The Fundamentals of a Wind Analysis

By: Mark S. Cooper P.E.

Many people who are building their first home ask us, "What is a Wind Analysis, and why do I need it?" The simple answer is that Florida Building Code section 1609 requires that an engineered wind analysis be performed prior to obtaining the permits necessary to build your new home. While that answer is correct, it does nothing to help people understand what the analysis is and how it will affect their home. Basically, the wind analysis provides a method to determine wind load-derived forces that will be applied to different aspects of the house. It allows the building designer and components manufacturers to design and provide materials and building elements based on the loads generated by your building configuration and at the structure's geographical location that will comply with code requirements.

Wind Analysis is a complex topic. This article will provide a quick overview on Detailed Wind Load Design (Method 2) per ASCE 7-02, which is what Blackhawk Engineering, Inc. utilizes for its wind analysis for residential homes.

Wind Zones

The Florida Building Code and ASCE7 (American Society of Civil Engineers "Minimum Design Loads for Building and Other Structures" is known as ASCE7) contain a wind speed map that sets forth the different wind zones for different geographical locations. These codes provide nominal design values based on three second gust wind speeds (MPH) at an elevation of thirty three feet above the ground for exposure "C".

Coastal regions in hurricane-prone areas, specifically the Gulf Coast and the Atlantic Coast, have higher wind speed requirements and wind-borne debris regions. The wind-borne debris region defined by ASCE7 is as follows:

1) Within one mile of the coast, with wind speeds of 110 mph or greater.
2) The wind speed is 120 mph or greater regardless of the building's proximity to the coast.

If the structure is considered to be within the wind-borne debris region, then the windows and doors must be constructed utilizing code-approved, impact-resistant materials to be considered non-openings. The concern within wind-borne debris is that flying debris may breach a window or door, allowing wind to flow into the structure and resulting in additional damage.

Wind Exposure

The wind analysis takes into account how the surrounding environment will affect the developed wind pressures on a structure. Minimally-sloped terrain free of trees or locations adjacent to large bodies of water provide an increase in wind pressures, while locations surrounded by trees (forest lands) or other structures (urban settings) provide a decrease in wind pressure due to the fact they obstruct the wind. To help provide a guide on Wind Exposure, the following four categories have been developed.

Exposure A – Large City Centers with at least fifty percent of the buildings having a height in excess of seventy feet. Use of this exposure category is limited to those areas for which terrain representative of Exposure A prevails in the upwind direction for a distance of at least one-half mile, or ten times the height of the building or other structure, whichever is greater. Please note that this category has been dropped from later versions of ASCE7, and was replaced with the recommendation that wind tunnel testing should be conducted to analyze the structure or to determine the appropriate wind pressures.

Exposure B – A structure in an urban, suburban, wooded location or other terrain with numerous close-spaced obstructions that are similar in size to a single family structure or larger. Exposure B is considered the default exposure if the structure location does not qualify for any other exposure category.

Exposure C - A building in an open area with scattered obstructions, or a building adjacent to shorelines in hurricane-prone regions. An area that lies within 1500 feet of the coastal construction control line, or within 1500 feet of the mean high tide line whichever is less.

Exposure D - A building exposed to wind flowing over open water for a distance of at least one mile, excluding shorelines in hurricane-prone regions. This applies to shorelines of inland waterways, the Great Lakes, and the Pacific Coast. This exposure shall apply only to those buildings and other structures exposed to the wind coming from over the water. A Florida example of this would be the Stiltsville community located on Biscayne Bay.

(Image from http://www.stiltsville.org/pages/history.html)

The exposure category for any area may change over time based on what new development has occurred, so it is not unheard of for an area that was previously classified as a Exposure C to be changed at a later date to a Exposure B. Conversely, an area surrounded by trees may be cleared, thus changing the appropriate exposure category to Exposure C when it was originally an Exposure B. When there is a question on which exposure to utilize, it is best to use the worst case to provide a conservative design.

Importance factor

Importance factor is just another way of classifying the intended usage of a building. The building usage determines the importance factor coefficient to be used in the calculation of the wind pressures. The larger the amount of people expected to occupy a building, the greater the importance factor, which results in larger wind pressures. There are four building classification categories, although Categories 3 and 4 use the same coefficient in wind pressure calculations.

Category I - A building that represents a low hazard to human life in the event of a failure.

Category II - Any building that doesn't meet the requirements of Categories I, III or IV

Categories III and IV - Buildings or other structures designed as essential facilities and that represent substantial hazard to human life in the event of a failure. Buildings used to store toxic and hazardous wastes fall into this category, as well as hospitals, police stations, fire stations and power-generation stations (just to list a few).

Single family residential structures, for example, are classified as Category II, while a commercial structure maybe classified as any of the four listed categories depending on the use of the building. Ultimately, it will be up to the design engineer to choose the proper classification.

Building Category

A structure may be classified as compliant with one of three different categories depending on the size and location of the openings within the building. The options are closed building, a partially enclosed building or an open building. The determination of which building category a structure belongs to will assign an Internal Pressure Coefficient, which is used to calculate the wind pressure on the internal and external surfaces of the building. The greater the amount and size of doors and windows in a structure, the larger the wind flow that enters the building. This wind flow increases the wind pressure that must be applied to the structure.

Open Building - is defined as one with each wall at least 80% open. Examples are a park pavilion, an open-sided car shelter or a boat shelter. Because wind is allowed to flow through an open building with minimal or no resistance from walls, no internal pressure develops.

Partially-Enclosed Building - is defined as a structure where:

1. The total area of openings in a wall receiving positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10 percent; and

2. The total area of openings in a wall receiving positive external pressure exceeds 4 square feet or 1 percent of the area of that wall (whichever is smaller) and the percentage of openings in the balance of the building envelope does not exceed 20 percent.

