CALHOUN

Engineering Bulletin 028

RE: What is wind pressure and how does it impact buildings?

Under Pressure: Withstanding Wind Loads

For anyone who invests in the construction of a building, understanding the effect of wind on the structure is critically important – and not just for those buildings located in high-wind or hurricane prone areas. Building codes everywhere address the high and surprisingly complex forces that wind can create, and this article will provide an overview of these loads and how designers and builders approach this design challenge.

Called wind pressure, this is the distributed force on sections of a building (exterior wall faces and roof faces) that results from air colliding with or blowing past these sections. Expressed as force per area (in pounds-per-square-foot or kilopascals), wind pressure creates uplift forces on roofs and shear forces on walls. These forces are transmitted to the foundation which must be appropriately designed to withstand them.

How to think about wind loads

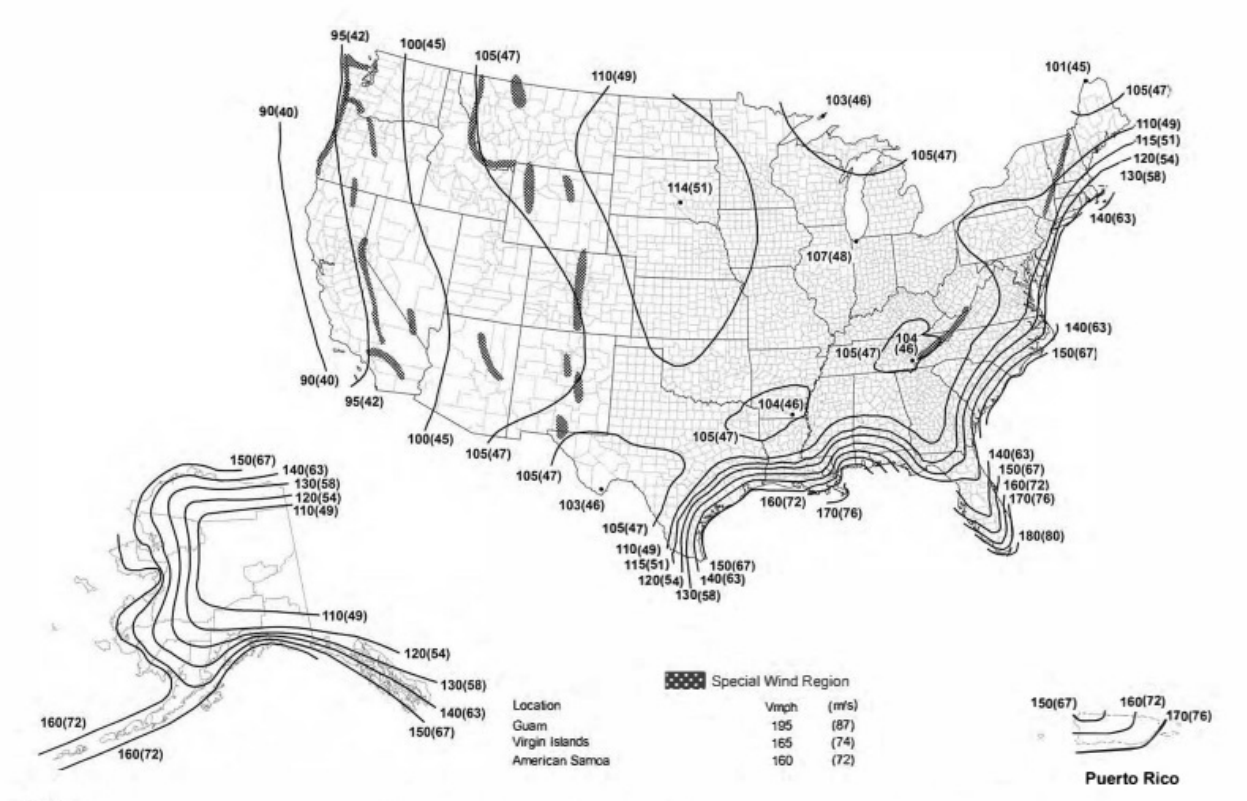
The parameters used to determine and design for wind loads are:

- Basic wind speed
- Wind direction
- Building Exposure Category
- Topographic factors
- Gust effect factors
- Building enclosure classification
- Pressure coefficients

The first five parameters listed above are dependent only on the building's site, while the last two parameters concern the building itself. While hurricane-prone areas such as the Gulf Coast and the Atlantic seaboard have additional parameters, these seven parameters are used everywhere to guide the design of structures so they can survive the probable wind conditions.

The first parameter, Basic Wind Speed, is a single number determined to be the highest wind speed that the building will be designed to withstand. Baked into this number is a Risk Category set by how the building will be used and how many people will be in it. Risk Category I, the lowest category, applies to unoccupied buildings like grain silos, barns, and other storage buildings. The highest risk category, Category IV, is reserved for highly populated buildings that would require evacuation of vulnerable people such as hospitals and nursing homes. Although

they might be sited in the same location, a salt and sand storage structure would be assigned a lower Basic Wind Speed than a hospital. As an example, the map below shows the Basic Wind Speed in the United States for Category II



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

The Basic Wind Speed is also rated by the Exposure Category of the building. Exposure Category refers to the prevailing wind direction relative to the surface roughness of the terrain or landscape surrounding the structure. Three Exposure Categories range from urban areas with houses or dwellings, to flat unobstructed areas or those with long stretches of open water. In the urban areas, the Basic Wind Speed is lower due to the protection of surrounding buildings, while a building on the open plain, without any obstacles to slow and divert the wind, would be subjected to higher wind speeds.

Coping with the wind

Wind loads can be one of the largest forces on a structure and are considered in combination with the gravity loads and snow loads. Intense winds on the windward side of a building (the side facing the wind) can cause windows to crack or be blown in and wall systems to flex, while

on the leeward side of the building (the side sheltered from the wind) a negative pressure will occur causing doors to be pulled open or windows to be blown outward. The structural system and building foundation must be designed to withstand these loads.

In extreme weather conditions such as those found in hurricanes, the wind pressure can become quite large. The wind pressure in a Category I hurricane (105 mph) can be as high as 28 psf but is generally manageable with standard construction techniques. For large fabric structures, this pressure can cause significant stress on the materials and the anchoring system. The fabric may billow, and if not properly tensioned, the billowing could lead to tears or rips. The anchoring points must be robust to prevent detachment from the ground or supporting framework. In a Category III hurricane, the wind pressure climbs to 47 psf and this pressure level can lead to severe structural damage. For large fabric structures, the impact is even more pronounced. The fabric must be of high strength and durability, capable of withstanding high tensile forces. The anchoring system must be exceptionally robust, often requiring deep foundations and multiple anchoring points to distribute the load evenly and prevent failure.

Ways to mitigate wind pressure impact

To design buildings for wind pressure, several practical measures can be implemented:

Strengthen Roof Structures: Use hurricane clips or straps to secure the roof to the walls – these and other measures can protect against deformation of the building due to shear loads created by the wind pressure. Also, ensure that shingles, tiles, or other roofing materials are securely fastened.

Install Impact-Resistant Windows: Use laminated glass or install shutters to protect windows from wind pressure and debris impact.

Reinforce Walls: Ensure that walls are constructed with materials and techniques designed to withstand high wind pressures. This includes using reinforced concrete, steel frames, or other robust materials. For fabric structures, ensure that the fabric is tensioned properly and check regularly for wear and tear.

Foundation Design: Use deep, secure anchors and foundation systems to resist the lateral loads created by the wind pressure on both the windward and leeward side of the building.

Regular Maintenance: Conduct regular inspections and maintenance of all structural components, including roofs, windows, walls, and anchoring systems.

Note: This article is based on US code and may not apply when snow load supersedes wind load.

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