FM 1-28 vs. ASCE 7: WHICH TO USE

By David Wells, RRC

In a hotel room in Little Rock, Arkansas, having run from the threat of Hurricane Ivan it is hard not to contemplate wind loads on these coastal structures and the documents used to determine them. Most of New Orleans is below sea level. Even the surrounding suburbs are only a few feet above sea level, which makes the area particularly vulnerable to hurricanes. The building codes – the International Code Council's International Building Code (IBC) and the National Fire Protection Association's NFPA 5000 – both require the use of the American Society of Civil Engineers' (ASCE) "Minimum Design Loads for Buildings and Other Structures," ASCE 7, to determine wind loads on structures. In the roofing industry, we also often use Factory Mutual *FM Global Property Loss Prevention Data Sheets* 1-28 to determine wind loads. Until 2002, the methods used by ASCE and FM were substantially different. The 2002 revision of the FM 1-28 document, with a few exceptions, adopted the ASCE method. Now that they are so similar, can they be used interchangeably? Do they always provide the same answer? This article will answer these questions.

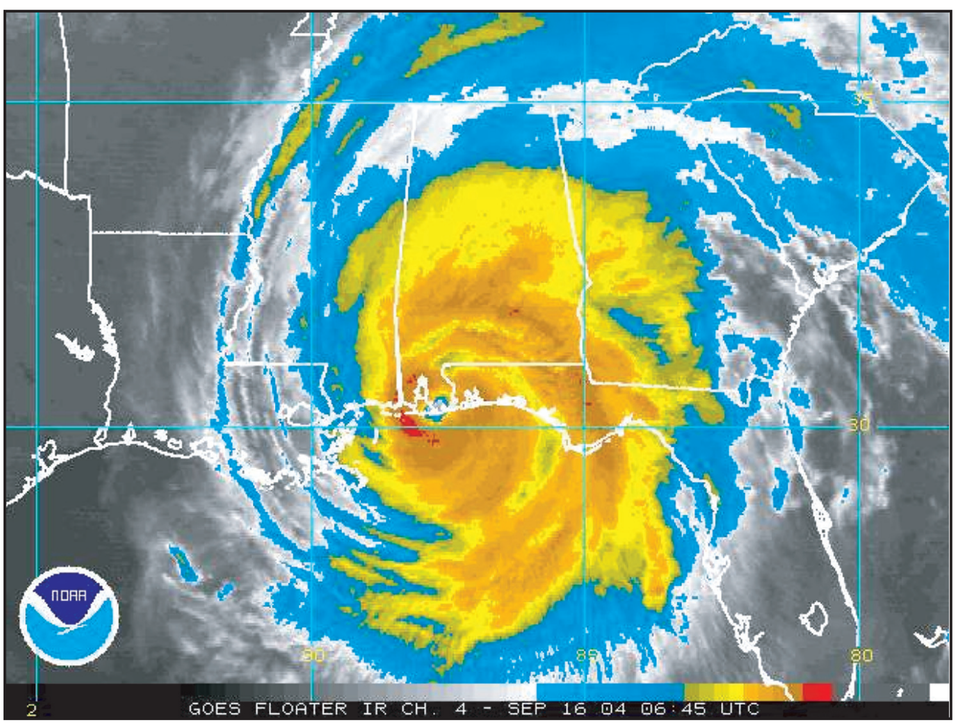

Figure 1: Hurricane Ivan at landfall on September 16, 2004, at Gulf Shores, Alabama, courtesy of the National Atmospheric and Oceanic Administration (NOAA).

The answer to the first question is short and simple. Both NFPA 5000 and the IBC require the use of ASCE 7 for determination of wind loads on a structure. The only time the FM 1-28 document should be used is when Factory Mutual or one of its member companies insures the structure. In this case, loads should be calculated using both the ASCE 7 and FM 1-28 procedures and the more conservative figures should then govern.

The answer to the second question is a little more involved. To illustrate, three fictional structures are provided below, along with the answers for each; first using ASCE 7, and then FM 1-28. For those unfamiliar with either of these methods, detailed calculations are included showing each step and all assumptions. The 2002 revision of both documents was used. FM 1-28 includes five exceptions that, in many circumstances, provide a more conservative answer than does ASCE 7. They are:

- Importance factor I = 1.15 for all buildings and other structures.
- When ground roughness A exists, use ground roughness B.
- Use ground roughness C for hurricane coastal areas where the basic wind speed V is equal to or greater than 120 mph.
- Wind-borne debris regions are defined in FM 1-28, Appendix A.
- Roof pressures are based on a maximum effective area of 10ft², regardless of the actual effective area.

