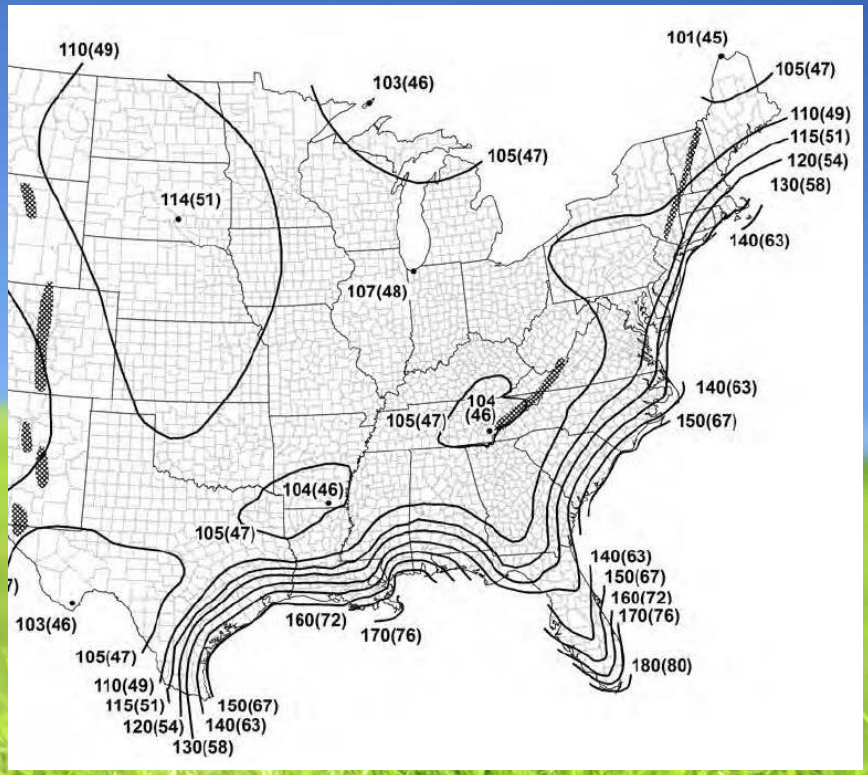
Compare ASCE 7-10 and ASCE 7-16 Maps



ASCE 7-10 Risk Category II



ASCE 7-16 Risk Category II

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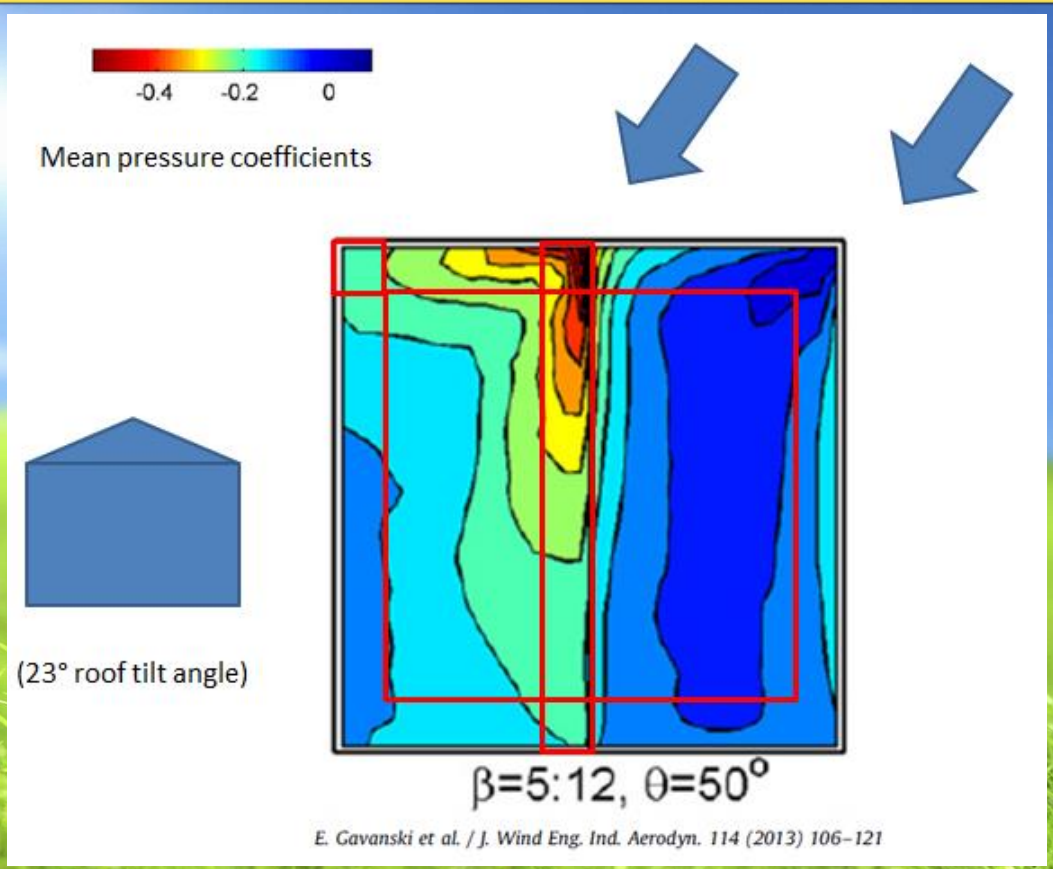
Development of Corner & Edge Roof Zones



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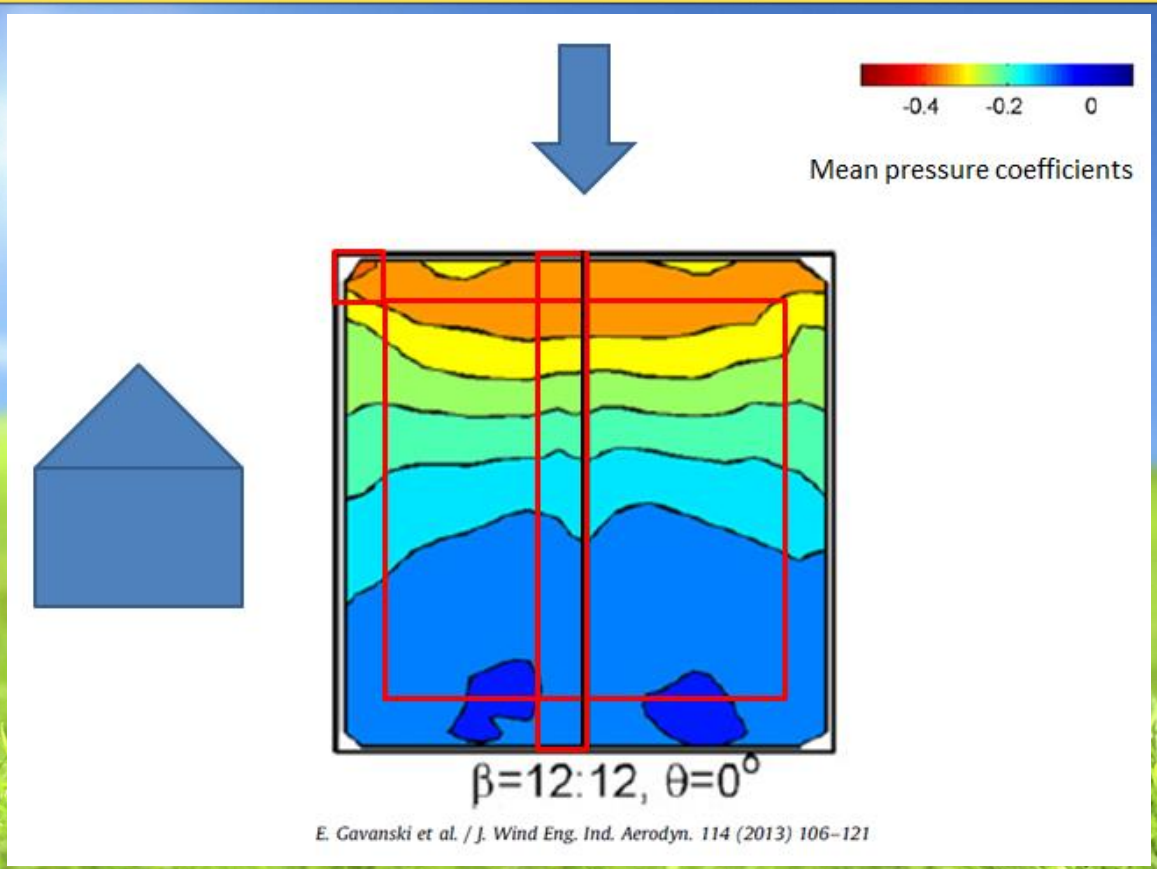
Development of Corner & Edge Roof Zones



