Catching Up With Solar PV Structural Requirements

SEIA Codes & Standards Symposium

Webinar Series #2

August 4th, 2020

Catching Up With Solar PV Structural Requirements

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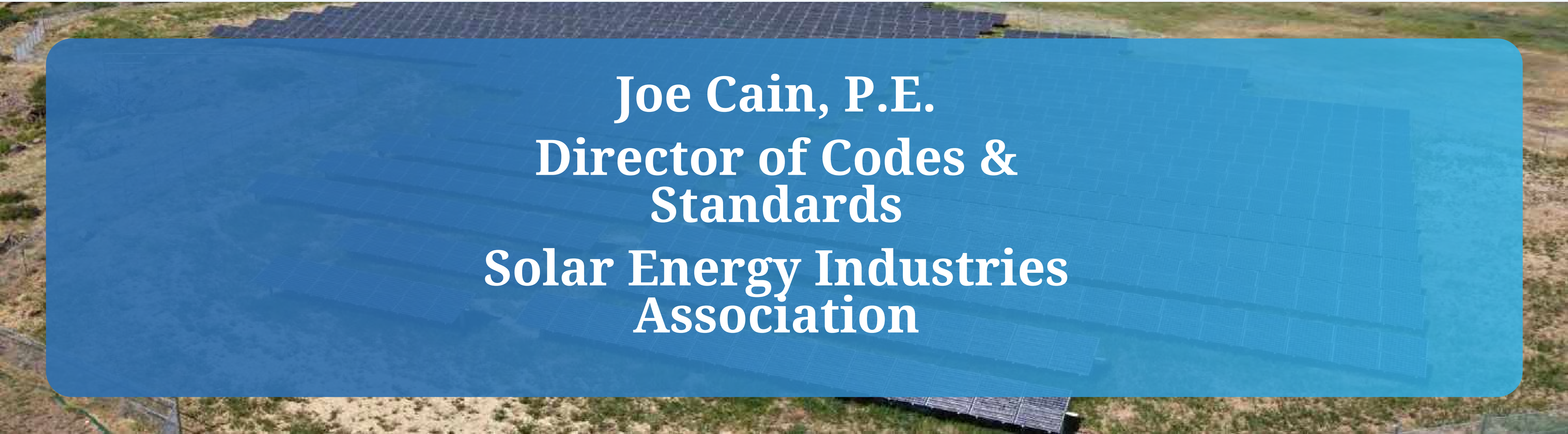
Catching Up With Solar PV Structural Requirements: A Structural Roadmap



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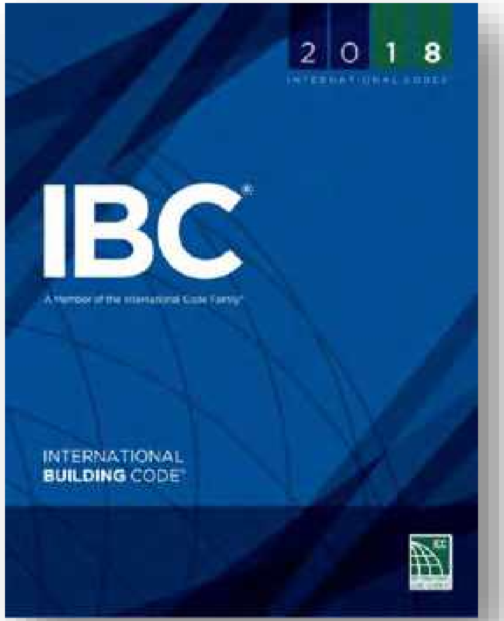
Joe Cain, P.E.

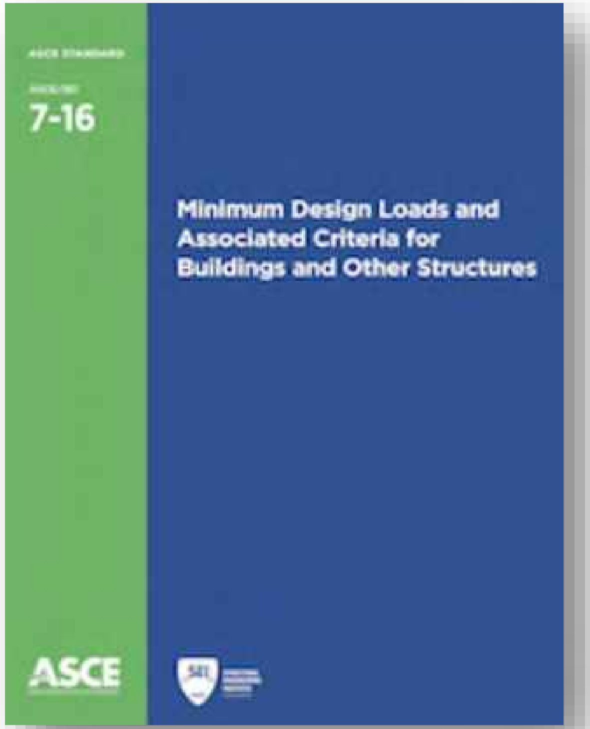
Director of Codes & Standards

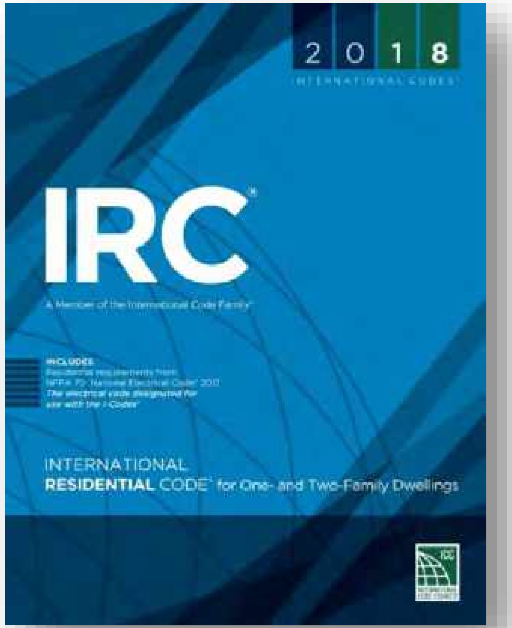
As Director of Codes & Standards, Joe leads SEIA's efforts in advocacy for development of reasonable and pragmatic codes & standards for design and installation of safe, reliable solar energy systems. In this capacity, he has authored and provided testimony as proponent of numerous SEIA code change proposals to improve national model codes, and has engaged in numerous speaking opportunities at Solar Power International and other industry and professional forums. He is staff liaison to the SEIA Codes & Standards Working Group and the Mounting System Manufacturers Committee. Prior to joining SEIA, Joe was Chair of the SEIA Codes & Standards Working Group since January 2011 -- near its inception.

2018 IBC and 2018 IRC Reference ASCE 7-16



CHAPTER 35
REFERENCED STANDARDS





CHAPTER 44
REFERENCED STANDARDS

ASCE/SEI	7—16	Minimum Design Loads and Associated Criteria for Buildings and Other Structures

ICC INTERNATIONAL CODE COUNCIL

2018 IBC Section 3111, Solar "Roadmap"

SECTION 3111

SOLAR ENERGY SYSTEMS

3111.1.1 Wind resistance.

Rooftop-mounted photovoltaic panels and modules and solar thermal collectors shall be designed in accordance with Section 1609.

3111.1.2 Roof live load.

Roof structures that provide support for solar energy systems shall be designed in accordance with Section 1607.13.5.

1609.1.1 Determination of wind loads.

Wind loads on every building or structure shall be determined in accordance with Chapters 26 to 30 of ASCE 7. The type of opening protection required, the basic design wind speed, *V*, and the exposure category for a site is permitted to be determined in accordance with Section 1609 or ASCE 7. Wind shall be assumed to come from any horizontal direction and wind pressures shall be assumed to act normal to the surface considered.

For wind resistance:

- IBC Section 3111.1.1 includes a pointer to IBC Chapter 16, Section 1609
- IBC Section 1609.1.1 includes a pointer to ASCE 7

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2018 IBC Section 1607.13.5 Live Load

3111.1.2 Roof live load.

Roof structures that provide support for solar energy systems shall be designed in accordance with Section 1607.13.5.

1607.13.5 Photovoltaic panel systems.

Roof structures that provide support for *photovoltaic panel systems* shall be designed in accordance with Sections 1607.13.5.1 through 1607.13.5.4, as applicable.

1607.13.5.1 Roof live load.

Roof structures that support photovoltaic panel systems shall be designed to resist each of the following conditions:

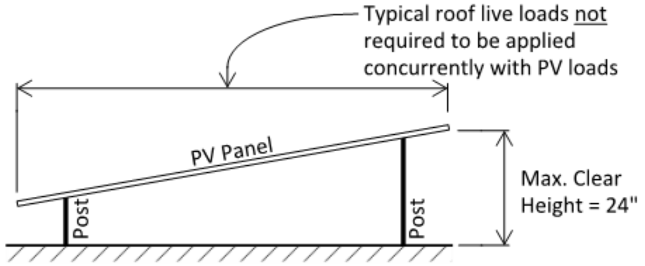
1. Applicable uniform and concentrated roof loads with the photovoltaic panel system dead loads.

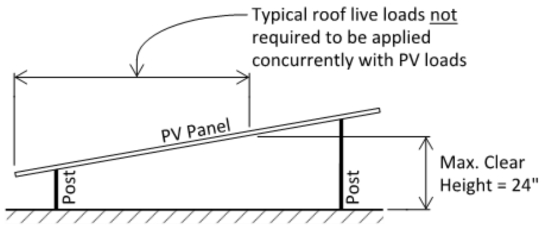
   Exception: Roof live loads need not be applied to the area covered by photovoltaic panels where the clear space between the panels and the roof surface is 24 inches (610 mm) or less.

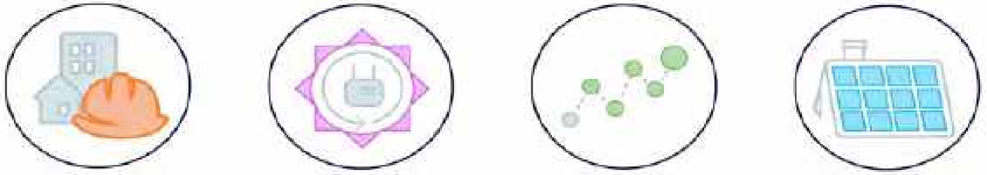
2. Applicable uniform and concentrated roof loads without the photovoltaic panel system present.

For Live Load:

- IBC 3111.1.2 includes a pointer to Section 1607.13.5
- For new buildings, roofs must be checked using live load with and without PV
- Live load can be offset (set to zero) for any portion of the roof where clear height below PV system is 24” or less







2018 IBC Section 1607.13.5 Live Load

1607.13.5.2 Photovoltaic panels or modules.

The structure of a roof that supports solar photovoltaic panels or modules shall be designed to accommodate the full solar photovoltaic panels or modules and ballast dead load, including concentrated loads from support frames in combination with the loads from Section 1607.13.5.1 and other applicable loads. Where applicable, snow drift loads created by the photovoltaic panels or modules shall be included.

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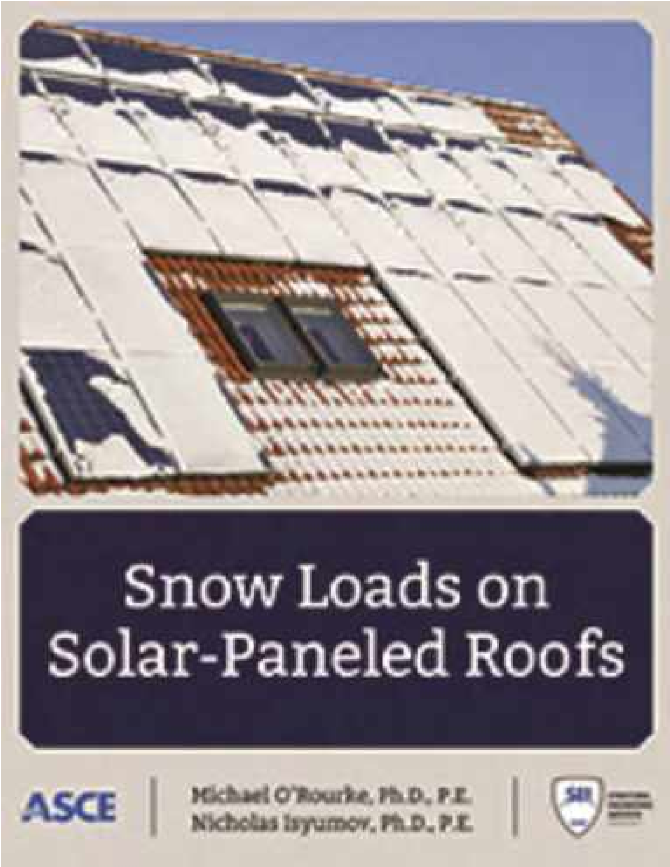
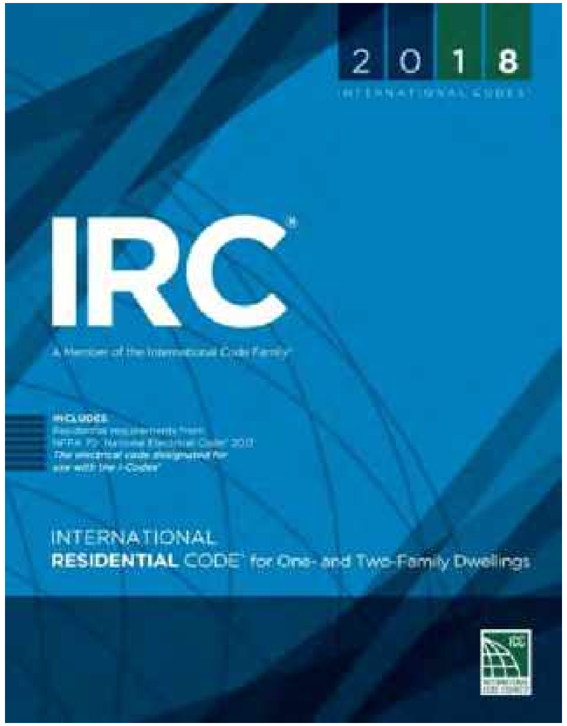
- More emphasis on considering concentrated loads, in addition to uniform loads
- General mention of snow drift loads
- ASCE published a guideline (not code) for Snow Loads on Solar-Paneled Roofs
- Extensive examples of snow drift patterns



https://ascelibrary.org/doi/pdf/10.1061/9780784480243

2018 IRC Section R324, Solar "Roadmap"



SECTION 324
SOLAR ENERGY SYSTEMS

R324.4 Rooftop-mounted photovoltaic systems.

Rooftop-mounted *photovoltaic panel systems* installed on or above the roof covering shall be designed and installed in accordance with this section.

R324.4.1 Structural requirements.

Rooftop-mounted *photovoltaic panel systems* shall be designed to structurally support the system and withstand applicable gravity loads in accordance with Chapter 3. The roof on which these systems are installed shall be designed and constructed to support the loads imposed by such systems in accordance with Chapter 8.

R324.4.1.1 Roof load.

Portions of roof structures not covered with *photovoltaic panel systems* shall be designed for dead loads and roof loads in accordance with Sections R301.4 and R301.6. Portions of roof structures covered with *photovoltaic panel systems* shall be designed for the following load cases:

1. Dead load (including *photovoltaic panel* weight) plus snow load in accordance with Table R301.2(1).
2. Dead load (excluding *photovoltaic panel* weight) plus roof live load or snow load, whichever is greater, in accordance with Section R301.6.

R324.4.1.2 Wind load.

Rooftop-mounted *photovoltaic panel* or *module* systems and their supports shall be designed and installed to resist the component and cladding loads specified in Table R301.2(2), adjusted for height and exposure in accordance with Table R301.2(3).

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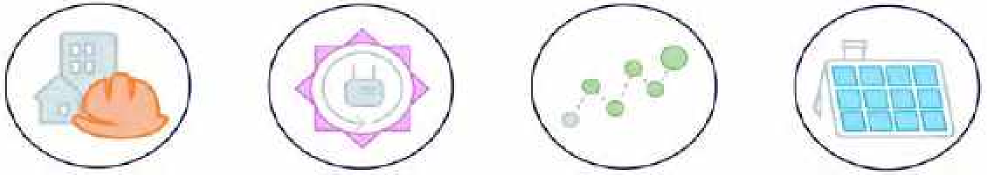
- As most residential installations are parallel-to-roof, IRC does not include 24" threshold for live load offset
- For wind load, engineers and designers are much more likely to use ASCE 7-16 provisions



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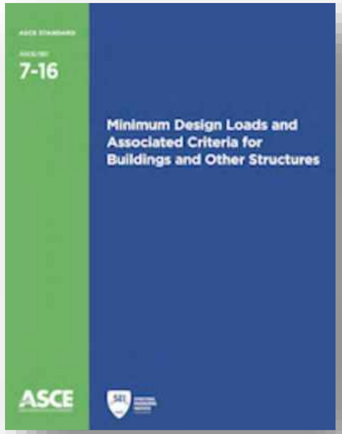
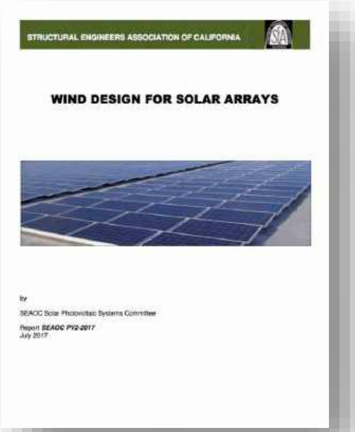
Progression of Solar Provisions – SEAOC/ASCE



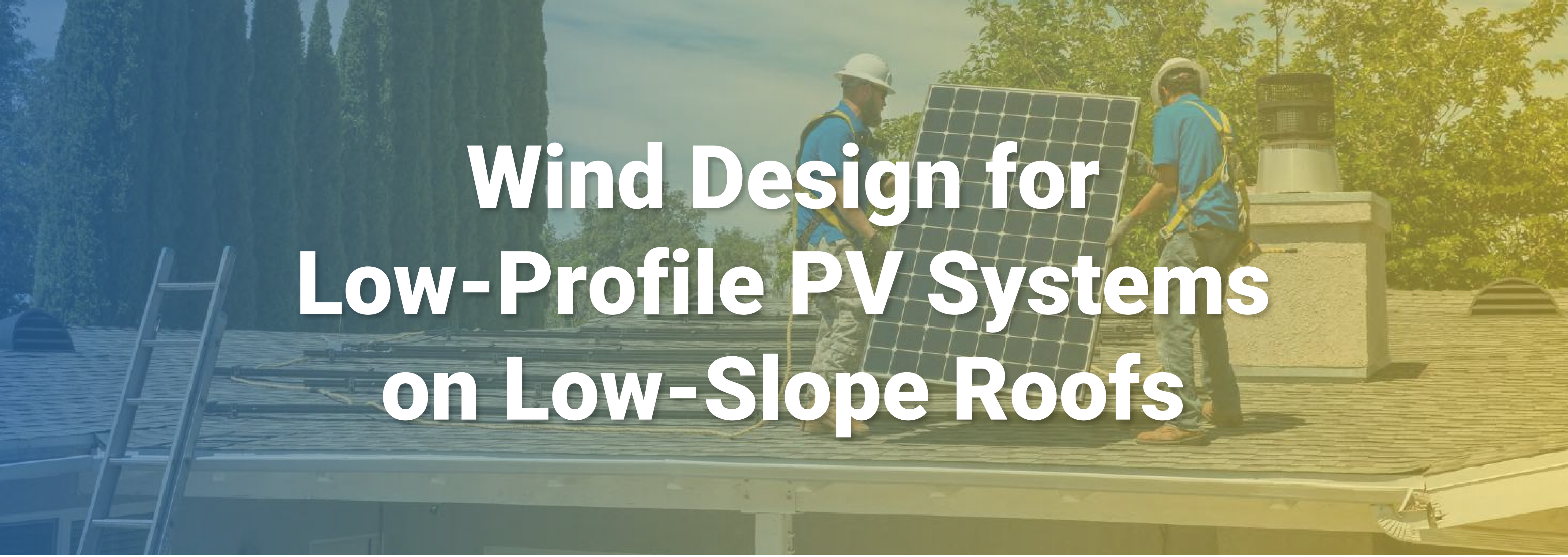


ASCE
7-22

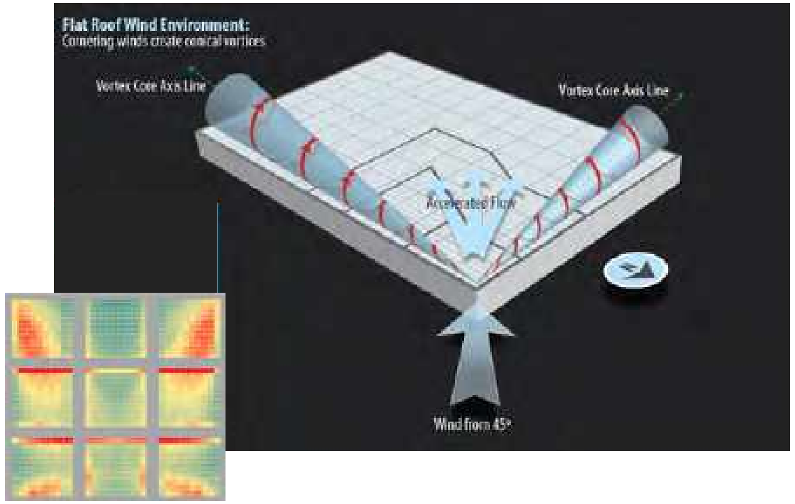
- ASCE 7-10 did not yet include any solar-specific provisions
- ASCE 7-16 is a Referenced Standard in the 2018 International Building Code (IBC)
- 2018 IBC/ASCE 7-16 effective date was January 1, 2020 in many states/regions
- ASCE 7-22 is under development, and will likely be referenced in 2024 IBC & IRC

ASCE 7-16 and SEAOC PV2-2017 (Update)

- For PV system design, strongly recommend considering SEAOC PV2-2017 as a companion document to ASCE 7-16
- https://www.seaoc.org/store/ViewProduct.aspx?id=10228815&hhSearchTerms=%2522pv2%2522
- SEAOC PV2-2017 includes “fixes” to Parallel-to-Roof Method, plus Ground Mount recommendations
- Proposals are in-progress to formalize these improvements in ASCE 7-22 (currently under development)



Wind Design for Low-Profile PV Systems on Low-Slope Roofs



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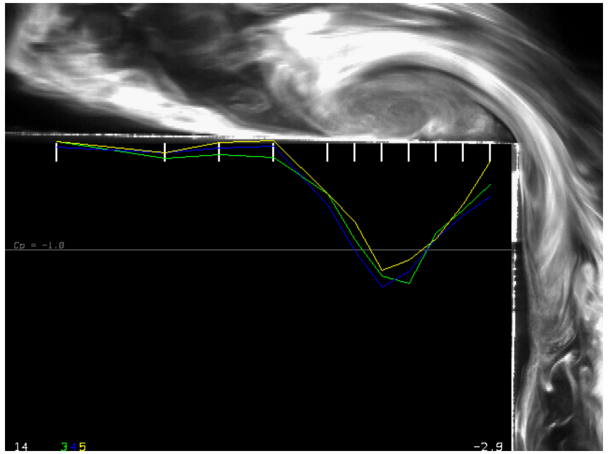

cpp CERMAK PETERKA PETERSEN

Low Profile PV Systems on Low-Slope Roofs

Fort Madison, Iowa,
300 kW

cpp CERMAK PETERKA PETERSEN

Section 29.4.3 Rooftop Solar Panels, All Heights

29.4.3 Rooftop Solar Panels for Buildings of All Heights with Flat Roofs or Gable or Hip Roofs with Slopes Less Than 7°. As illustrated in Fig. 29.4-7, the design wind pressure for rooftop solar panels apply to those located on enclosed or partially enclosed buildings of all heights with flat roofs, or with gable or hip roof slopes with $\theta \leq 7°$, with panels conforming to:

$L_p \leq 6.7$ ft (2.04 m),
$\omega \leq 35°$,
$h_1 \leq 2$ ft (0.61 m),
$h_2 \leq 4$ ft (1.22 m),

with a minimum gap of 0.25 in. (6.4 mm) provided between all panels, and the spacing of gaps between panels not exceeding 6.7 ft (2.04 m). In addition, the minimum horizontal clear distance between the panels and the edge of the roof shall be the larger of $2(h_2 - h_{pt})$ and 4 ft (1.2m) for the design pressures in this section to apply. The design wind pressure for rooftop solar panels shall be determined by Eq. (29.4-5) and (29.4-6):

$$p = q_h (GC_{rn}) (\text{lb/ft}^2) \quad (29.4\text{-}5)$$

$$p = q_h (GC_{rn}) (\text{N/m}^2) \quad (29.4\text{-}5.\text{si})$$

where

$$(GC_{rn}) = (\gamma_p)(\gamma_c)(\gamma_E)(GC_{rn})_{\text{nom}} \quad (29.4\text{-}6)$$

where

$\gamma_p = \min(1.2, 0.9 + h_{pt}/h)$;
$\gamma_c = \max(0.6 + 0.06L_p, 0.8)$; and
γ_E = 1.5 for uplift loads on panels that are exposed and 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 for uplift loads and for all downward loads, as illustrated in Fig. 29.4-7. A panel is defined as exposed if d_1 to the roof edge $> 0.5h$ and one of the following applies:

1. d_1 to the adjacent array $> \max(4h_2$, 4 ft (1.2m) or
2. d_2 to the next adjacent panel $> \max(4h_2$, 4 ft (1.2m).

$(GC_{rn})_{\text{nom}}$ = nominal net pressure coefficient for rooftop solar panels as determined from Fig. 29.4-7.

When, $\omega \leq 2°$, $h_2 \leq 0.83$ ft (0.25 m), and a minimum gap of 0.25 in. (6.4 mm) is provided between all panels, and the spacing of gaps between panels does not exceed 6.7 ft (2.04 m), the procedure of Section 29.4.4 shall be permitted.

- Design example problems are found in updated SEAOC PV2-2017 paper and new SEAOC Wind Design Manual
- Keep an eye on array edge effect factor γ_E

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Figure 29.4-7: Rooftop Solar Panels for Roofs θ ≤ 7º

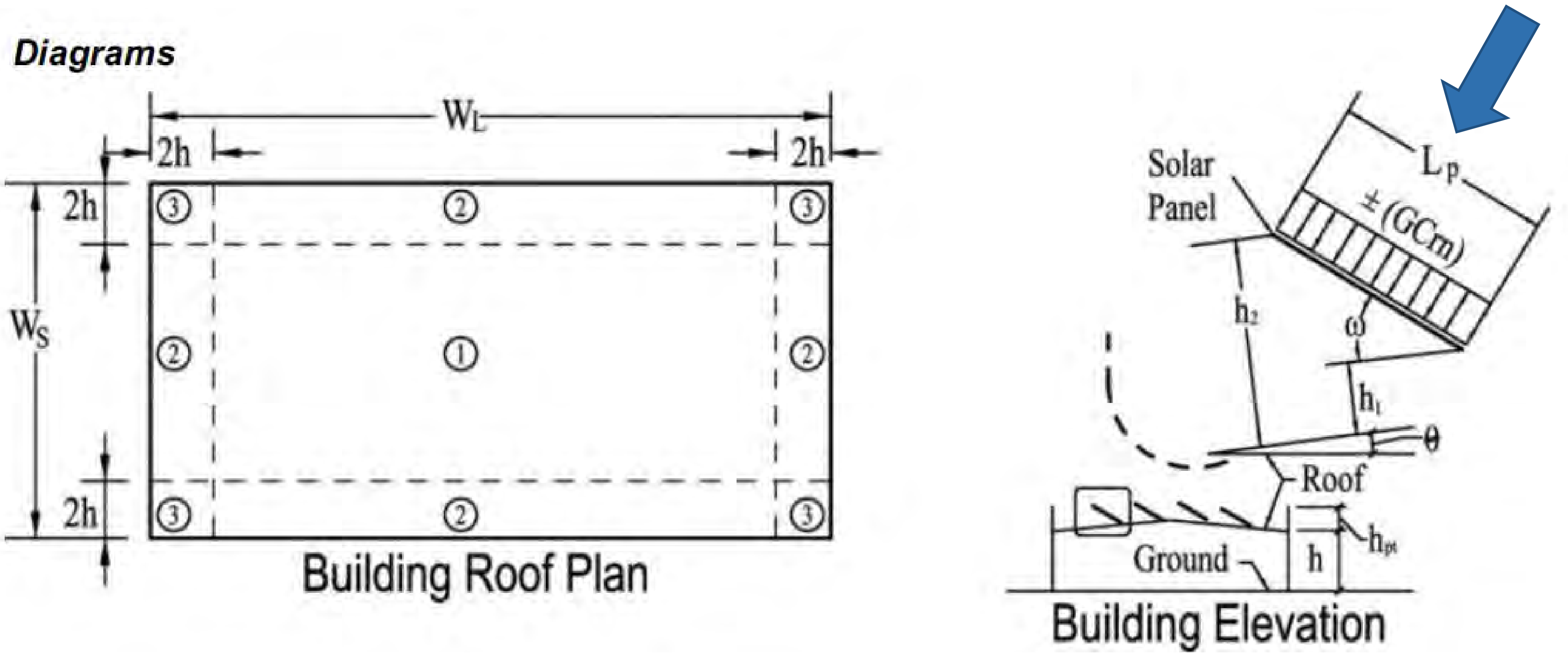

FIGURE 29.4-7 Design Wind Loads (All Heights): Rooftop Solar Panels for Enclosed and Partially Enclosed Buildings, Roof $\theta \leq 7°$

- Keep an eye on panel chord length, L_p

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Figure 29.4-7: Rooftop Solar Panels for Roofs θ ≤ 7º