Closed building - is defined a structure that doesn't meet the requirements of an open building or a partially enclosed building.

Some designers consider windows and doors as non-openings if the building is located outside of the wind-borne debris regions (i.e. within one mile of the coast, with wind speeds of 110 mph or greater or if the wind speed is 120 mph or greater regardless of the building's proximity to the coast). If the building is within the wind-borne debris region, all windows and doors must be constructed using code-approved impact-resistant materials to be considered non-openings. The main concern is that flying debris may penetrate a window or door, allowing wind to flow into the building and resulting in increased internal wind pressures. The designer is ultimately responsible for deciding the proper building category based on the project type, location, and construction of structure.

Based on our experience at Blackhawk Engineering, Inc. we utilize the worst-case scenario of a partially-enclosed building, which results in the greatest internal pressures. This is done to assume your home can withstand breaching, which could be created from wind-borne debris from a neighboring home. Once a breach has occurred in the structure, the wind will enter the structure, causing the internal pressures to increase. This results in a situation similar to the Partially-Enclosed building category. This approach ensures that you have every advantage to withstand the wind pressures, when a partial failure occurs. Lastly, the cost differential in materials and time is negligible to meet the higher loads. It basically will mean some tighter nailing patterns, a few more straps and clips, and possibly a few hold-downs.

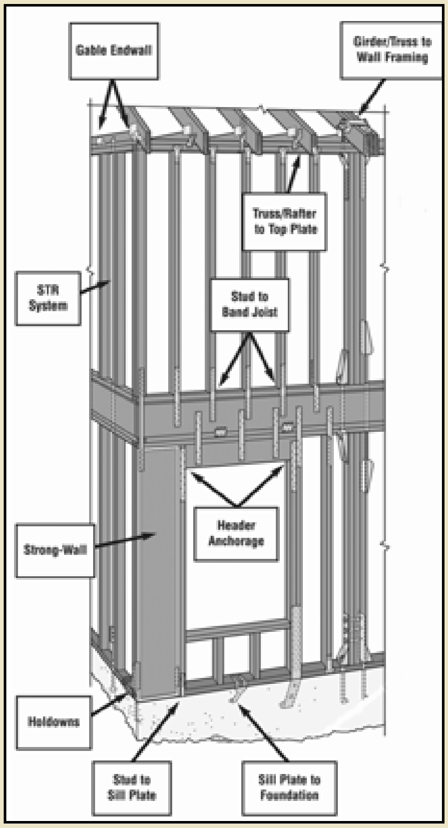
Wind Load Distribution

Wind load is transferred through a structure from one building component to the next. The distribution of that load can be represented by assuming a uniformly-distributed wind load acting on any one face of the building at any one time. Normally, a wind load design requires a separate analysis of wind from two perpendicular directions (i.e. wind from the north or south and then from the east or west). But let's take the example of a flat-roofed, rectangular wood framed building. Now the wall receiving the direct pressure from the wind transfers the top half of its horizontal wind load to the roof and the bottom half to the foundation. Basically, the wall acts as a vertical beam with two simple horizontal supports. The load transferred to the foundation is then distributed to the ground, while the portion that goes to the roof causes lateral movement that is resisted by the end walls in the form of shear load. This shear load is transferred through the end walls down to the foundation, and then the ground.

Uplift

When wind is applied to a structure the air flows over the roof and creates an upward suction, similar to the way wind creates lift on an airplane wing. The wind pressure tries to remove the shingles and the sheathing off the roof, the sheathing pulls on its fasteners to the trusses, and the trusses pull on the hurricane clips to the top plates. The wall plates try to lift the wall diaphragm; the wall diaphragm tries to lift the floor or foundation, and so on. If any part of this load path for uplift fails, the additional parts of the structure will fail, causing a cascade effect that can destroy the entire structure.

Understanding this aspect of wind analysis is very important, so that the entire structure can be designed to counteract these forces.



Shear Walls & Diaphragms

Shear walls and diaphragms transfer in-plane forces by acting as deep beams. Their in-plane shear capacity is provided by the structural sheathing and fasteners to the cords. The shear walls also provide both axial tension and compression capacity through their cord members. Thus, they can provide resistance to lateral movement of in-plane shear forces, resistance to uplift forces (tension), as well as support for gravity load forces (compression).

While shear walls and diaphragms can be designed by using the principles of engineering mechanics, it is standard practice to utilize tabulated values for common configurations of wall and floor diaphragms. By using these tables of standard configurations, engineers can verify that the assemblies of the walls and diaphragms conform to all conditions and requirements of an analysis. The building industry as a whole has been using these standards for years and this has become second nature to the building community.

Load Duration Factor

For people that are not familiar with wood design, the strength of a wood member is dependent on the length of time that member is required to support a given load. The shorter the time, the larger the load duration factor that is allowed to be applied to the wood member. The recommended load duration factor for lumber and fasteners supporting wind loads in this area is 1.60. This is important to understand for the fact that many manufactures like Simpson's Strong Tie provide specifications and values for Load Duration Factors of 1.33 and 1.60.

What does it all mean?

We have discussed several aspects of wind load analysis, and did not even go into some areas like components and cladding pressures, or main wind force resisting systems. We have attempted to give you a brief overview of the fundamental elements of a wind analysis, without teaching a course on the subject matter. We hope that this article shows you the many different factors that and engineer must take into consideration in designing your structure. It is extremely important to have the proper design before attempting to build anything. The wind has can cause major damage and should not be taken lightly. It is easier and less expensive to plan for wind load prior to construction, as compared to trying to correct something that was built incorrectly in the first place.