E. Gavanski et al. / J. Wind Eng. Ind. Aerodyn. 114 (2013) 106–121

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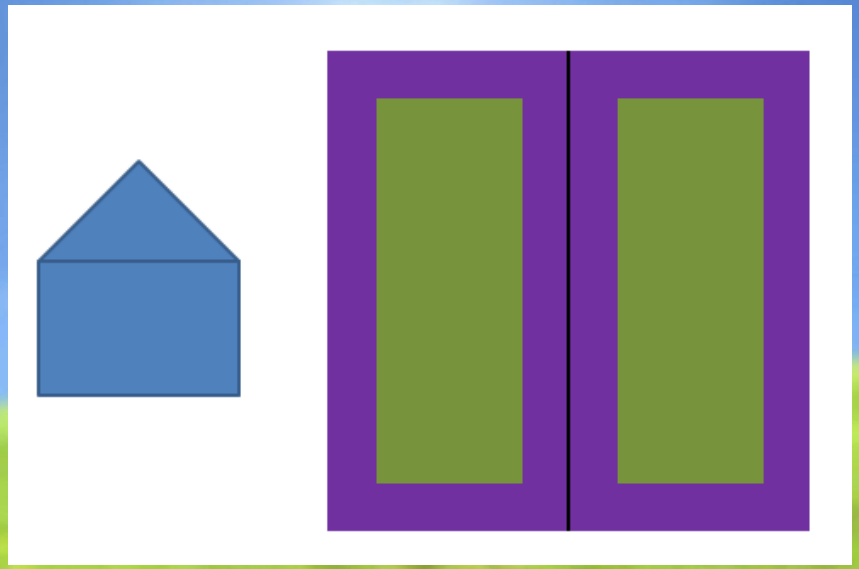
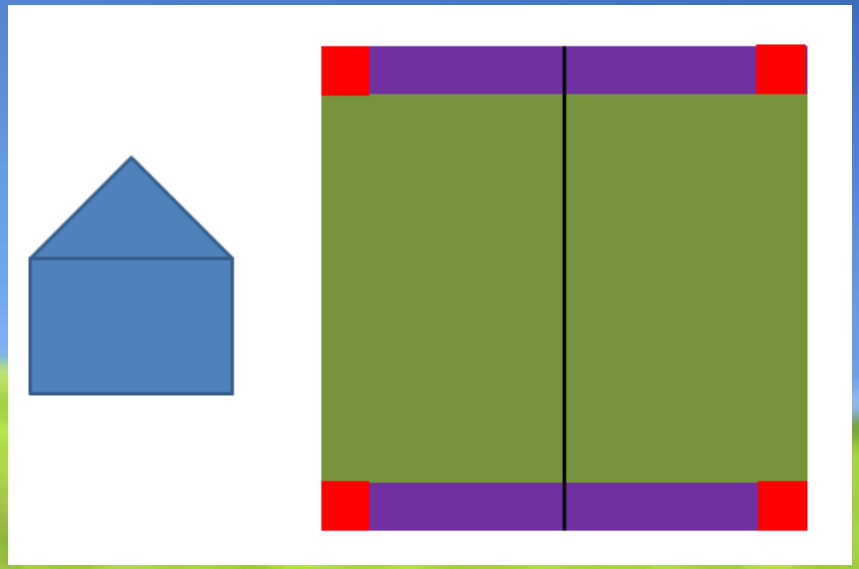
Development of Corner & Edge Roof Zones



ASCE 7-10 Roof Zones



ASCE 7-16 Roof Zones

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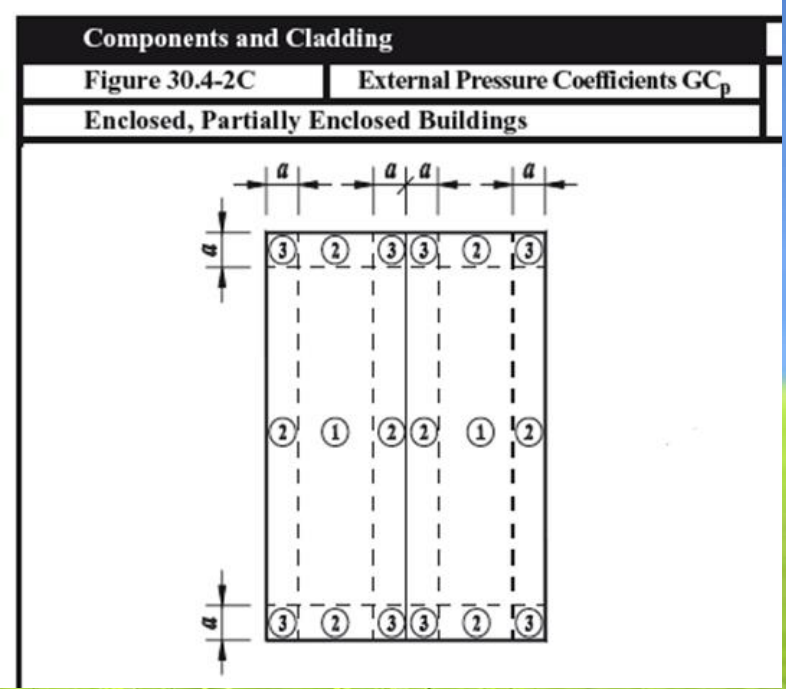
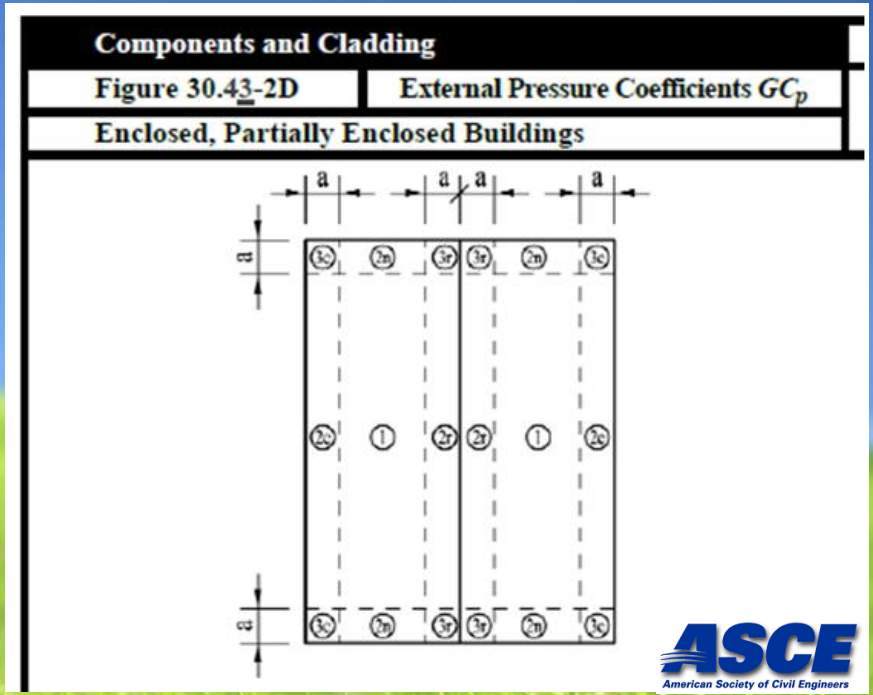
C&C Roof Zones: ASCE 7-10 to 7-16