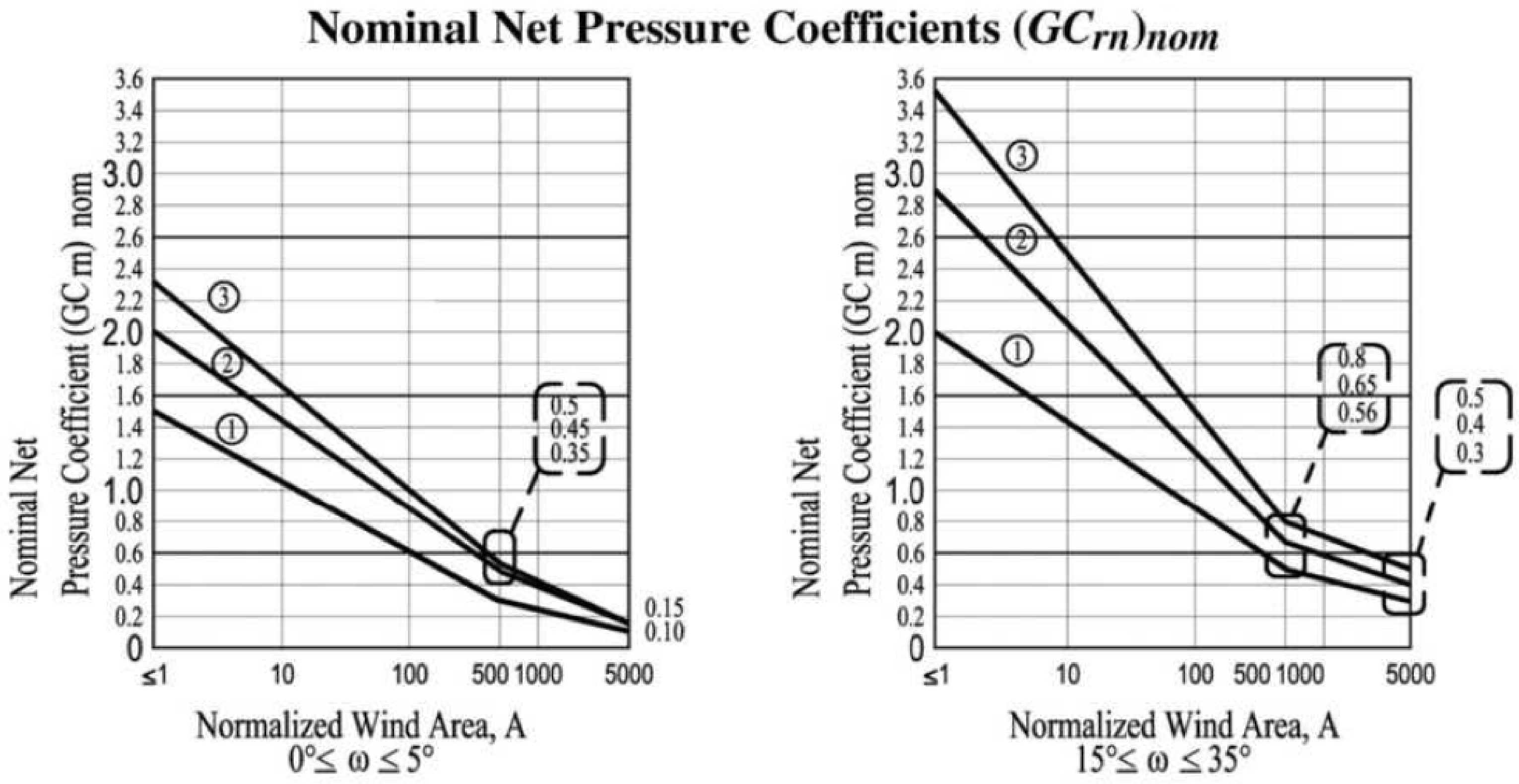


FIGURE 29.4-7 Design Wind Loads (All Heights): Rooftop Solar Panels for Enclosed and Partially Enclosed Buildings, Roof θ ≤ 7°

Figure 29.4-7: Rooftop Solar Panels for Roofs θ ≤ 7º

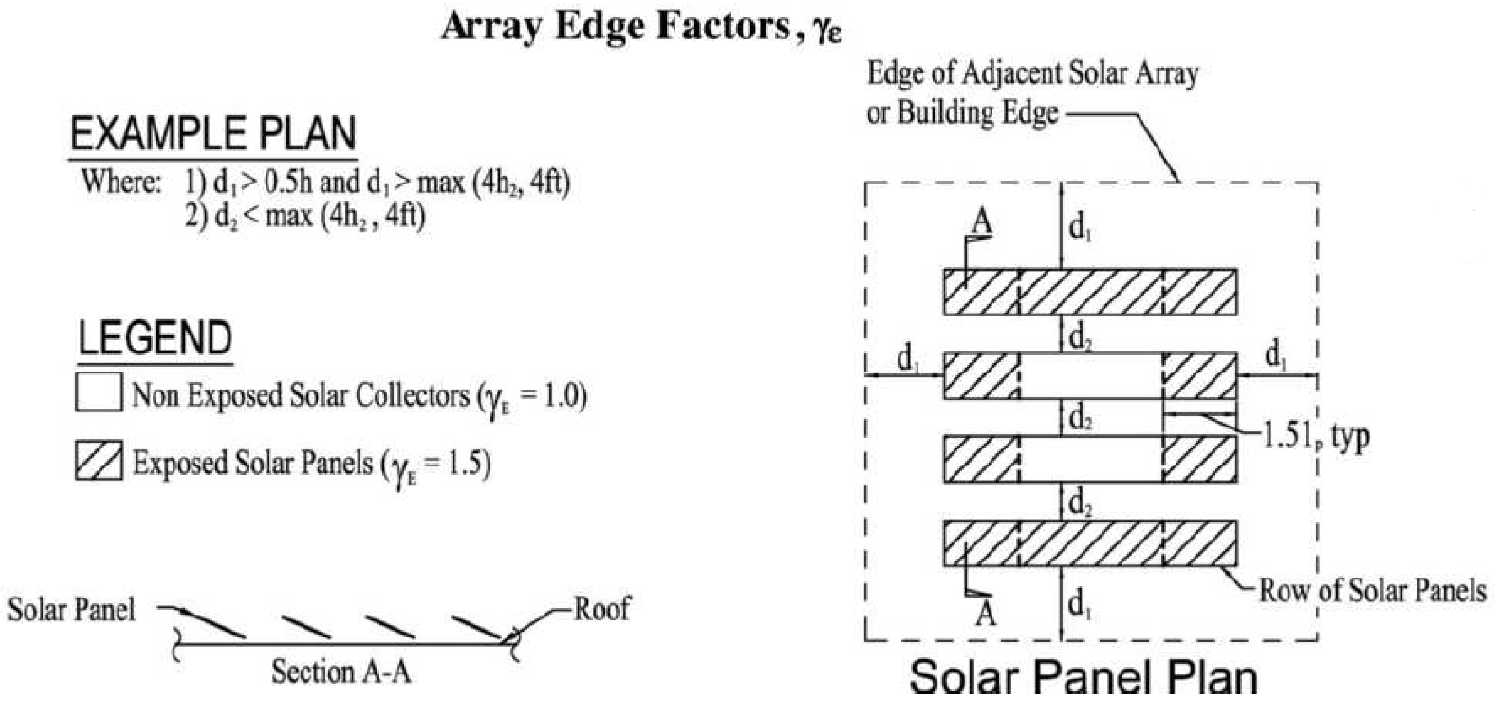


FIGURE 29.4-7 Design Wind Loads (All Heights): Rooftop Solar Panels for Enclosed and Partially Enclosed Buildings, Roof θ ≤ 7°

- For large arrays, it makes sense that array edge effects would extend into the array a distance of approximately 1.5 times the chord length
- For downforce, $\gamma_E = 1.0$

Figure 29.4-7: Rooftop Solar Panels for Roofs θ ≤ 7º

Notation

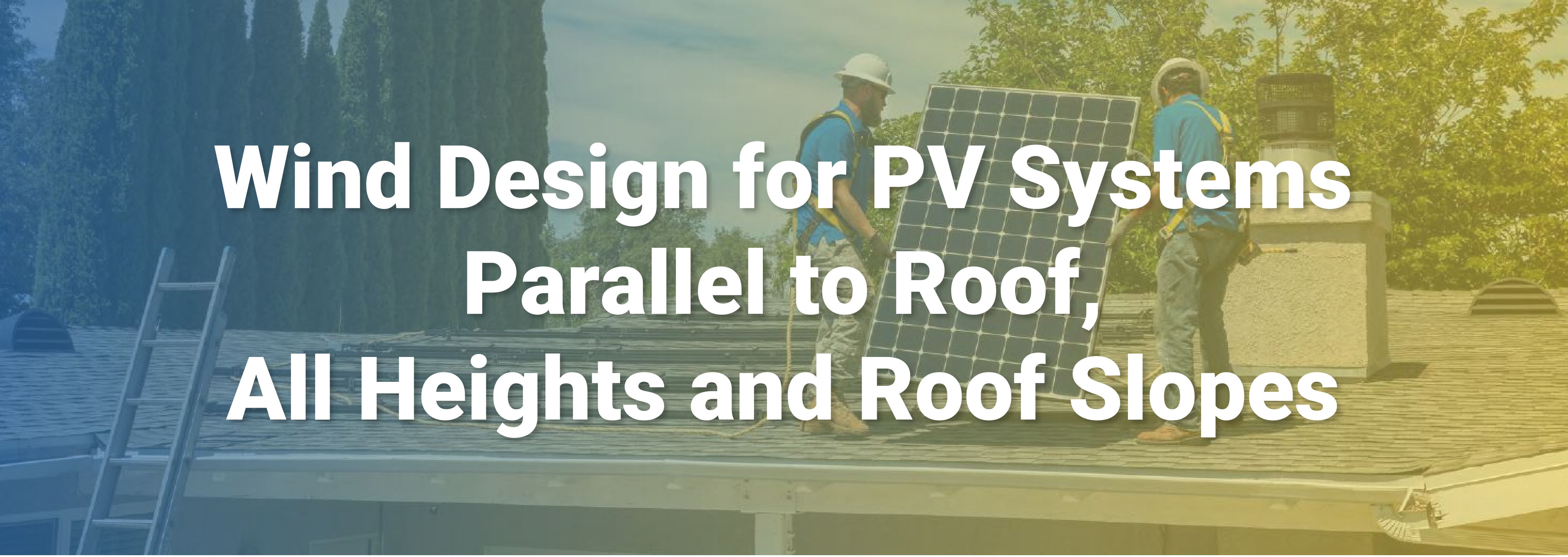
A = Effective wind area, in ft^2 (m^2).
A_n = Normalized wind area, non-dimensional.
d_1 = For rooftop solar array, horizontal distance orthogonal to the panel edge to an adjacent panel or the building edge, ignoring any rooftop equipment in Fig. 29.4-7, in ft (m).
d_2 = For rooftop solar arrays, horizontal distance from the edge of one panel to the nearest edge in the next row in Fig. 29.4-7, in ft (m).
h = Mean roof height of a building except that eave height shall be used for roof angle θ less than or equal to 10°, in ft (m).
h_1 = Height of the gap between the panels and the roof surface, in ft (m).
h_2 = Height of a solar panel above the roof at the upper edge of the panel, in ft (m).
h_{pt} = Mean parapet height above the adjacent roof surface for use with Eq. (29.4-5), in ft (m).
L_p = Panel chord length.
W_L = Width of a building on its longest side in Fig. 29.4-7, in ft (m).
W_S = Width of a building on its shortest side in Fig. 29.4-7, in ft (m).
γ_E = Array edge factor as defined in Section 29.4.4.
θ = Angle of plane of roof from horizontal, in degrees.
ω = Angle that the solar panel makes with the roof surface in Fig. 29.4-7, in degrees.

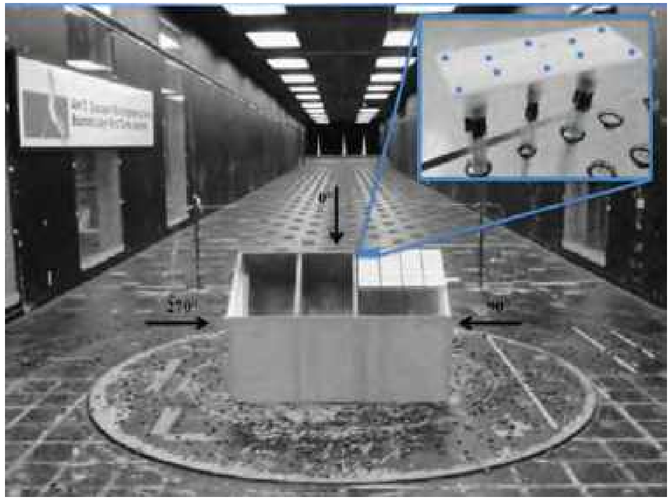
Notes

1. (GC_m) acts toward (+) and away (-) from the top surface of the panels.
2. Linear interpolation is allowed for ω between 5° and 15°.
3. $A_n = (1,000/[\max(L_b, 15)^2]A$, where A is the effective wind area of the structural element of the solar panel being considered, and L_b is the minimum of $0.4(hW_L)^{0.5}$ or h or W_s in ft (m).

FIGURE 29.4-7 (*Continued*). Design Wind Loads (All Heights): Rooftop Solar Panels for Enclosed and Partially Enclosed Buildings, Roof θ ≤ 7°

Wind Design for PV Systems Parallel to Roof, All Heights and Roof Slopes





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

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Western University · Canada

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Section 29.4.4: Parallel to Roof, All Heights and Roof Slopes

29.4.4 Rooftop Solar Panels Parallel to the Roof Surface on Buildings of All Heights and Roof Slopes. The design wind pressures for rooftop solar panels located on enclosed or partially enclosed buildings of all heights, with panels parallel to the roof surface, with a tolerance of 2° and with a maximum height above the roof surface, h_2, not exceeding 10 in. (0.25 m) shall be determined in accordance with this section. A minimum gap of 0.25 in. (6.4 mm) shall be 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 rooftop solar collectors shall be determined by Eq. (29.4-7):

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

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

- The form of Formula 29.4-7 is very familiar; it is a velocity pressure times a combined pressure coefficient
- Array edge factor, γ_E, is carried over
- Solar panel pressure equalization factor, γ_a, is new
- **Important: "A minimum gap of 0.25 in. (6.4 mm) shall be provided between all panels"**
- What if a rail-less or shared-rail system has zero gap in one direction?
- The 6.7 ft maximum spacing between gaps does not work for solar thermal panels, which are typically 8 ft or 10 ft in longest dimension
- **Important: The array shall be located at least $2h_2$ from the roof edge**

Section 29.4.4: Parallel to Roof, All Heights and Roof Slopes

where

(GC_p) = external pressure coefficient for C&C of roofs with respective roof zoning, determined from Figs. 30.3-2A-I through 30.3-7 or 30.5-1;

γ_E = array edge factor = 1.5 for uplift loads on panels that are exposed and 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 for uplift loads and for all downward loads, as illustrated in Fig. 29.4-7. A panel is defined as exposed if d_1 to the roof edge $> 0.5h$ and one of the following applies:

1. d_1 to the adjacent array > 4 ft (1.2 m) or
2. d_2 to the next adjacent panel > 4 ft. (1.2 m);

γ_a = solar panel pressure equalization factor, defined in Fig. 29.4-8.

- The method for determining array edge factor, γ_E, was carried over from low-slope roof section without a needed modification, and is addressed in SEAOC PV2-2017 white paper
- Solar panel pressure equalization factor, γ_a, is overly conservative, and is addressed in SEAOC PV2-2017 white paper

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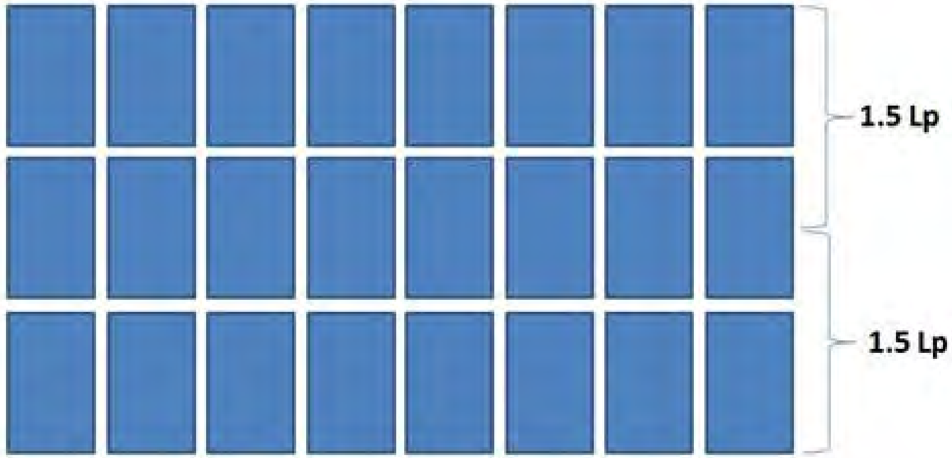
Section 29.4.4: Parallel to Roof, All Heights and Roof Slopes

γ_E = array edge factor = 1.5 for uplift loads on panels that are exposed and 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 for uplift loads and for all downward loads, as illustrated in Fig. 29.4-7. A panel is defined as exposed if d_1 to the roof edge $> 0.5h$ and one of the following applies:

1. d_1 to the adjacent array > 4 ft (1.2 m) or
2. d_2 to the next adjacent panel > 4 ft. (1.2 m);



- Array Edge Factor γ_E ("gamma E") is a direct, linear multiplier to the wind pressure
- The value of γ_E in uplift 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
- Oops

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Mitigation for γ_E in SEAOC PV2-2017 and ASCE 7-22

5.3.3. Width of array perimeter strip for applying array edge factor

For flush-mounted panels, γ_E may be taken as 1.5 for the portion of exposed panels that is within a distance $2h_2$ from the edge of the array.

Flush mount only

Commentary: ASCE 7-16 Section 29.4.4 (flush-mounted arrays) defines the width of the array perimeter strip for applying the array edge factor γ_E in the same way that it is defined in Section 29.4.3 (tilted panels on flat roofs): 1.5 times the panel chord length, L_p. However, for flush-mounted arrays, the height h_2 of the top of panels above the roof surface is more influential than the panel chord length. (Also L_p is not well-defined for the continuous surface created by flush-mounted panels.)

Thus, for flush-mounted arrays, we recommend defining the array perimeter strip in terms of the height h_2 of the top of panels above the roof surface. For flush-mounted systems, elevated pressures at array edges are largely the result of flow separation from the roof and reattachment on the top of the panels, which occurs over a distance roughly $2h_2$ from the edge of the array.

Flush mount only

- In ASCE 7-16, panels within 1.5 L_p from end of row are exposed
- This is a mistake that is corrected in SEAOC PV2-2017
- SEAOC PV2-2017 clarifies the array edge distance should be $2*h_2$, which is consistent with roof edge distance
- A similar correction is in-progress for ASCE 7-22

Figure 29.4-8: Parallel to Roof, All Heights and Roof Slopes

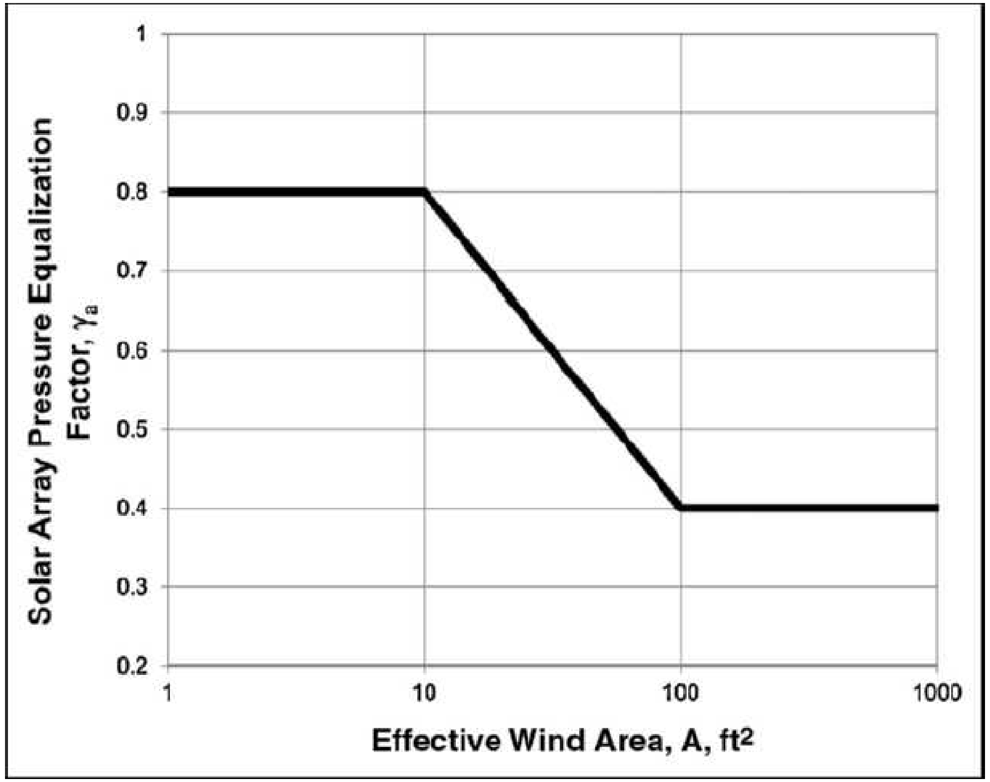

FIGURE 29.4-8 Solar Panel Pressure Equalization Factor, γ_a, for Enclosed and Partially Enclosed Buildings of All Heights

- Equalization Factor γ_a is a direct multiplier to wind pressure
- Wind pressure is reduced for gaps between panels
- Single "curve" in ASCE 7-16 with 0.8 γ_a is based on compound worst-case of ¼" gaps and 10 in. above roof
- A public comment for ASCE 7-16 was not approved by the Wind Loads Subcommittee

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Mitigation for γ_a in SEAOC PV2-2017 and ASCE 7-22

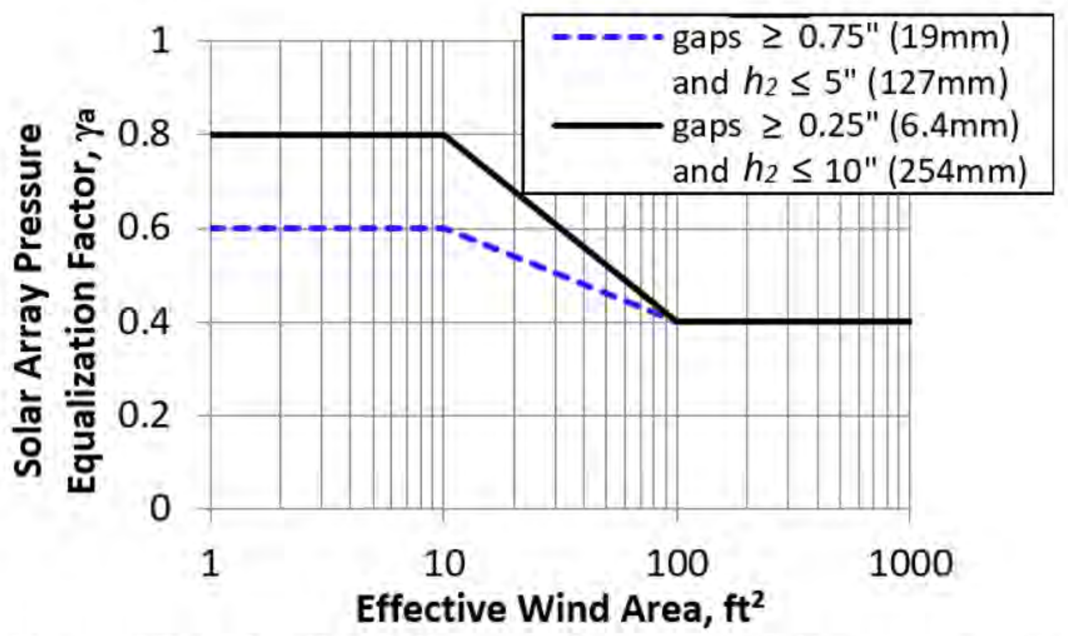

Figure 12: Solar Panel Pressure Equalization Factor, γ_a, with proposed alternative to ASCE 7-16 Figure 29.4-8 to permit smaller design pressures for conditions with larger gaps between modules and smaller height above the roof.

- SEAOC PV2-2017 includes more options for pressure equalization
- Variables 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
- This same improvement (with minor variation) is in progress for future ASCE 7-22

Seismic Design and Associated Criteria for Ballasted, Unattached Solar Arrays on Low-Slope Roofs

2018 IBC Section 1613.3 Ballasted PV Systems

1613.3 Ballasted photovoltaic panel systems.

Ballasted, roof-mounted *photovoltaic panel systems* need not be rigidly attached to the roof or supporting structure. Ballasted nonpenetrating systems shall be designed and installed only on roofs with slopes not more than one unit vertical in 12 units horizontal. Ballasted nonpenetrating systems shall be designed to resist sliding and uplift resulting from lateral and vertical forces as required by Section 1605, using a coefficient of friction determined by acceptable engineering principles. In structures assigned to *Seismic Design Category* C, D, E or F, ballasted nonpenetrating systems shall be designed to accommodate seismic displacement determined by nonlinear response-history or other approved analysis or shake-table testing, using input motions consistent with ASCE 7 lateral and vertical seismic forces for nonstructural components on roofs.

- Applies to roof slopes not more than 1:12

In SDC C, D, E or F:

- Shake table testing
- Non Linear Response History (NLRH) Analysis
- Other *approved* analysis

ICC INTERNATIONAL CODE COUNCIL

- Although ASCE 7-16 has criteria for ballasted, unattached PV systems, the language in Section 1613.3 is also important

ASCE 7-16 Section 13.6.12

13.6.12 Rooftop Solar Panels. Rooftop solar panels and their attachments shall be designed for the forces and displacements determined in Section 13.3.

EXCEPTION: Ballasted solar panels without positive direct attachment to the roof structure are permitted on Risk Category I, II, and III structures six stories or fewer in height and having a maximum roof slope equal to or less than 1 in 20, provided that they comply with the following:

Ballasted, unattached PV systems are permitted to be installed as an Exception to Section 13.6.12

- A total of 7 “associated criteria” conditions must be met

We can parse the provisions in Section 13.6.12 into three categories of requirements:

- Qualifying Criteria
- Design Criteria
- Installation Criteria

ASCE 7-16 Section 13.6.12 - Qualifying Criteria

13.6.12 Rooftop Solar Panels. Rooftop solar panels and their attachments shall be designed for the forces and displacements determined in Section 13.3.

EXCEPTION: Ballasted solar panels without positive direct attachment to the roof structure are permitted on Risk Category I, II, and III structures six stories or fewer in height and having a maximum roof slope equal to or less than 1 in 20, provided that they comply with the following:

1. The height of the center of mass of any panel above the roof surface is less than half the least spacing in plan of the panel supports, but in no case greater than 3 ft (0.9 m).

(See conditions 2 through 6 on other slides)

7. Where justified by testing and analysis, the maximum roof slope for structures assigned to SDC C and D shall be permitted to be 1 in 12 provided that independent peer review is conducted in accordance with Section 1.3.1.3.4.

Qualifying Criteria:

- Exception: Risk Category I, II, or III only
- Exception: Structures six stories or fewer in height
- Exception: Maximum roof slope equal to or less than 1 in 20
- Condition 7. Where justified, maximum roof slope in SDC C and D equal to or less than 1:12 with independent peer review
- Note IBC Section 1613.3 allows up to 1:12 pitch roofs without peer review, and where the model code (IBC) disagrees with a referenced standard (ASCE 7), the model code governs
- Condition 1 requires that this method is valid for low-profile PV systems (low center of mass) only

ASCE
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ASCE 7-16 Section 13.6.12 - Design Criteria

2. Each panel is designed to accommodate without impact, instability, or loss of support a seismic displacement, δ_{mpv}, of the panel relative to any roof edge or offset and any other curb or obstruction to sliding on the roof surface where δ_{mpv} is determined in accordance with Eq. (13.6-1), but is not taken as less than 2 ft (1.2 m):

$$\delta_{mpv} = 5I_e(S_{DS} - 0.4)^2 [\text{ft(m)}] \qquad (13.6\text{-}1)$$

The minimum separation between adjacent unattached panels shall be taken as $0.5\delta_{mpv}$. Signage or roof markings (e.g., yellow stripes) shall be provided delineating the area around the panel that must be kept free of obstructions. Alternatively, δ_{mpv} may be determined by shake table testing or nonlinear response history analysis, whereby the value of δ_{mpv} shall not be taken as less than 80% of the value given by Eq. (13.6-1) unless independent peer review is conducted in accordance with Section 1.3.1.3.4.

Design Criteria:

- Formula 13.6-1 establishes maximum expected displacement for PV systems, based on S_{DS} and Importance Factor, I_e
- Alternatively, δ_{mpv} may be determined by shake table testing, or
- Nonlinear response history (NLRH) analysis
- For NLRH Analysis, the value of δ_{mpv} shall not be taken as less than 80% of the value given by Eq. (13.6-1)
- For NLRH Analysis, the value of δ_{mpv} may be less than 80% with independent peer review
- SEIA "floor modification" for 2018 IBC development process added "*approved* analysis" to the list of allowed methods

ASCE 7-16 Section 13.6.12 – Design Criteria

3. Each panel is interconnected to resist a horizontal force of $0.2S_{DS}W_{pi}$, across any section cut by a vertical plane, where W_{pi} is the weight of the smaller of the two portions.
4. Panel framing and supports are designed for a seismic force path from the center of mass of each component to locations of friction resistance equal to the lesser of F_p from Section 13.3.1 and $0.6W_p$, where W_p is the weight of each component.

Design Criteria (continued):

- Condition 3: Mounting system must be interconnected to resist horizontal force of 0.2SDSWpi
- **IMPORTANT: A proposal under development for ASCE 7-22 will specifically disallow this force to be transmitted through PV panels, unless specifically tested or justified for that condition**
- Condition 4: Mounting system must be designed to distribute lateral forces and deliver them to the roof surface
- NOTE: These design criteria will discourage arrays of odd shape that are unable to distribute seismic forces

ASCE
American Society of Civil Engineers

ASCE 7-16 Section 13.6.12 – Installation Criteria

6. All edges and offsets of roof surfaces on which panels are placed are bounded by a curb or parapet not less than 12 in. (0.3 m) in height and designed to resist a concentrated load applied at the probable points of impact between the curb or parapet and the panel of not less than $0.2S_{DS}$ times the weight of the panel. Alternatively, a panel may be placed so that all parts of the panel are a minimum of $2.0\delta_{mpv}$, but not less than 4 ft (1.22 m), from any roof edge or offset.

Installation Criteria:

- Condition 6: Place arrays such that all parts of the array are a minimum of $2.0\delta_{mpv}$ from any roof edge or offset

  -- and –

- Condition 6: All parts of any array not less than 4 feet from any roof edge or offset

Because: You do not want to design curbs or parapets for impact loads of not less than $0.2S_{DS}$ times the weight of the "panel."

ASCE
American Society of Civil Engineers

ASCE 7-16 Section 13.6.12 – Installation Criteria

2. Signage or roof markings (e.g., yellow stripes) shall be provided delineating the area around the panel that must be kept free of obstructions.

5. All electrical cables leading from a panel to another panel or to another roof object are designed to accommodate, without rupture or distress, differential movements between cable connection points of $1.0\delta_{mpv}$, with consideration given to torsional movement of the panel and its possible impingement on the electrical cables.