These exceptions can be found in paragraph 2.1.1 of the FM 1-28 document.

Figure 2: Damage caused by Hurricane Ivan on the Florida panhandle.

EXAMPLE 1

ASCE 7 PROCEDURE

Destin, FL
School, evacuation facility
200 ft. from waterfront
Top floor partially enclosed
Flat terrain
Roof slope (Ø)= 1.2˚

Note: The following variables are defined in ASCE 7-02

q_z = velocity pressure at height z (at eave height-low slope roofs) above ground level, in lb/ft², equation 6-15
q_h = velocity pressure at height h (at mean roof height-steep slope roofs) above ground level, in lb/ft², equation 6-15
K_z = velocity pressure exposure coefficient evaluated at height z, paragraph 6.5.6.6 and Table 6-3
K_h = velocity pressure exposure coefficient evaluated at height h, paragraph 6.5.6.6 and Table 6-3
K_{zt} = topographic factor, paragraph 6.5.7.2 and Figure 6-4
K_d = wind directionality factor, paragraph 6.5.4.4 and Table 6-4
V = basic wind speed, in mph, Figure 6-1
I = importance factor, Table 6-1 and Table 1-1

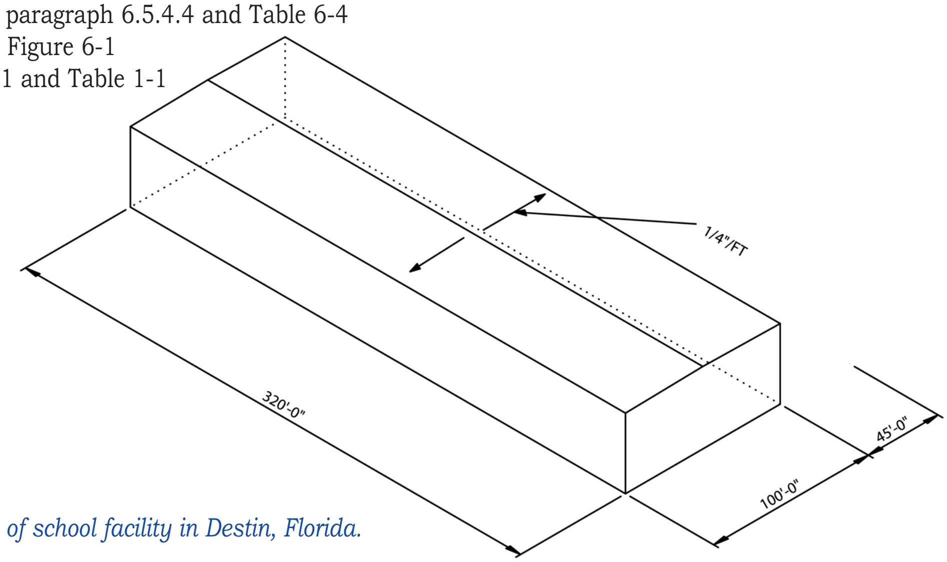

Figure 3: Configuration of school facility in Destin, Florida.

$q_z = q_h = 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times I$ Eq. 6-15

$K_z = 1.07$ (Table 6-3, z = h = 45', exposure C, within hurricane prone region)

$K_{zt} = 1.0$ (Figure 6-4)

$K_d = 1.0$ (¶6.5.4.4, unfactored loads)

V = 130 mph (Figure 6-1b)

I = 1.15 (Table 1-1, Category IV, Table 6-1, hurricane prone V>100 mph)

$q_z = q_h = 0.00256 \times 1.07 \times 1.0 \times 1.0 \times 130^2 \times 1.15 = 53.24$ lbs./ft²

$p = q_h \times ((GC_p) - (GC_{pi}))$ Eq. 6-22

$GC_{p\ zone\ 1} = +0.2, -1.0$ (Table 6-11b, Ø = 1.2°<7°, no overhang)

$GC_{p\ zone\ 2} = +0.2, -1.8$

$GC_{p\ zone\ 1} = +0.2, -2.8$

$GC_{pi} = +0.55, -0.55$

P_{zone1} = 53.24 x ((+0.2)-(-0.55)) = +39.93 lbs/ft²
= 53.24 x ((+0.2)-(+0.55)) = -18.63 lbs/ft²
= 53.24 x ((-1.0)-(-0.55)) = -23.96 lbs/ft²
= 53.24 x ((-1.0)-(+0.55)) = **-82.52lbs/ft² Controls**
x 2.0 Factory Mutual Safety Factor
-165.04 lbs/ft²

After calculating the roof pressure using ASCE, the pressure is multiplied by 2 (or use Table 6 in the FM 1-28 document) to determine an equivalent FM system requirement. This requires an FM 1-180 roof system in the field of the roof.