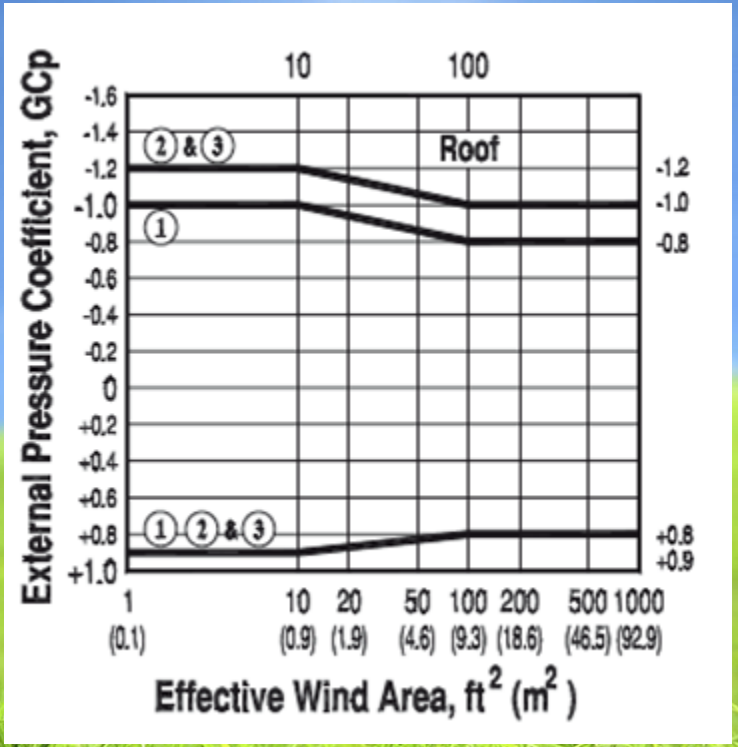


ASCE 7-10 Figure 30.4-2C

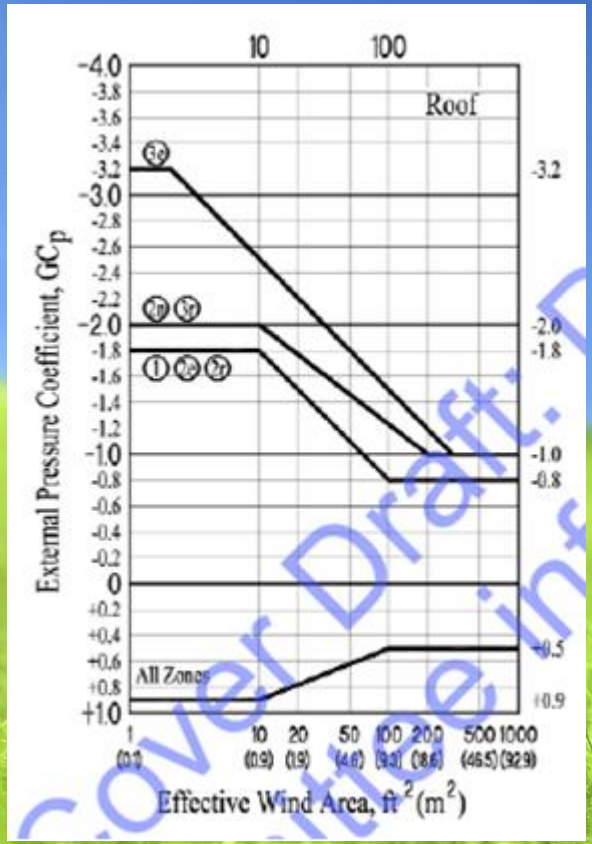


ASCE 7-16 Figure 30.43-2D

Roof GC_p Coefficients: ASCE 7-10 to 7-16

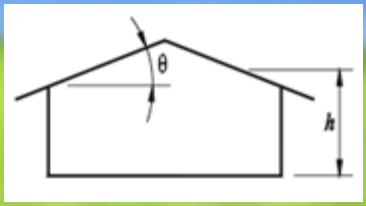


ASCE 7-10 Figure 30.4-2C



ASCE 7-16 Figure 30.43-2D

h ≤ 60 ft.
Gable Roofs 27° < θ ≤ 45°



Cover Draft

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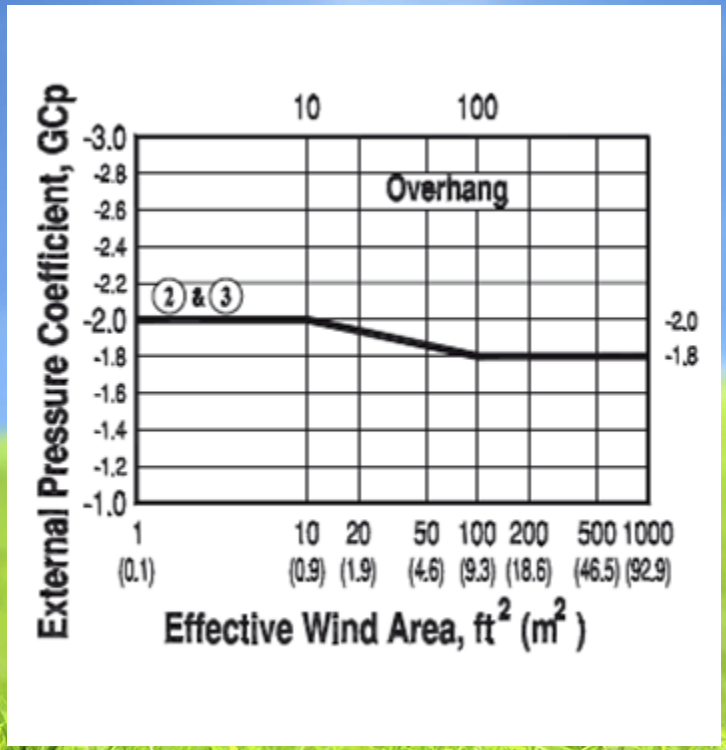
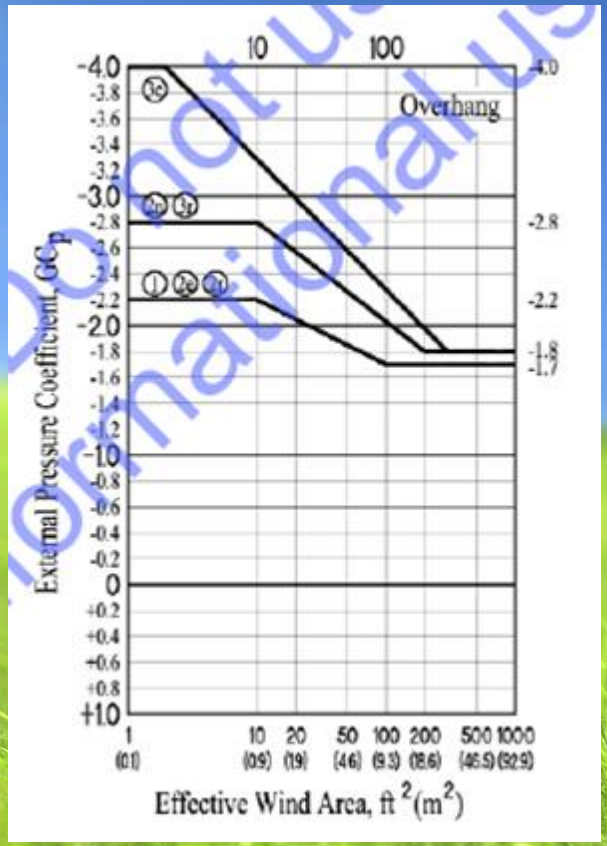
Overhang Coefficients: ASCE 7-10 to 7-16



ASCE 7-10 Figure 30.4-2C



ASCE 7-16 Figure 30.43-2D

h ≤ 60 ft.
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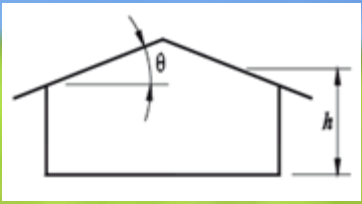

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Journal of Wind Engineering and Industrial Aerodynamics

journal homepage: www.elsevier.com/locate/jweia

Wind loads on photovoltaic arrays mounted parallel to sloped roofs on low-rise buildings

Sarah E. Stenabaugh[a], Yumi Iida[a], Gregory A. Kopp[a,*], Panagiota Karava[b]

ABSTRACT

The objective of this study was to determine the effects of geometry on the wind loads acting on photovoltaic panel arrays with modules mounted parallel to roof surfaces of low-rise buildings. Specific attention was made to determine the effects of varying the spacing between individual modules, *G*, and the mounting height above the roof surface, *H*. The photovoltaic system was modeled as an array of 28 modules on a 1/20 scale building model with a roof slope of 30°. In addition, limited studies were carried out with the array mounted on a flat-roof to assess the impact of roof slope. In general, it was found that larger gaps between modules, *G*, and smaller gaps between the panels and the roof surface, *H*, were found to yield lower net wind loads. Minimum loads tend to occur for $G/H > \sim 1$, for the particular panel size considered in the study. Pressure equalization between the upper and lower surfaces of the modules results in the magnitudes of the net panel pressures typically being lower than those for the bare roof surface. A pressure equalization factor, *Ceq*, was used as a measure of how much the peak net wind loads on the panels are reduced relative to the peak external loads.

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- Experiments were conducted in UWO boundary layer wind tunnel
- Two primary areas of investigation
- Height of PV system above roof
- Pressure equalization from various gaps between PV panels

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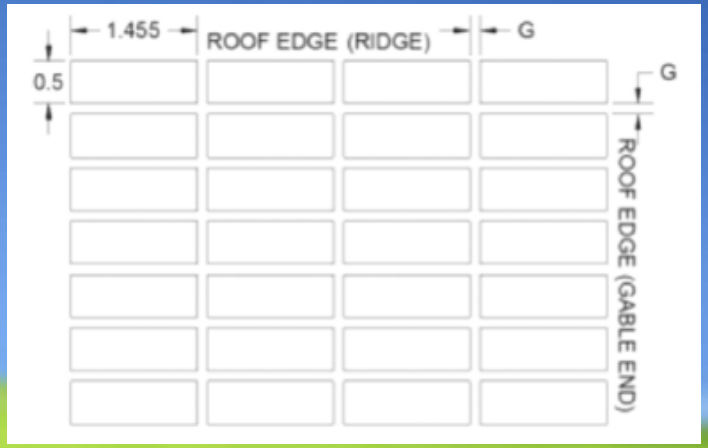