Installation Criteria:

- Condition 2: Roof marking such as yellow stripes shall be provided on the physical surface of the roof -- or --
- Condition 2 alternative: Signage or marking denotes boundary where sliding may occur
- Condition 5: Electrical connections must be capable of accommodating movement of $1.0\delta_{mpv}$

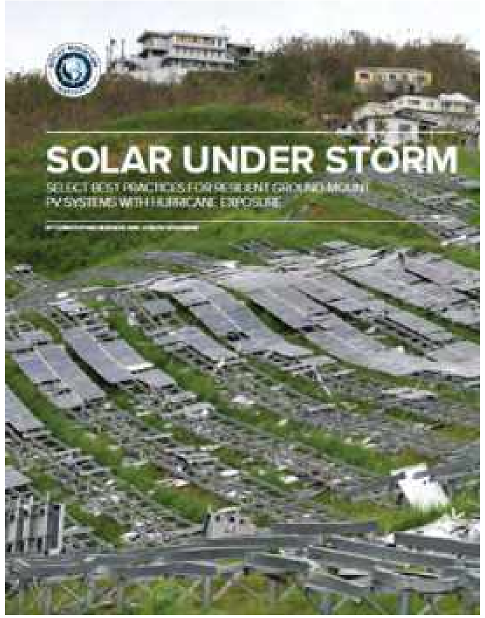
2020 NFPA 70 (NEC) Section 690.31(F)

(F) Wiring Methods and Mounting Systems. Roof-mounted PV array mounting systems shall be permitted to be held in place with an approved means other than those required by 110.13 and shall utilize wiring methods that allow any expected movement of the array.

Informational Note: Expected movement of unattached PV arrays is often included in structural calculations.

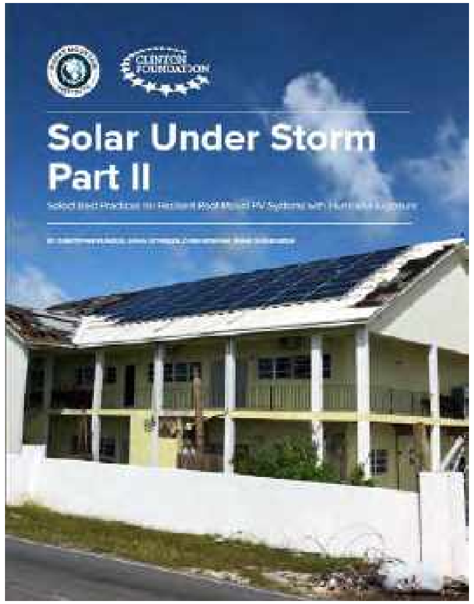
Additional Resources

RMI Report: Solar Under Storm Parts I and II



Part I: Ground Mount

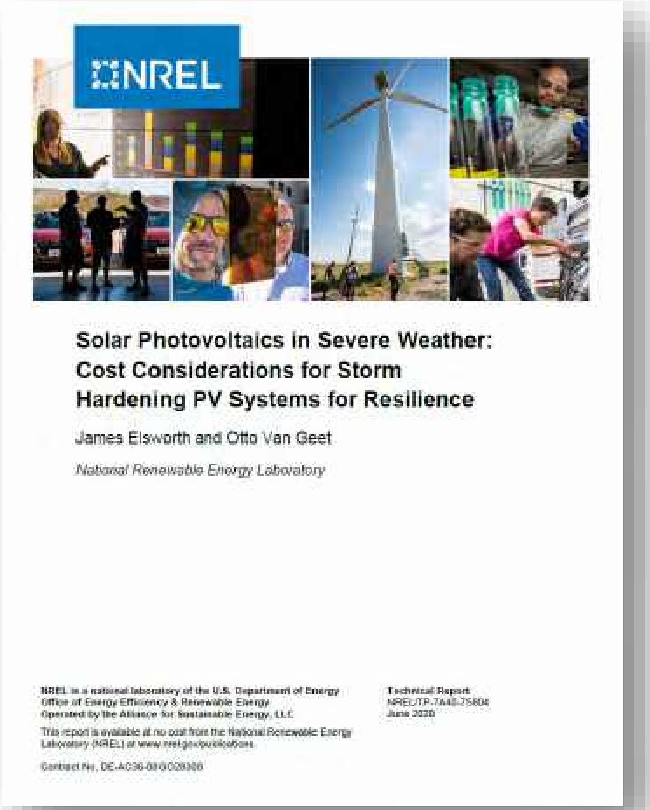
- Solar Under Storm focuses on performance of PV systems in Puerto Rico during Hurricanes Irma and Maria
- Study of characteristics in common of those systems that performed well, versus systems that experienced partial or complete failure
- Reports include detailed Failure Modes & Effects Analysis (FMEA) for individual system components
- Finding and recommendations are relevant to any PV systems designed and installed in high-wind regions



Part II: Roof Mount

https://rmi.org/solar-under-storm-designing-hurricane-resilient-pv-systems/
https://rmi.org/solar-under-storm-part-ii-designing-hurricane-resilient-pv-systems/
https://rmi.org/solar-under-storm-for-policymakers/#:~:text=The%20Solar%20Under%20Storm%20for,system%20construction%20oversight%20and%20approval.

NREL: Cost Considerations for Storm Hardening



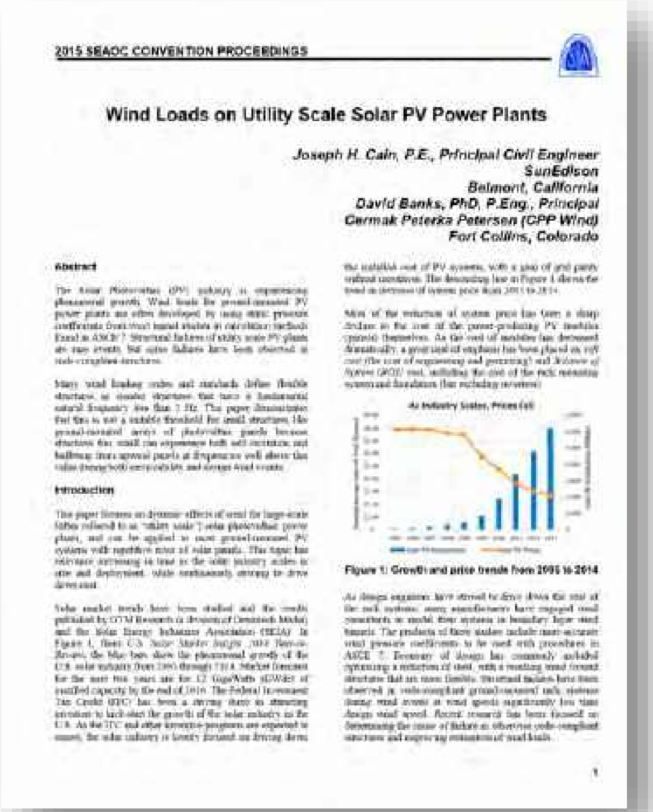
https://www.nrel.gov/docs/fy20osti/75804.pdf

Previous efforts have identified various system measures and practices that can increase the likelihood of a PV system surviving a severe weather event (Robinson 2018; Burgess 2018; FEMA 2018). This report provides initial estimates for the up-front cost premiums for various methods of storm hardening PV systems.

This report aims to:

- Provide an initial estimate of the additional costs of various storm hardening measures for PV systems
- Disseminate information and about strengthening PV systems and to foster greater industry communication and momentum around the topic
- Promote a greater consideration for potential lifetime PV system maintenance costs
- Encourage a greater consideration of the site environmental conditions and extreme weather events a PV system is likely to encounter over its operational lifetime
- Help developers weigh the costs of storm hardening a PV system compared to the costs of recovering, repairing, and repowering a compromised system following an extreme weather event
- Provide a resource for developers installing systems in severe weather locations, site operators, investors, codes and standards developers, among others.
- Promote the installation of more resilient PV systems
- Form the foundations of future work to more accurately estimate the costs of installing resilient PV systems.

SEAOC Conference Papers – Cain & Banks


2015 SEAOC CONVENTION PROCEEDINGS

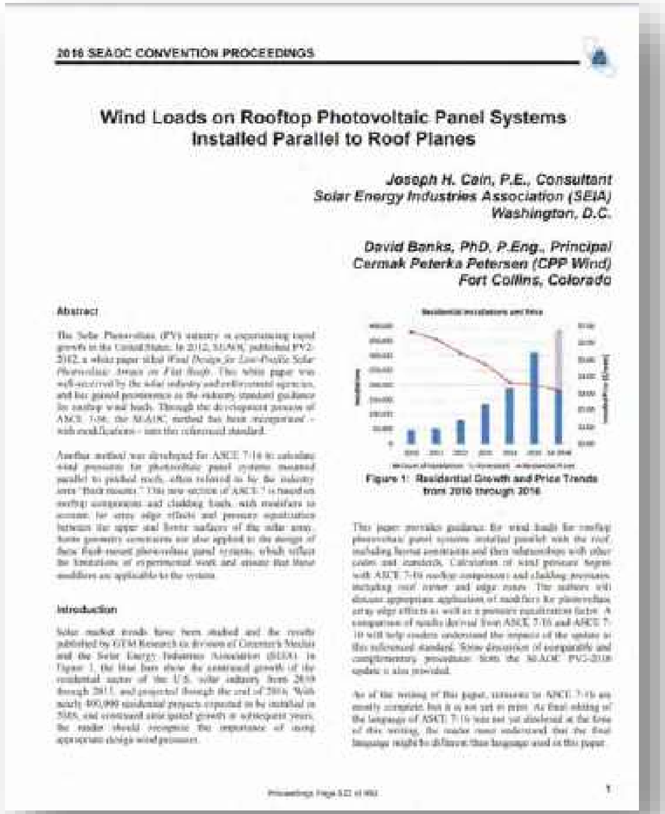
Wind Loads on Utility Scale Solar PV Power Plants

Joseph H. Cain, P.E., Principal Civil Engineer
SunEdison
Belmont, California
David Banks, PhD, P.Eng., Principal
Cermak Peterka Petersen (CPP Wind)
Fort Collins, Colorado

Abstract

Introduction

Figure 1: Growth and price trends from 2005 to 2014


2016 SEAOC CONVENTION PROCEEDINGS

Wind Loads on Rooftop Photovoltaic Panel Systems Installed Parallel to Roof Planes

Joseph H. Cain, P.E., Consultant
Solar Energy Industries Association (SEIA)
Washington, D.C.

David Banks, PhD, P.Eng., Principal
Cermak Peterka Petersen (CPP Wind)
Fort Collins, Colorado

Abstract

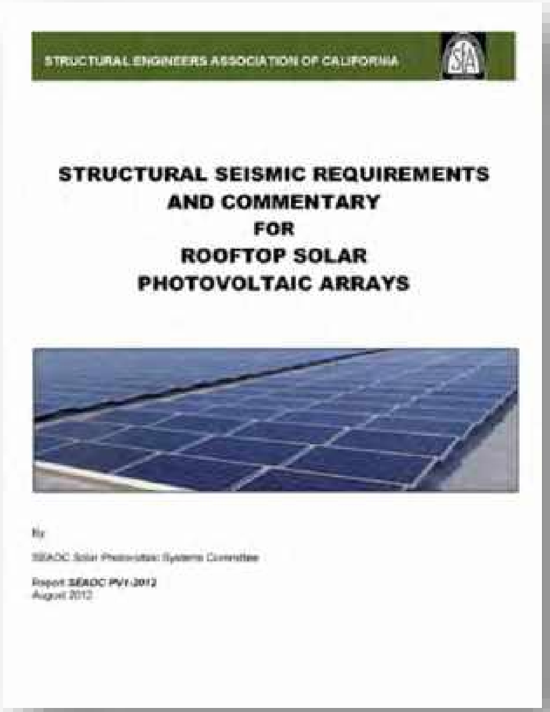
Introduction

Figure 1: Residential Growth and Price Trends from 2010 through 2016

- Conference papers represent the opinions of the authors, and are not peer-reviewed
- Papers provide insight on structural concerns within and beyond ASCE 7-16
- 2015 paper includes discussion of dynamic wind effects for ground mounts

https://www.seia.org/research-resources/seaoc-conference-papers

Papers from SEAOC PV Systems Committee


STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA

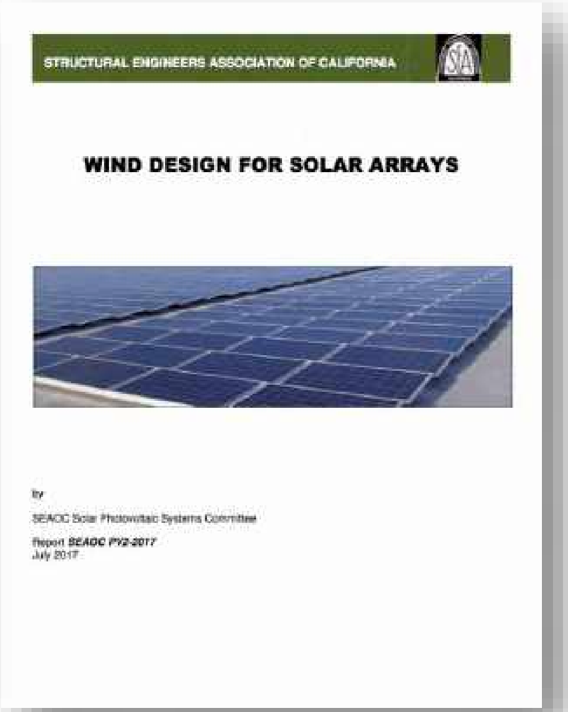
STRUCTURAL SEISMIC REQUIREMENTS AND COMMENTARY FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS

By

SEAOC Solar Photovoltaic Systems Committee

Report *SEAOC PV1-2012*
August 2012

PV1: SEISMIC


STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA

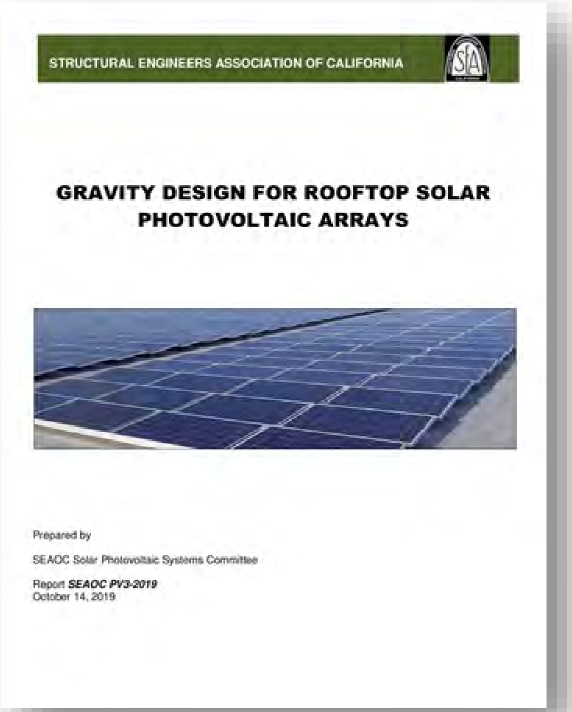
WIND DESIGN FOR SOLAR ARRAYS

By

SEAOC Solar Photovoltaic Systems Committee

Report *SEAOC PV2-2017*
July 2017

PV2: WIND


STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA

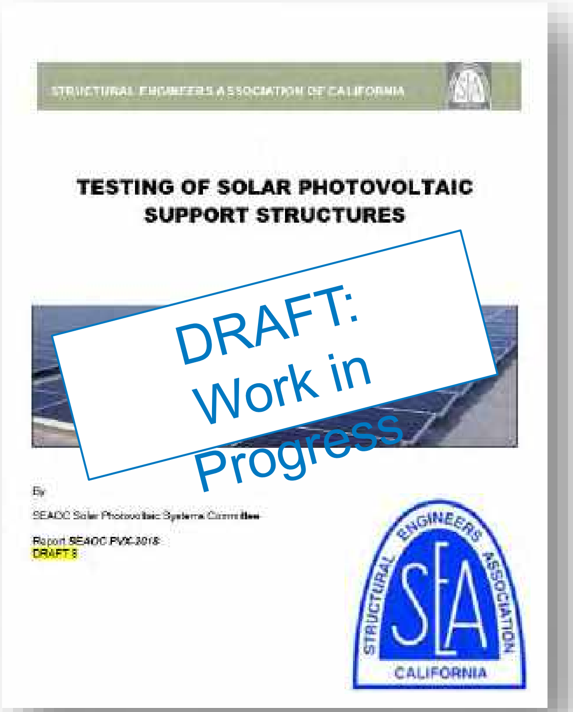
GRAVITY DESIGN FOR ROOFTOP SOLAR PHOTOVOLTAIC ARRAYS

Prepared by

SEAOC Solar Photovoltaic Systems Committee

Report *SEAOC PV3-2019*
October 14, 2019

PV3: GRAVITY LOADS


STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA

TESTING OF SOLAR PHOTOVOLTAIC SUPPORT STRUCTURES

DRAFT: Work in Progress

By

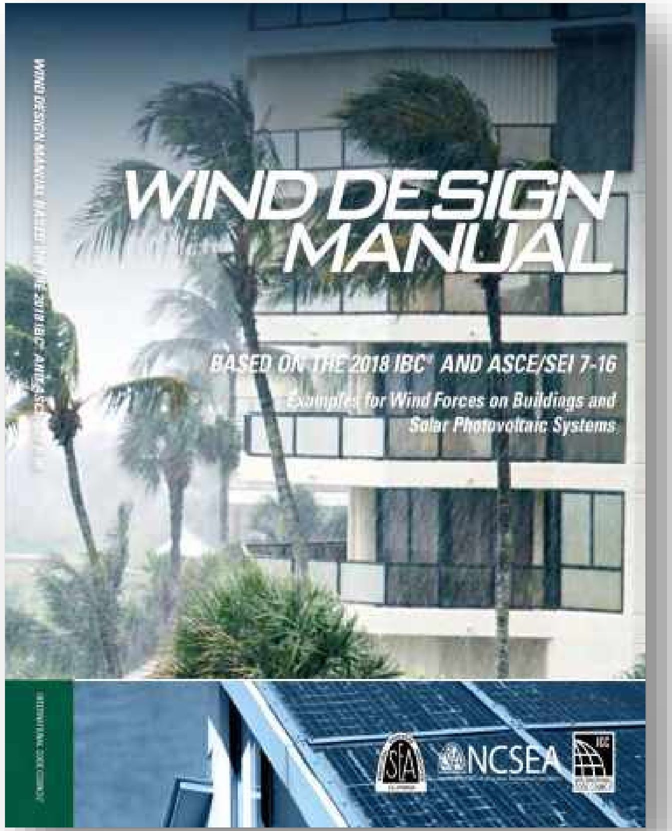
SEAOC Solar Photovoltaic Systems Committee

Report SEAOC PVX-2018
DRAFT 8

STRUCTURAL ENGINEERS ASSOCIATION CALIFORNIA

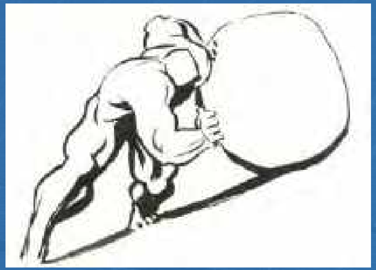
PV4: TESTING

SEAOC Wind Design Manual



https://www.seaoc.org/page/2018WDM

Solar Energy Industries Association®



Questions?

Joe Cain, P.E.
Director of Codes & Standards
E-mail: jcain@seia.org
JoeCainPE@gmail.com
Phone: 408-605-3934

CATCHING UP WITH SOLAR PV STRUCTURAL REQUIREMENTS

WIND DESIGN MANUAL

AUGUST 4TH, 2020

KLEINFELDER
Bright People. Right Solutions.

SEIA Solar Energy Industries Association®

JENNIFER CAREY, P.E.

ABOUT ME:

- SR GEOTECHNICAL/STRUCTURAL ENGINEER @ KLEINFELDER
- 9 YEARS OF SOLAR EXPERIENCE
  - RESIDENTIAL/COMMERCIAL ROOF AND GROUND
  - UTILITY GROUND MOUNTED STRUCTURES

CONTRIBUTED TO:

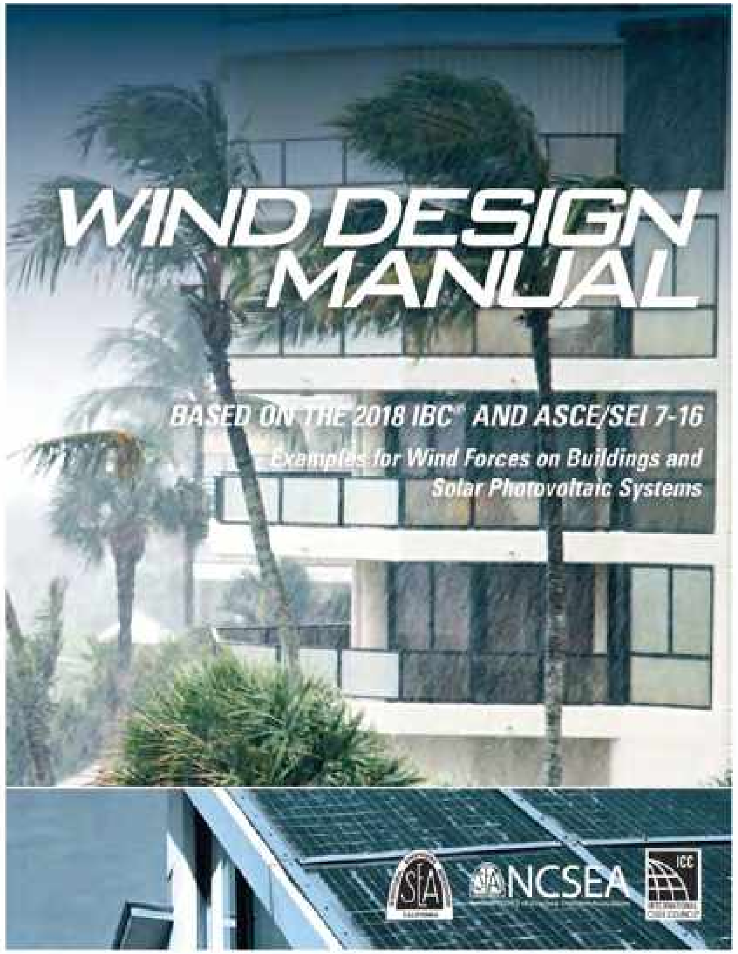
- SEAOC PV2 REPORT (2017)
- SEAOC PV3 REPORT (2019)
- SEAOC PV4 REPORT (IN PROGRESS)
- WIND DESIGN MANUAL (2018)
- ASCE 7-22 (IN PROGRESS)

MEMBER OF:

- ASCE
  - ASCE 7-22 WIND LOAD SUBCOMMITTEE
  - ASCE 7-22 SEISMIC SUBCOMMITTEE
  - ASCE SUBCOMMITTEE ON WIND LOADS ON SOLAR COLLECTORS
- SEAOC
  - SEAOC SOLAR PHOTOVOLTAIC SYSTEMS COMMITTEE
- SEIA
  - CODES AND STANDARDS
  - CORROSION PROTECTION

WIND DESIGN MANUAL (WDM)

- **WIND DESIGN MANUAL** BASED ON THE 2018 IBC AND ASCE/SEI 7-16 EXAMPLES FOR WIND FORCES ON BUILDINGS AND SOLAR PHOTOVOLTAIC SYSTEMS
- DEVELOPED BY THE **STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA (SEAOC)**
- 7 SOLAR PHOTOVOLTAIC EXAMPLES



FROM: SEAOC WIND DESIGN MANUAL

WDM CONTENTS - NON-SOLAR SPECIFIC

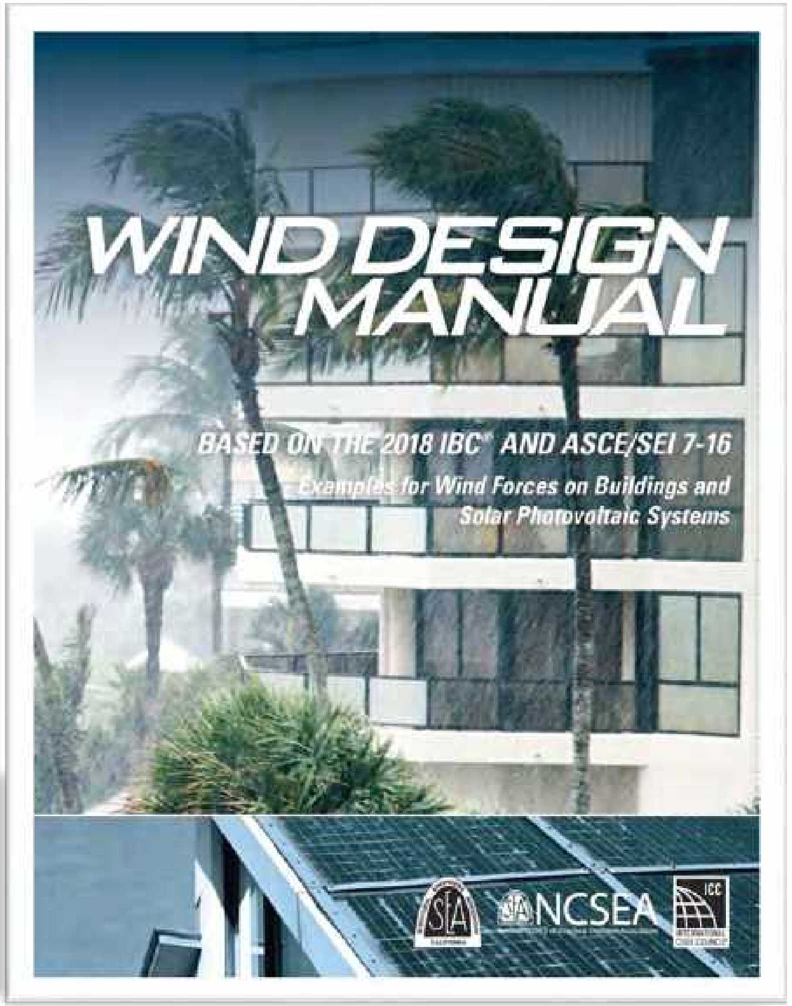
- **DE 1** - ENCLOSURE CLASSIFICATION
- **DE 2** - TOPOGRAPHIC EFFECTS
- **DE 3A** - EXPOSURE CATEGORY/SURFACE ROUGHNESS CATEGORY
- **DE 3B** - DETERMINATION OF INTERMEDIATE EXPOSURE AT A TRANSITION ZONE
- **DE 4** - GUST FACTOR
- **DE 5** - TORNADO STORM SHELTER
- **DE 6** - HIGH WINDS EXAMPLE
- **DE 7A** - WIND FORCES ON A SIMPLE DIAPHRAGM BUILDING – PART 2 METHOD
- **DE 7B** - WIND FORCES ON A SIMPLE DIAPHRAGM BUILDING – PART 1 METHOD
- **DE 8A** - WIND FORCES ON A THREE-STORY, L-SHAPED BUILDING
- **DE 8B** - COMPONENTS AND CLADDING WIND FORCES ON A THREE-STORY, L-SHAPED BUILDING
- **DE 9** - DESIGN WIND FORCES ON A 14-STORY OFFICE BUILDING

WDM CONTENTS - SOLAR SPECIFIC

- **DE 10** - ROOFTOP SOLAR PANELS FOR BUILDINGS OF ALL HEIGHTS WITH FLAT ROOFS OR GABLE OR HIP ROOFS WITH SLOPES LESS THAN 7 DEGREES – SMALL COMMERCIAL BUILDINGS
- **DE 11** - ROOFTOP SOLAR PANELS OF ALL HEIGHTS WITH FLAT OR GABLE OR HIP ROOFS WITH SLOPES LESS THAN 7 DEGREES – LARGE COMMERCIAL BUILDINGS
- **DE 12** - ROOFTOP SOLAR PANELS PARALLEL TO THE ROOF SURFACE ON BUILDINGS OF ALL HEIGHTS AND ROOF SLOPES – SINGLE FAMILY RESIDENCE
- **DE 13** - ROOFTOP SOLAR PANELS PARALLEL TO ROOF SURFACE ON BUILDINGS OF ALL HEIGHTS AND ROOF SLOPES – SPORTS COMPLEX

WDM CONTENTS - SOLAR SPECIFIC

- **DE 14** - SEISMIC DESIGN OF A LOW-PROFILE UNATTACHED SOLAR PV SYSTEM ON A LOW-SLOPE ROOF
- **DE 15** - CONSIDERATION OF GRAVITY LOADS ON EXISTING ROOFS SUPPORTING SOLAR PV ARRAYS
- **DE 16** - CARPORT PV SYSTEMS



FROM: SEAOC WIND DESIGN MANUAL

WIND ON FLAT ROOF (DESIGN EXAMPLES – 10/11)

- ROOFTOP SOLAR PANELS FOR BUILDINGS OF ALL HEIGHTS WITH FLAT ROOFS OR GABLE OR HIP ROOFS WITH SLOPES LESS THAN 7 DEGREES – SMALL COMMERCIAL BUILDINGS
- ROOFTOP SOLAR PANELS OF ALL HEIGHTS WITH FLAT OR GABLE OR HIP ROOFS WITH SLOPES LESS THAN 7 DEGREES – LARGE COMMERCIAL BUILDINGS

FROM: JENNIFER CAREY

WIND ON FLAT ROOF (DESIGN EXAMPLES – 10/11)

- NEW METHODOLOGY
- NEW VARIABLES
  - PARAPET HEIGHT FACTOR
  - PANEL CHORD FACTOR
  - EXPOSURE FACTOR
  - EFFECTIVE WIND AREA
  - NORMALIZED WIND AREA
- CODES/REPORTS
  - ASCE 7-16, SECTION 29.4.3
  - SEAOC PV-2, 2017
- LIMITATIONS

