

The Wind Investigator:

How to Approximate Wind Velocities at Roof Level

By Phil Dregger, PE, RRC, FRCI

In the wake of major hurricanes such as Katrina that recently devastated much of the Gulf Coast area near New Orleans, roofing professionals are often asked to investigate the cause of roof wind damages. A key to many damage investigations is approximating the maximum gust wind velocity experienced at roof level. Although wind velocity data are usually available from the National Weather Service (NWS), the National Oceanic and Atmospheric Administration (NOAA), and other sources, the data are usually for terrain exposures, heights above ground, and averaging times different than what is needed. This article discusses how to adjust wind velocity data for site-specific terrain exposures, heights, and averaging times.

Wind Warranty Claim

To illustrate how these adjustments work, we will use the following hypothetical example scenario:

On August 29, 2005, a 2-year-old, built-up roof covering on a 45-foot tall building in a mostly suburban and wooded area southeast of New Orleans,

Louisiana, lifted near one corner and peeled back (see *Figure 1*). The building owner submitted a warranty claim, but it was denied because, according to the manufacturer, wind gusts in the greater New Orleans area exceeded those covered by the warranty. The warranty excludes coverage for damages experienced by “wind gusts greater than 100

mph at the roof.” The building owner hires you to provide an approximation of the maximum wind gust velocity experienced at roof level on his building. No nearby wind velocity data are available, but the site is within the geographic region covered by “wind swath” data published by NOAA shortly after Hurricane Katrina made landfall.



Figure 1: A built-up roof covering lifted and peeled back near one corner.

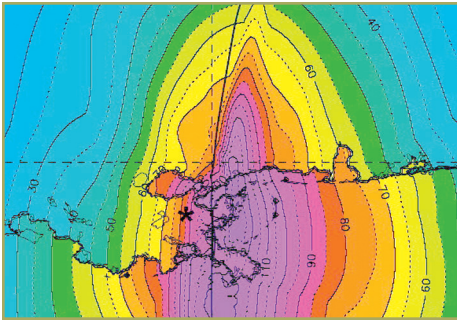


Figure 2: Excerpt from Hurricane Katrina wind swath data published by NOAA.

NOAA H*Wind

Figure 2 shows an excerpt from wind swath data published by NOAA shortly after Hurricane Katrina made landfall on August 29, 2005. The graph shows the estimated maximum sustained winds in miles per hour along the hurricane path at a height of 33' (10 meters) in open terrain (exposure C). Sustained winds are defined as the maximum velocity averaged over a 1-minute interval. See the NOAA Hurricane Research Division, Surface Wind Analysis website (www.aoml.noaa.gov/hrd/data_sub/wind.html) for information about how the data were gathered and reduced to graphical form.

Because many roofs are not positioned at a height of 33' in open terrain, and because current wind design guides (and many wind warranties) are based on three-second gusts, not one-minute winds, the NOAA wind swath data often need to be

adjusted for height, exposure, and/or averaging time before they can be used.

Approximate Sustained Winds

Approximating the maximum sustained winds experienced at a building site is simply a matter of interpolation between the wind isotach lines on the NOAA H*Wind map. Assuming the example building site is located at the asterisks on Figure 2 yields a maximum sustained wind velocity of 85 mph.

Adjust For Averaging Time

The H*Wind data are wind velocities averaged over one minute. Wind velocities referred to in most building codes and most roof manufacturers' warranties are wind gusts. Wind gusts are typically wind velocity data averaged over three seconds. The "Durst Curve" (Durst 1960 and ASCE 7-02) can be used to adjust one-minute wind velocities to equivalent wind gust velocities.

The Durst Curve (Figure 3) shows how wind velocities averaged over "t" seconds compare to wind velocities from the same windstorm averaged over one hour (3600 seconds). The ratio is 1.0 for an averaging time of one hour and something higher for shorter averaging times.

