

WIND EXPOSURE CATEGORY

BACKGROUND

Wind exposure category is a critical input parameter for structural designs including commercial rooftop PV systems. Most typical building sites fall into category B (urban, suburban, wooded) or C (Open terrain with scattered obstructions). Category D sites (flat, unobstructed areas) are less common.

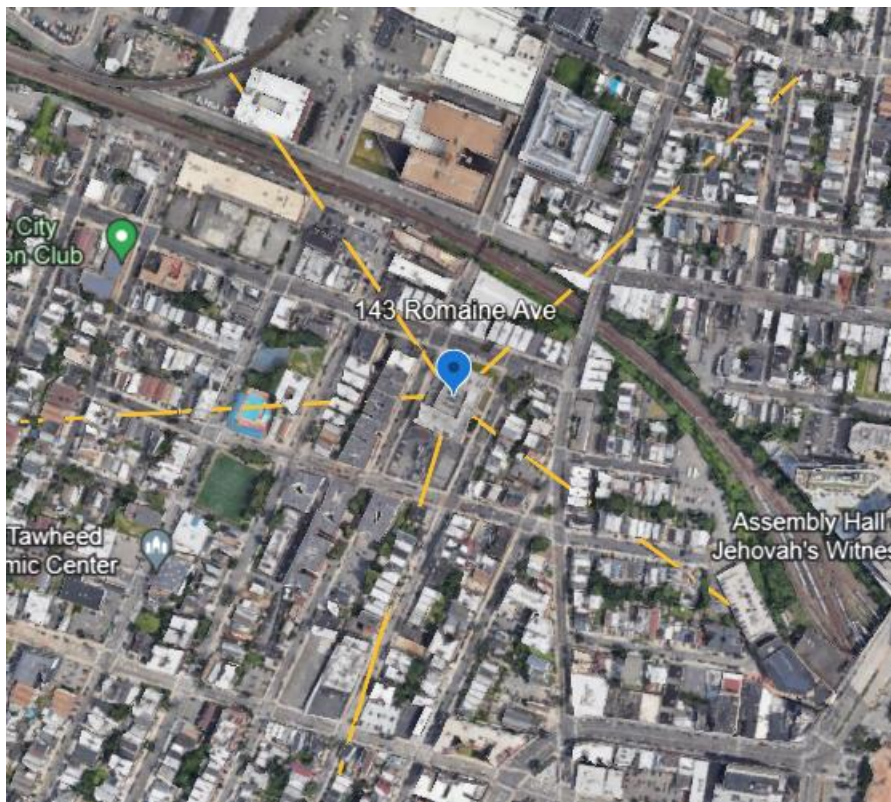
Wind exposure category affects wind pressures on a structure significantly. Therefore, applying the appropriate value for a given site is critical. Using the wrong setting can result in structural failure or overdesign. Arguably, the former is worse than the latter, but most stakeholders do not want to overspend needlessly.

The main definitions for exposure categories in ASCE 7 are very simple and do not explore how to determine and account for large or small transitions in exposure. For instance, it is common to require an understanding of the effect of large openings in an otherwise typical Exposure B. The ASCE 7 commentary includes guidance to determine the net effect of open patches. Code revisions prior to ASCE 7-16 included such commentary which left quite a bit of room for interpretation. In the 7-16 and 7-22 revisions, used by most US AHJ's today, the commentary is more formulaic thus eliminating most ambiguities of previous revisions.



DETERMINING EXPOSURE CATEGORY

For some project sites, determination of the correct wind exposure is straightforward. As an example, the building site highlighted below¹ is obviously located in an urban area and the surrounding area is consistent with surface roughness B conditions² for over 1500 ft. in all upwind directions.