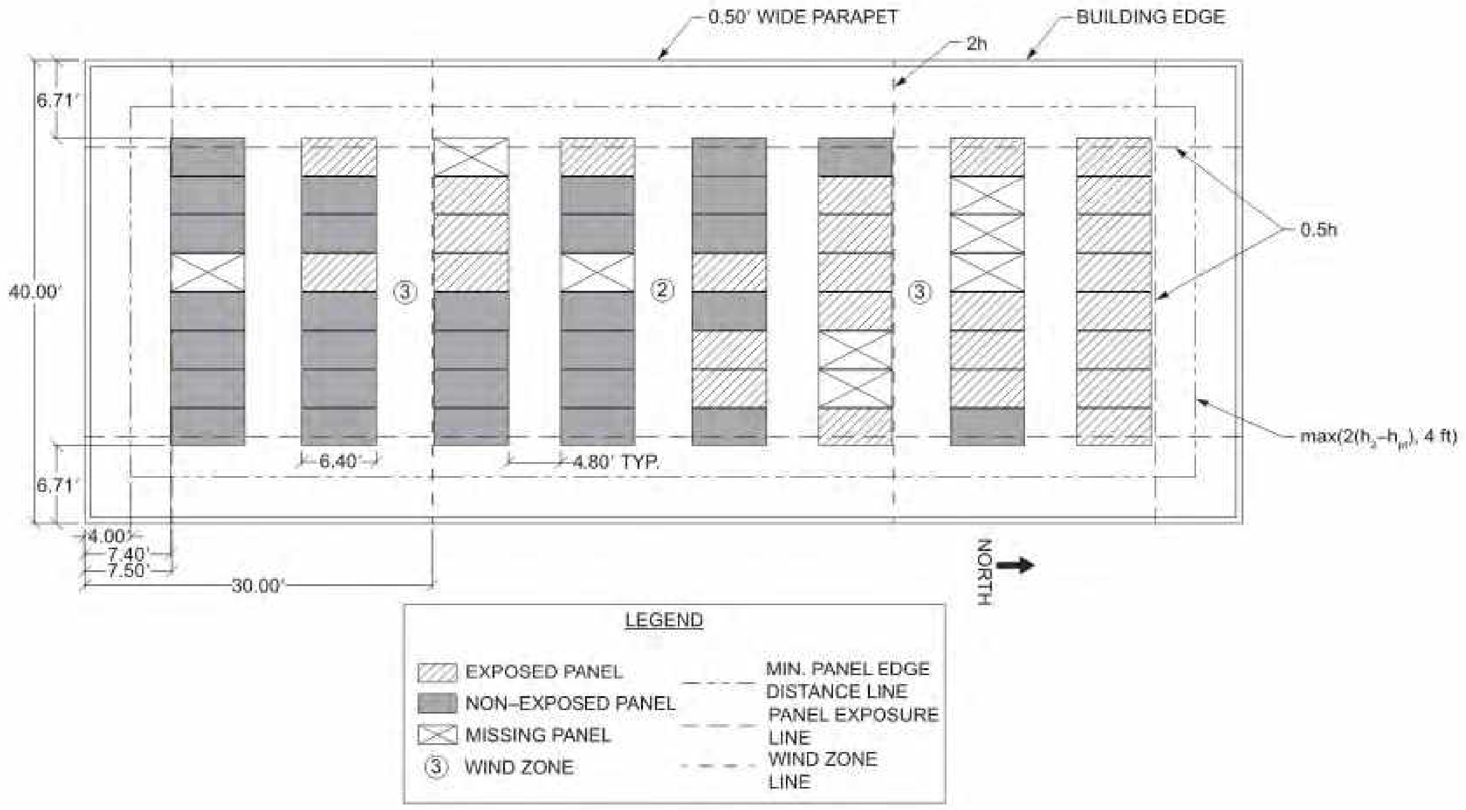
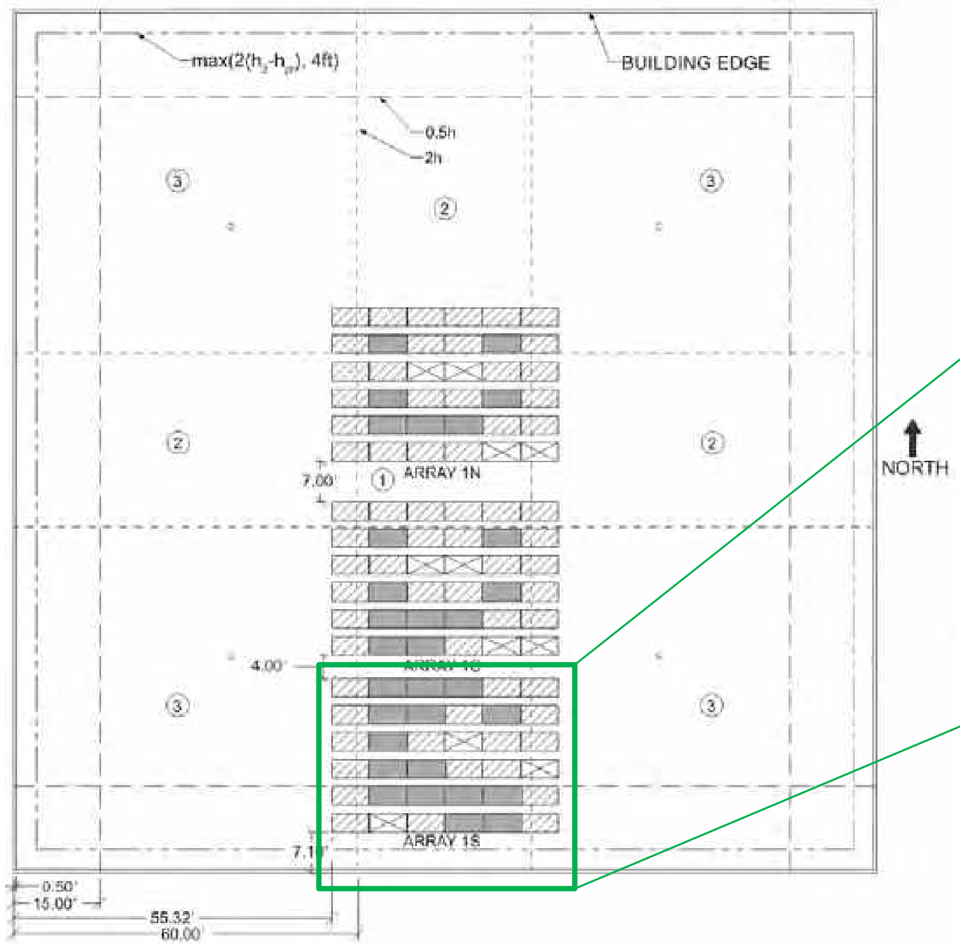
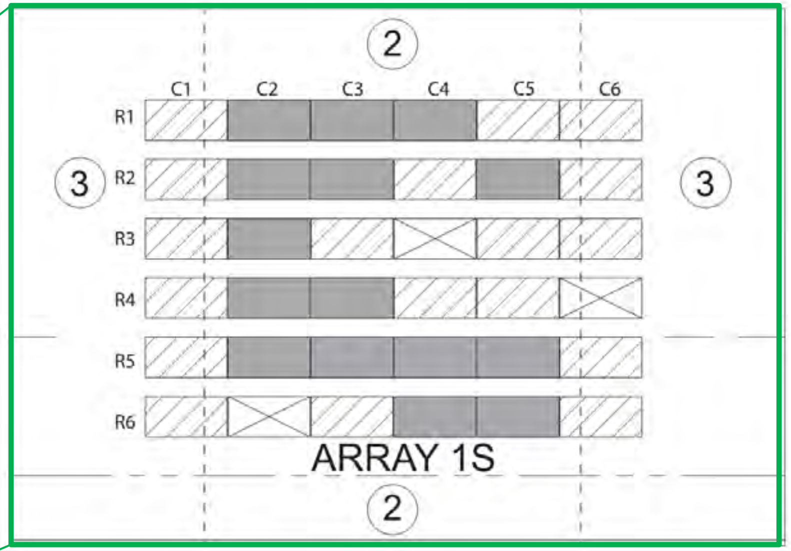


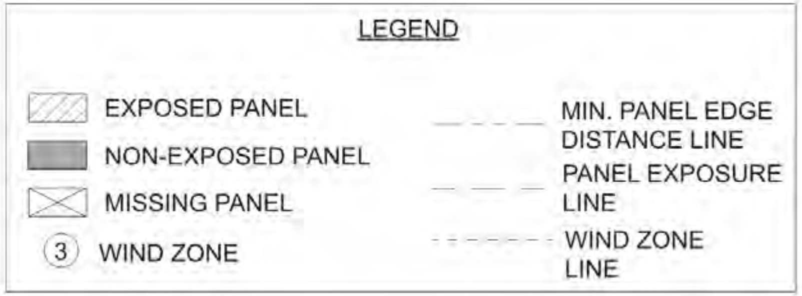
Figure 10–4. Array top view with defined areas

FROM: DE 10 - SEAOC WIND DESIGN MANUAL

WIND ON FLAT ROOF (DESIGN EXAMPLE – 11)







FROM: DE 11 - SEAOC WIND DESIGN MANUAL

WIND ON FLAT ROOF (DESIGN EXAMPLES – 10/11)

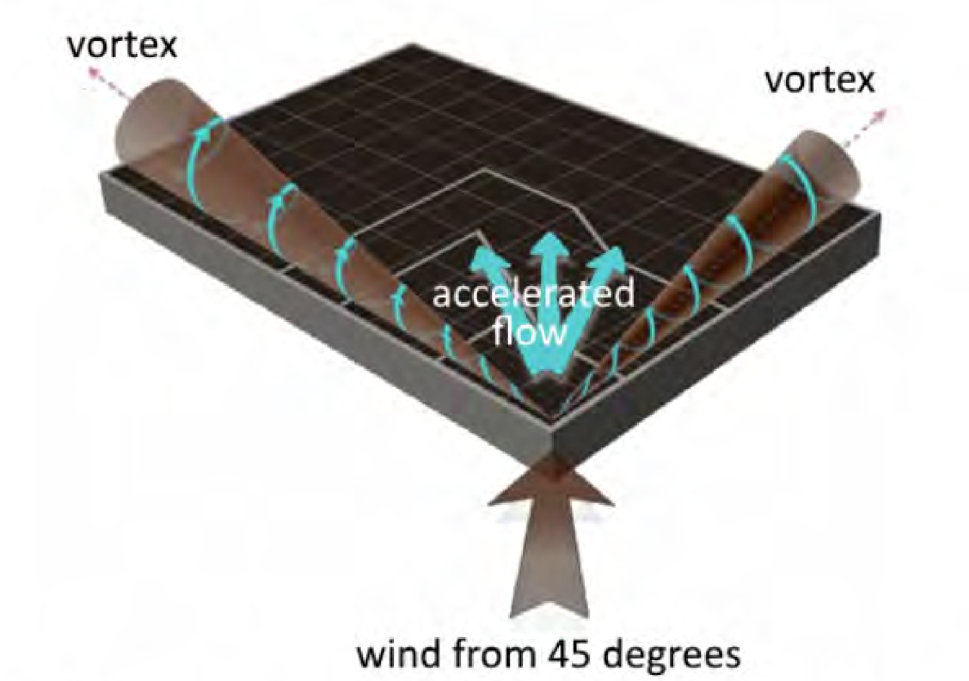


Figure 7: Corner vortices on a roof top. (Figure courtesy of CPP)

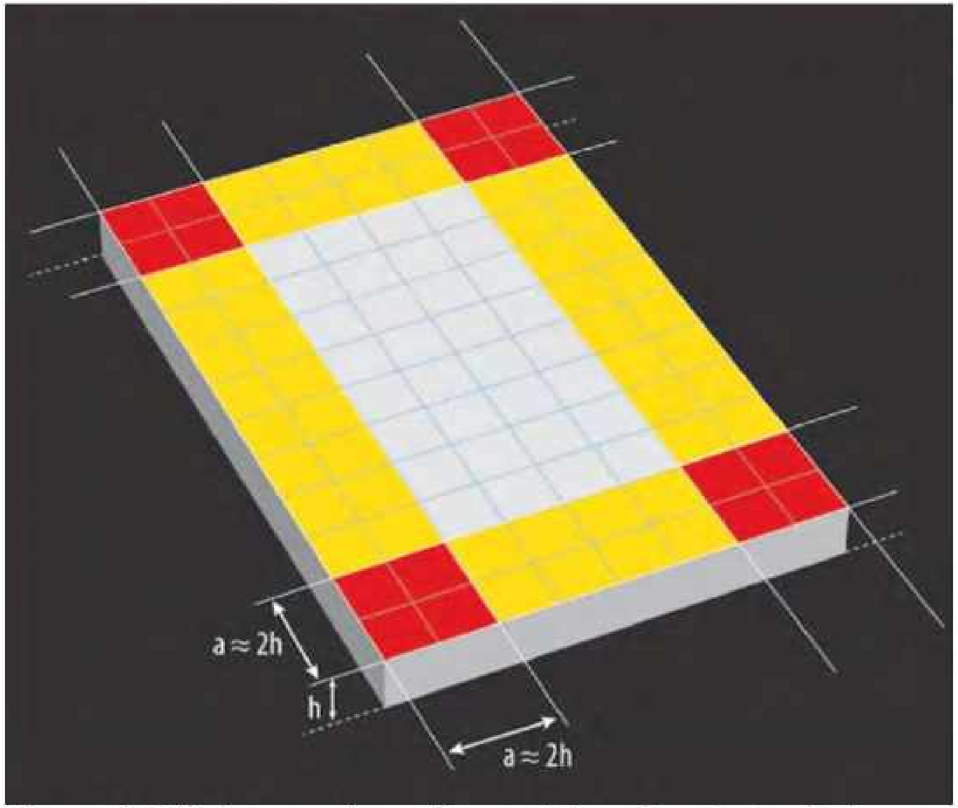
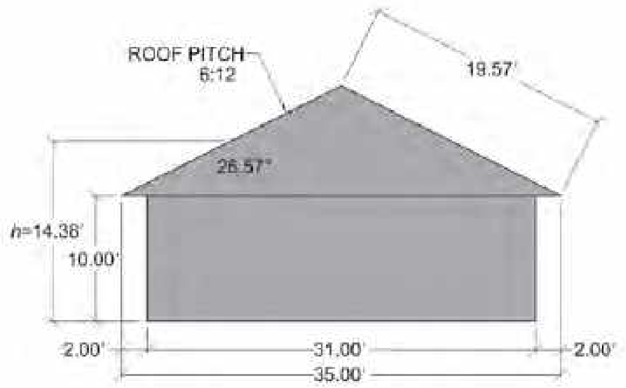


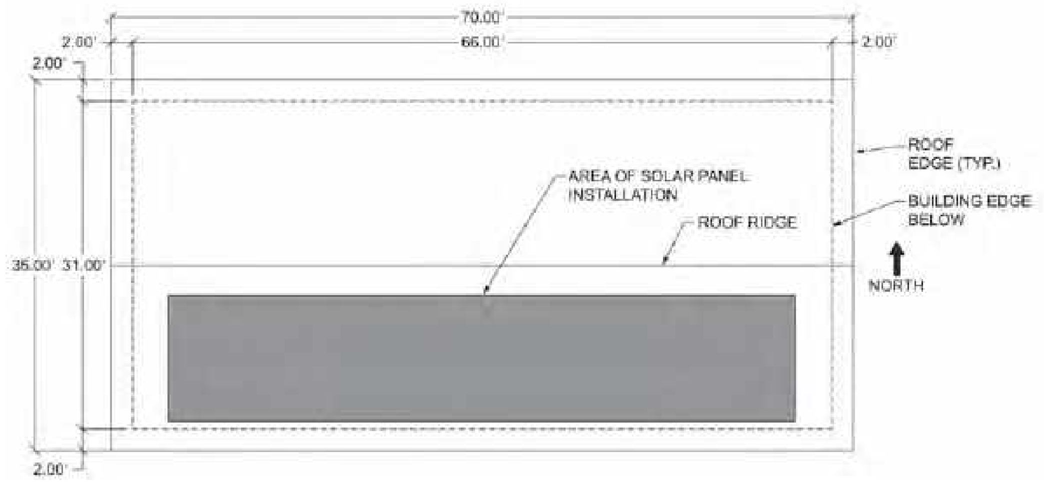
Figure 10: Wind zones for a flat roof for solar photovoltaic array wind loading, per ASCE 7-16.

FROM: SEAOC PV-2 REPORT (2017)

WIND ON PITCHED ROOF (DESIGN EXAMPLES – 12/13)

- ROOFTOP SOLAR PANELS PARALLEL TO THE ROOF SURFACE ON BUILDINGS OF ALL HEIGHTS AND ROOF SLOPES – SINGLE FAMILY RESIDENCE
- ROOFTOP SOLAR PANELS PARALLEL TO ROOF SURFACE ON BUILDINGS OF ALL HEIGHTS AND ROOF SLOPES – SPORTS COMPLEX

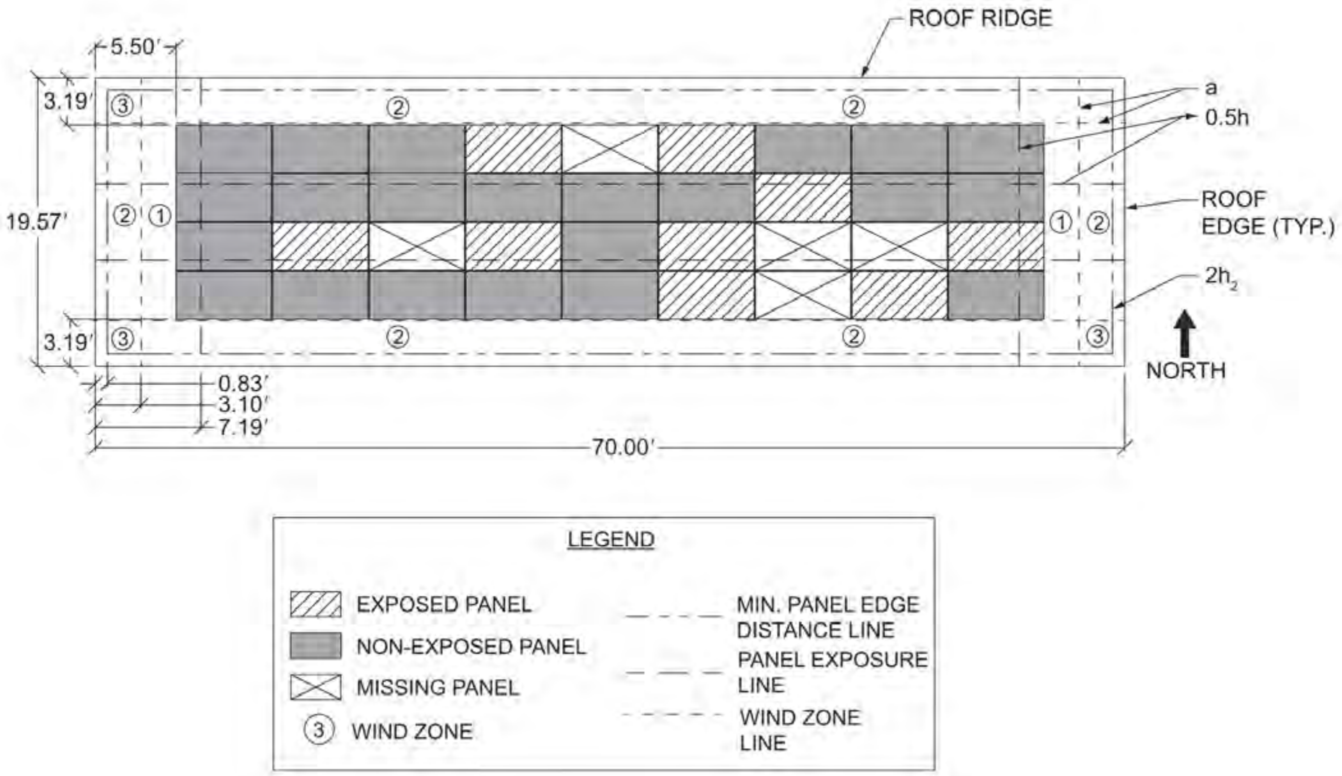




FROM: DE 12 - SEAOC WIND DESIGN MANUAL

WIND ON PITCHED ROOF (DESIGN EXAMPLES – 12/13)

- METHODOLOGY
- NEW VARIABLES
  - EXPOSURE FACTOR
  - SOLAR ARRAY PRESSURE EQUALIZATION FACTOR
- CODES/REPORTS
  - ASCE 7-16, SECTION 29.4.4
  - SEAOC PV-2, 2017
- LIMITATIONS



FROM: DE 12 - SEAOC WIND DESIGN MANUAL

WIND ON PITCHED ROOF (DESIGN EXAMPLE – 13)

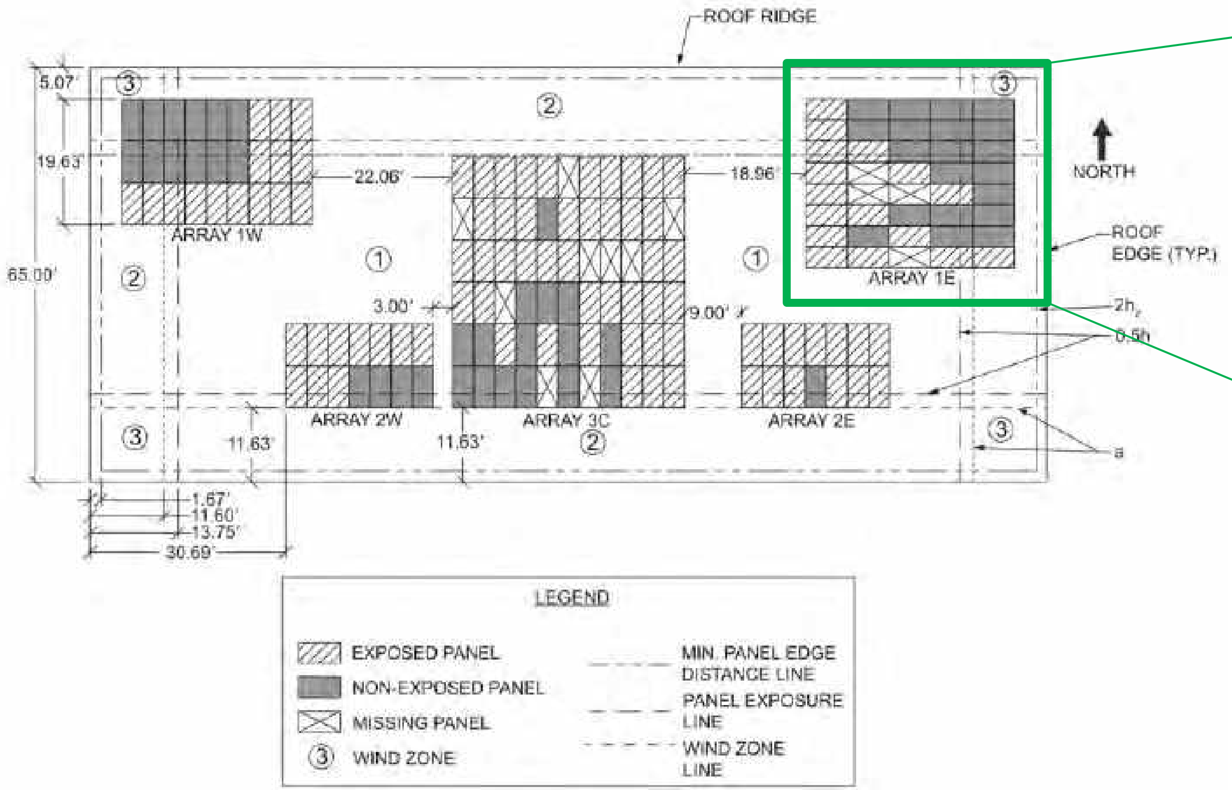
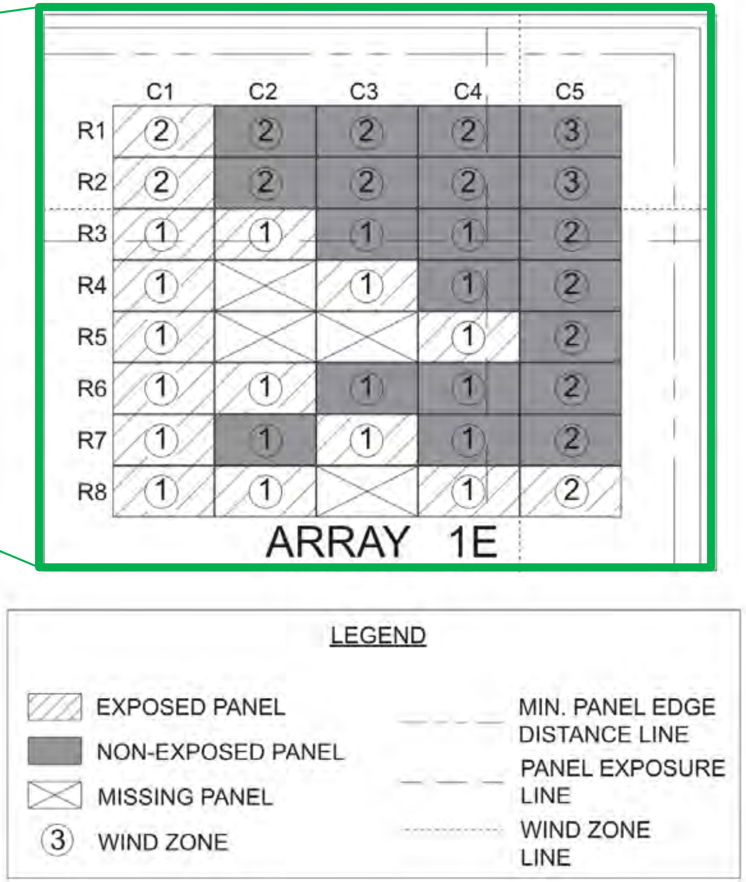


Figure 13–4. Array top view



FROM: DE 13 - SEAOC WIND DESIGN MANUAL

SEISMIC FLAT ROOF (DESIGN EXAMPLE – 14)

- SEISMIC DESIGN OF A LOW-PROFILE UNATTACHED SOLAR PV SYSTEM ON A LOW-SLOPE ROOF
- METHODOLOGY
- CODES/REPORTS
  - ASCE 7-16, SECTION 13.6.12
  - SEAOC PV-1, 2017

FROM: JENNIFER CAREY

SEISMIC FLAT ROOF (DESIGN EXAMPLE – 14)

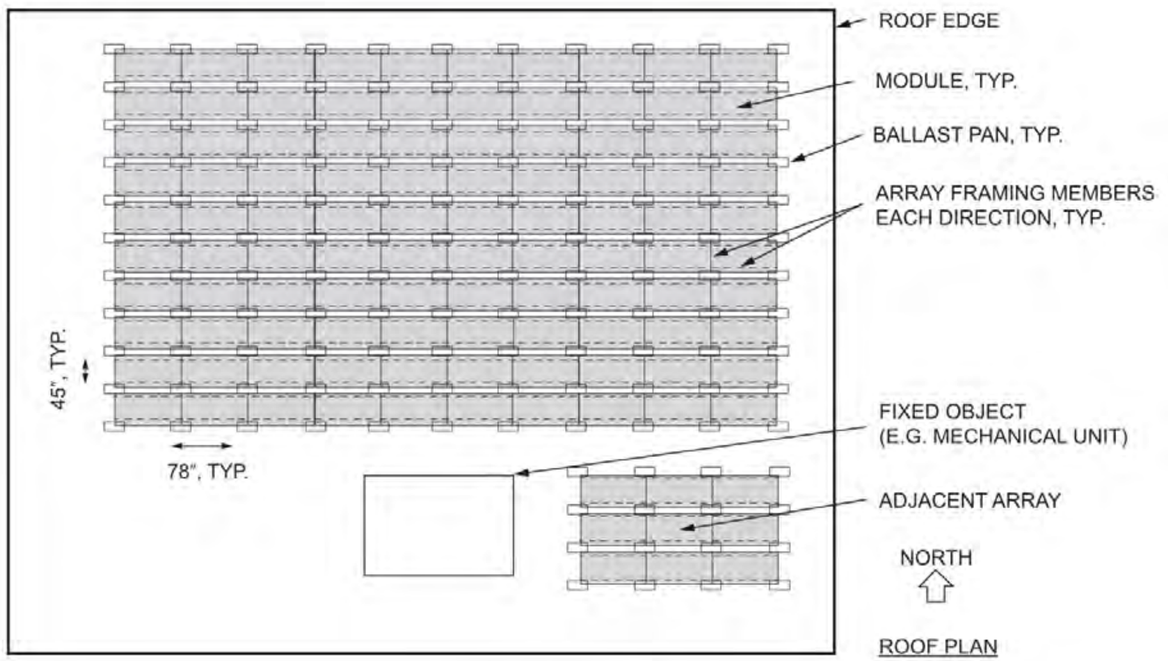


Figure 14–1. Array

FROM: DE 14 - SEAOC WIND DESIGN MANUAL

- SEISMIC DISPLACEMENT
  - SEPARATION BETWEEN ADJACENT ARRAYS
  - SEPARATION BETWEEN ARRAY AND FIXED OJBECT ON THE ROOF
  - SEPARATION BETWEEN ARRAY AND ROOF EDGE
  - DIFFERENTIAL MOVEMENT
- INTERCONNECTION STRENGTH
- MEMBER STRENGTH
- LIMITATIONS

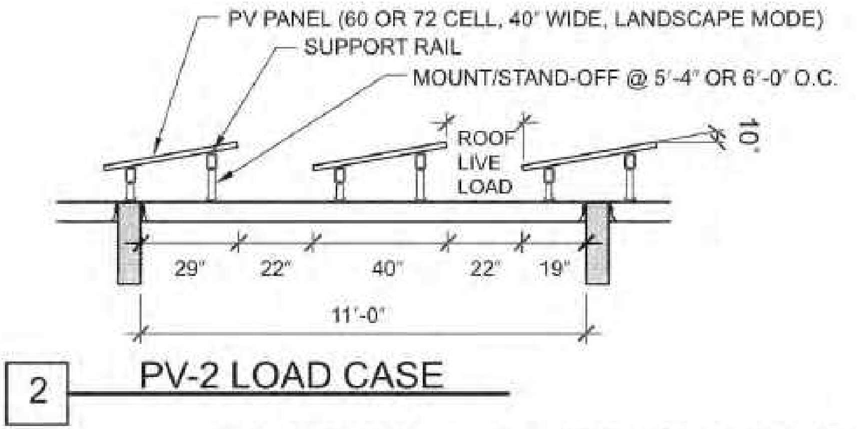
ROOF GRAVITY LOADS (DESIGN EXAMPLE – 15)

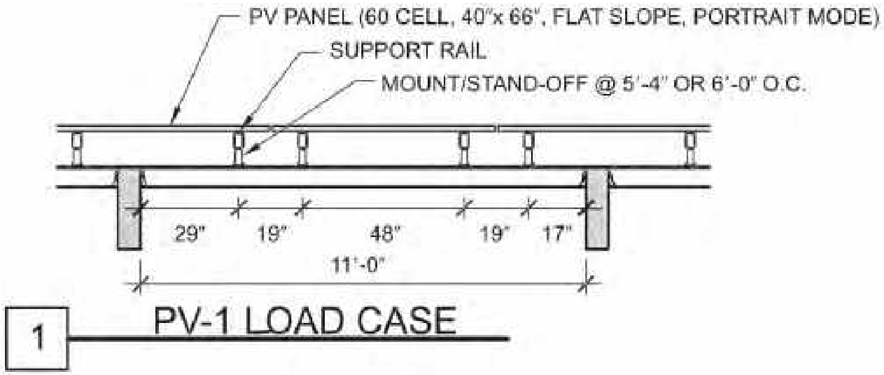
- CONSIDERATION OF GRAVITY LOADS ON EXISTING ROOFS SUPPORTING SOLAR PV ARRAYS

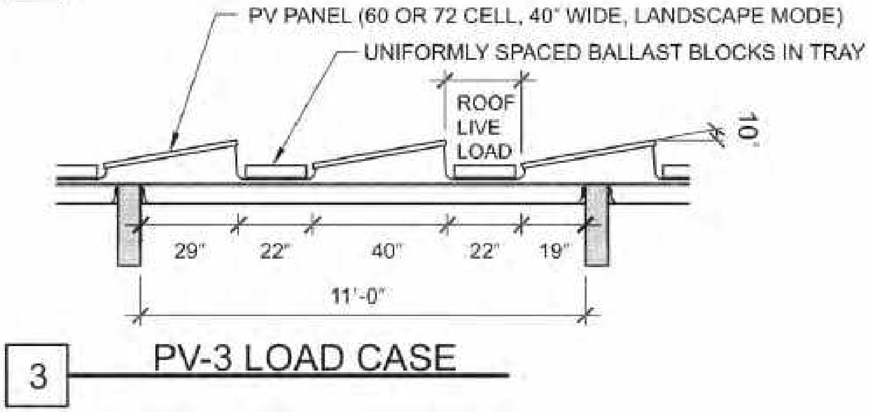
FROM: GOOGLE EARTH

ROOF GRAVITY LOADS (DESIGN EXAMPLE – 15)