For our example, the Durst Curve indicates a 103 mph 3-second gust wind velocity is considered equivalent to an 85 mph 1-minute wind velocity. The math for this is found in Formula 1.

$$\frac{V_{60}}{V_{3600}} = 1.25; \quad \frac{V_3}{V_{3600}} = 1.52;$$

$$V_3 = 85 \text{ mph} \left(\frac{1.52}{1.25} \right) = 103.4 \text{ mph}$$

Formula 1

Adjust for Height

Winds in a wind stream are assumed to be moving at a constant velocity above a certain height (i.e., the gradient height, Z_g). Winds in this same wind stream but below the gradient height are moving at a slower velocity. They are slowed by friction between the wind stream and the ground. Figure 4 illustrates how the rate of wind stream slowing increases as the terrain gets "rougher" [source: Texas Tech University].

The wind velocities discussed in our example so far are applicable to a roof height of 33' (10 meters). However, while the wind is blowing at 103 mph at a height of 33', it is blowing faster at greater heights.

The Power Law can be used to adjust wind velocity data from one height to another. The Power Law equation shows the relationship between the wind velocity at a given height (V_z) and the gradient velocity (V_g). (See Formula 2.)

$$V_z = V_g \left[\frac{z}{Z_g} \right]^{1/\alpha} \quad 0 \leq z \leq z_g$$

Formula 2

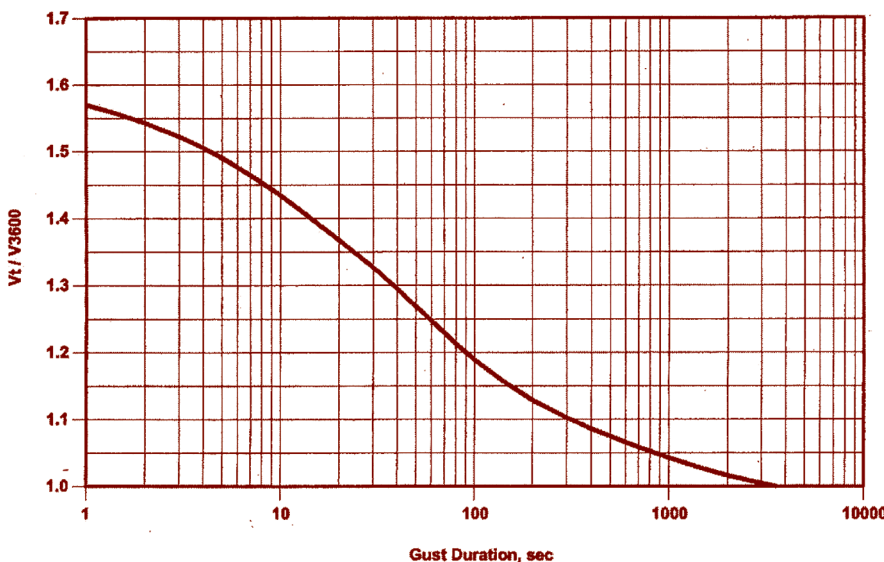


Figure 3: The Durst Curve [Durst 1960 and ASCE 7-02] shows how wind velocities averaged over "t" seconds compare to wind velocities from the same wind storm averaged over 1-hour (3600 seconds).

Figure 5 provides numeric values for gradient heights (Z_g) and the alpha exponents for different terrain exposure categories [Davenport, 1960].

For our example, the Power Law is used in a two-step manner to indicate that a 107-mph gust measured at a height of 45' is considered equivalent to a 103-mph gust measured at a height of 33'. The math for this is found in Formula 3.

Adjust for Terrain

The wind velocities discussed so far are applicable to open terrain (Exposure C), a terrain similar to that surrounding most airports. Since the rate at which a wind stream is slowed by "friction" depends on

$$V_g = \frac{103.4}{\left[\frac{33}{900}\right]^{.1052}} = 146.4 \text{ mph}; V_{45} = 146.4 \left[\frac{45}{900}\right]^{.1052} = 106.8 \text{ mph}$$

Formula 3

ground roughness, wind velocities need to be adjusted if the building is in a terrain exposure other than C. See the commentary of ASCE 7, “Minimum Design Loads for Buildings and Other Structures” for descriptions and photo examples of different terrain exposures.

