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THE EFFECTS OF WIND ON ROOF SYSTEMS FOR BUILDINGS

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Abstract: *This paper presents a study on climatic factors, especially wind, that can affect a roof's structure. Studies have shown that most damage occurs because various building elements have limited wind resistance due to inadequate design, application, material deterioration, or roof system abuse. In order to assess the risk caused by high winds on roof systems, the building aerodynamics, the topography, the wind-building interactions, the atmospheric corrosion etc. must be taken into account.*

Key words: *climatic factors, roof system, wind resistance.*

1. Introduction

The durability of the roofing system is the result of many parameters, such as, but not limited to: local climate, local temperature which is correctly considered as a result of changes in solar radiation, wind, rain, and other environmental influences. Another important factor is the resistance to water penetration under driving rain and deluge conditions [1].

2. Basic Wind Speed

ASCE 7 defines the basic wind speed as the wind speed with a 50-year mean recurrence interval (2% annual probability), measured at 33 feet above grade in Exposure C (flat open terrain). If the building is located in Exposure B or D, rather than C, an adjustment for the actual exposure is made in the ASCE 7 calculation procedure.

In determining wind pressures, the basic wind speed is squared; therefore, as the velocity is increased, the pressures are exponentially increased. For example, the uplift load on a 30-foot high roof covering at a corner area of an office building in Exposure B is 37.72 pounds per square foot (psf) with a basic wind speed of 85 mph (per ASCE 7-02). If the speed is doubled to 170 mph, the roof corner load increases by a factor of four to 151 psf [4].

3. Wind-Building Interactions

When wind interacts with a building, both positive and negative pressures occur simultaneously (Figure 1). Negative pressures are less than ambient pressure, and positive pressures are greater than ambient pressure.

A building must have sufficient strength to resist the applied loads in order to prevent wind-induced building failure [2]. The magnitude of the pressures is influenced by the following primary factors: exposure, basic wind speed, topography, building height, internal pressure, building aerodynamics etc.

It is important to calculate wind

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pressures for both the structural frame (called the Main Wind Force Resisting System, or MWFRS, in ASCE 7-98) and for building components and cladding.

Components and cladding include elements such as roof sheathing, roof coverings, exterior siding, windows, doors, soffits, facia, and chimneys.

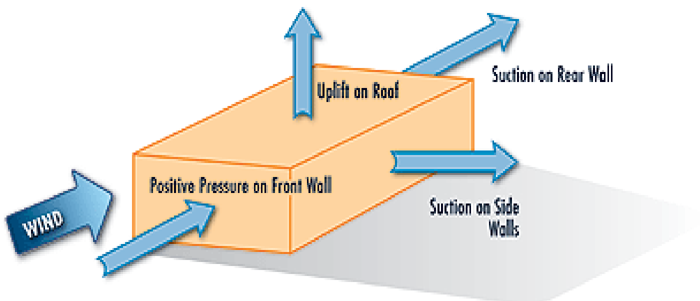

Fig. 1. *Schematic of wind-induced pressures on a building [4]*

Investigations of wind-damaged buildings after disasters have shown that many buildings failures start because a component or piece of cladding is blown off the building, allowing wind and rain to enter the building. The uncontrolled entry of wind into the building creates internal pressure that, in conjunction with negative external pressures, can blow the building apart [3].

The effects of wind on buildings can be summarized as follows:

- windward walls and steep-sloped roofs are acted on by inward-acting, or positive pressures;
- leeward walls and steep and low-sloped roofs are acted on by outward-acting, or negative pressures;
- air flow separates at sharp edges and it points where the building geometry changes;
- localized suction or negative pressures at eaves, ridges, and the corners of roofs and walls are caused by turbulence and flow separation. These pressures affect loads on components and cladding.

Figure 2 shows the effects of wind on buildings.

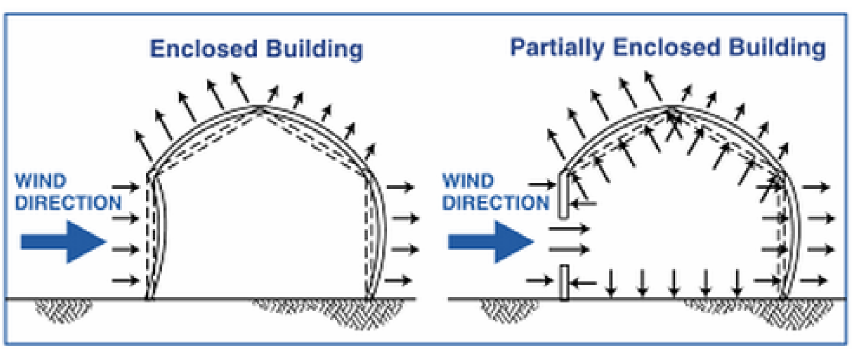

Fig. 2. *The effects of wind on buildings [6]*

The phenomena of localized high pressures occurring at points where the building geometry changes are accounted for by the various shape coefficients in the equations for both the MWFRS and components and cladding. Internal pressures must be included in the determination of wind pressures and are additive to (or subtractive from) the external pressures. Openings and the natural porosity of the building components contribute to internal pressure.