- THREE CASES
  - FLAT PANEL ATTACHED ARRAY
  - SLOPED PANEL ATTACHED ARRAY
  - SLOPED PANEL BALLASTED ARRAY
- WIND LOAD
- SNOW LOAD
- SEISMICITY
- LIVE LOADS
- PONDING





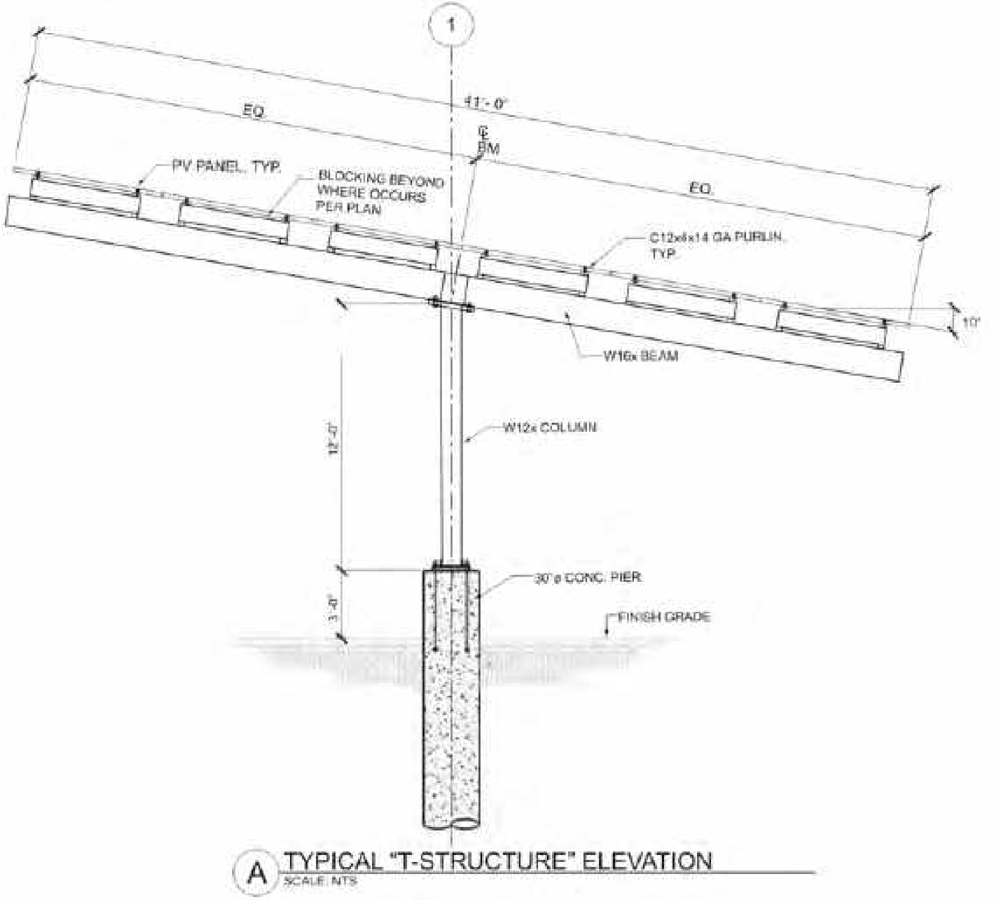


FROM: DE 15 – SEAOC WIND DESIGN MANUAL

CARPORT PV SYSTEM (DESIGN EXAMPLE – 16)

- CARPORT PV SYSTEMS

PHOTO BY: JENNIFER CAREY



FROM: DE 16 - SEAOC WIND DESIGN MANUAL

CARPORT PV SYSTEM (DESIGN EXAMPLE – 16)

- LIVE LOADS
- SEISMIC LOADS

PHOTO BY: JENNIFER CAREY

CARPORT PV SYSTEM (DESIGN EXAMPLE – 16)

- MAIN WIND FORCE RESISTING SYSTEM
- COMPONENTS AND CLADDING

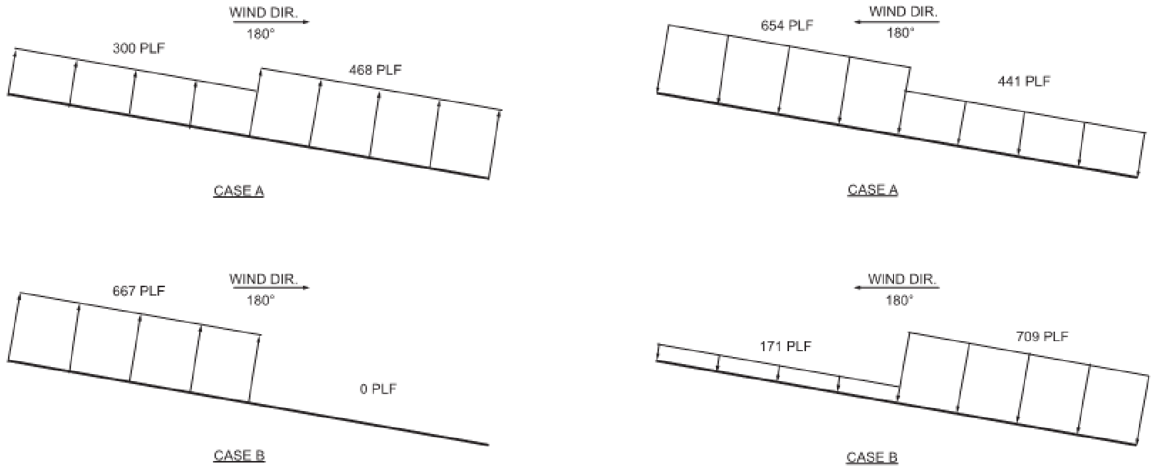


Figure 16–3. MWFRS wind loading diagram

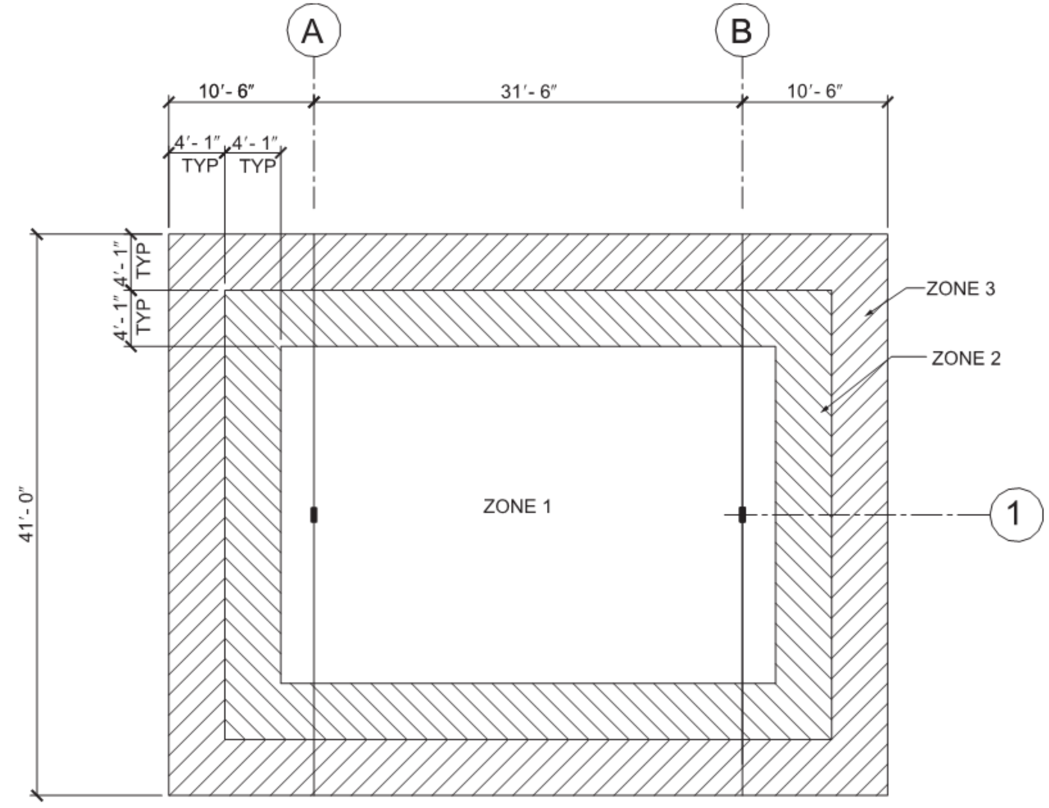


Figure 16–5. Summary of C&C zones

FROM: DE 16 - SEAOC WIND DESIGN MANUAL

CARPORT PV SYSTEM (DESIGN EXAMPLE – 16)

- SNOW LOADS

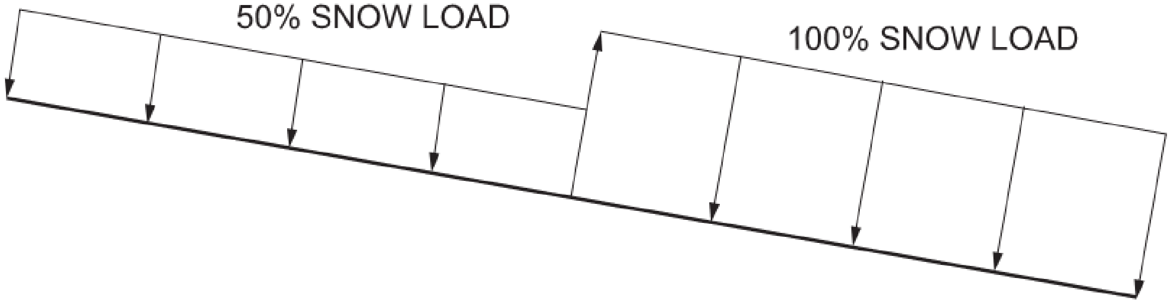


Figure 16–7. Unbalanced snow-loading diagram

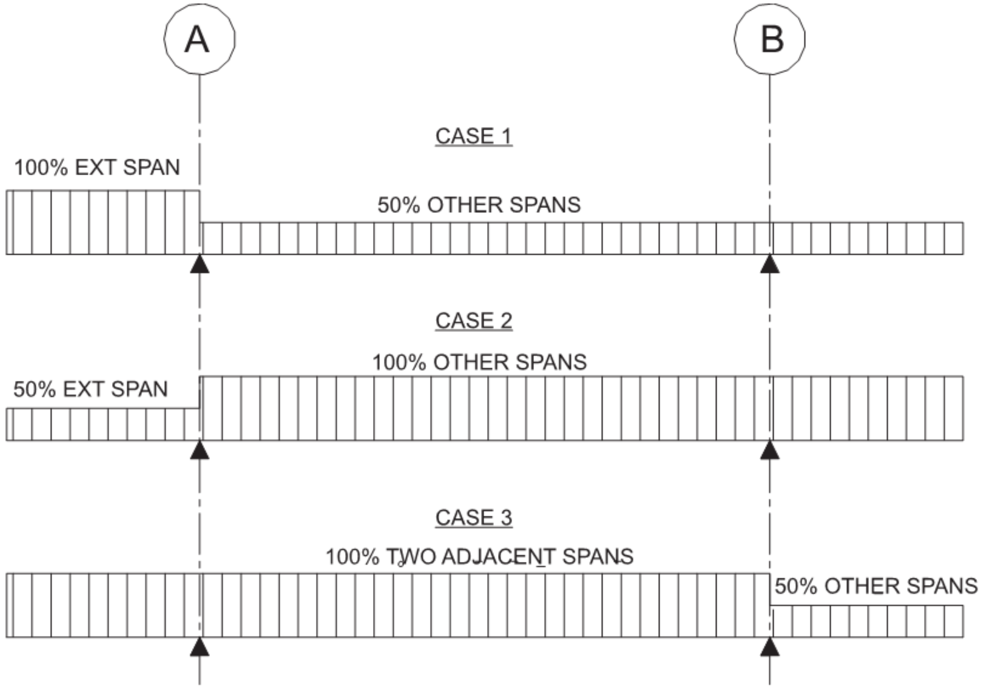


Figure 16–8. Partial snow-loading diagram

FROM: DE 16 - SEAOC WIND DESIGN MANUAL

SUMMARY

- PRACTICAL IN-DEPTH DESIGN EXAMPLES
- CLEARER UNDERSTANDING OF CODE APPLICATION

PHOTOS BY: JENNIFER CAREY

WDM

- HTTP://SHOP.ICCSAFE.ORG
- SEARCH FOR THE WIND DESIGN MANUAL (SKU – 9000S18)
- DISCOUNT CODE: “SEIA2020”

PHOTOS BY: JENNIFER CAREY

REFERENCES

- AMERICAN SOCIETY OF CIVIL ENGINEERS/STRUCTURAL ENGINEERING INSTITUTE (ASCE/SEI) 2016. “MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES” ASCE 7-16, PUBLISHED BY ASCE, 2017.
- STRUCTURAL ENGINEERS ASSOCIATION OF CALIFORNIA (SEAOC) SOLAR PHOTOVOLTAIC SYSTEMS COMMITTEE 2017. “WIND DESIGN FOR SOLAR ARRAYS” SEAOC PV2-2017, PUBLISHED BY SEAOC, 2017.
- SEAOC. “WIND DESIGN MANUAL BASED ON THE 2018 IBC AND ASCE/SEI 7-16, EXAMPLES FOR WIND FORCES ON BUILDINGS AND SOLAR PHOTOVOLTAIC SYSTEMS” WDM, PUBLISHED BY SEAOC, 2018.

THANK YOU!

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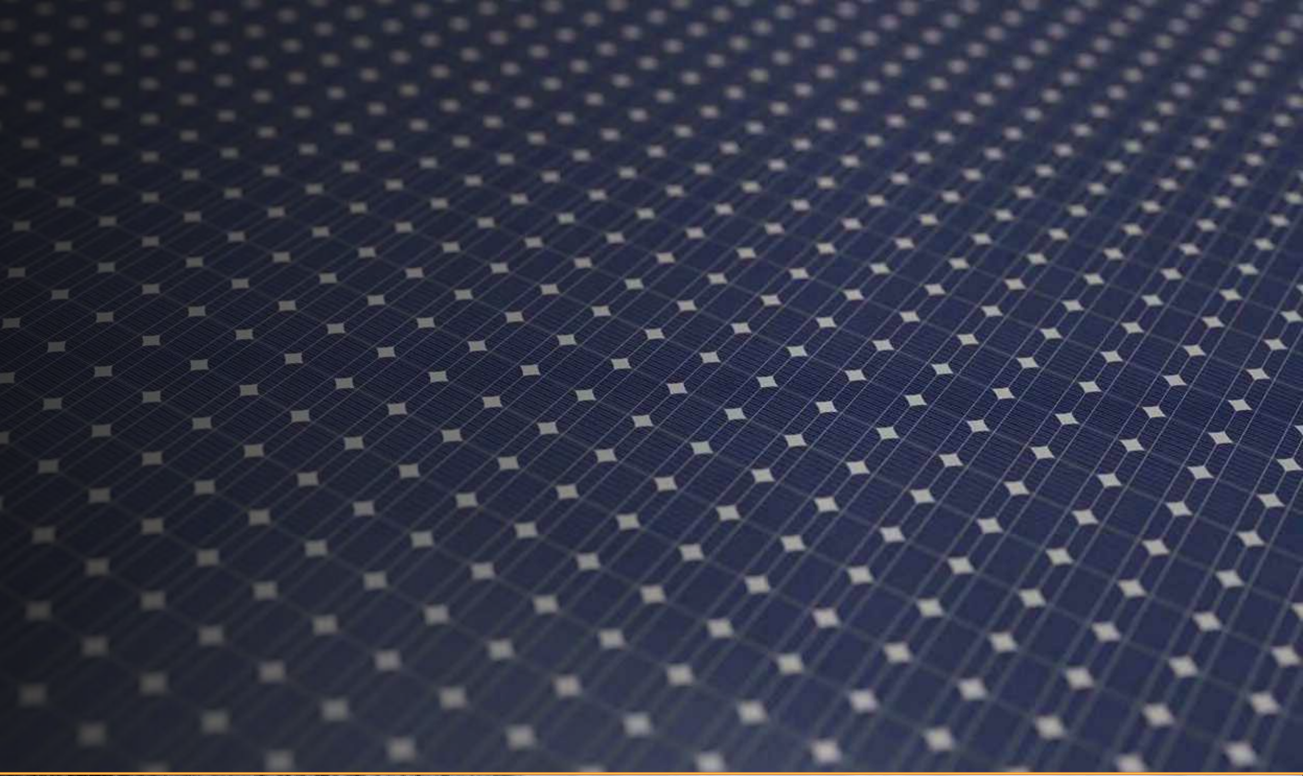
Kleinfelder – Denver, CO
JCarey@Kleinfelder.com

SEIA 2020: Catching Up With Solar PV Structural Requirements
PV Systems & Snow Country



Design Loads- Wind and Snow


S-5.com
It's just *the right way!®*
S-5!®
The Right Way!®

- Dustin is the VP of R&D at S-5! Attachment Solutions, Metal Roof Innovations, and Chair of the SEIA Mounting System Manufacturers Committee.
- Dustin has collaborated and led many efforts in standards and codes development with organizations which include the ICC, UL, and Intertek and universities and institutes such as the University of Adelaide and the Karlsruhe Institute of Technology in the fields of metal roofing, roofing attachments and racking and mounting systems.
- In addition to chairing SEIA's mounting systems manufacturers committee, Dustin chairs the UL Non-Combustible Roof Group of the MBMA Insurance Committee, co-chairs the Metal Construction Association (MCA) Accessary Council, serves on the UL 2703 and UL 1703 Standards Technical Panels and the Microgeneration Certification Scheme (MCS) Roofing Work Group.
- He has 10 issued patents and more than 20 co-patents on file or pending USA and internationally.

The forces that must be resisted:

- **Snow Loads**
  - **What is a “slippery surface”?**
  - **What is "design snow load"?**
  - **What are vector loads: cause of rooftop avalanches?**
  - **What is snow retention?**
  - **What mistakes are made?**
- **Module / Racking / Snow retention Testing**
  - **How are these components tested for different loads?**
  - **UL2703 / UL1703 / IEC 61730**

Q: What is a ”slippery surface”?
A: a surface with a low coefficient of friction, e.g.

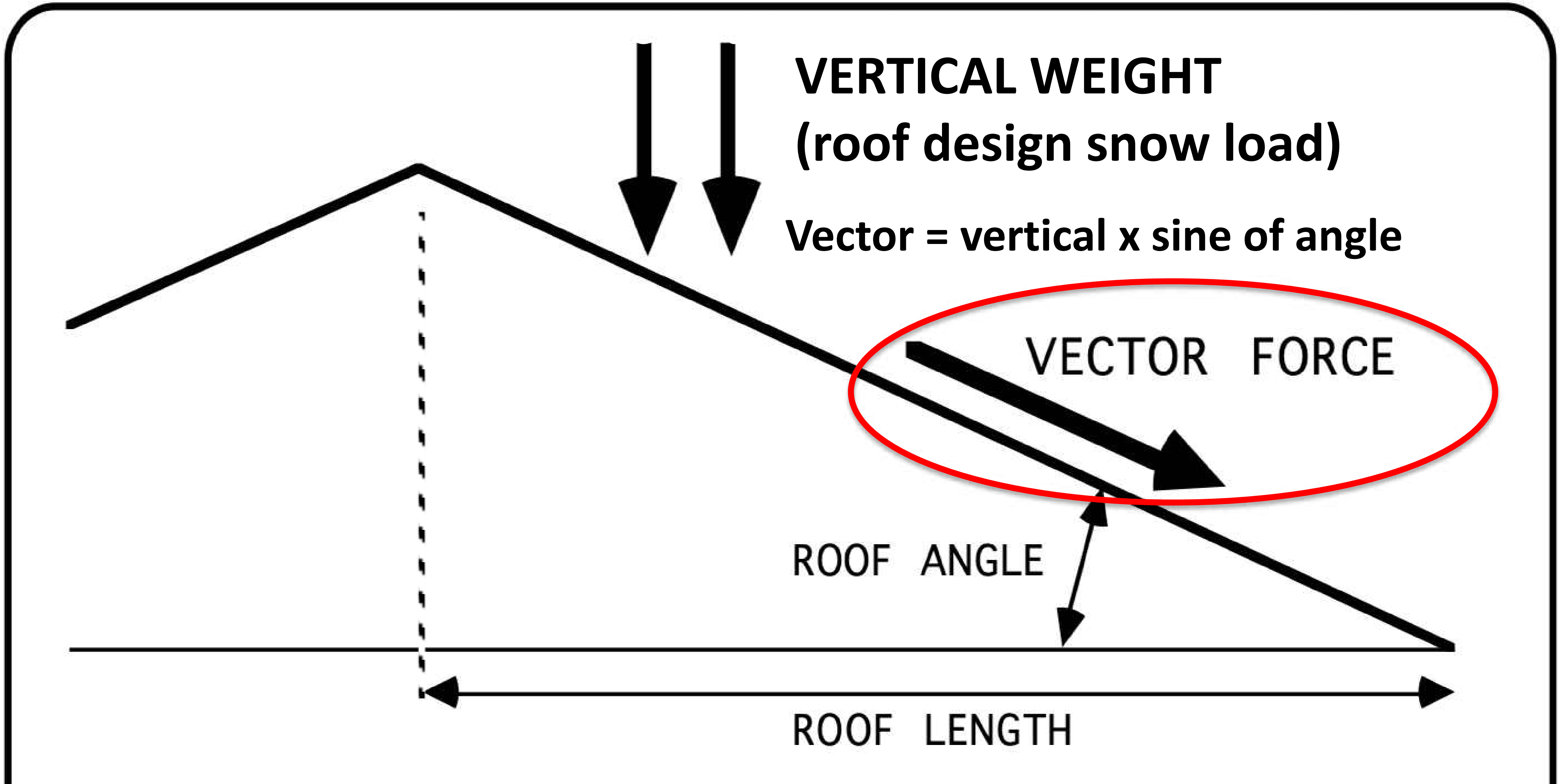
- Slate
- Membranes like TPO, EPDM, PVC
- Glazed, non-porous tile
- **Metal** with glossy or smooth finish
- **Glass**

Q: What are examples that are not "slippery"?

- Glass and metal have much in common:
- They both have very low frictional coefficients
- We (S-5!) have many decades of experience with "slippery surfaces"
- When you install glass modules onto any roof surface, you are creating a "slippery roof surface".

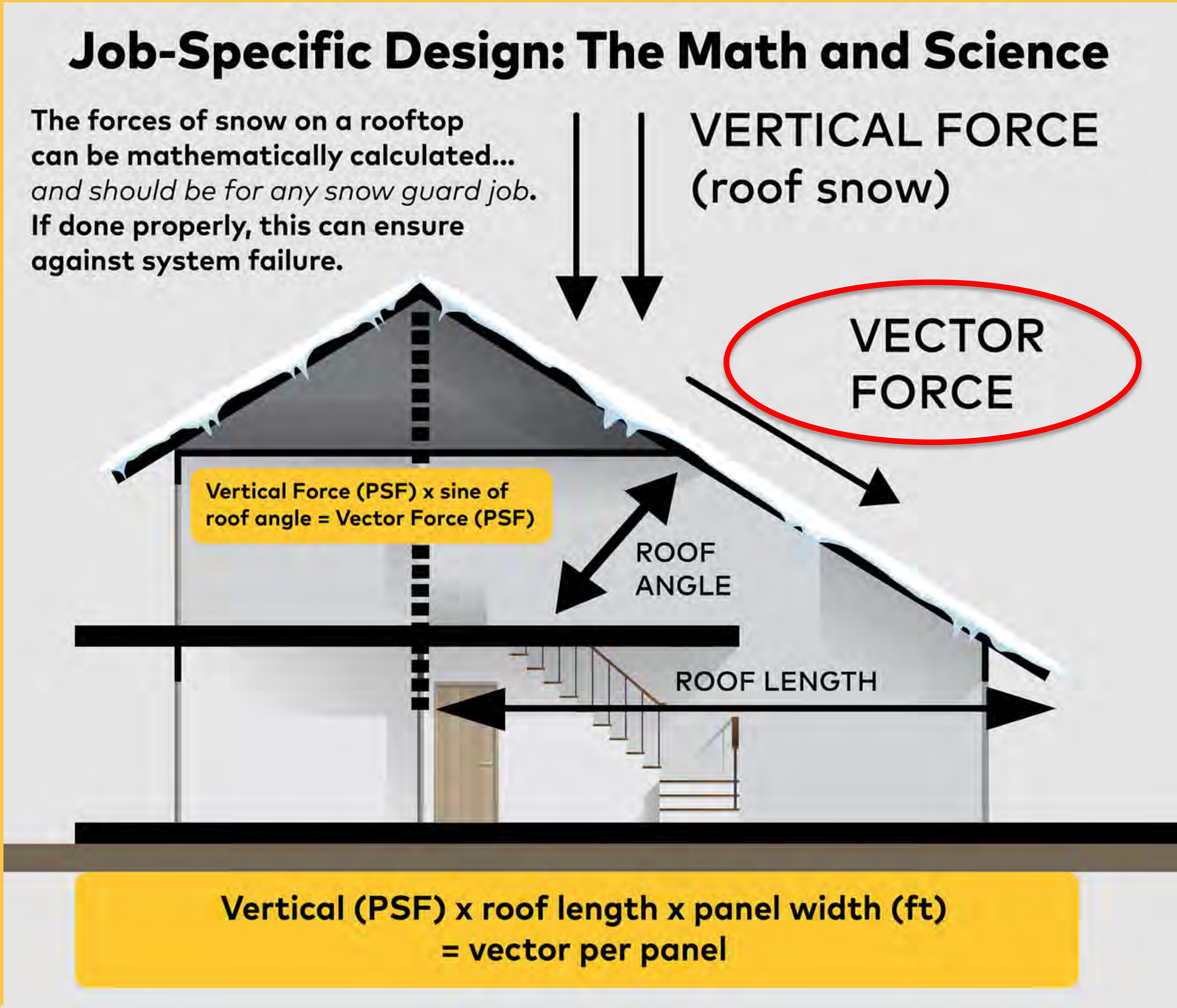
- Granular surface asphalt shingles
- Tile with coarse, porous surfacing
- Metal shingles with granular surface
- Split wood shingles, esp with coarse surfaces
- Mod-bit single ply membranes with granular surface

Snow Effects on Roofs (or Modules) in 2 Load Directions



Vector Load is also called “drag load” or “gravity load”

Snow has effects on roofs (or modules) in 2 load directions



That was somewhere between 5 and 6 TONS of snow evacuating that small roof in just under 5 seconds... So, vector loads can be serious business.

The safety risks are not just hypothetical…

Snow from Idaho cabin roof buries 3 children; 1 dead, 2 in hospital

Several feet of snow fell from this cabin roof and buried three children. (EastIdahoNews.com)

A 2-year-old girl was killed and two other children were seriously injured when snow slid off a cabin roof in Idaho and buried them, officials said Saturday.

2018

abc NEWS VIDEO LIVE SHOWS

Mother and 7-year-old son killed in 'freak accident' at California ski resort

By BILL HUTCHINSON

Mar 6, 2018, 11:23 AM ET

Share Tweet

Woman dies after being buried under several feet of snow in Wyoming

Casper Star-Tribune 18 hrs ago

2019

A 67-year-old woman died after several feet of snow fell off the roof of a Casper Mountain house and trapped her Monday, according to the Natrona County Sheriff's Office.

The woman, who was not identified in the office's announcement, and a man were clearing snow off opposite sides of the roof when the man heard snow crashing down, according to the release. The man found the woman buried and called 911.