The gradient velocity of a given wind stream is the same no matter what the terrain exposure is. The Power Law can be used to adjust wind velocities from one exposure condition to another. Referring again to Figure 4, one could say terrain-adjusted wind velocities are approximated by “sliding up” to the gradient velocity along one terrain curve and “sliding down” another.

The “suburban and wooded” terrain surrounding our example building is classified as terrain Exposure B. Using the previous approximation that the wind stream at this site has a gradient wind velocity of 146 mph, the Power Law (with exposure B values), indicates the wind gust velocity at 45' in Exposure B would be 92 mph, which is less than the 107 mph approximated for Exposure C. The math for this final step is shown below in Formula 4.

$$V_{45} = 146.4 \left[\frac{45}{1200}\right]^{.1052} = 91.6 \text{ mph}$$

Formula 4

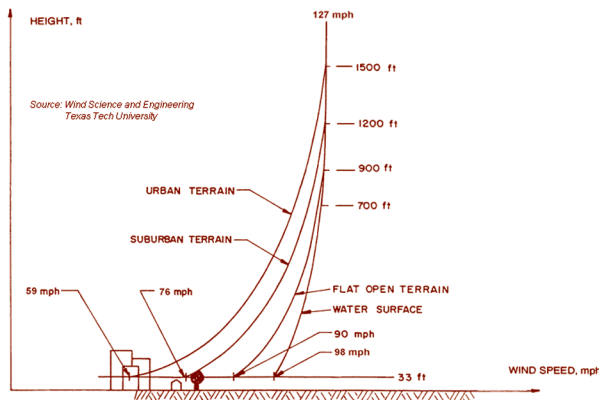


Figure 4: Illustration of how the rate of wind stream slowing increases as the terrain gets “rougher” [source: Texas Tech University].

Terrain	Exposure	Z _g	α
Water	D	700 ft	11.5
Open	C	900 ft	9.5
Suburban	B	1200 ft	7.0
Urban	A	1500 ft	5.0

Figure 5: Numeric values for gradient heights (Z_g) and the alpha exponents for different terrain exposure categories [Davenport, 1960].

Since the final approximated wind gust velocity of 92 mph at roof level in our example is less than 100 mph, the building owner thanks you and submits your information, along with his warranty claim for reconsideration.

Be Careful


Warranties are legal documents and require legal assistance to interpret. Roofing professionals are encouraged to limit the information they offer as part of warranty claims to technical considerations.

The procedures discussed provide approximations of site-specific wind velocities based on generalized wind field type data. Wind velocities at specific sites can vary significantly from these types of generalized data. Investigators are encouraged to supplement and to corroborate NWS and NOAA data with wind velocity data obtained from other sources. More sophisticated analytical procedures, including wind tunnel modeling and/or site instrumentation, are recommended when data beyond approximations are desired.

This article focuses on the velocity of the wind stream as it approaches a building. It does not address how wind velocities are affected as the wind stream is diverted up, over, and around a building and it does not address how wind streams are affected by upstream terrain features such as escarpments and valleys. Readers are directed to ASCE 7 for more information.

This article also does not address how roof wind damages can start and progress, yet these considerations are important in terms of what may or may not be covered by roof warranties.

Summary

A key to many wind damage investigations is approximating the maximum gust wind velocity at roof level. Wind velocity data available to investigators, however, are often for heights, terrain exposures, or averaging times different than what is needed. For example, the NOAA H*Wind data represents one-minute sustained wind velocities at a height of 33' in open terrain (Exposure C). The Durst Curve and the Power Law can be used to adjust NOAA data, as well as data from other sources, for desired averaging times, roof heights, and terrain exposures. 

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If your home or business was affected by Hurricane Katrina and you would like to share your experiences with members in *RCIitems*, please e-mail Kristen Ammerman (kammerman@rci-online.org) or Catherine Moon (cmoon@rci-online.org), or call 1-800-828-1902

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