

Determining Wind Loads On Buildings – what's the big deal?

By Craig H. Wagner, P.E.

If you've ever picked up a building code or design standard intent on determining the wind design pressure for a building and found yourself in an extreme state of confusion; relax, you're not alone. You may however, be wondering why it has to be so complicated.

In its simplest form, the process involves converting wind speed to wind pressure. Sounds easy enough. Wind is air with mass traveling at a given velocity. Convert it to pressure – right? So what's the big deal? Why do these wind engineers have to make it so complicated? It's been suggested that they make it complicated so that only an engineer can do it.

Look; all they have to do is establish a design wind speed for every possible terrain, in every geographical location, for every possible type and use of building, in every possible setting. Then, establish what pressures the wind will impose at any location on every surface of every possible size, shape and configuration of building for all possible wind directions. Next they need to take the extreme variations in pressures that exist on the building surfaces at any instant in time and give us a nice uniform pressure to work with. Simple, right!

Ok, I'm trying to make a point. Whether you're amused or not, the fact is that the effects of wind on buildings is a very complex phenomenon. Research engineers have long strived to reduce these complexities to a practical set of equations and coefficients that can be used in practice to safely design buildings for wind. So, what are these complexities and how do the design provisions deal with them? Before we go on, let's first dispel a few myths.

- The wind design criteria is not something imagined or conjured up from some ivory tower theory. It is derived from a huge database of actual wind pressure measurements.

- Wind speed is not constant and surface pressures are not uniform.
- Negative pressure really does exist.
- Internal pressure really does exist.
- All codes are not created equal.

Codes and Standards

There are four major model codes used in the US. The *BOCA National Building Code*, the *Standard Building Code*, the *Uniform Building Code* and the new *International Building Code*. Each of these codes publish wind load design provisions. In addition, they each recognize Chapter 6 of *ASCE 7 Minimum Design Loads For Buildings And Other Structures* for wind load design. ASCE 7 in one of its many versions is the foundation of all the wind load provisions used in the US. The most significant change in wind load provisions used today occurred with ASCE 7-95 when the use of 3-second gust wind speed replaced fastest-mile wind speed for the basic wind velocity used in design. Basically what this means is that wind speeds are recorded differently than they have been in the past. The wind load provisions in the current major model codes, except the new International Building Code, are all still based on fastest-mile wind speeds. Since the building codes also recognize ASCE 7 by reference, it essentially gives you two options for determining the design pressures. In addition, some codes and ASCE 7-98 now provide a simplified method that, depending on your building, may provide a third method. This can of course be controlled by a well-written project specification that dictates which criteria to use. Even more ideal would be a project that specifies the design pressures for the building. Sure would level the playing field for bidding, wouldn't it?

Wind Velocity

Ok, so either by choice or by directive, you've determined which criteria you're going to use. Now you need to select the basic wind velocity. That's easy. Find your project location on the wind speed map and hope that it doesn't fall in one of those *special regions* where "anomalies in wind-speed values exist". Also, be careful, your competitor may interpolate between the wind speed contours and use a lower velocity than you. That's allowed you know.

Exposure Classification

Now, we must account for how the wind speed will be affected by the terrain and setting for the building site. The basic wind speed for your geographical area on the map is based on flat, open terrain. The same wind passing through your neighborhood, wooded area or city center will be affected by numerous obstructions of various size and shape. Wind speed also varies with height. The degree to which wind speed varies with height depends upon the terrain and obstructions that exist at ground level. What is the height of your building and what obstructions, if any, are surrounding it? The design provisions provide criteria for classifying the surrounding setting and provide adjustment factors based on building height accordingly. This is known as the *exposure classification*.

Then there are the special adjustment factors. Is the building located within a hurricane prone region? The probability of the design wind speed being exceeded in these areas is greater (the newer 3-sec wind speed mapping already considers this). Is the building located on a hill? Wind can speed-up on hills. Is it a 2-dimensional hill like a ridge or is it a 3-dimensional hill like a knoll? Use of ASCE 7-95 and 7-98 includes wind speed-up factors to account for these conditions.

Building Importance

Next you need to know what the building will be used for. Importance factors are established for use in the equations to account for the type of building being designed. Chicken barns don't get designed to the same factor of safety as essential facilities like police stations, fire stations and hospitals. Of course, if the farmer wants to spend the money, he can specify that his chickens have the same level of protection.

Variation in Surface Pressures

While we like to design with uniform design pressures (it's simple), the reality is that there's nothing uniform about the actual wind pressures on a building surface. During exposure to wind, the surface areas of a building are subjected to extreme variations in pressure that are constantly changing. At any given instant, the pressure on the surface of a building, if visible, would look like a mountain range with peaks and valleys. At a given location the pressure can be very high at one moment and seconds later be practically nothing. To address this, pressure coefficients were derived that involve time and area averaging to provide design pressures for varying area size on the building surface. It is also known that pressures are significantly greater where airflow is disrupted, such as corners and roof overhangs. Wind pressures at the corner of a building can be two times the pressures in the mid-areas of the wall. To account for this, the surface area is mapped into zones with different sets of coefficients derived for each zone.

Let's say we want the design pressure for a window. You need to know the size of the window (wind area) and the location on the wall (height and distance to corner or roof eave). Some use of these coefficients reveals that a larger window may have a lower design pressure than a smaller window at

the same location. Does this make any sense? Remember that the actual pressures are peaks and valleys throughout the surface area. The larger the area, the lower the average pressure on that area. Conversely, smaller windows are subjected to greater average loads.

Negative Pressure

Pressure coefficients are further derived for positive and negative pressures. Positive pressures, as one would expect, act toward the surface. This is easy to comprehend - wind blows against the building. Negative pressure (acting away from the surface - suction), is a little more difficult for some to accept. When wind blows against a building, the windward side feels positive pressure. The wind flowing around the sides and collapsing around the back (leeward) side develops negative surface pressures. Because wind can come from any direction, we must consider both positive and negative wind pressures. The coefficients provided in the design provisions are developed from measurements of pressure from wind in all directions.

Internal Pressure

Openings in the building envelope create portals for airflow and the development of internal pressures. The magnitude of internal pressure depends upon the ratio of open area on one side to the open area on the remainder of the building envelope. As with external pressure, internal pressure can be positive or negative depending on the location of the opening relative to the wind direction. The design provisions provide criteria to classify the potential for internal pressure based on openness and assigns pressure coefficients accordingly.

Design Pressure

The design pressure for a given component (window, door, mullion, etc.) can now be

determined. The basic velocity pressure for the building is established considering its geographical location, exposure (height and surrounding setting), and use (school, hospital, home, shed, etc.). The exterior pressure coefficients are established based on the component size and location on the building. The internal pressure coefficients are determined based on the potential for wind being blown into or sucked out of the building.

The product of all these factors give the positive and negative design pressures for the component - Simple, right?

Could it be simpler? Sure it could. It could be simplified to the point that anyone can pick up the code and determine the required wind pressure without calculations, coefficients and layers of adjustment factors for special conditions. But, how conservative are we willing to be in the interest of simplification? The objective in engineering is to provide an adequate level of safety to public and property with the most efficient and economical use of resources. So, for today at least, this is as simple as it gets.

From my perspective, the researchers have performed a monumental task in taking a very dynamic and complex event and reducing it to something a building designer can use in practice to make buildings safer. Given the enormous complexities involved, I think they've made it pretty simple. But then, everything's relative and I'm an engineer.



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