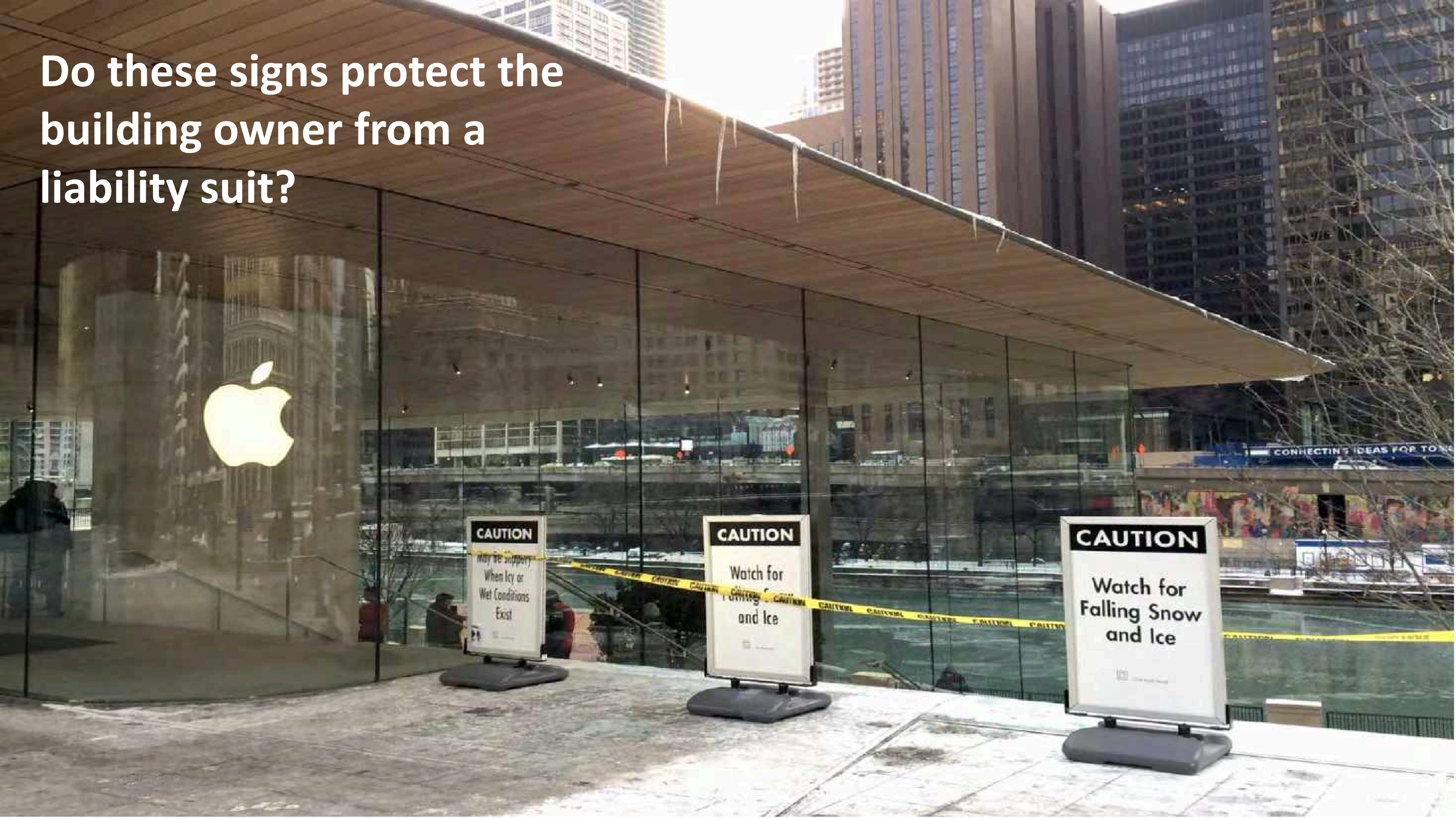
March 15, 2019

BILLINGS GAZETTE

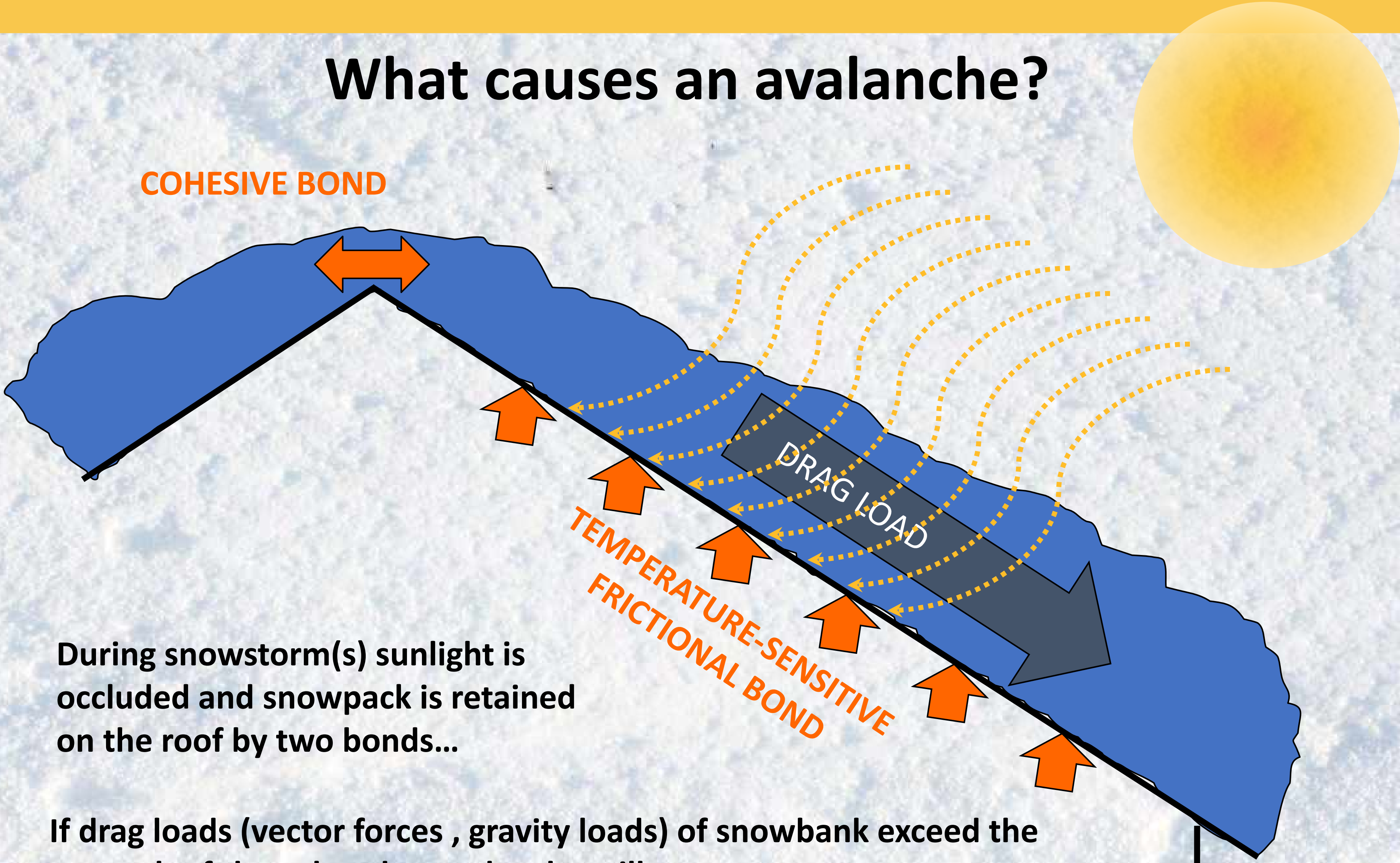
Protect Vehicles

Limit Liability

Do these signs protect the building owner from a liability suit?



What causes an avalanche?

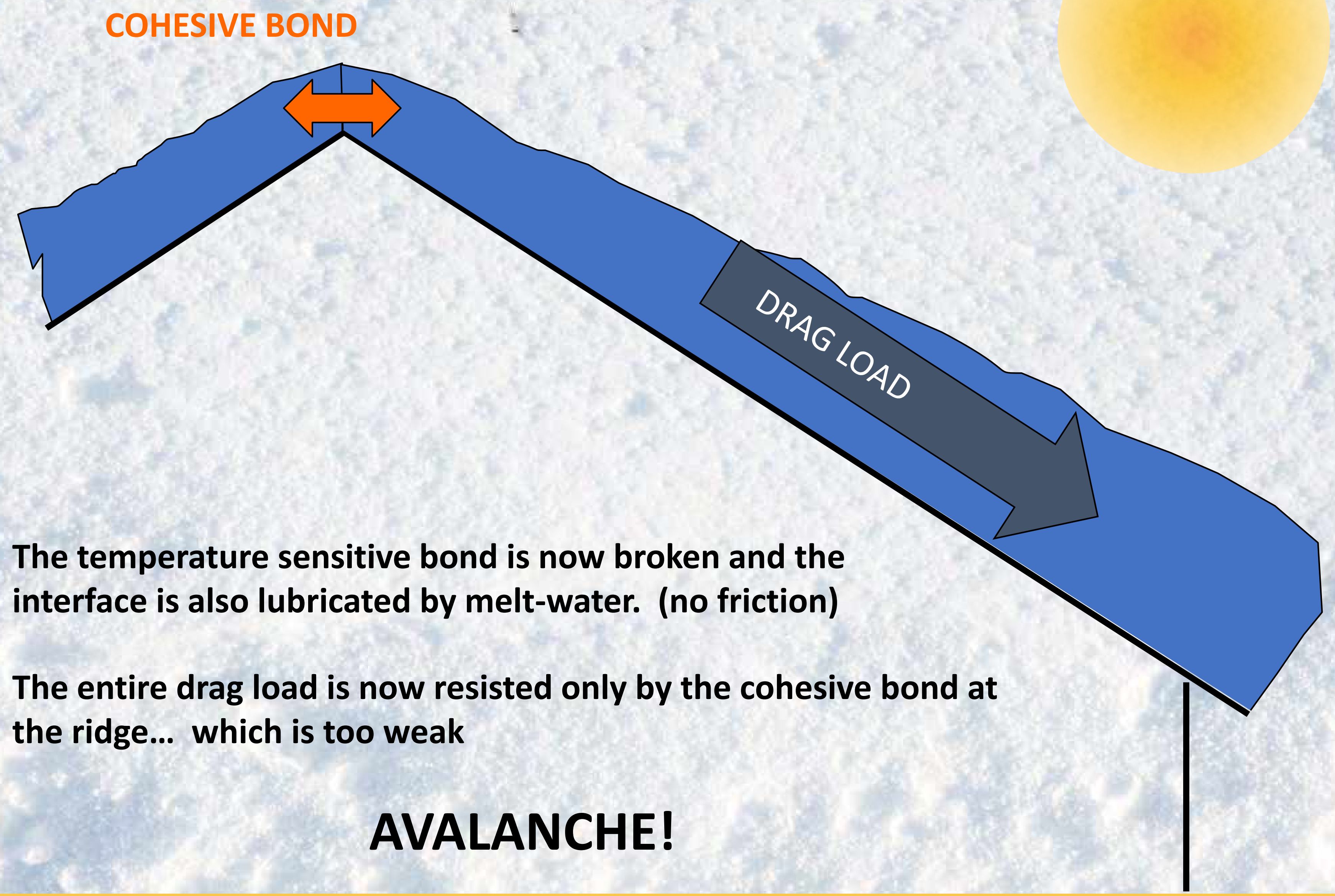


During snowstorm(s) sunlight is occluded and snowpack is retained on the roof by two bonds…

If drag loads (vector forces , gravity loads) of snowbank exceed the strength of those bonds-- avalanche will occur.

When storms pass, UV rays from the sun pass through the snowpack warming the roof below… and freeing the temperature-sensitive bond.

What causes an avalanche?



The temperature sensitive bond is now broken and the interface is also lubricated by melt-water. (no friction)

The entire drag load is now resisted only by the cohesive bond at the ridge… which is too weak

AVALANCHE!

What is a Snow Guard?

A **snow guard** is a mechanical device or system that increases friction between roof and snow, to retain snowpack on the roof, so that it evacuates in a **predictable and controlled fashion** (sublimation and thaw) rather than by a sudden and dangerous rooftop avalanche.

- **Snow guards must be engineered** and populated to resist the loads to which they are exposed.
- **Snow guards may be necessary** when converting a non-slippery surface to a slippery one!

Is this a slippery surface?

Unintentional Snow Guards

Notice how the lip of the module frame is retaining snow?

Is it designed to do that?

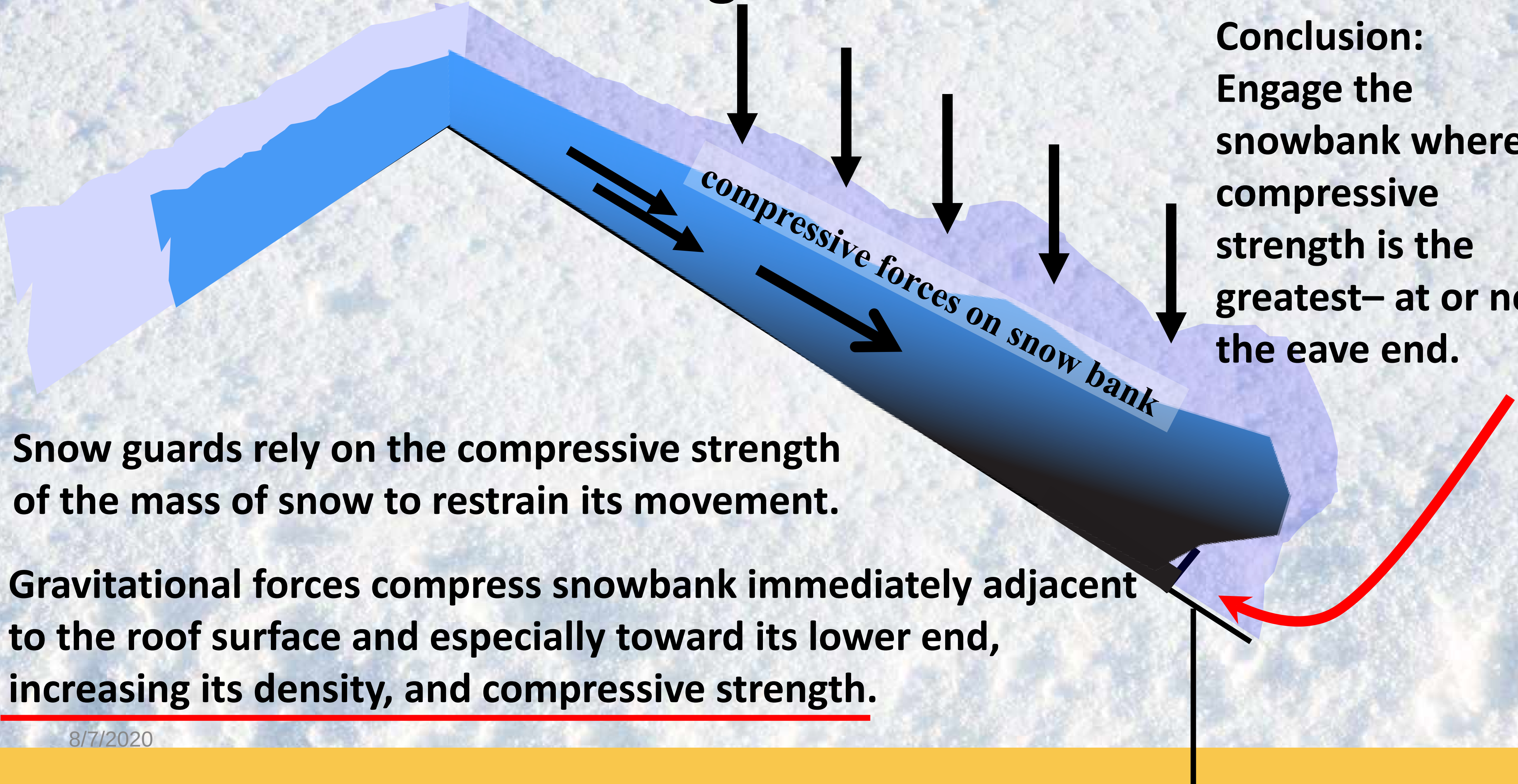
Unintended snow guards?
– sort of,
But not designed for that.

Unintentional Snow Guards

SCHOTT Solar AG

Designing PV Systems for Environmental Extremes: Page 2 of 6 | SolarPro Magazine | David Brearley

So where and what is the logic of engaging the snowbank with snow guard devices?



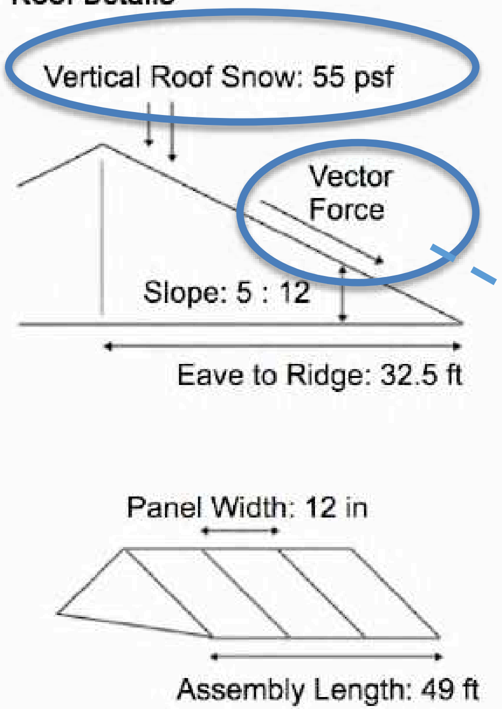
Conclusion:
Engage the snowbank where compressive strength is the greatest– at or near the eave end.

Snow guards rely on the compressive strength of the mass of snow to restrain its movement.

Gravitational forces compress snowbank immediately adjacent to the roof surface and especially toward its lower end, increasing its density, and compressive strength.

What Kind of Loads Do We See? (Example below)

Roof Details



Roof Name:	Wheelerville Bus Garage	**Project Name:**	Wheelerville Bus Garage
Roof / Calculation ID:	50082-0	**Date:**	22 Feb, 2018

User-Submitted Roof Information

Vertical Roof Snow	55 psf
Slope	5 : 12
Eave to Ridge	32.5 ft
Assembly Length	49 ft
Roof Style	Gable
Panel Width	12 in
Seam Height	1.75 in
Seam Orientation	Vertical
Panel Description	24 ga steel | Vertical Seam | Metal Sales

Calculated Roof Data

Vector	Vertical Roof Snow Load x Sine of Angle 55 psf x 0.385 21.154 psf
Vector/Panel	Vector x Eave to Ridge x Panel Width 21.154 psf x 32.5 ft x 1.000 ft
Design Vector Force	688.0 lb per panel
Allowable System Load	941.5 lb per clamp (based on a safety factor of 2)
Service Load	688.0 lb per clamp
Job Requires	1 row(s) of assembly, with a clamp on every seam

A single module of 18 s.f. will experience 381# of vector force

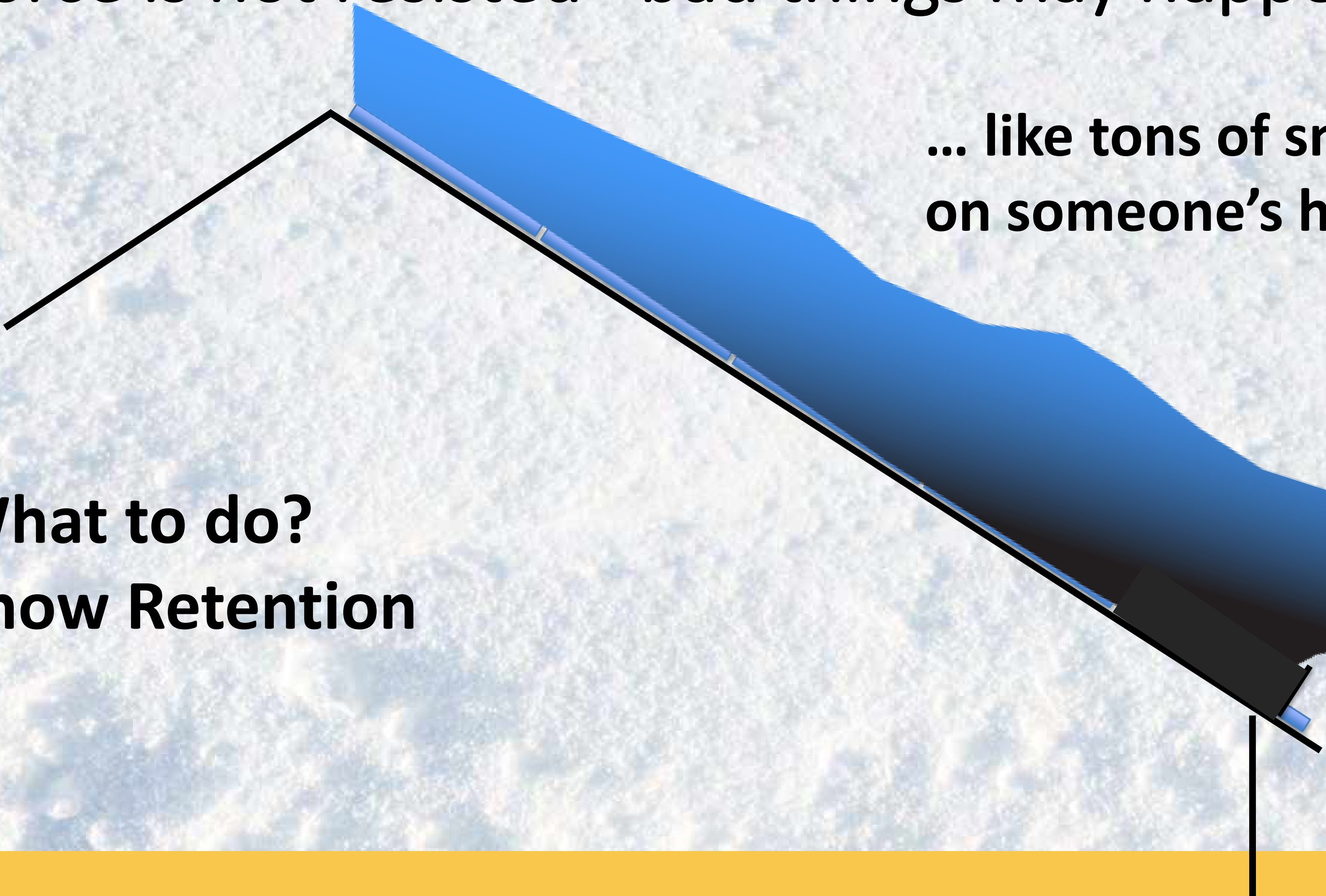
These forces are project-specific and will vary depending on slope, design roof snow loads and module size.

What Kind of Loads Do We See?

And a single column of 5 modules will experience 1,905# of vector load

If that force is not resisted– bad things may happen…

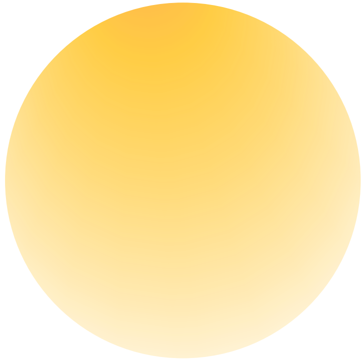
… like tons of snow landing on someone's head



What to do?

Snow Retention

What kind of loads do we see– even on flat roofs?



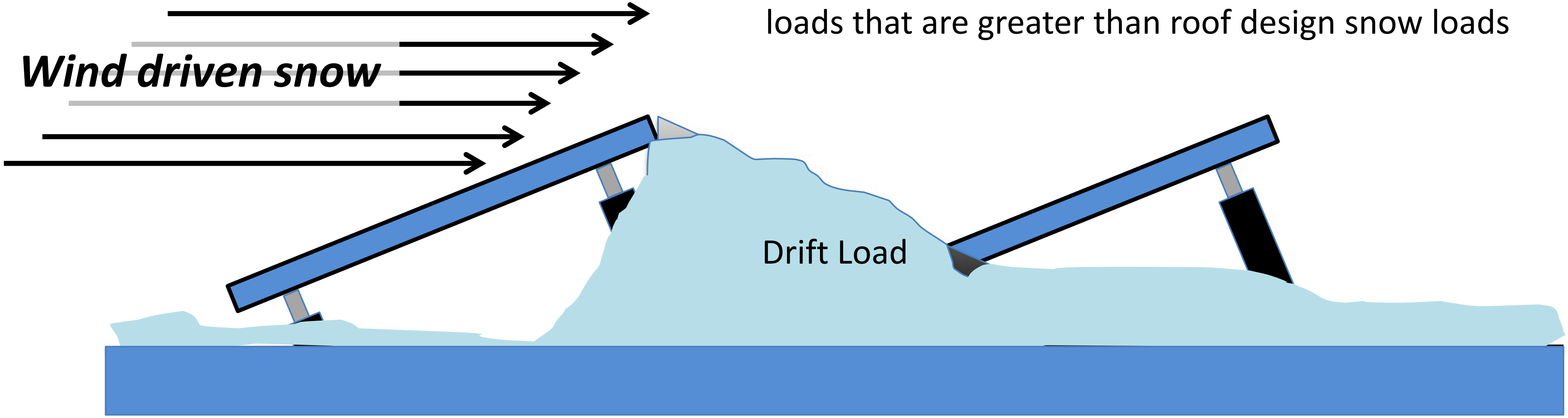
We are all familiar with shading

Added **dead** load of about 2.5 psf +/-

Much **more** if the system is ballasted

What about Added **live** loads?

Aerodynamic shade in snow country can create snow drift loads that are greater than roof design snow loads



Existing low slope roof with a proposed tilted PV array

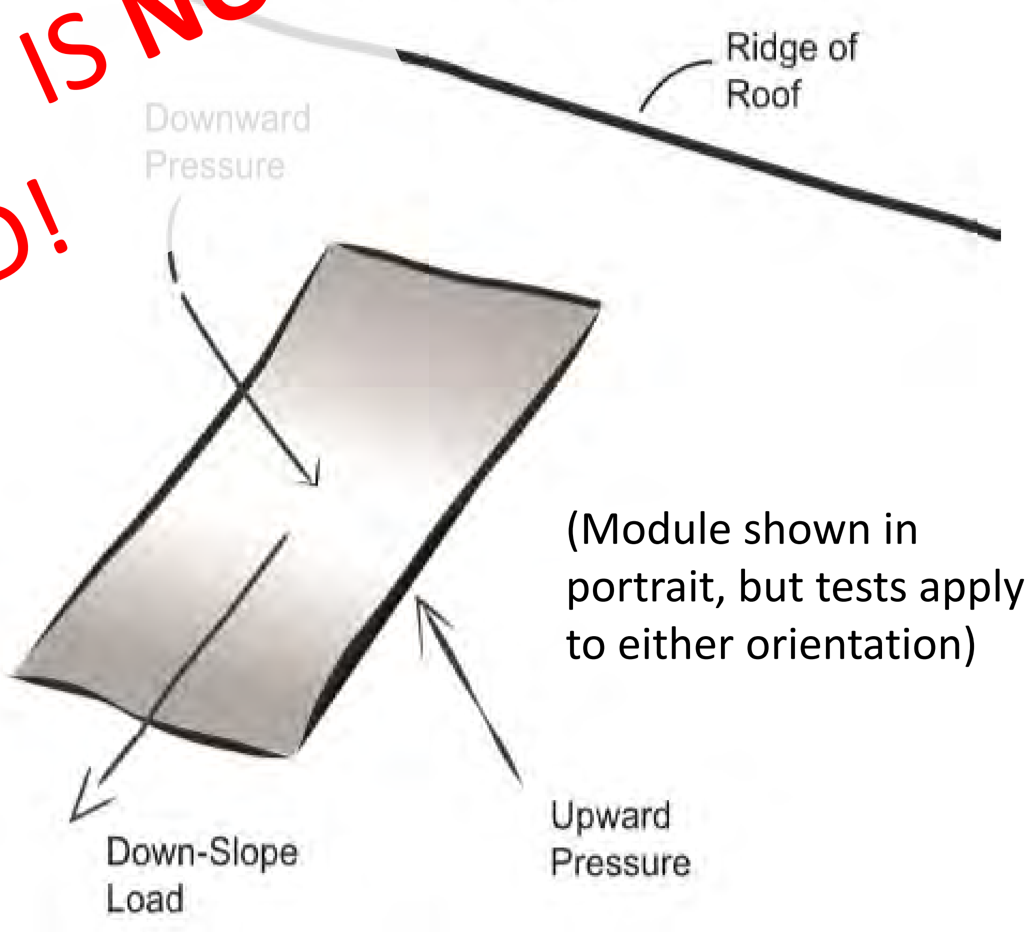
What are the standard tests for mechanical loads?

WHAT'S MISSING?

- UL 1703
  - **Module Only** Testing (single module)
    - 30 psf (1436 Pa) Design Load
    - 45 psf (2155 Pa) Test Load
    - Factor of Safety = 1.5
- IEC 61730 (61730-1 / 61730-2)
  - **Module Only** Testing (single module)
    - Similar to UL 1703; however modules are tested to ultimate structural capacity >50 psf (2394 Pa)
    - Factor of Safety (61730-2) = 1.5[1]
- UL 2703 (tests assembly– incl racking)
  - **Module/Rack** Testing (module pair)
    - 10 psf (479 Pa) Down Minimum Design Load
      5 psf (239 Pa) Up Minimum Design Load
    - Tested in 3 Orientations incl Down-Slope[2]
    - Factor of Safety = 1.5

RACK-TO-ROOF IS NOT TESTED!

Figure 21.1
Mechanical loading



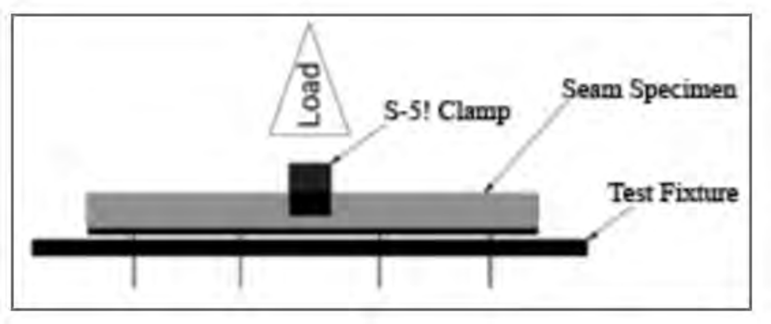
(Module shown in portrait, but tests apply to either orientation)

[1]Be careful! Many vendors may publish only ultimate load (NO FS)
[2]Down-slope is related to to walking/traffic loads—NOT snow vectors!

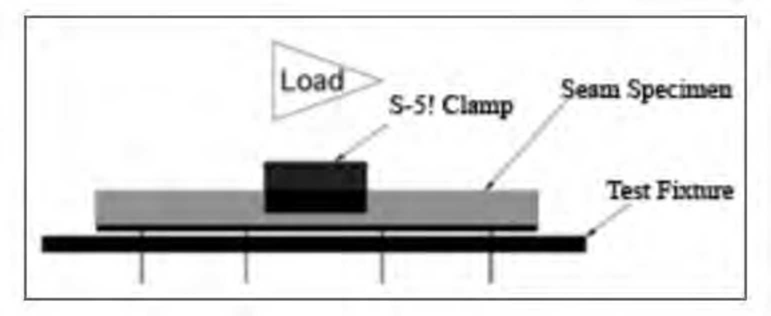
THE WEAK LINK IN THIS CHAIN OF TESTS & STANDARDS IS THE ATTACHMENT OF THE “RACK” (OR RAIL) TO THE ROOF.

IT IS ALSO LIKELY THE LOWEST COST COMPONENT OF A FISHISHED ARRAY

- So, what about the anchorage of the modules, rails or racking to the roof to resist wind uplift?
- And what about vector loads? Or snow guards?
- There are no codes, standards or mandates for these kinds of testing with very few jurisdictional exceptions. BUYER BEWARE!!