P_{zone2} = 53.24 x ((+0.2)-(-0.55)) = +39.93 lbs/ft²
= 53.24 x ((+0.2)-(+0.55)) = -18.63 lbs/ft²
= 53.24 x ((-1.8)-(-0.55)) = -66.55 lbs/ft²
= 53.24 x ((-1.8)-(+0.55)) = **-125.14lbs/ft² Controls**
x 2.0 Factory Mutual Safety Factor
-250.28 lbs/ft²

P_{zone3} = 53.24 x ((+0.2)-(-0.55)) = +39.93 lbs/ft²
= 53.24 x ((+0.2)-(+0.55)) = -18.63 lbs/ft²
= 53.24 x ((-21.8)-(-0.55)) = -119.79 lbs/ft²
= 53.24 x ((-2.8)-(+0.55)) = **-178.35lbs/ft² Controls**
x 2.0 Factory Mutual Safety Factor
-356.70 lbs/ft²

This requires an FM 1-255 roof system at the roof edge and an FM 1-360 system at corners of the roof. The zone 2 and zone 3 pressures are used to determine fastener patterns for rigid board insulations on a metal deck. These pressures are also used to select metal flashing gauges and face dimensions. (Refer to FM 1-49 and SPRI RP-4 for more information on design of metal flashings.)

Factory Mutual Procedure

V=130 mph (Figure 1, Part 4)

Ground Roughness C

Roof height = 45'

Roof slope 1/4"/ft

p_{zone1} = 61.5 lbs/ft² (Table 3, z=h=45', V=130 mph, partially enclosed)
X1.31 (Table 4, Ø<10°, h<60')
80.57 lbs/ft²

P_{zone2} = 61.5 x 1.99 = 122.4 lbs/ft² (Table 4)

P_{zone3} = 61.5 x 2.85 = 175.3 lbs/ft² (Table 4)

The final roof pressures can be selected from either Table 4 or Table 6 as shown below.

	Table 4	Table 6
p_{zone1}	FM 1-165	FM 1-165
p_{zone2}	FM 1-255	FM 1-240
p_{zone3}	FM 1-360	FM 1-345

In this example, the structure using the ASCE 7 procedure also complies with the exceptions required by FM 1-28. Once we get the roof pressure in the field of the roof (zone 1) using the FM procedure, either Table 4 or Table 6 can be used to determine the pressures at the roof edge (zone 2) and roof corners (zone 3). FM and ASCE disagree for zone 1 only if two significant digits are used. However, FM and ASCE agree for zones 2 and 3 if FM Table 4 is used but disagree if FM Table 6 is used. Which is the correct answer? For a structure that is not FM insured, ASCE is the default. If it is not insured by Factory Mutual or one of its member carriers, then the building code, budget, and the client's wishes will dictate.

EXAMPLE 2

ASCE 7 Procedure

Spring, TX (Houston suburb)
Agricultural facility – farm shed roof
Open sides
Flat terrain, wooded
Roof slope (Ø)= 9.5˚
H=23.3'