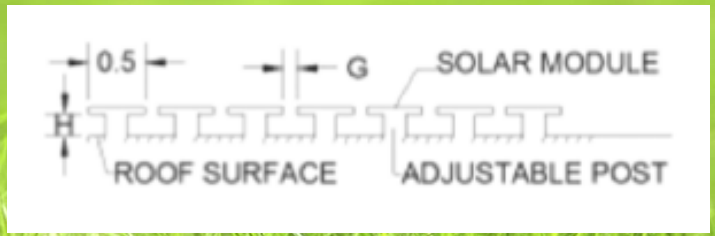

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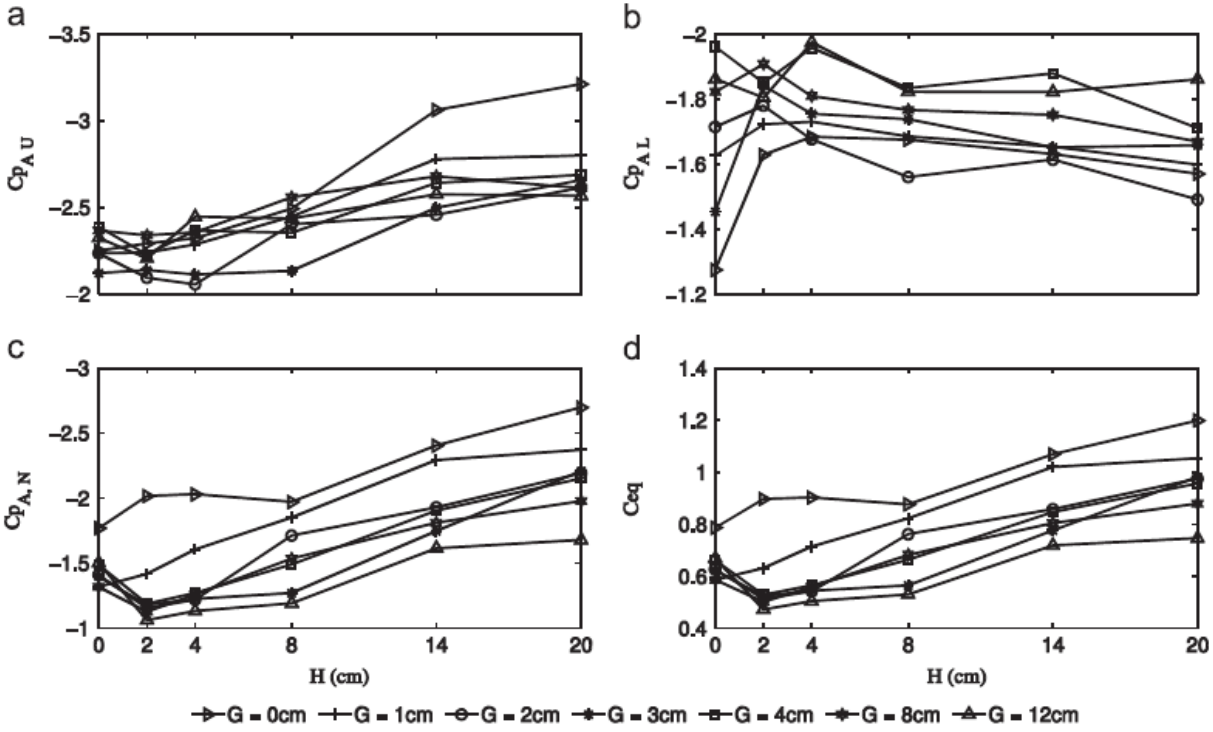

Fig. 5. The worst case values of the peak (suction) external on the (a) upper surface, (b) lower surface, and (c) net pressure coefficients measured, area-averaged over a single PV module and (d) the pressure equalization coefficient (*Ceq*) with respect to *H*.

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ASCE 7-16 with "Associated Criteria"

29.4.4 ROOFTOP SOLAR COLLECTORS, PARALLEL TO THE ROOF SURFACE, ON BUILDINGS OF ALL HEIGHTS AND ROOF SLOPES

The design wind pressures for rooftop solar collectors in this section apply to those located on enclosed or partially enclosed buildings of all heights, with panels parallel to the roof surface, within a tolerance of 2°, and with a maximum height above the roof surface, h_2, not exceeding 10 inches (0.25m). There shall be a minimum gap of 0.25 inches (6.4 mm) provided between all panels, with the spacing of gaps between panels not exceeding 6.7 ft (2.04 m). In addition, the array shall be located at least $2h_2$ from the roof edge, a gable ridge, or a hip ridge. The design wind pressure for

Physical constraints of ASCE 7-16 method:

- Required minimum distance from roof edge or ridge $2h_2$
- Height above roof between 2 inches and 10 inches
- Minimum gap of 0.25 inch between *all panels*

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DRAFT ASCE 7-16 Section 29.4.4

gable ridge, or a hip ridge. The design wind pressure for rooftop solar collectors shall be determined by Eq. 29.4-7:

$$p = q_h (GC_p)(\gamma_E)(\gamma_a) \quad (\text{lb/ft}^2)\ (\text{N/m}^2) \quad (29.4\text{-}7)$$

where

(GC_p) = external pressure coefficient for Components and Cladding of roofs with respective roof zoning, determined from Figures 30.3-2 through 30.3-7, or 30.5-1 in ASCE 7-16.

γ_E = 1.5 for panels that are exposed and those within a distance $1.5(L_p)$ from the end of a row at an exposed edge of the array; $\gamma_E = 1.0$ elsewhere, as illustrated in Figure 29.4-8. A panel is defined as exposed if d_1 to the roof edge > $0.5h$ and one of the following applies:

- d_1 to the adjacent array > 4 ft (1.22m)
- d_2 to the next adjacent panel > 4 ft (1.22m)

- Basic form of Equation 29.4-7 is very familiar
- Velocity pressure q_h times pressure coefficient GC_p
- Velocity pressure includes the square of wind speed
- New coefficients γ_E and γ_a are solar-specific for “flush mounts” installed parallel to roof

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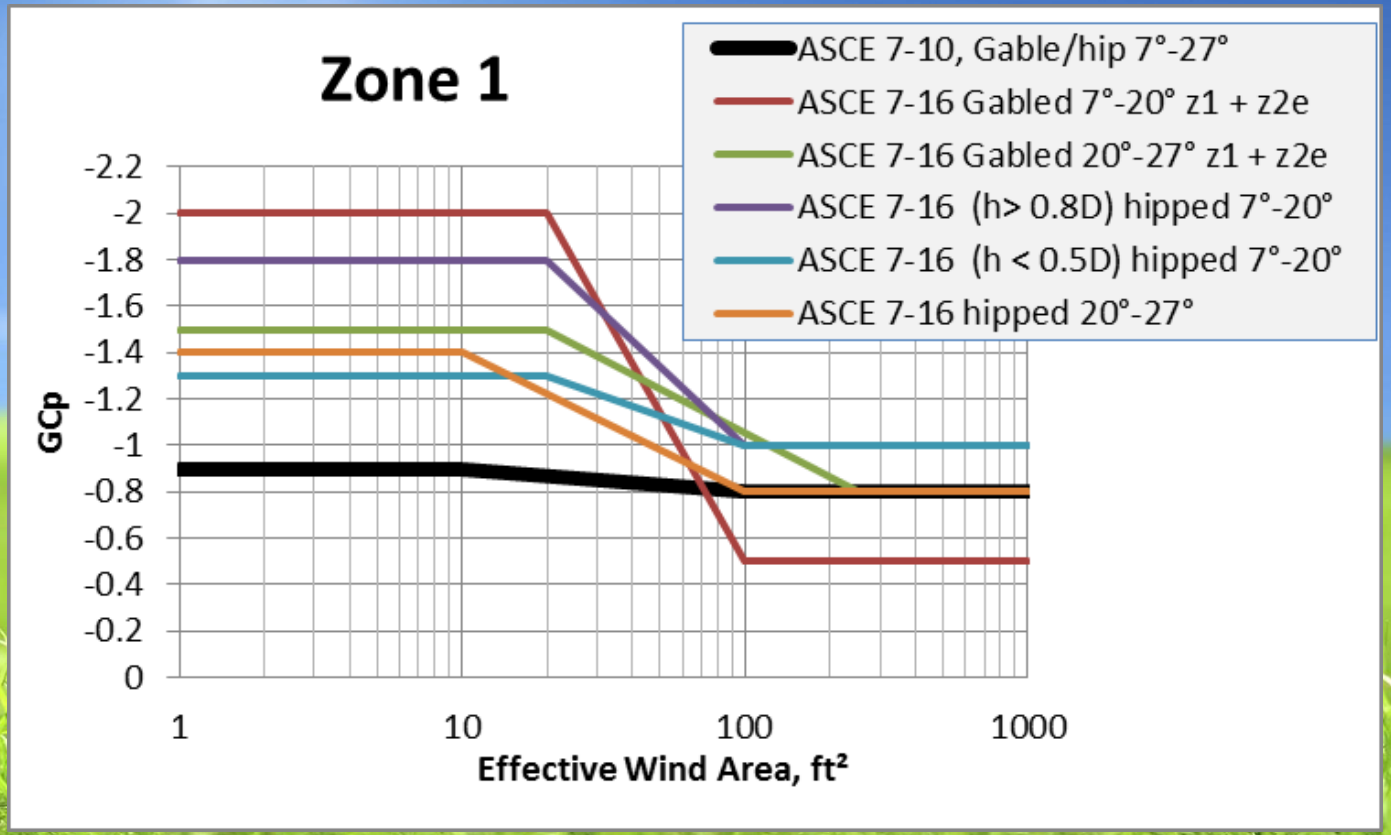
Zone 1: ASCE 7-16 GC_p Pressure Coefficients