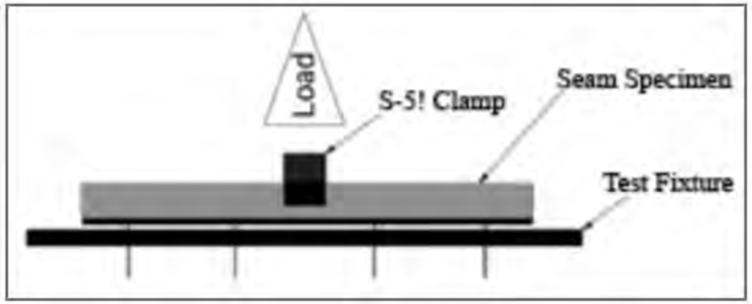


Normal to roof (wind uplift)



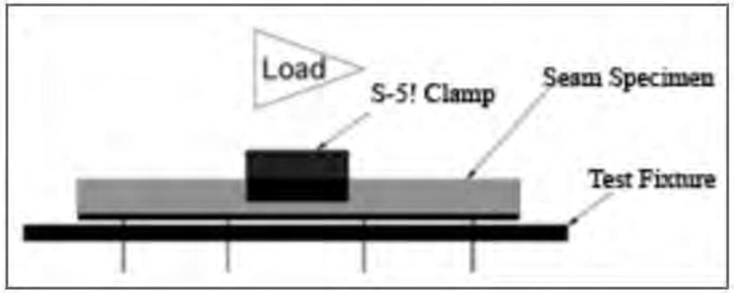
Parallel to roof (vector of snow)

- So, testing must be done voluntarily by producer.
- Testing should be done in ISO 17025 certified lab.
- Anchorages should be tested in minimum of two load directions- negative normal and parallel to roof.
- Test should be specific to the actual roof material (substrate) used on the project.
- Results from this testing should be published to purchaser WHO SHOULD DEMAND IT.
- Then the components must be produced in a certified factory (ISO-9001-15)



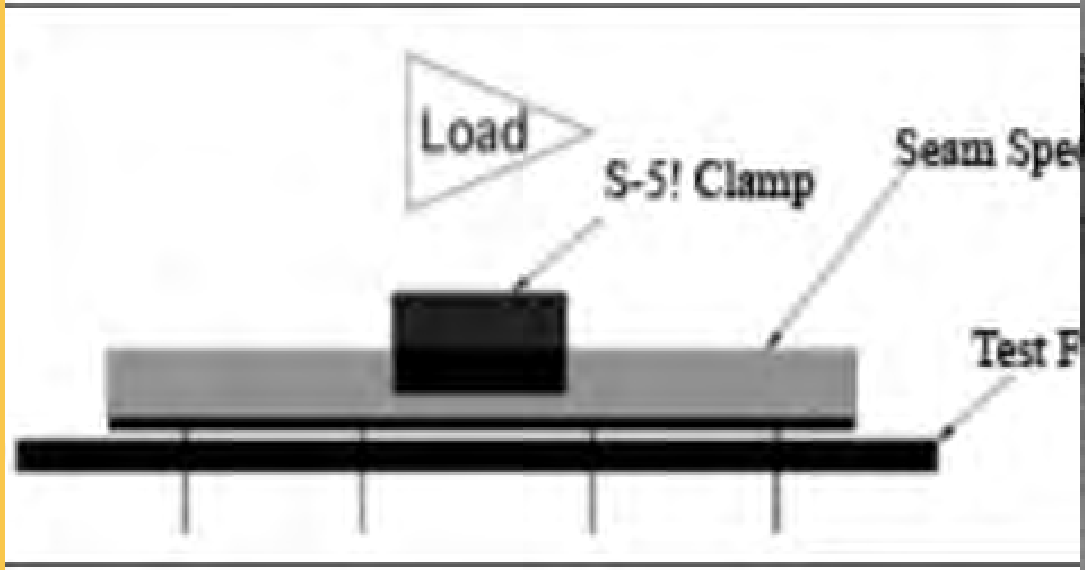
Normal to roof (wind uplift)

Without all these steps, proper system design and engineering is impossible!

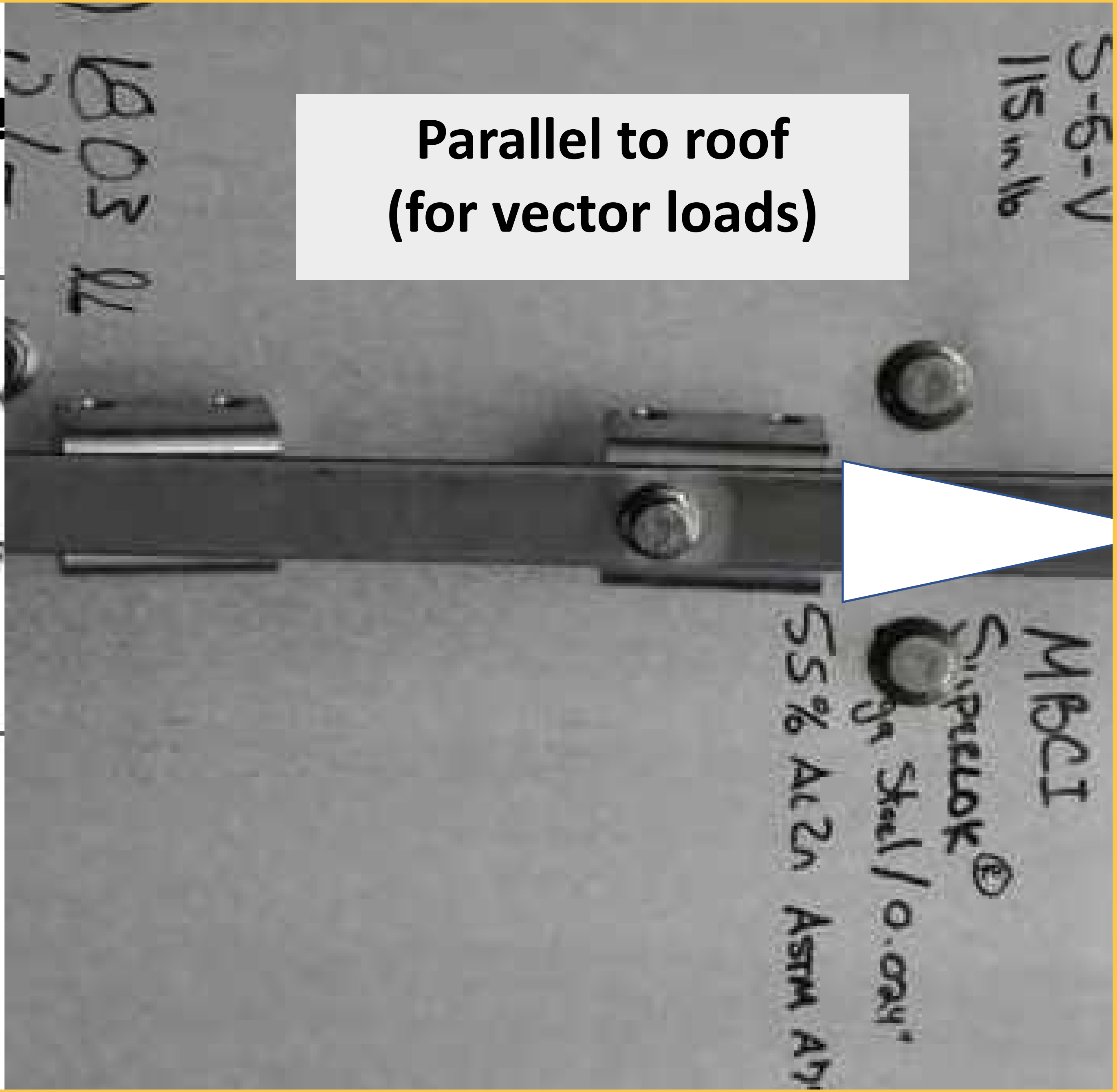


Parallel to roof (vector of snow)

Mo
(S-5!



Parallel to roof
(for vector loads)



Appropriate testing for mechanical loads parallel (Snow)

Panel Manufacturer: Sheet Metal Supply LTD

Product: All Products

Units: Imperial

Safety Factor: 2

SHOW RESULTS

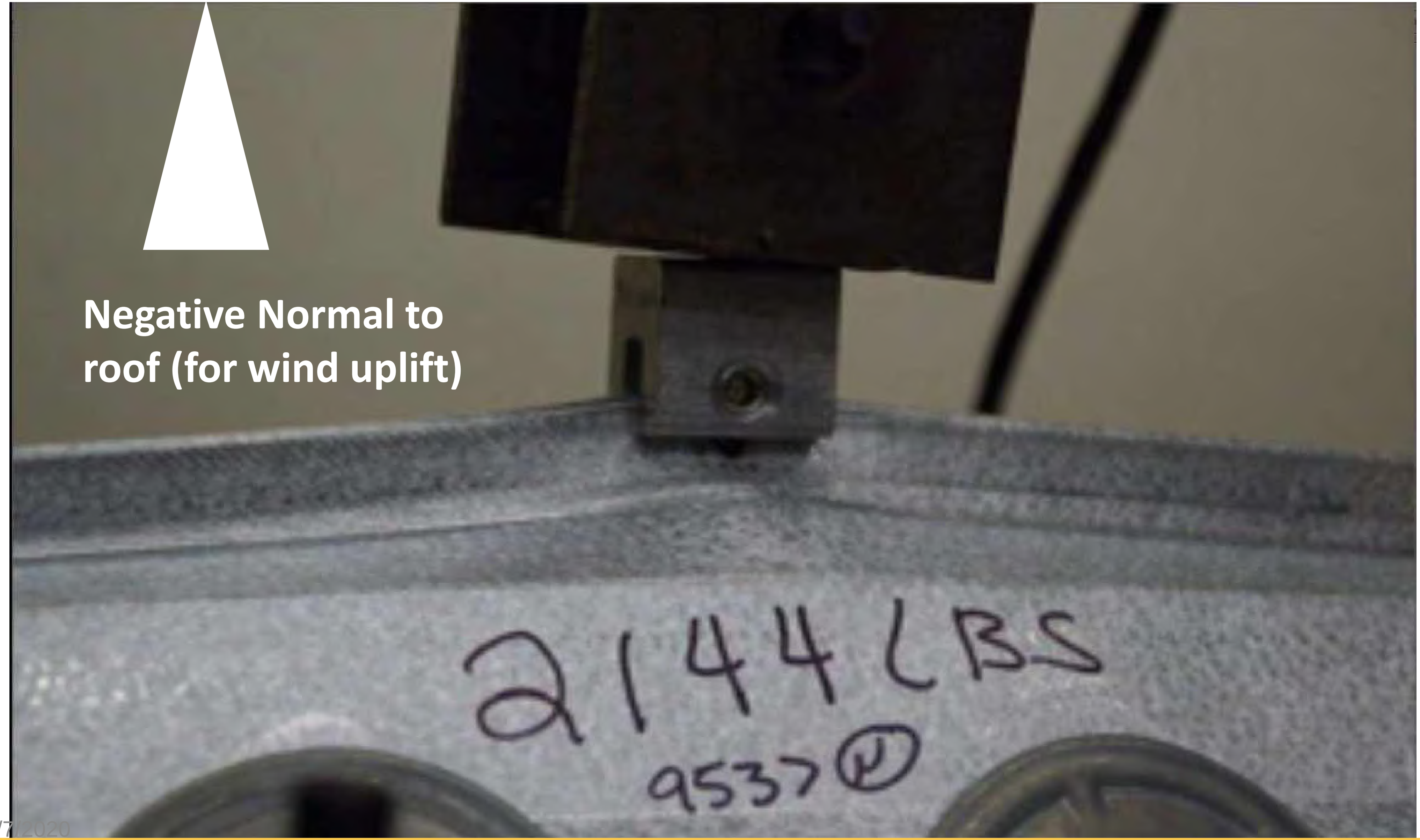
18 entries for ONE roof manufacturer

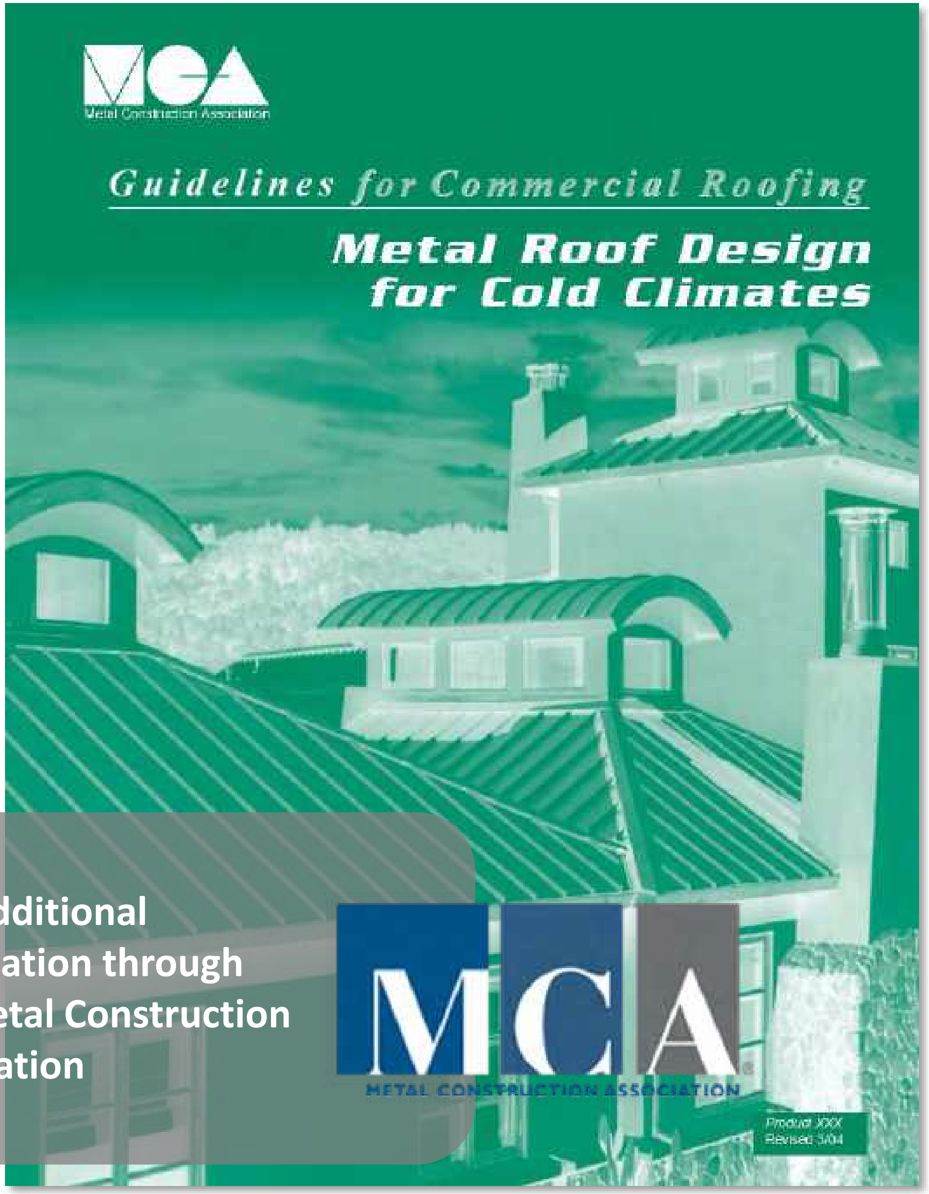
Different profiles, materials, thickness will yield different test results

Showing Test Results for Sheet Metal Supply LTD

S-5! CLAMP	MANUFACTURER	PRODUCT	THICKNESS MATERIAL	SCREW TENSION (inch-lbs)	ULTIMATE LOAD (lbs)	FAILURE MODE	ALLOWABLE LOAD (lbs)	NOTES
S-5-B	Sheet Metal Supply LTD	ML-1.5 (DBF)	20 Oz Copper	115	1397	B/F	699	
S-5-E	Sheet Metal Supply LTD	ML-1.5 (DBF)	0.8mm Zinc	115	1268	F	634	
S-5-B	Sheet Metal Supply LTD	ML-1.5 (DBF)	16 oz Copper	115	1475	B/F	738	
S-5-S	Sheet Metal Supply LTD	ML-1.5 (SF)	.032 alum	115	1075	F	538	
S-5-B	Sheet Metal Supply LTD	MLF-2 (DBF)	16 oz Copper	115	1152	F	576	
S-5-U	Sheet Metal Supply LTD	MLF-2 (SF)	24 ga steel	115	1351	B	676	3
S-5-H90	Sheet Metal Supply LTD	MLF-2 (SF)	24 ga steel	115	1351	B	676	3
S-5-N	Sheet Metal Supply LTD	NS-1	.032 alum	115	855	B/F	428	
S-5-N	Sheet Metal Supply LTD	NS-1	24 ga steel	115	1075	B	538	
S-5-N	Sheet Metal Supply LTD	NS-1	26 ga steel	115	1004	B/F	502	
S-5-Z	Sheet Metal Supply LTD	NS-1.5	24 ga steel	115	764	B/F	382	
S-5-N 1.5	Sheet Metal Supply LTD	NS-1.5	24 ga steel	115	676	C/B	338	
S-5-Z	Sheet Metal Supply LTD	NS-1.5	26 ga steel	115	705	B	353	
S-5-S	Sheet Metal Supply LTD	SL-1	.032 alum	115	808	B/F	404	
S-5-S	Sheet Metal Supply LTD	SL-1	24 ga steel	115	1360	F	680	
S-5-S	Sheet Metal Supply LTD	SL-1.5	24 ga steel	115	1729	F	865	
S-5-S	Sheet Metal Supply LTD	SL-1.5	.032 alum	115	1075	E/F	538	

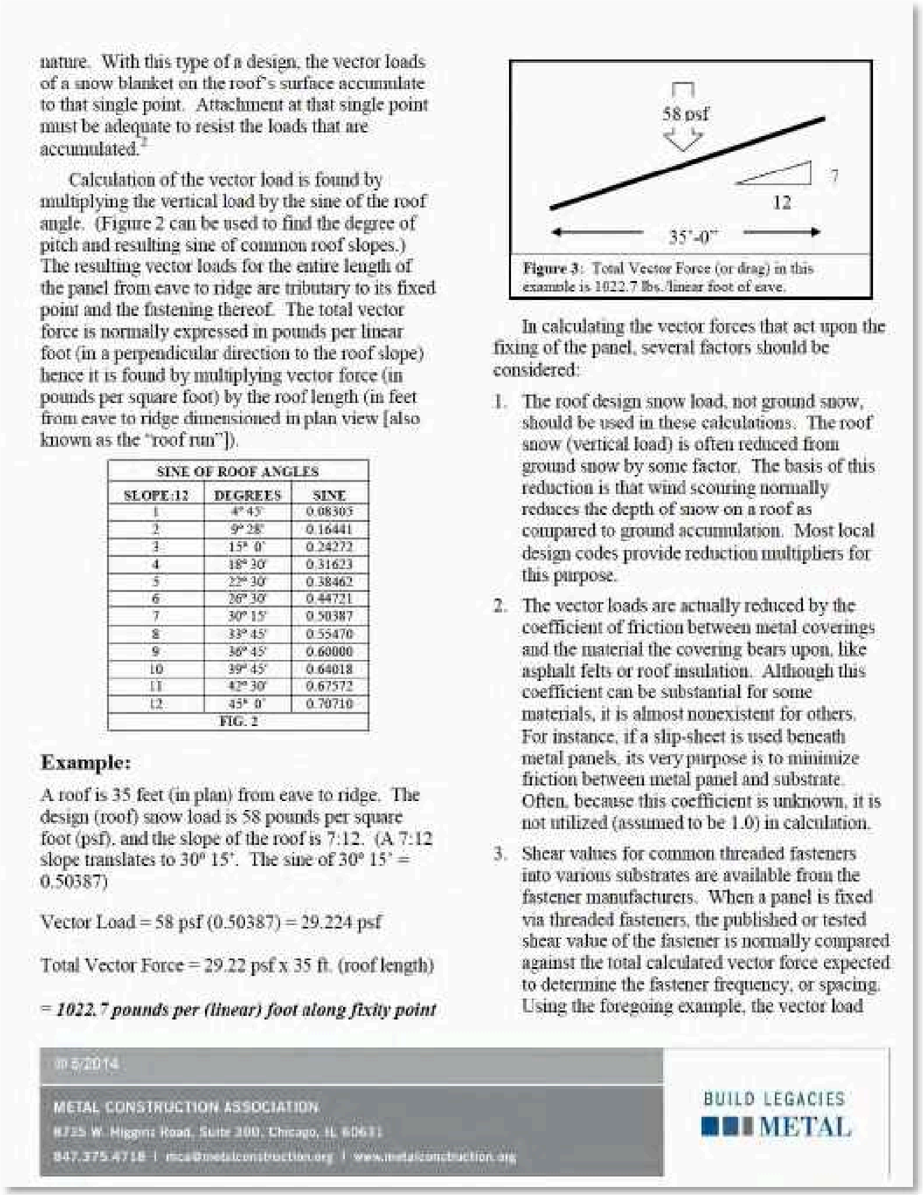
Appropriate Testing for Mechanical Loads Negative-Normal





Find additional information through the Metal Construction Association

MCA
METAL CONSTRUCTION ASSOCIATION



nature. With this type of a design, the vector loads of a snow blanket on the roof's surface accumulate to that single point. Attachment at that single point must be adequate to resist the loads that are accumulated.[2]

Calculation of the vector load is found by multiplying the vertical load by the sine of the roof angle. (Figure 2 can be used to find the degree of pitch and resulting sine of common roof slopes.) The resulting vector loads for the entire length of the panel from eave to ridge are tributary to its fixed point and the fastening thereof. The total vector force is normally expressed in pounds per linear foot (in a perpendicular direction to the roof slope) hence it is found by multiplying vector force (in pounds per square foot) by the roof length (in feet from eave to ridge dimensioned in plan view [also known as the "roof run"]).

SINE OF ROOF ANGLES		
SLOPE:12	DEGREES	SINE
1	4° 45'	0.08303
2	9° 28'	0.16441
3	15° 0'	0.24272
4	18° 30'	0.31623
5	22° 30'	0.38462
6	26° 30'	0.44721
7	30° 15'	0.50387
8	33° 45'	0.55470
9	36° 45'	0.60000
10	39° 45'	0.64018
11	42° 30'	0.67572
12	45° 0'	0.70710

FIG. 2

Example:

A roof is 35 feet (in plan) from eave to ridge. The design (roof) snow load is 58 pounds per square foot (psf), and the slope of the roof is 7:12. (A 7:12 slope translates to 30° 15'. The sine of 30° 15' = 0.50387)

Vector Load = 58 psf (0.50387) = 29.224 psf

Total Vector Force = 29.22 psf x 35 ft. (roof length)

= *1022.7 pounds per (linear) foot along fixity point*

58 psf
7
12
35'-0"

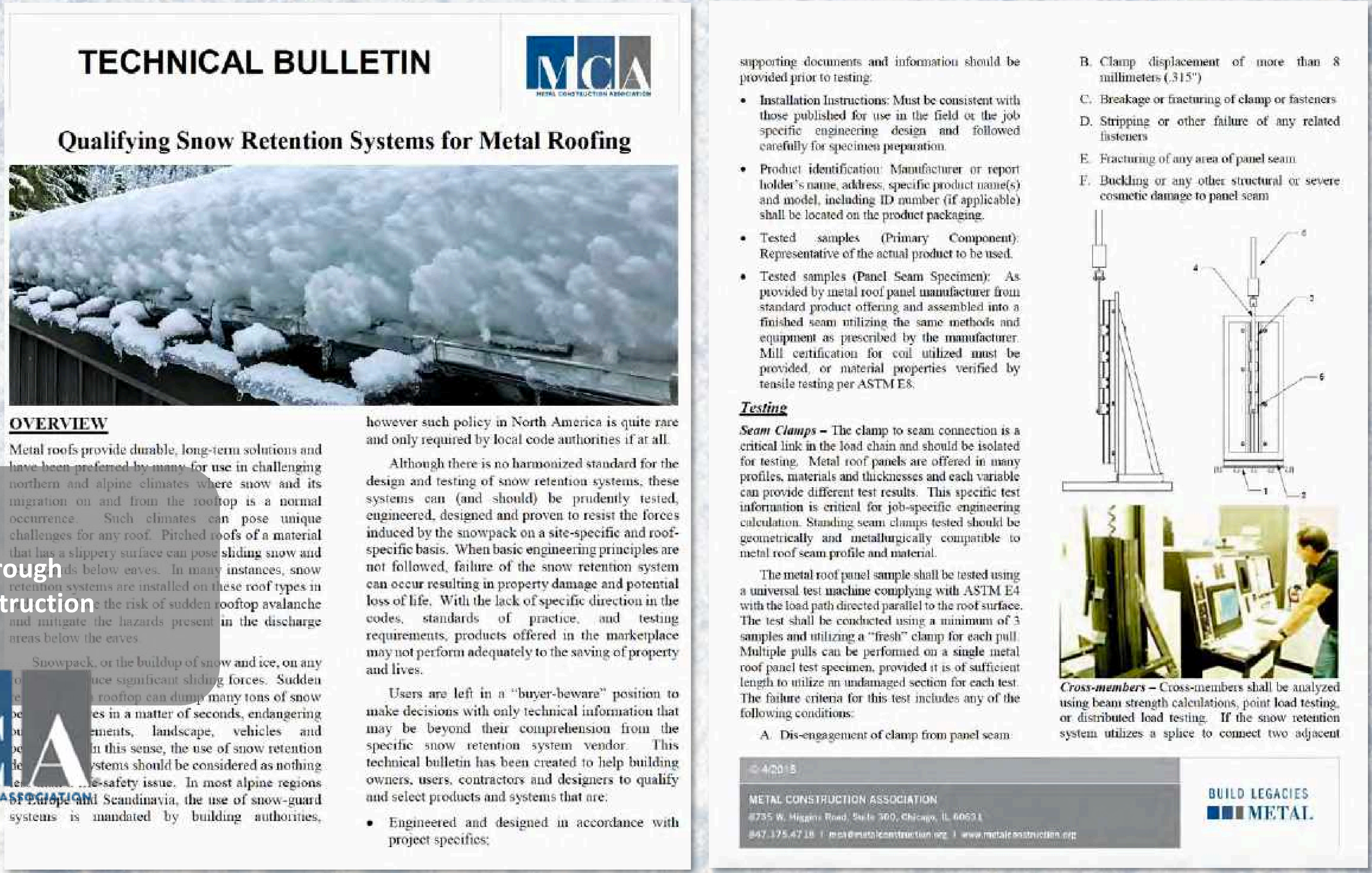
Figure 3: Total Vector Force (or drag) in this example is 1022.7 lbs./linear foot of eave.

In calculating the vector forces that act upon the fixing of the panel, several factors should be considered:

1. The roof design snow load, not ground snow, should be used in these calculations. The roof snow (vertical load) is often reduced from ground snow by some factor. The basis of this reduction is that wind scouring normally reduces the depth of snow on a roof as compared to ground accumulation. Most local design codes provide reduction multipliers for this purpose.
2. The vector loads are actually reduced by the coefficient of friction between metal coverings and the material the covering bears upon, like asphalt felts or roof insulation. Although this coefficient can be substantial for some materials, it is almost nonexistent for others. For instance, if a slip-sheet is used beneath metal panels, its very purpose is to minimize friction between metal panel and substrate. Often, because this coefficient is unknown, it is not utilized (assumed to be 1.0) in calculation.
3. Shear values for common threaded fasteners into various substrates are available from the fastener manufacturers. When a panel is fixed via threaded fasteners, the published or tested shear value of the fastener is normally compared against the total calculated vector force expected to determine the fastener frequency, or spacing. Using the foregoing example, the vector load

http://www.metalconstruction.org/download.php/education/downloads/MetalRoofDesignforColdClimates

Find additional information through the Metal Construction Association


TECHNICAL BULLETIN

MCA METAL CONSTRUCTION ASSOCIATION

Qualifying Snow Retention Systems for Metal Roofing

OVERVIEW

Metal roofs provide durable, long-term solutions and have been preferred by many for use in challenging northern and alpine climates where snow and its migration on and from the rooftop is a normal occurrence. Such climates can pose unique challenges for any roof. Pitched roofs of a material that has a slippery surface can pose sliding snow and [illegible]ds below eaves. In many instances, snow retention systems are installed on these roof types in [illegible] the risk of sudden rooftop avalanche and mitigate the hazards present in the discharge areas below the eaves.

Snowpack, or the buildup of snow and ice, on any ro[illegible]uce significant sliding forces. Sudden re[illegible] rooftop can dump many tons of snow be[illegible]es in a matter of seconds, endangering bu[illegible]ements, landscape, vehicles and pe[illegible] In this sense, the use of snow retention de[illegible]ystems should be considered as nothing le[illegible]fe-safety issue. In most alpine regions of Europe and Scandinavia, the use of snow-guard systems is mandated by building authorities, however such policy in North America is quite rare and only required by local code authorities if at all.

Although there is no harmonized standard for the design and testing of snow retention systems, these systems can (and should) be prudently tested, engineered, designed and proven to resist the forces induced by the snowpack on a site-specific and roof-specific basis. When basic engineering principles are not followed, failure of the snow retention system can occur resulting in property damage and potential loss of life. With the lack of specific direction in the codes, standards of practice, and testing requirements, products offered in the marketplace may not perform adequately to the saving of property and lives.

Users are left in a "buyer-beware" position to make decisions with only technical information that may be beyond their comprehension from the specific snow retention system vendor. This technical bulletin has been created to help building owners, users, contractors and designers to qualify and select products and systems that are:

- Engineered and designed in accordance with project specifics;

supporting documents and information should be provided prior to testing:

- Installation Instructions: Must be consistent with those published for use in the field or the job specific engineering design and followed carefully for specimen preparation.
- Product identification: Manufacturer or report holder's name, address, specific product name(s) and model, including ID number (if applicable) shall be located on the product packaging.
- Tested samples (Primary Component): Representative of the actual product to be used.
- Tested samples (Panel Seam Specimen): As provided by metal roof panel manufacturer from standard product offering and assembled into a finished seam utilizing the same methods and equipment as prescribed by the manufacturer. Mill certification for coil utilized must be provided, or material properties verified by tensile testing per ASTM E8.

Testing

Seam Clamps **–** The clamp to seam connection is a critical link in the load chain and should be isolated for testing. Metal roof panels are offered in many profiles, materials and thicknesses and each variable can provide different test results. This specific test information is critical for job-specific engineering calculation. Standing seam clamps tested should be geometrically and metallurgically compatible to metal roof seam profile and material.