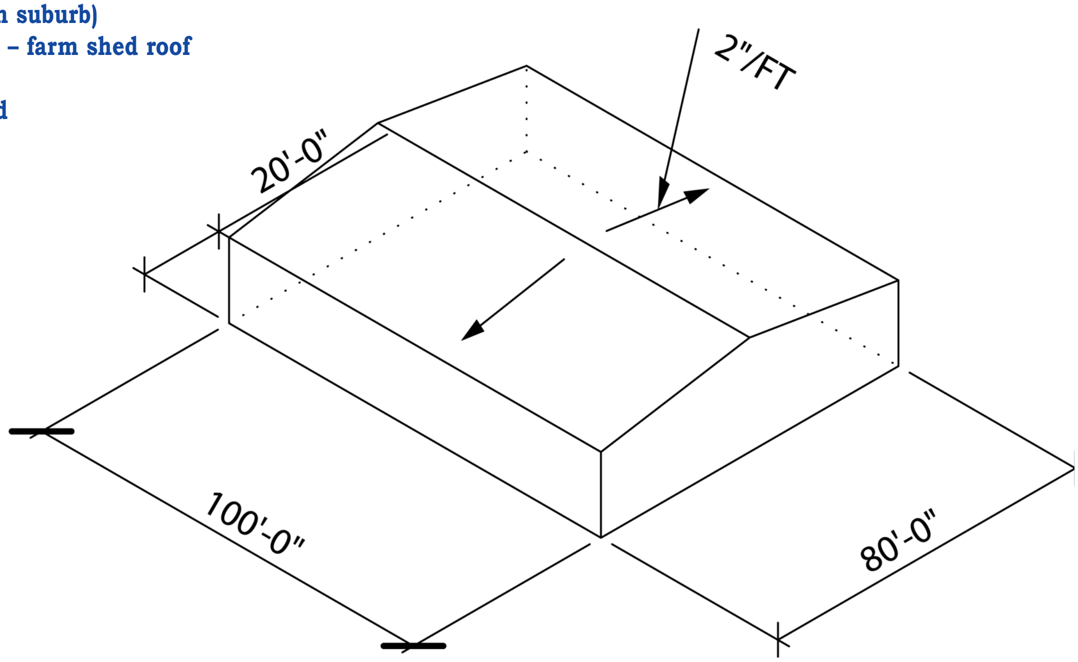

Figure 4: Configuration of an agricultural facility north of Houston, Texas,

$q_z = q_h = 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times I$ Eq. 6-15
$= 0.00256 \times 0.70 \times 1.0 \times 1.0 \times 1102 \times 0.77 = 16.70$ lbs./ft^2

$F = q_z \times G \times C_f \times A_f$ Eq. 6-25
$= 16.7 \times 0.85 \times 0.27 \times 667.0 = 2556.4$ lbs
2556.4/667.0 = 3.8 lbs/ft^2

Notice that there are no roof "zones." The shed roof is similar to a sign on a pole. In example 1, the wind has to rise over or around the building, forcing the wind to travel at a higher velocity and increasing the pressure on the building. In this example, the wind can travel over or under the roof. As a result, the uplift pressure is much lower.

Factory Mutual Procedure

V=110 mph (Figure 1, Part 3)
Ground Roughness B
Roof height = 23.3'
Roof slope 2"/ft
p_{zone1} = 25.0 lbs/ft^2 (Table 1, z=h=23.3', V=110 mph, open – use enclosed)
x 1.00 (Table 4, Ø<10°, h<60')
25.0 lbs/ft^2

Again, use Table 4 and Table 6 to determine pressures in the various zones.

	Table 4	Table 6
p_{zone1}	FM 1-60	FM 1-60
p_{zone2}	FM 1-90	FM 1-105
p_{zone3}	FM 1-135	FM 1-165

The FM procedure has no provision for an open structure. The closest compromise using the FM procedure is to assume that the structure is enclosed. Note that the calculated load using the FM procedure is approximately six times greater than the load calculated by ASCE. Also, note that there are no zone 2 or 3 areas using ASCE. Factory Mutual requires a design pressure of either 1-135 or 1-165 in the corners depending on whether Table 4 or 6 is used. Using the ASCE 7 procedure and applying the FM factor of safety, we select a roof system that can withstand 7.6 lbs/ft^2.

EXAMPLE 3

ASCE 7 Procedure

Wilmington, N.C.
High-rise
700 ft from waterfront
Top floor enclosed
Flat terrain
Roof slope (Ø)= 1.2°

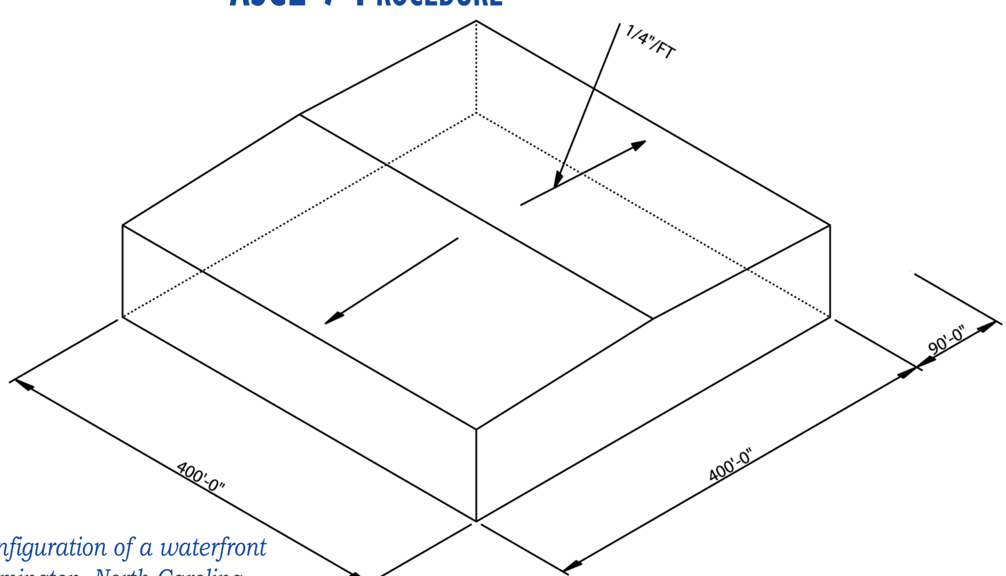

Figure 5: Configuration of a waterfront highrise, Wilmington, North Carolina.