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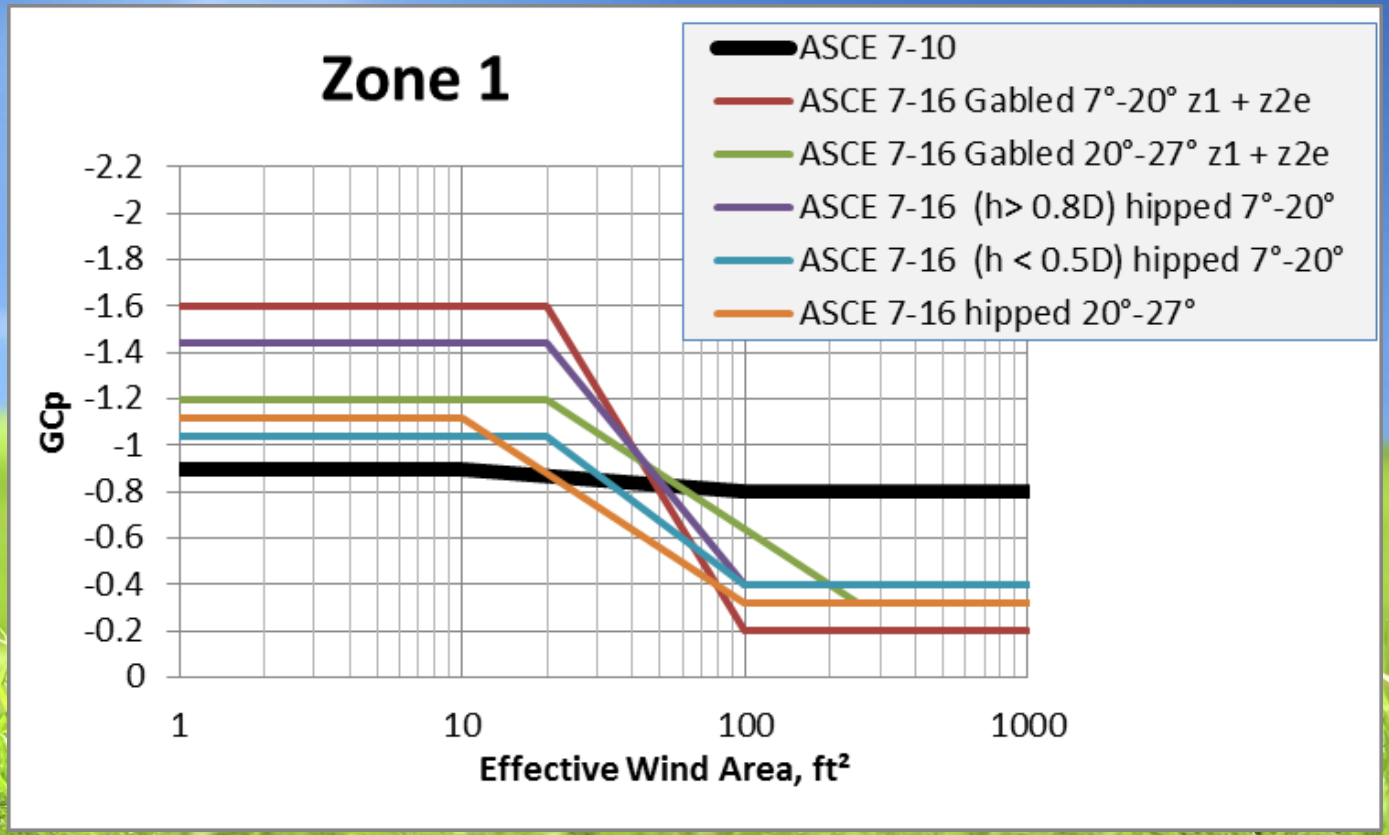
Zone 1: Wind Pressure Equalization Factor



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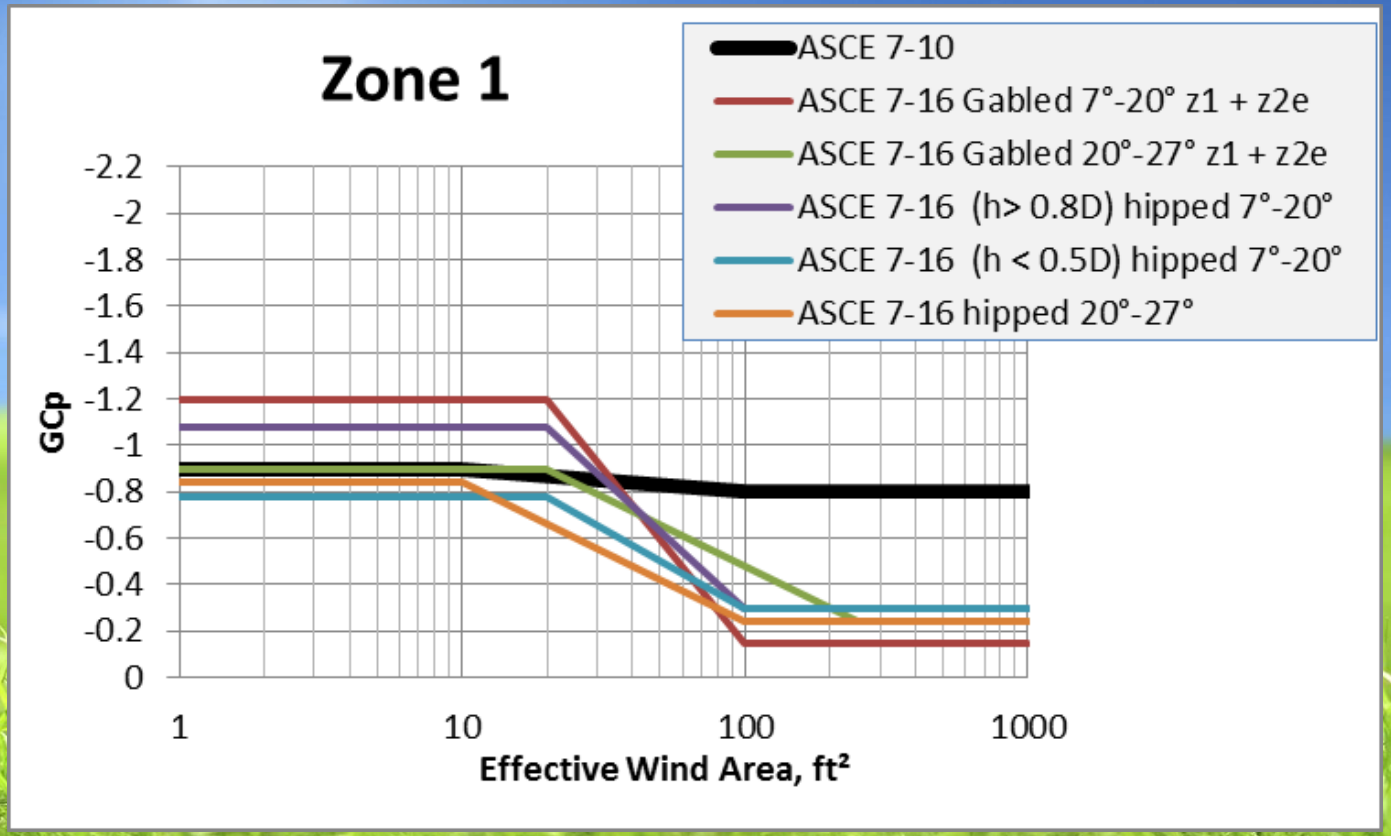
Zone 1: Add ASCE 7-16 CA Wind Speeds