The metal roof panel sample shall be tested using a universal test machine complying with ASTM E4 with the load path directed parallel to the roof surface. The test shall be conducted using a minimum of 3 samples and utilizing a "fresh" clamp for each pull. Multiple pulls can be performed on a single metal roof panel test specimen, provided it is of sufficient length to utilize an undamaged section for each test. The failure criteria for this test includes any of the following conditions:

A. Dis-engagement of clamp from panel seam

B. Clamp displacement of more than 8 millimeters (.315")

C. Breakage or fracturing of clamp or fasteners

D. Stripping or other failure of any related fasteners

E. Fracturing of any area of panel seam

F. Buckling or any other structural or severe cosmetic damage to panel seam

Cross-members **–** Cross-members shall be analyzed using beam strength calculations, point load testing, or distributed load testing. If the snow retention system utilizes a splice to connect two adjacent

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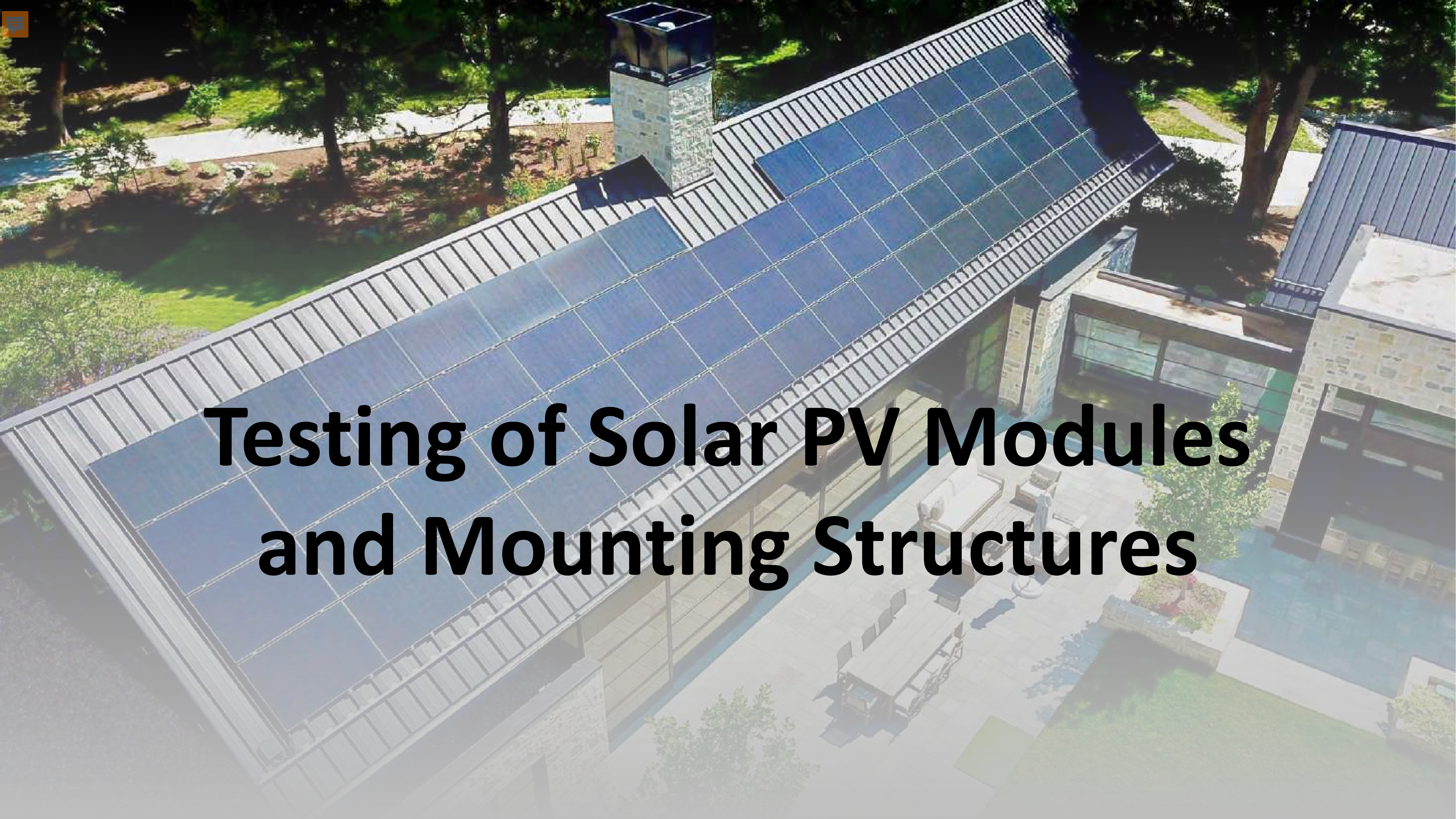

Testing of Solar PV Modules and Mounting Structures

Mark Gies – Panelist

Director of Business Development – S-5!

>11 years in solar industry
Additional 20 years engineering and management – multiple industries

Prior to S-5!:

VP Engineering – Ballasted PV Mounting Systems
Business Development – Solar Developer/EPC/Installer

Vice-Chair of SEIA's Mounting System Manufacturers Committee
Member – SEAOC PV Committee
Founding Member – UL 2703 Standards Technical Panel

MBA – Olin School of Business at Babson College
ME, BA (Mechanical Engineering) – Dartmouth College

“Economics” of Permitting/Project Requirements

Project Requirements
IBC, IRC
ASCE 7

White Papers
SEAOC PV

Wind Tunnel

Test Data/Standards
UL 61730 (UL & IEC)
UL 2703
*New UL 7103 BIPV
FM 4478

Acceptance & Evaluation Criteria

Other Standards & Standard Testing Methods (i.e. ASTM)

Project-Specific Calcs

Benefits of Standards/Methods/ACs/ECs/Etc.

PV System Design (PV Module and Support Structure)

Sometimes Structural Analysis and Calculations are not enough to prove compliance

- Consensus-Driven
- Universally known and accepted
- Standardized approach
- Multi-faceted; Compliance to many critical parameters
- Reduces project-specific work – onerous
    - SAVES TIME AND MONEY – Standards Make it Easier
- Ensures safety and quality – Issues don’t fall through the cracks

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ES ICC EVALUATION SERVICE
ICC-ES Evaluation Report

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SHINING LIGHT ON ROOFTOP SOLAR

Division of the State Architect
CALIFORNIA DEPARTMENT OF GENERAL SERVICES

Photovoltaic Panels and Modules
IEC/UL 61730 Conformance

USA and International Access in One Standard

UL 61730-1

STANDARD FOR SAFETY

Photovoltaic (PV) Module Safety Qualification –
Part 1: Requirements for Construction

UL 61730-2

STANDARD FOR SAFETY

Photovoltaic (PV) Module Safety Qualification –
Part 2: Requirements for Testing

Development of Global Consensus-Based Standards by:
International Harmonization Committee (IHC) and Standards Technical Panel (STP)

Harmonized UL1703 and IEC 61730

Mechanical Load Test per UL 61730-2 Safety

10.23 Static Mechanical Load: MST 34 (Equivalent to IEC 61215-2 MQT 16)

- IEC 61215 test protocol was chosen during harmonization process
- Safety Factor of 1.5 added from UL 1703

  - Minimum Design Load: 33psf (1600 Pa) – Test Load: 50 psf (2400 Pa)
  - Higher design load ratings upon request
  - Positive (down) and Negative (up) can have different load ratings
    - Example: 33 psf up design load and 50 psf down design load
  - Procedure: 3 tests each direction (up and down) for 60 minutes each test
    - Mechanical failure cannot occur during testing
    - Electric continuity must be maintained after testing

  - Modules can be tested for “Reduced Mechanical Load”
    - Design Load 17 psf (800 Pa); Test Load 25 psf (1200 Pa)
    - Reduced Load rated modules can only be installed in the interior section of a large utility-scale ground mount PV array

UL Mechanical Load Testing

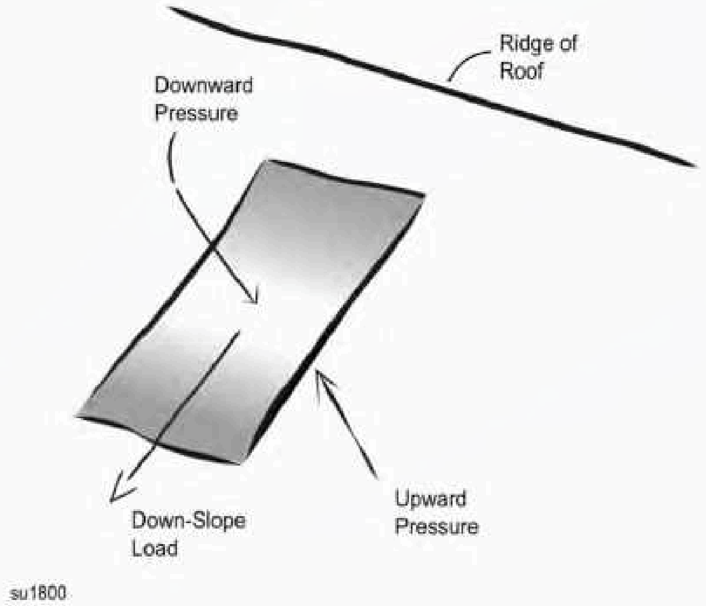
ANSI/UL 2703, Mounting Systems, Mounting Devices, Clamping/Retention Devices, And Ground Lugs for use with Flat-Plate Photovoltaic Modules

CONSTRUCTION

PERFORMANCE

Figure 21.1

Mechanical loading



21.4 The minimum design load rating in each direction shall be:

a) Downward Pressures – 10 psf allowable load.

b) Upward Pressure – 5 psf allowable load.

c) Down-Slope Load – 5.0 psf allowable load.

All design pressures/loads shall be multiplied by a minimum factor of safety of 1.5 to determine the "test" pressure/load to meet the minimum requirement, as shown in 21.5.

21.5 The minimum test load in each direction shall be:

a) Downward Pressures – 15 psf.

b) Upward Pressure – 7.5 psf.

c) Down-Slope Load – 7.5 psf.

UL Mechanical Load Testing

UL Mechanical Load Testing

Important Notes:

- Lower minimum ratings may be misunderstood – Product rating (supply) must match site demand
  - That has always been a point of confusion – even before UL 2703 changed
- Ratings are for specific combinations of modules and racking
  - 33 psf rated module + 10 psf racking as tested is only rated to 10 psf
- UL 2703 listing does not need to have mechanical load testing – Beware

SUMMARY OF REQUIREMENTS
FOR
Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels
UL 2703, 1st Ed, Revised 5/29/2019
Proposed Effective Date: 2/28/2022
Review ID 2703-2019-005

6.4	Revised	Change: clarify type of sheet metal screws that are not allowed for bonding/grounding, but that may be allowed for mechanical/structural connections. Impact: No impact on existing certifications; no change to testing procedure.
6.5, C.1	Revised	Change: (6.5) clarify intention of safety factor requirements; modify clamp load equation to bring in line with existing industry conventions. Safety factor on clamping load, and additional clarity to clamping load calculation Impact. (C.1) Update sample calculation based on modifications to equation in 6.5. Impact: No impact on existing certifications; no change to testing procedure.
6.7	Revised	Change: Reduction in requirements: slight reduction in margin of safety for threaded rods not under a clamp load. Impact: No impact on existing certifications; no change to testing procedure.
7.4	Revised	Change: Increase RTI requirements for components in direct contact with PV backing; reduce RTI requirements if not in direct contact with PV. Impact: Action Required, previously listed polymeric mounting systems that come into direct contact with PV backing material may not comply with the new more stringent requirements. This type of construction is rare, as mounting systems use metallic components where contact is made with the module. However, an industry file review is recommended to determine if any listed products require additional review or testing

Sheet Metal Screw can be used for Mechanical Connections

Min SF: 3:1

Min SF: 6:1

Now: 105/90/70 degrees C
w/exception: 61730 Temperature Test

A New Building Integrated Photovoltaics (BIPV) Standard

Scott Jezwinski, John Taecker – UL LLC

BIPV Safety Evaluations for Conformance

As solar photovoltaic (PV) technology matures, it is increasingly being integrated into building construction and used to replace conventional materials in parts of the building envelope such as roofs, curtain walls and windows. As conventional roof installation costs continue to increase, and PV prices decrease, building integrated photovoltaics (BIPV) are growing in popularity.

Architects are now integrating PV technology into their designs for the aesthetic value and to help building owners reduce energy costs with environmentally-friendly electric generation. BIPV is a way to achieve compliance with energy conservation codes and sustainability requirements and helps in earning a LEED building certification.

What is BIPV?

BIPV are PV modules that are integrated into a building and have been designed following the basic requirements for both photovoltaic products and construction materials, or the components and cladding they are intended to replace. BIPV products are intended for mounting integrally to the structure or protective surfaces of a building in one of two primary installation methods:

- As a roof, or as a **major component of the roofing system** of a building
- As part of a structural or non-structural component of a building such as a curtain wall, facade, atrium or skylight

BIPV Testing and Certification Requirements

BIPV testing and certification is required by the International Residential Code (IRC) (sections R905.16 and R905.17) and the International Building Code (IBC) (sections 1507.17 and 1507.18) for photovoltaic shingles and BIPV roof panels. Testing and evaluation includes electrical, temperature, mechanical loading, wind resistance, impact and fire tests. The product's output wiring system is also investigated for conformance with the provisions of the National Electrical Code (NEC), including Article 690 Solar Photovoltaic (PV) Systems.

Currently, BIPV systems and their mounting means for roofing systems are evaluated separately for compliance to several standards:

- UL 1703, Standard for Safety of Flat-Plate Photovoltaic Modules and Panels, and
- UL 790, Standard Test Methods for Fire Tests of Roof Coverings, and
- Either ASTM D3161 Standard Test Method for Wind-Resistance of Steep Slope Roofing Products (Fan-Induced Method) or UL 1897, Uplift Tests for Roof Covering Systems.

The results of evaluation to these various requirements may be captured in separate certification reports that must be reviewed to determine compliance with all model code requirements. Having one standard to address all aspects of concern for BIPV safety and code compliance makes it far easier for code authorities to determine compliance with the applicable electrical and building codes.

The recently published UL 7103, Outline of Investigation for Building-Integrated Photovoltaic Roof Coverings, brings together all the testing standards required for BIPV by the model installation codes. UL 7103 includes additional requirements to address concerns regarding these unique products and their specific labeling (marking) requirements.

UL 7103 – The New Standard for BIPV Roofing Products

Safety certification for BIPV products is more stringent than certification for conventional PV modules. The NEC, IBC and IRC require that all PV products installed on or around a building must be certified by a Nationally Recognized Testing Laboratory (NRTL) in accordance with the applicable standards. Because of these model code requirements, all BIPV products are subjected to the same electrical certification, performance and safety testing standards as conventional PV modules and more.

Product installation concerns for PV panel systems include:

- Utility compatibility and interaction
- Environment, e.g., indoor, outdoor, hazardous location, etc.
- Max. number of modules affecting voltage, current and short-circuit
- Fire exposure ratings
- Wind and snow loading
- Mounting and attachment
- Grounding and bonding
- Shading

Since BIPV is designed to directly replace roofing material, a BIPV system must be evaluated not only as a PV module but also as a roofing material with additional model code required testing such as:

- Fire resistance
- Impact testing
- Wind resistance
- Wind driven rain
- Environmental testing for conditions like temperature and humidity

Integration of PV systems into building products and architectural designs is growing. Certification to a single, all-inclusive standard provides a solid foundation upon which to certify BIPV technologies and deliver confidence in the safety and performance of new BIPV products for architects, installers and code authorities.

Roof Integrated

Photo Source: standardindustries.com/solar

Roof Shingle

Photo Source: certainteed.com/solar

Roof System

Photo Source: tesla.com/solarroof

BIPV Solar Modules act as both PV Modules and as the Roof System……. So they need to be evaluated as such

<u>Subject UL 7103 is a combination of:</u>
UL 61730 (UL 1703)
UL 2703

<u>And these Roofing Standards:</u>
UL 580: Test for Uplift Resistance of Roof Assemblies

UL 1897: Standard for Uplift Tests for Roof Covering Systems

ASTM D3161 Standard Test Method for Wind Resistance of Steep Slope Roofing Products (Fan-Induced Method)

FM Approvals

Approval Standard
for
Roof-Mounted Rigid
Photovoltaic Module Systems

Class Number 4478

FM 4478

- Listed Systems: Combination of Roof, PV Module, Mounting System
- Every Combination Has to be Evaluated and Possible Tested

- Testing Includes
  - Gravity Load Test: Minimum Listing: 32 PSF (Higher Available)
    - 1 Hour Test Duration, Safety Factor: 1.0
  - Wind Uplift Test: Minimum Listing: 60 psf (Higher Available)
    - Uplift Forces from Vacuum Chamber
    - 1 Minute Intervals until Failure, Safety Factor 1.25

Vacuum Chamber for Wind Uplift Test

FM Global

FM Global
Property Loss Prevention Data Sheets 1-15
July 2014 Interim Revision February 2020

- FM Global's Rules for Insurance Compliance
- It is the Demand-Side of the Equation
- A lot of Additions in 2020 Version (in red)

2.1.1 Wind

2.1.1.1 Design all roof-mounted, rigid PV solar panels and their securement using basic wind pressures in accordance with DS 1-28, *Wind Design*. Adhere to the following recommendations except where noted otherwise:

A. Use the design wind speeds as noted in Data Sheet 1-28. Do not further reduce the design wind speed to that of a lower MRI based on assumptions regarding the expected lifespan of the arrays.

B. Use Exposure C in non-coastal areas unless all conditions for Exposure B are met as outlined in DS 1-28. Use Exposure D where needed per DS 1-28.

2.1.1.7 Use concrete paver blocks for ballasted PV panels that meet specifications in ASTM C1491 and are tested in accordance with ASTM C1262 (does not include pass/fail criteria) for exposure to freeze-thaw cycles. The cumulative weight loss measured in the test should not exceed 5% of the initial weight of the specimen. (Use comparable standards outside the United States.)

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ESR-3187

Reissued 03/2016

This report is subject to renewal 03/2018.

DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

HILTI, INC.

7250 DALLAS PARKWAY, SUITE 1000
PLANO, TEXAS 75024

EVALUATION SUBJECT:

HILTI HIT-HY 200 ADHESIVE ANCHORS AND POST INSTALLED REINFORCING BAR CONNECTIONS IN CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2015, 2012, 2009 and 2006 *International Building Code®* (IBC)
- 2015, 2012, 2009 and 2006 *International Residential Code®* (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

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ICC-ES Evaluation Report

ESR-3869

Issued July 2019
This report is subject to renewal July 2020.

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DIVISION: 05 00 00—METALS
Section: 05 05 23—METAL FASTENINGS

REPORT HOLDER:

S-5! METAL ROOF INNOVATIONS, LTD.

EVALUATION SUBJECT:

S-5! STANDING SEAM CLAMPS

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2018, 2015, 2012 and 2009 International Building Code (IBC)
- 2018, 2015, 2012 and 2009 International Residential Code (IRC)

standing seam metal roof. The connection of the nonstructural components to the S-5! clamps must be designed by a registered design professional and must not exceed the published values in Table 1. The ability of the standing seam metal roof to resist the applied loads by the clamps must be determined by a registered design professional.

4.2 Installation:

The S-5! clamps are designed to fit the seam configuration of the standing seam metal roof. Installation is limited to the standing seam metal roofs described in Table 1 of this report. Once the clamp and insert has been placed on the seam, the set screws must be tightened to a torque as indicated in Table 1 of this report. Ancillary items are fixed to the clamps using the supplied bolts. The bolt-thread must engage the clamp a minimum of 0.32-inch (8.1 mm).

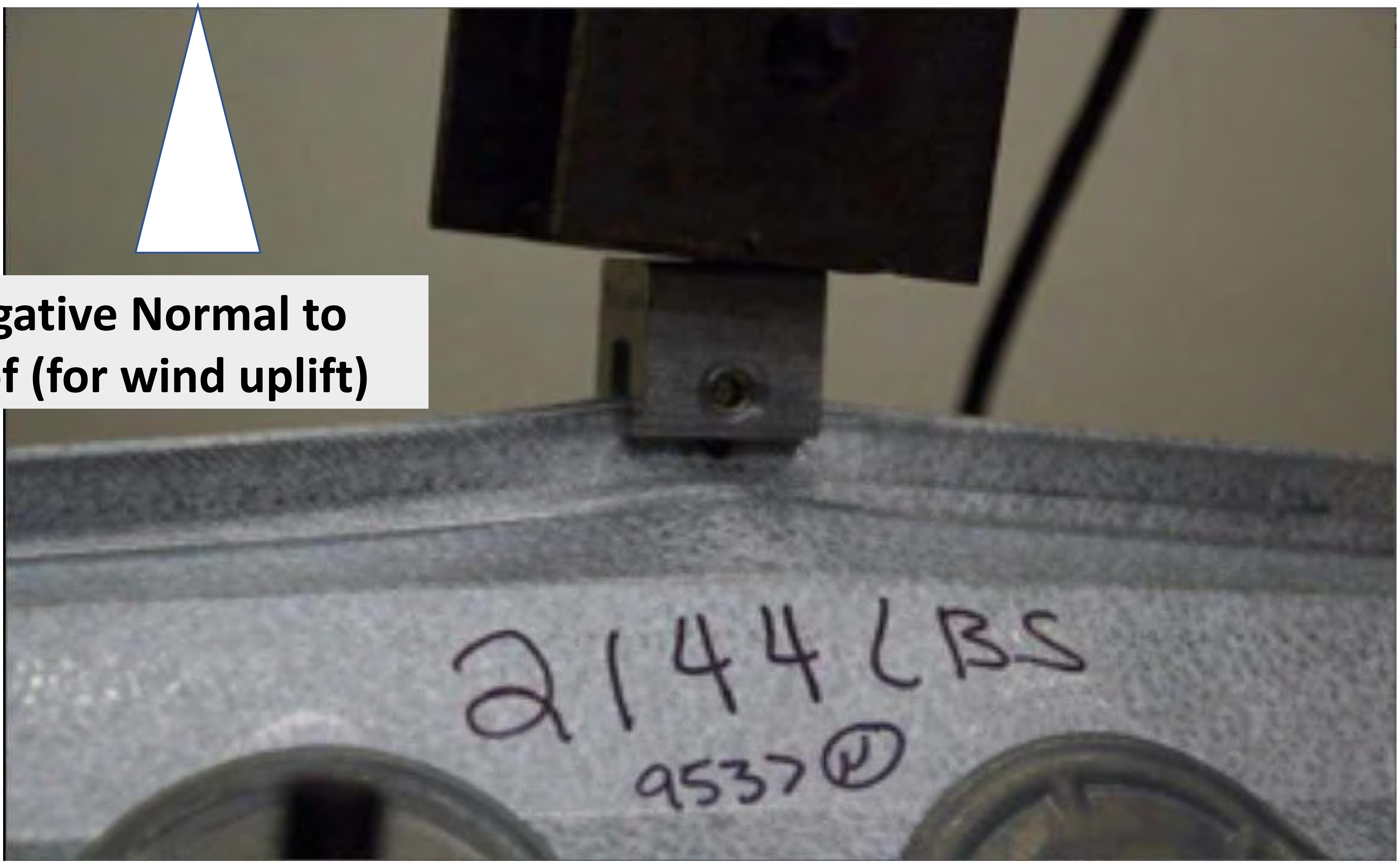
4.3 Special Inspection:

TABLE 1—ALLOWABLE CONNECTION CAPACITY OF THE S-5! CLAMPS TO STANDING SEAM METAL ROOF[1]

S-5! Clamps	Standing Seam Metal Roof			Installed Torque (in-lb)	Allowable Connection Capacity (lbf)		
					Uplift	Lateral	
	Manufacturer	Product Designation	Yield Strength (ksi)		Normal to Seam	Parallel to Seam	Normal to Seam
S-5-T	Garland	R-Mer® Span (22 ga. G90 and PVDF coated steel)	50.5	160-180	779	1093	N/A
		R-Mer® Span (0.04-inch Aluminum with PVDF coating)	25.9	130-150	548	775	N/A
		R-Mer® Span (24 ga. G90 and PVDF coated steel)	52.3	130-150	685	505	N/A
S-5-T mini		R-Mer® Span (22 ga. G90 and PVDF coated steel)	50.5	160-180	671	389	N/A
		R-Mer® Span (0.04-inch Aluminum with PVDF coating)	25.9	130-150	381	575	N/A
		R-Mer® Span (24 ga. G90 and PVDF coated steel)	52.3	130-150	466	N/A	N/A
S-5-H90	MBCI	BattenLok® HS (22 ga. steel with AZ55 & Galvalume Plus)	54.1	160-180	1013	687	N/A
		BattenLok® HS (24 ga. steel with AZ55 & Galvalume Plus)	62.3	130-150	1029	595	N/A
S-5-H90 mini		BattenLok® HS (22 ga. steel with AZ55 & Galvalume Plus)	54.1	160-180	944	513	N/A
		BattenLok® HS (24 ga. steel with AZ55 & Galvalume Plus)	62.3	130-150	756	474	N/A
		Ultra-Dek® (22 ga. steel with AZ55 & Galvalume Plus)	54.0	160-180	1204	548	N/A
		Ultra-Dek® (24 ga. steel with AZ55 & Galvalume Plus)	54.8	130-150	482	600	N/A
		SuperLok® (22 ga. steel					

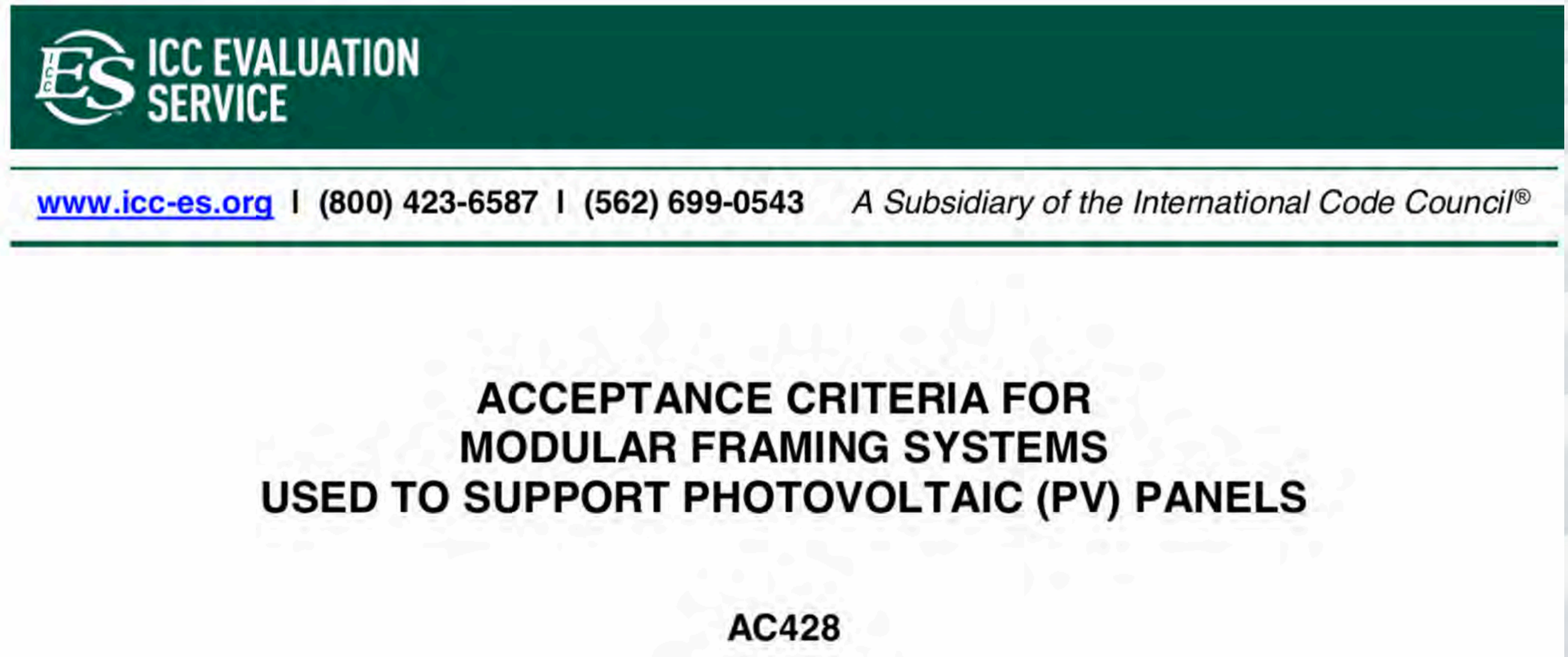
Appropriate testing for mechanical loads negative-normal

Negative Normal to roof (for wind uplift)



Acceptance Criteria (ICC-ES)
Evaluation Criteria (IAPMO)

- Non-Standard Product Performance
- Consensus-Driven Criteria for Universal Acceptance
- Roof Attachments – Left out of Scope in Other Standards



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

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EVALUATION CRITERIA FOR

Standing Seam Metal Roof-Mounted Rail-Type Snow Retention Systems

EC 029 - 2018
(November 2018)

1.0 INTRODUCTION

1.1 **Purpose:** The purpose of this evaluation criteria is to establish requirements for roof-mounted rail(fence)-type snow retention systems for standing seam metal roofs to be independently reviewed and recognized in an evaluation report issued by a certification body. This criteria provides for recognition under the 2018, 2015, 2012, 2009 and 2006 *International Building Code*® (IBC®) and the 2018, 2015, 2012, 2009 and 2006 *International Residential Code*® (IRC®). The basis for recognition is contained in 2018 and 2015 IBC Section 1709.1; 2012, 2009, and 2006 IBC Section 1708.1; IRC Section R301.1.3; and IBC Section 104.11 and IRC Section R104.11.

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Ontario, California – USA 91761-2816
Ph: 909.472.4100 | Fax: 909-472-4171
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INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS
UNIFORM EVALUATION SERVICES

EVALUATION CRITERIA FOR

Standing Seam Metal Roof-Mounted Rail-Type Snow Retention Systems

EC 029 - 2018
(November 2018)

1.2 Scope:

1.2.1 This Evaluation Criteria establishes the testing requirements and procedures, the documentation required for review, and analysis methods used to determine allowable loads for roof-mounted snow retention systems for recognition in an evaluation report issued by an approved certification body accredited in accordance with ISO/IEC 17065.

1.2.2 This criteria is intended for use to evaluate the design of rail-type snow retention systems connected to standing seam metal roof covering panels using seam clamps to resist in-plane, down-slope snow loads. Uplift, sideways, or prying loads such as those that may be imposed by the attachment of solar panels, fall restraint systems, or similar roof mounted equipment are not considered in this document.

Acceptance Criteria (ICC-ES)
Evaluation Criteria (IAPMO)

- AC467: Proprietary Attachment Systems of PV Arrays to Roof Systems

- The proprietary attachment system connect to the roof covering system by a combination of heat-welded tie-downs and caps, as well as using fasteners and proprietary metal plates

- Product/Project Specific Testing
  - Certified (PE/SE Stamped)
  - Use of Standardized Testing Methods is best
  - Use of NRTLs or ISO 17025 Labs are important

<u>Important Test Factors</u>

- Load Rate
- Measurement
- Number of Tests
- Safety Factor
- Etc, Etc, Etc

References Standards and Methods from AC428

1.3 Codes and Referenced Standards: Where standards are referenced in this criteria, these standards shall be applied consistently with the code upon which compliance is based. The requirements prescribed in a specific edition of the IBC apply to the corresponding IRC, unless noted otherwise. Table 1 summarizes the specific date applicable to each code.

1.3.1 2012, 2009 and 2006 *International Building Code*® (IBC), International Code Council.

1.3.2 2012, 2009 and 2006 *International Residential Code*® (IRC), International Code Council.

1.3.3 ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers.

1.3.4 ADM1, Aluminum Design Manual, The Aluminum Association.

1.3.5 AISI North American Specification for the Design of Cold-formed Steel Structural Members, American Iron and Steel Institute.

1.3.6 AISC 360, Specification for Structural Steel Buildings, American Institute of Steel Construction.

1.3.7 ASTM A90, Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM International.

1.3.8 ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International.

1.3.9 ASTM A924, Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by Hot-Dip Process, ASTM International.

1.3.10 ASTM B557, Standard Test Method for Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products, ASTM International.

1.3.11 ASTM E4, Practices for Force Verification of Testing Machines, ASTM International.

1.3.12 UL 1703, Flat-plate Photovoltaic Modules and Panels, Underwriters Laboratories LLC.

Presenter – Mark Gies
Director of Business Development

mgies@s-5.com
719-388-3036


Question & Answer

August 4th, 2020

www.seia.org