$$q_z = q_h = 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times I \quad \text{Eq. 6-15}$$
$$= 0.00256 \times 1.24 \times 1.0 \times 1.0 \times 130^2 \times 1.0 = 53.6\ \text{lbs./ft}^2$$

$$p = q \times (GC_p) - q_i(GC_{pi}) \quad \text{Eq. 6-22}$$

$GC_{p\ zone\ 1} = -1.4$ (Fig. 6-17)
$GC_{p\ zone\ 2} = -2.3$
$GC_{p\ zone\ 1} = -3.2$

$GC_{pi} = +0.18, -0.18$

$p_{zone1} = 53.6 \times ((-1.4)-(-0.18)) = -65.4\text{lbs/ft}^2$
$= 53.6 \times ((-1.4)-(+0.18)) =$ **-84.7lbs/ft^2 Controls**
x 2.0 Factory Mutual Safety Factor
-169.4lbs/ft^2

This requires an FM 1-180 roof system in the field of the roof.

$p_{zone2} = 53.6 \times ((-2.3)-(-0.18)) = -113.6\text{lbs/ft}^2$
$= 53.6 \times ((-2.3)-(+0.18)) =$ **-132.9lbs/ft^2 Controls**
x 2.0 Factory Mutual Safety Factor
-265.8lbs/ft^2

$p_{zone3} = 53.6 \times ((-3.2)-(-0.18)) = -161.9\text{lbs/ft}^2$
$= 53.6 \times ((-3.2)-(+0.18)) =$ **-181.2lbs/ft^2 Controls**
x 2.0 Factory Mutual Safety Factor
-362.4lbs/ft^2

LEED Canada is Launched

Canada has adopted the LEED™ program originally developed by the U.S. Green Building Council (USGBC). The Canadian Green Building Council (CGBC) has licensed LEED-BC as its first rating system, launched on Dec. 1, 2004. There are 80 possible points in the Canadian version. As of that date, there were already five buildings in Canada certified by LEED. By December, the CGBC had over 500 members and was growing at the rate of 10% per month.

— Roofing Canada

FACTORY MUTUAL PROCEDURE

V = 130 mph (Figure 1, Part 4)
Ground Roughness C
Roof height = 90'
Roof slope 1/4"/ft
p_{zone1} = 83.0 lbs/ft^2 (Table 2, z = h =90', V = 130 mph, enclosed)
X1.0 (Table 4, Ø<10°, h>60')
83.0 lbs/ft^2
p_{zone2} = 83.0 x 1.57 = 130.3 lbs/ft^2 (Table 4)
p_{zone3} = 83.0 x 2.14 = 177.6 lbs/ft^2 (Table 4)

The final roof pressures can be selected from either Table 4 or Table 6 as shown below.

	Table 4	Table 6
p_{zone1}	FM 1-180	FM 1-180
p_{zone2}	FM 1-255	FM 1-270
p_{zone3}	FM 1-375	FM 1-360

FM and ASCE agree for zone 1. However, in zone 2, ASCE agrees with FM Table 4, and agrees with FM Table 6 in zone 3. Using the FM procedure, predicting which table will yield the more conservative answer is not always obvious.

Figure 6: Damage caused by Hurricane Ivan on the Florida panhandle. This structure appears to have a large damaged door opening facing the water. The structure would likely be considered "partially enclosed."

So, what's the answer to the second question? Obviously, ASCE and FM do not always provide the same answer. Often the wind uplift resistances required are close enough to require the same FM rating. When these problems were made up, the difference in answers between FM and ASCE was expected. However, the difference in the first example produced by the round-off of the calculations was unforeseen. Neither was the flip-flop in answers of the last example using the FM procedure in Tables 4 and 6 expected. What does this mean in practice? First, always use ASCE 7. Then, when a building is insured by Factory Mutual or one of its member companies, use both ASCE 7 and FM 1-28 and choose the more conservative answer.

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