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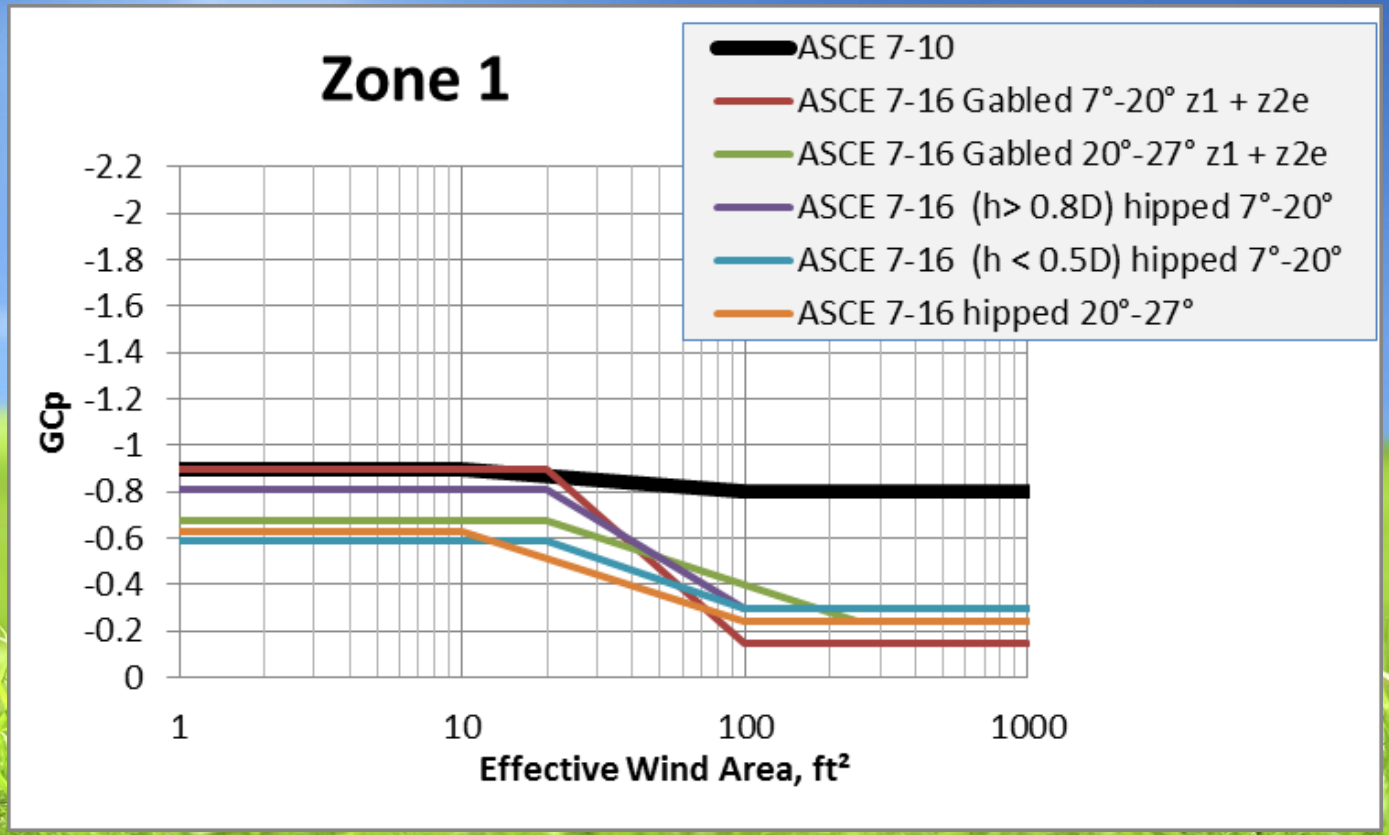
Zone 1: Closer to Roof, with PV2-2016 Equalization



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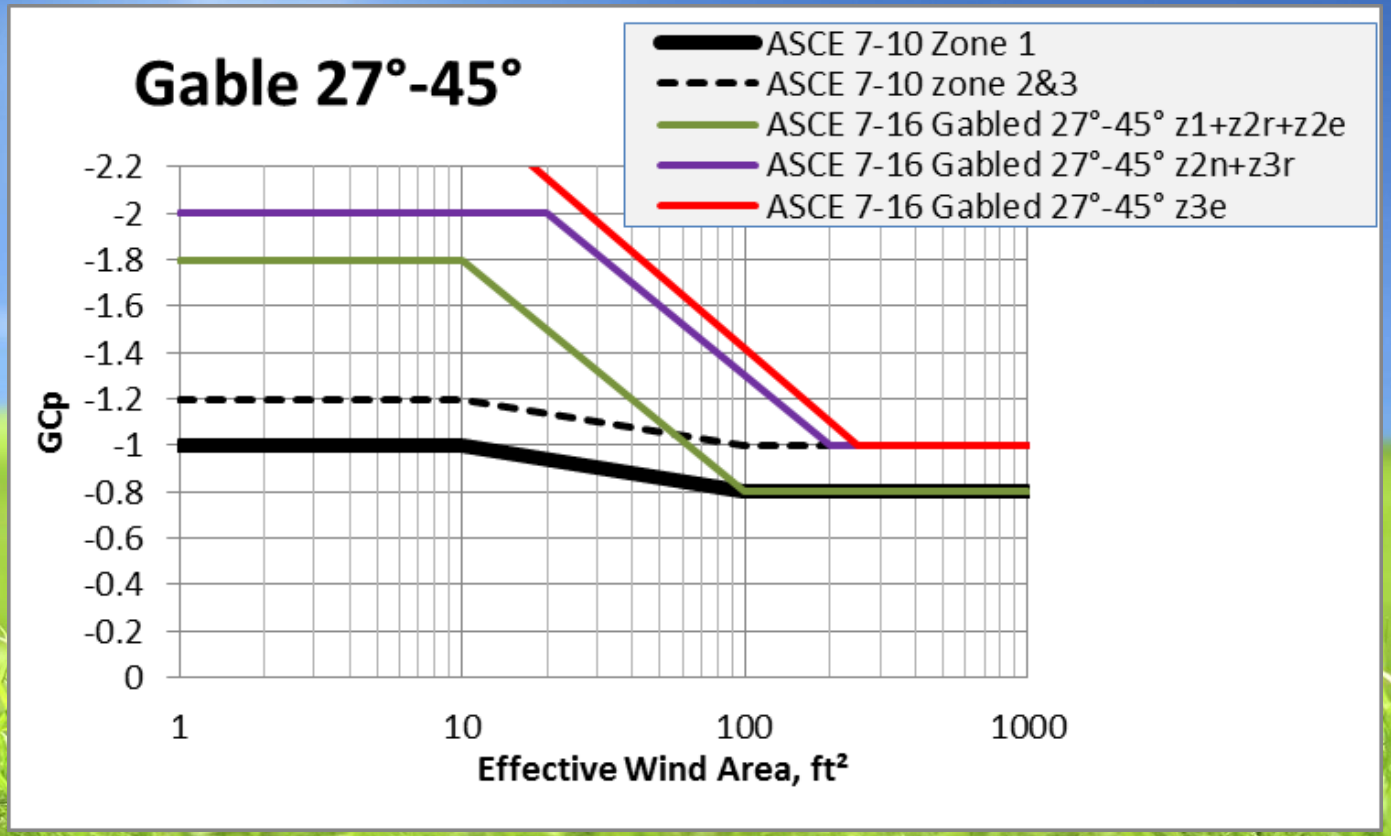
Gable 27º - 45º: ASCE 7-16 GC_p Pressure Coefficients



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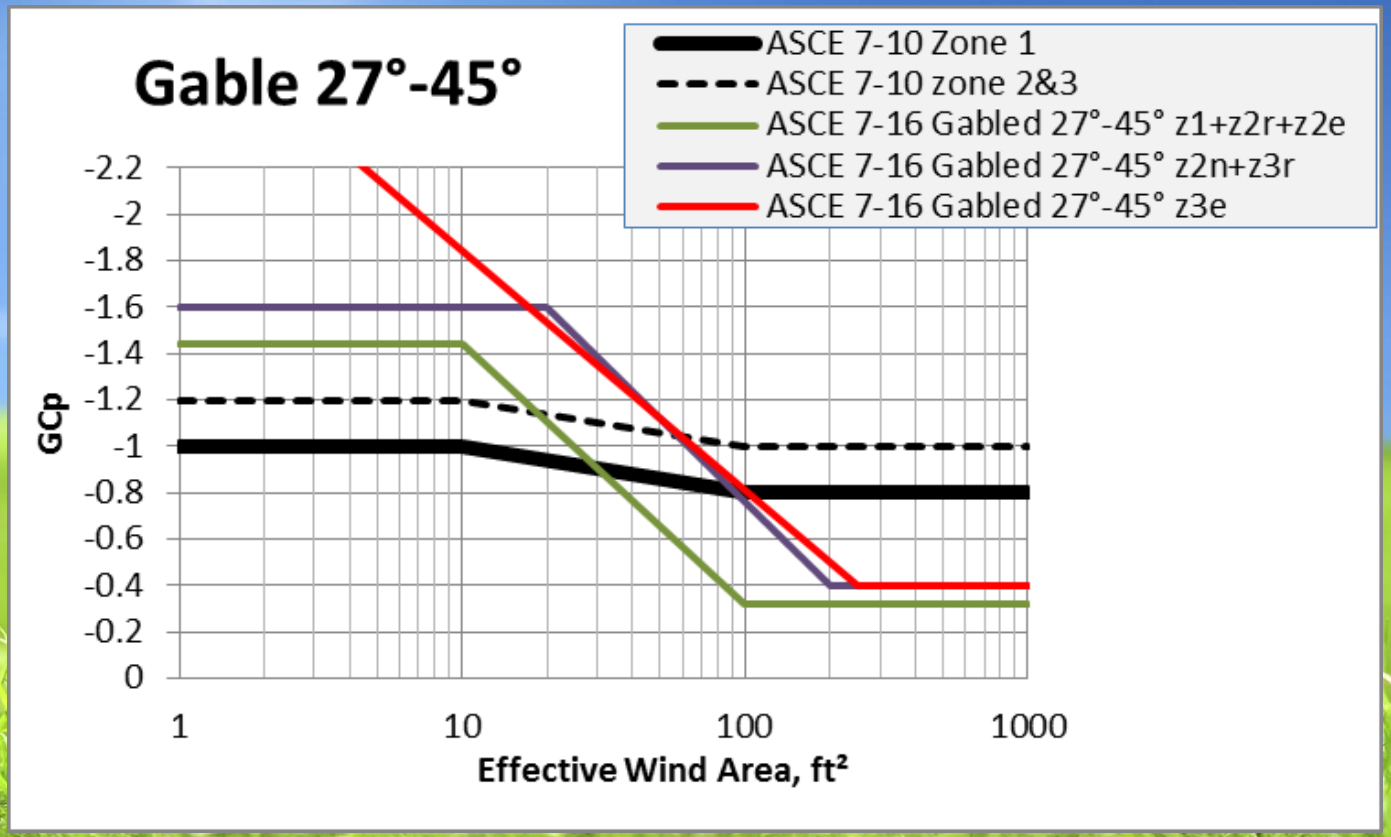
Gable 27º - 45º: With Pressure Equalization Factor