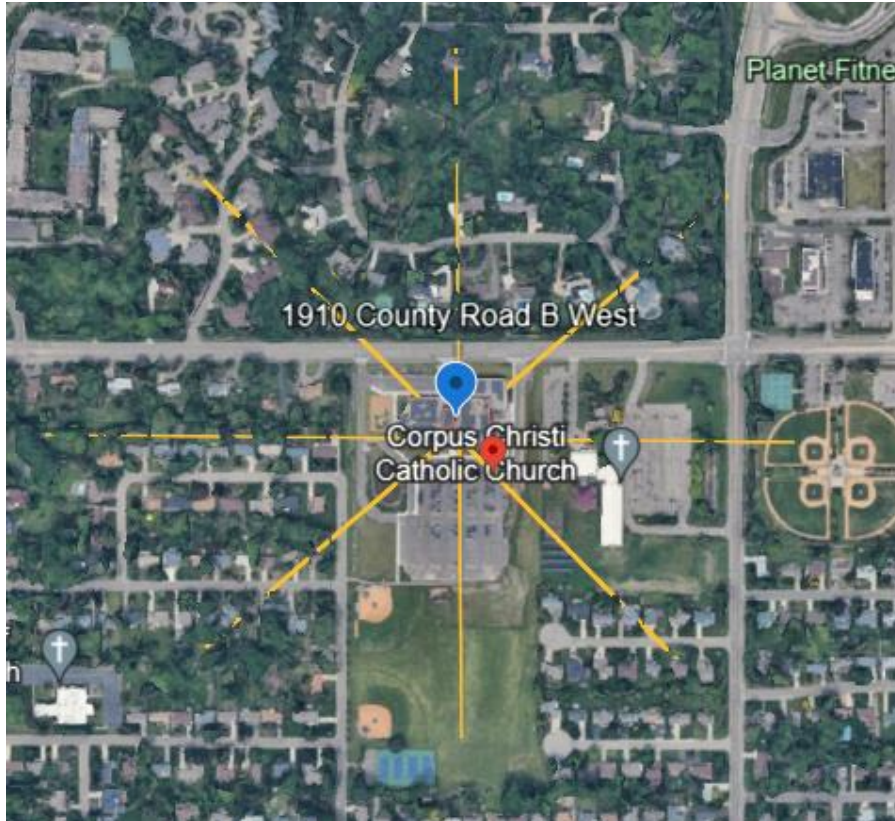


For this project, the total wind uplift force on the PV system came to approximately 90,000 lbs. It's interesting to note that switching to exposure C increases the total uplift to over 126,000 lbs. (40% higher!).

¹ Building height = 30 ft.

² See appendix for details.

Sorting out the exposure category is not always so simple although careful consideration of the code guidelines leads to the appropriate selection. In the example shown below, one might conclude that exposure B is the correct value to apply.



ASCE 7 requires evaluation of all wind directions on a sector-by-sector basis where each sector covers 45 degrees of the compass. The two sectors extending on either side of the selected wind direction are used to determine exposure for that direction, with the sector with the highest wind loads representing the controlling case. Although it is permitted to consider exposure for each wind direction, this adds a tremendous amount of complexity to projects. It is common practice and generally recommended to consider the worst-case wind exposure for the entire project. Winds approaching this site from most directions experience surface roughness B, but winds from the south and east ‘see’ roughness C. Therefore, the design must use C for the entire project.

Like the first example, applying exposure B rather than C yields a design plan with substantially less ballast. The 'C' design has 2400 ballast blocks and 6 roof anchors whereas using exposure B results in just 1307 ballast blocks and no anchors. This version of the design is unsafe and would likely sustain damage early in its service lifetime.

Most commercial and industrial PV project locations fall into exposure category C simply because this property type is typically found in suburban areas where the surrounding land area is at least partially clear of meaningfully sized structures. If a building's roof height exceeds 30 ft., the site is even more likely to meet exposure C criteria because the qualifications to meet for exposure B extend up to 2,600 ft (a 73% increase). Intermediate exposure between the predefined categories may be appropriate for some sites.

PanelClaw and its structural engineering partners follow the sector analysis methodology in the commentary of recent code revisions because this approach yields safer solar designs. PV racking design differs from low-rise building design in that PV systems are aerodynamically sensitive and largely controlled by wind uplift and overturning. In other words, PV projects are inherently more susceptible to catastrophic damage from wind loads whereas under-designed building envelopes, e.g. roof membranes, typically sustain only minor damage when under-designed. Furthermore, PV structures designed utilizing the Boundary Layer Wind Tunnel (BLWT) testing inherently have smaller margins of error than those using the guidance in Chapter 29 of ASCE 7 which is conservative for most flat roof PV structures on the market.

CONCLUSION

Rooftop PV systems are subjected to localized wind pressures that vary significantly over the surface of a building. Structural designs must account for peak wind loads that may affect small areas of a building's envelope to ensure components can resist wind-induced forces without failing. Ballasted flat roof PV structures are aerodynamically sensitive and failures due to uplift or sliding can be sudden and catastrophic. **Use of *aggressive or optimistic* design criteria, including wind exposure category, can result in damage from winds well below the expected worst case conditions**³. If PanelClaw specifies a given exposure for a project site, e.g. C, and another racking vendor suggests a different, less conservative one, e.g. B, stakeholders would be wise to question such determinations.



Racking product depicted is from a vendor that is no longer in business.

³ Check out the animation [here](#) for a visual representation of what can happen.

APPENDIX⁴

Surface roughness and Exposure Category definitions from ASCE 7-22

26.7.2 Surface Roughness Categories. A ground surface roughness within each 45° sector shall be determined for a distance upwind of the site, as defined in Section 26.7.3, from the categories defined in the following text, for the purpose of assigning an exposure category as defined in Section 26.7.3.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous, closely spaced obstructions that have the size of single-family dwellings or larger.