The magnitude of internal pressures depends on whether the building is enclosed, partially enclosed, or open as defined by ASCE 7-98.

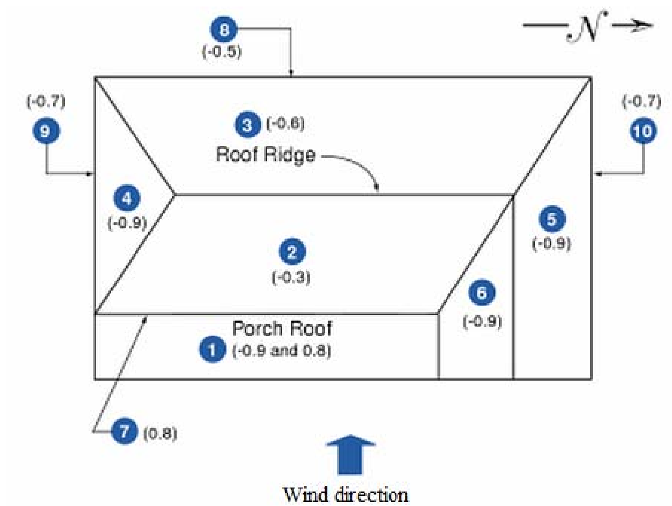

Fig. 3. *Wind pressure zones for MWFRS* [6]

The external pressure coefficients (C_P) for the 10 zones indicated are provided for the case of wind direction from the east (Figure 3) [6]. The summary of wind pressures (p) for MWFRS is presented in Table 1.

Summary of Wind Pressures (p) for MWFRS [5] Table 1

Wind Pressure Zone	Wind Direction			
	East	West	North	South
1. Porch overhang	**-45.45**	-12.30	-22.14	**-45.45**
2. Front roof	-12.63	-20.01	**-27.39**	**-27.39**
3. Rear roof	-20.01	-12.63	**-27.39**	**-27.39**
4. Left hip roof	**-27.39**	**-27.39**	-20.01	4.60
5. Right hip roof	**-27.39**	**-27.39**	4.60	-20.01
6. Left front gable	**-27.39**	**-27.39**	-20.01	4.60
7. Front wall	14.44	-17.55	**-22.47**	**-22.47**
8. Rear wall	-17.55	14.44	**-22.47**	**-22.47**
9. Left side wall	**-22.47**	**-22.47**	-15.09	14.44
10. Right side wall	**-22.47**	**-22.47**	14.44	-15.09

Locations on the building are taken from the east, facing the building. All pressures are in lb/ft^2 and have been rounded to the nearest two decimal places, positive pressures act toward the building and negative pressures act away from the building. Highest pressures are indicated in bold. The wind pressure zones for components and cladding are shown in Figure 4.

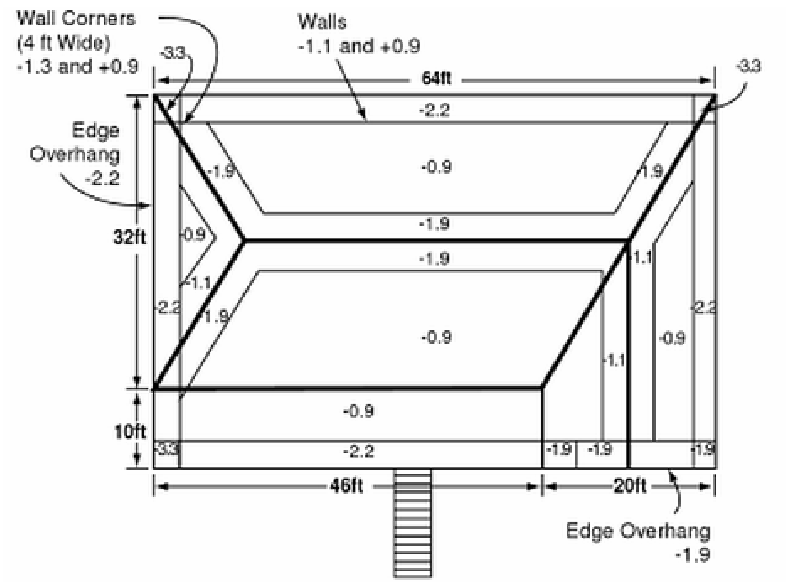

Fig. 4. *Wind pressure zones for components and cladding and most severe negative pressure coefficients shown* [6]

The computed pressures are listed in Table 2. All pressures are in lb/ft^2 and have been rounded to the nearest two decimal places.