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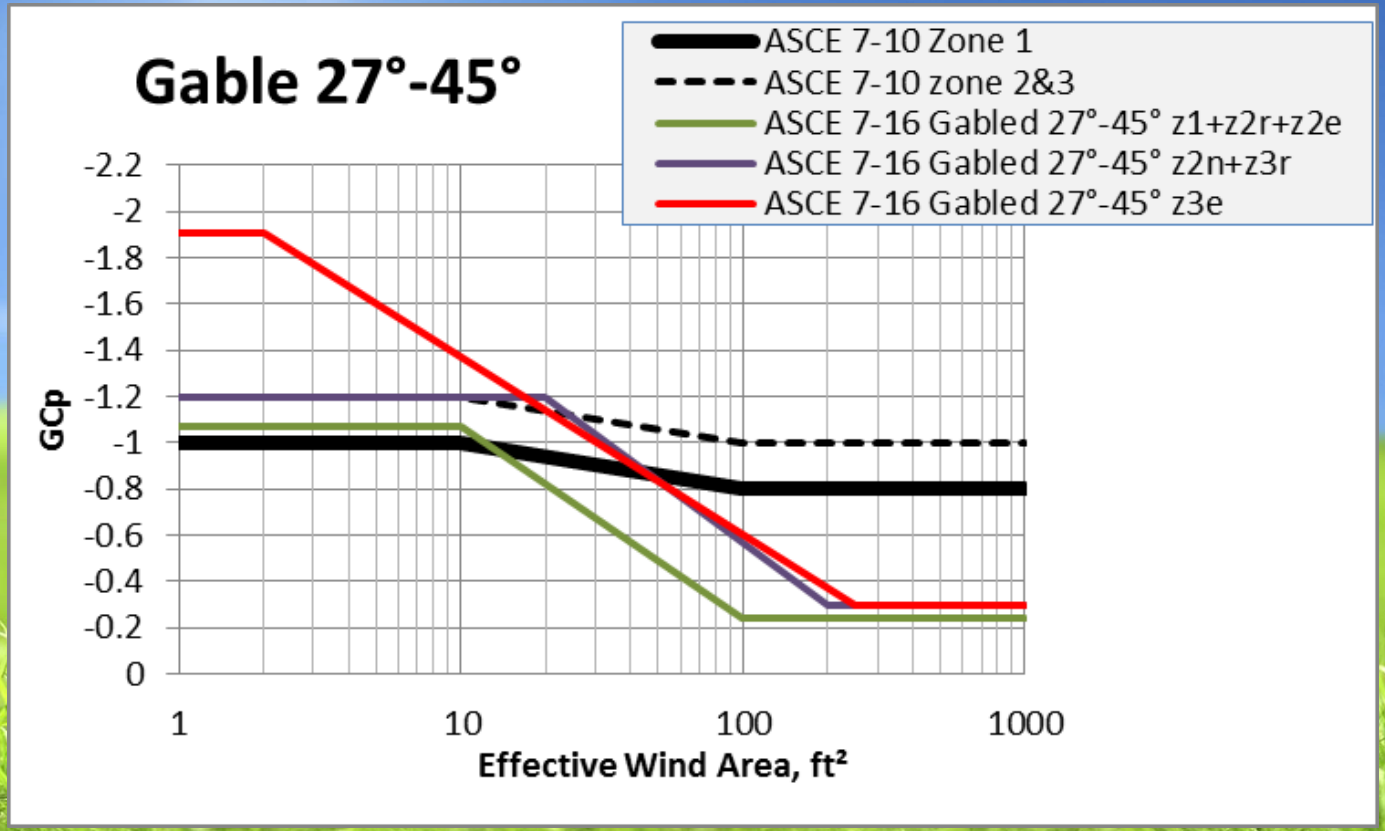
Gable 27º - 45º: Add ASCE 7-16 CA Wind Speeds



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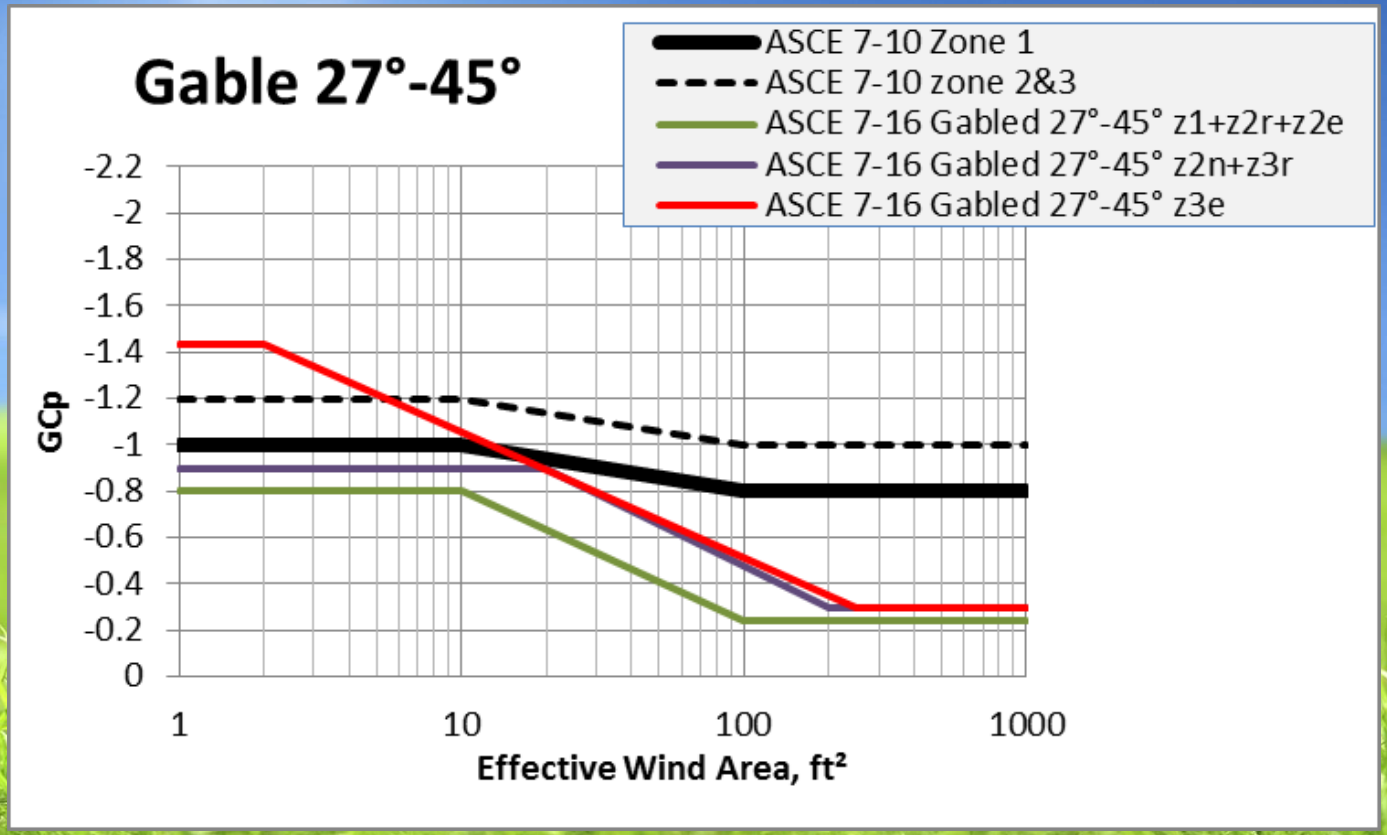
Gable 27º - 45º: Qualify for SEAOC PV2 Equalization



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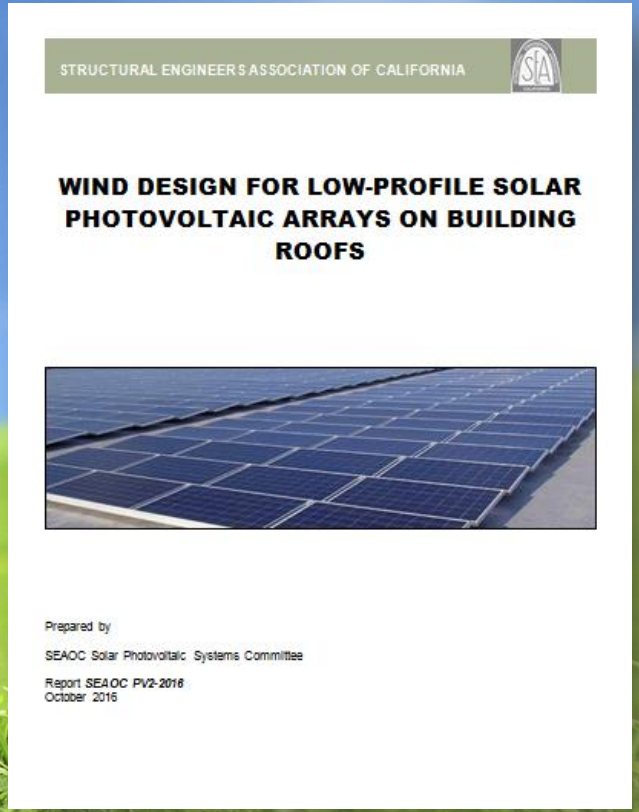
DRAFT Update to SEAOC PV2 Wind Paper


STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA

WIND DESIGN FOR LOW-PROFILE SOLAR PHOTOVOLTAIC ARRAYS ON BUILDING ROOFS

Prepared by

SEAOC Solar Photovoltaic Systems Committee

Report *SEAOC PV2-2016*
October 2016

- Original SEAOC PV 2 wind paper was published in October 2012
- Dr. David Banks of CPP Wind is primary author of PV2 update
- PV2 paper is updated to all requirements of ASCE 7-16
- Updated PV2 is expected to be published by the end of 2016
- ASCE 7-16 intended to be referenced in the 2018 IBC, and in effect by January 1, 2020 in most states

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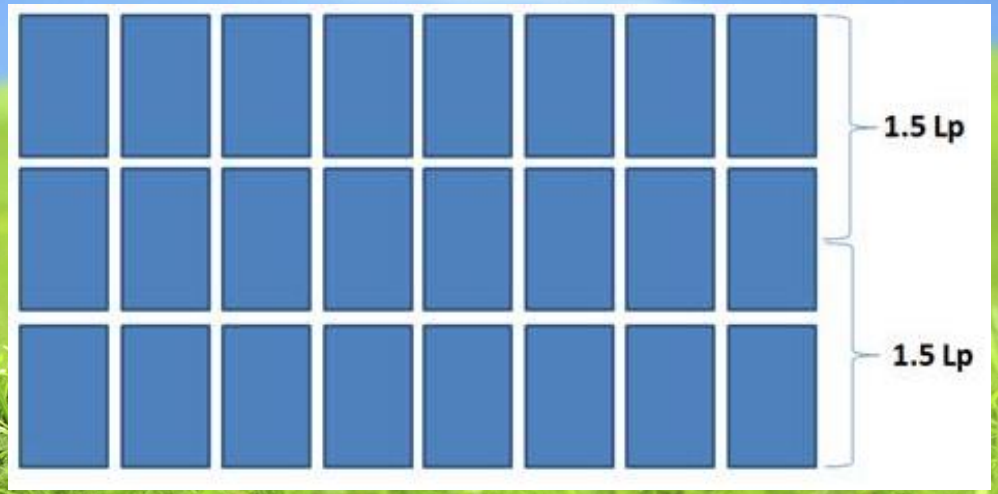
ASCE 7-16: Exploring the Edge Factor, γ_E

γ_E = 1.5 for panels that are exposed and those within a distance 1.5(L_p) from the end of a row at an exposed edge of the array; γ_E = 1.0 elsewhere, as illustrated in Figure 29.4-8. A panel is defined as exposed if d_1 to the roof edge > 0.5h and one of the following applies:

- d_1 to the adjacent array > 4 ft (1.22m)
- d_2 to the next adjacent panel > 4 ft (1.22m)



- Edge Factor γ_E ("gamma E") is a direct, linear multiplier to the wind pressure
- The value of γ_E is either 1.5 or 1.0
- In ASCE 7-16, panels within 1.5 L_p from end of row are exposed
- Result is three rows or fewer are 100% edge

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Mitigation for γ_E in (DRAFT) SEAOC PV2 Update

4.2. Optional and Alternate Procedures

The following method will provide more accurate results, and will generally decrease loads when compared to the above procedures.

In these calculations, h_1 and h_2 are defined as the distance from the roof surface to the upper surface of the panel.

4.2.1. Size of edge factor zone is a multiple of array height.

γ_E = 1.5 need only be applied to that portion of the panels within $3*h_2$ from the array edge,

4.2.2. Edge factor applies to one array edge at a time

γ_E = 1.5 need only be applied to one array edge at a time (e.g. for calculation of the total load on the array).

4.2.3. Edge factors apply only to uplift values.

γ_E = 1.0 for downforce calculations.

Flush mount only

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ASCE 7-16: PV Pressure Equalization Factor, γ_a

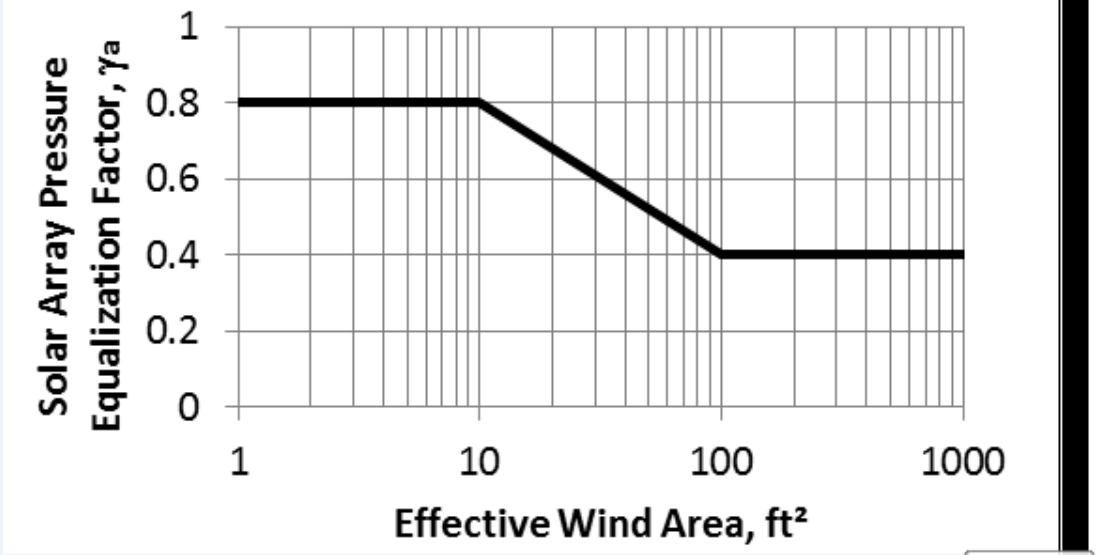

Figure 29.4-8. Solar Collector Pressure Equalization Factor, γ_a, for enclosed and partially enclosed buildings of all heights.

- Equalization Factor γ_a is a direct multiplier to wind pressure
- Wind pressure is reduced for gaps between panels
- John Wolfe public comment was disapproved by the ASCE Wind Subcommittee

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Mitigation for γ_a in DRAFT SEAOC PV2 Update

4.2.5. Increased porosity

The blue line in Figure 4.2.1 can be used if the gaps between panels are wide enough and the height above the roof is small enough. Interpolation is allowed

i. for gaps from 0.25 inches (6.4 mm) to 0.75 inches (19 mm) if h_1 <= 5 inches (127 mm) from the roof surface, or

ii. for h_1 between 5 inches (127 mm) and 10 inches (254 mm) if gaps >= 0.75 inches (19 mm).

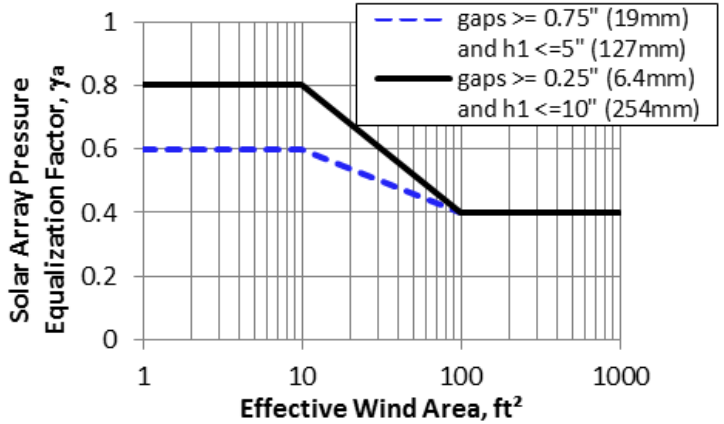

Figure 4.2.1: Pressure Equalization Factor, γ_a

- SEAOC PV2 update will include more options for pressure equalization
- Options are height of PV system above roof and gaps between modules
- This alternative method rewards designs that consider optimization for wind
- Wind pressures can be reduced by 25 percent from worst-case basis of ASCE 7-16

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Recommendations

- Communicate with AHJ's about SEAOC PV2 Wind paper
- Consider early adoption of 2*h* as minimum roof edge setback
- Ensure fire setbacks are observed if they apply to your project, based on local code adoption and local policy
- Consider panel height above the roof in the optimal range of 4 inches – 5 inches
- Consider using gap of 3/4 inch between panels

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Questions?

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