Surface Roughness C: Open terrain with scattered obstructions that have heights generally less than 30 ft (9.1 m). This category includes flat, open country and grasslands.

Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

26.7.3 Exposure Categories.

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

Exposure C: Exposure C shall apply for all cases where Exposure B or D does not apply.

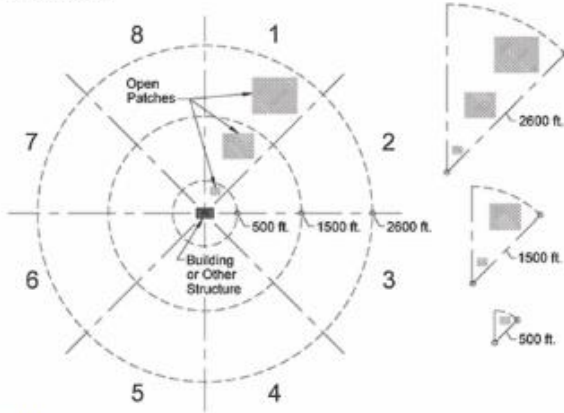
Exposure D: Exposure D shall apply where the ground surface roughness, as defined by Surface Roughness D, prevails in the upwind direction for a distance greater than 5,000 ft (1,524 m) or 20 times the building or structure height, whichever is greater. Exposure D shall also apply where the ground surface roughness immediately upwind of the site is B or C, and the site is within a distance of 600 ft (183 m) or 20 times the building or structure height, whichever is greater, from an Exposure D condition as defined in the previous sentence.

For a site located in the transition zone between exposure categories, the category resulting in the largest wind forces shall be used.

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

Sector analysis rules from ASCE 7-22 Commentary

Diagrams



Notes:

1. For each selected wind direction at which the wind loads are to be determined, the exposure of the building or structure shall be determined for the two upwind sectors extending 45 degrees to either side of the selected wind direction.
2. Consider open patches of sizes equal to or greater than the areas given in Figure C26.7-4 per Commentary Section C26.7.
3. Determine the proportion of open patches in any 45-degree sector within radii of 500 ft (152 m), 1,500 ft (457 m), or the greater of 2,600 ft (790 m) or 20 times the height of the structure.
4. If the proportion of open patch within any of the three radii is less than 25% of the sector area, the sector is considered to meet the requirements for Exposure B. Where the proportion within any of the three radii exceeds 25% of the sector area but is not greater than 50%, the values of K_z are taken as the average of the Exposure B and C values within 100 ft (31 m) height above grade. Above 100 ft (31 m), Exposure B values shall still apply. Where the proportion of open patches within any of the three radii of the structure exceeds 50%, the values of K_z shall be based on Exposure C.
5. Apply the exposure requirements of Section 26.7.4 once the directional exposures are determined for each sector. See Commentary Section C26.7.4.

Figure C26.7-3. Sector analysis for Exposure B with upwind open patches.

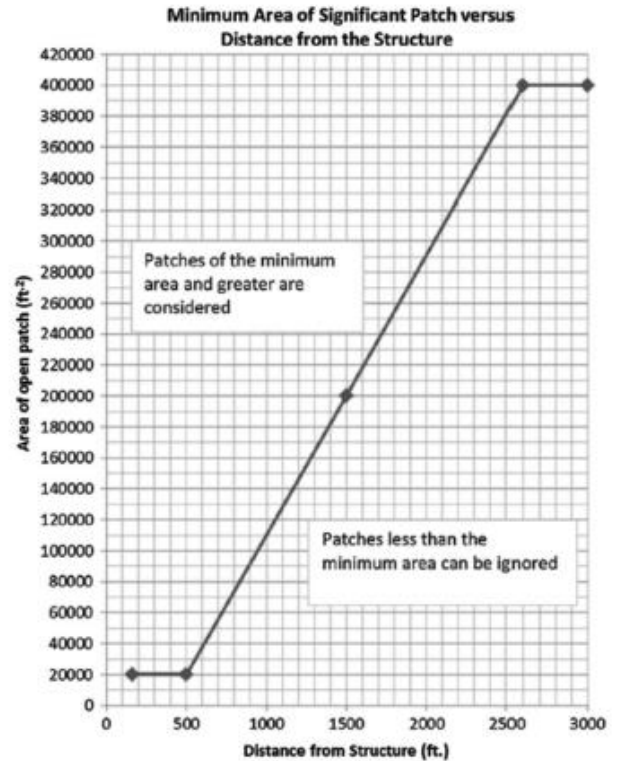


Figure C26.7-4. Minimum area of individual open patches affecting qualification of Exposure B.

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