Positive pressures act in toward the building and negative pressures act away from the building. An effective area of 20 ft^2 is assumed.

The computed pressures [5] Table 2

Wind Pressure Zone	GC_p Coeficients	Wind Pressure (lb/ft^2)
Corners of hip roof and front porch	-3.3	-119.48
Interior of hip and porch roofs	-0.9	-31.47
Steep-sloped hip and gable roofs	-0.9	-31.47
Hip roof overhang edge	-2.2	-87.42
Steep hip and gable and edges	-1.9	-78.68
Wall corner	-1.3	-43.13
Main wall area	-1.1	-37.3
Porch roof edge	-2.2	-69.36

Wind striking a building can cause either an increase in the pressure within the building (positive pressure), or it can cause a decrease in the pressure (negative pressure). Internal pressure changes occur because of the porosity of the building envelope.

If the porosity of the windward wall is greater than the combined porosity of the side and rear walls, the interior of the building is pressurized.

A pressurized building increases the wind load on the side and rear walls (Figure 5) as well as on the roof.

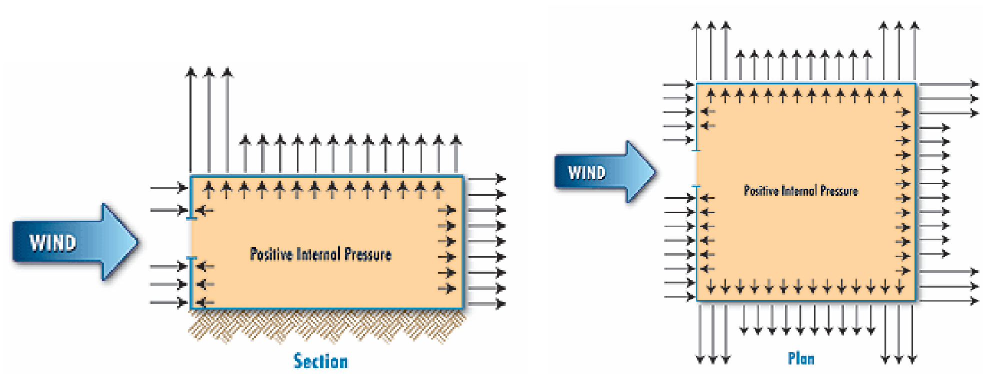

Fig. 5. *Schematic of internal pressure condition when the dominant opening is in the windward wall [4]*

When a building is pressurized, the internal pressure pushes up on the roof.

When a building is depressurized, the internal pressure pulls the roof down, which reduces the amount of uplift exerted on the roof.

The decreased internal pressure also pulls inward on the windward wall, which increases the wind load on that wall (Figure 6).

In both figures arrays indicate direction and amplitude of applied force.

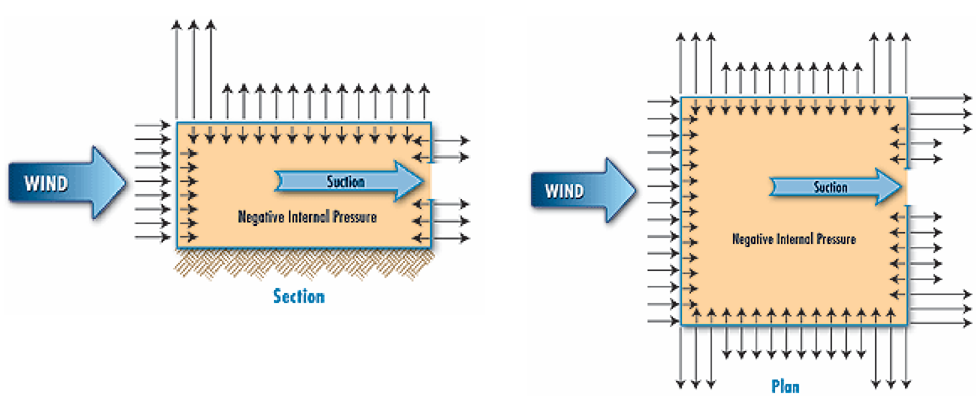

Fig. 6. *Schematic of internal pressure condition when the dominant opening is in the leeward wall* [4]

4. Conclusions

A well-designed building may be damaged by a wind event that is much stronger than what the building was designed for. The most damage occurs because various building elements have limited wind resistance due to inadequate design or material deterioration.

When high winds affect a building, it is well established that the highest forces occur along the building edges. On the roof, these locations are near the eaves, ridges, hips and rakes. Damage initiated on these edges can lead to progressive failure of the rest of the roofing.

The magnitude and frequency of strong wind varies by locale, and buildings should be constructed to avoid wind damage.

When designing a new roof, the designer must determine the design wind pressure for the geographic location and selects a roofing system appropriate for the local climatic wind conditions.

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