Chapter 7

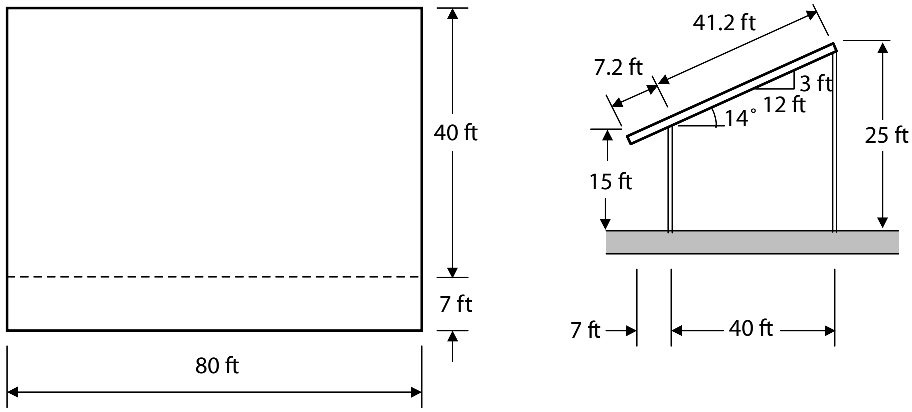
Commercial Building with Monoslope Roof and Overhang

In this example, design pressures for a typical retail store in a strip mall are determined. The building's dimensions are shown in **Fig. G7-1**. The building data are listed in **Table G7-1**.

7.1 Analytical Procedure

The building does not meet the requirements of chapter 27, part 2, of the Standard for a simple diaphragm building, because the roof is not flat, gable, or hip (see Fig. 27.6-2 of the Standard), so the simplified procedure cannot be used. If the roof is not gable, flat, or hip the low-rise building provisions of chapter 28, part 1, of the Standard should not be used. Therefore, chapter 27, part 1, of the Analytical Procedure, is used (see Section 27.2 of the Standard) for MWFRS. For components and cladding, chapter 30, part 1, for low-rise buildings is used.

Fig. G7-1
Building characteristics for commercial building with monoslope roof and overhang



Building Classification, Enclosure Classification, and Exposure Category

The building is not an essential facility, nor is it likely to be occupied by more than 300 persons at any one time. Use Category II (see Table 1.5-1 of the Standard). Wind speed map in Fig. 26.5-1A is appropriate for this category of building.

The building is sited in a suburban area and satisfies the criteria for Exposure B (see Section 26.7 of the Standard).

Since the building is sited within 1 mi of the coastal water, it is considered in a wind-borne debris region. It has glazing (that must be impact resistant) occupying 50 percent of a wall that receives positive pressure. The building could be classified as enclosed (see Sections 26.10.3 and 26.2 of the Standard). The standard does not require that the building be classified as partially enclosed if it is located in a wind-borne debris region; it just requires that the openings be protected with impact-resistant glazing or shutters. The wind-borne debris region is defined in Section 26.2.

Table G7-1 Data for Commercial Building with Monoslope Roof and Overhang

Location	Boston, Massachusetts, within 1 mi of the coastal mean high watermark
Topography	Homogeneous
Terrain	Suburban
Dimensions	40 ft × 80 ft in plan Monoslope roof with slope of 14° and overhang of 7 ft in plan Wall heights are 15 ft in front and 25 ft in rear $h = 20$ ft
Framing	Walls of CMU on all sides supported at top and bottom; steel framing in front (80-ft width) to support window glass and doors Roof joists span 41.2 ft with 7.2-ft overhang spaced at 5 ft on center
Cladding	Glass and door sizes vary; glazing is debris impact-resistant and occupies 50 percent of front wall (80 ft in width) Roof panels are 2 ft wide and 20 ft long

Basic Wind Speed

The wind speed contours of 130 and 140 mph traverse either side of Boston, Massachusetts (Fig. 26.5-1A of the Standard); use a basic wind speed of 135 mph (interpolating between the 130 and 140 mph isotachs).

Velocity Pressures

The velocity pressures for MWFRS (**Table G7-2**) are calculated using the following equation (see Section 27.3.2 of the Standard):

$$\begin{aligned} q &= 0.00256\ K_z K_{zt} K_d V^2 \text{ (psf)} \qquad \text{(Eq. 27.3-1)} \\ &= 0.00256\ K_z(1.0)(0.85)(135)^2 \\ &= 39.66\ K_z \text{ (psf)} \end{aligned}$$

where

K_z = value obtained from Table 27.3-1 of the Standard for MWFRS and Table 30.3-1 of the Standard for C&C

K_{zt} = 1.0 homogeneous terrain

K_d = 0.85, see Table 26.6-1 of the Standard

Since the Exposure Category is B for the building location, values of K_z are different for MWFRS and C&C.

Design Pressures for the MWFRS

The equation for rigid buildings of all heights is given in Section 27.4.1 of the Standard as follows:

$$p = qGC_p - q_i(GC_{pi}) \qquad \text{(Eq. 27.4-1)}$$

where

q = q_z for windward wall

q_i = q_h for windward and leeward walls, side walls and roof for enclosed buildings

G = value determined from Section 26.9 of the Standard

C_p = value obtained from Figure 27.4-1 of the Standard

(GC_{pi}) = value obtained from Table 26.11-1 of the Standard

For positive internal pressure evaluation, the Standard permits q_i to be conservatively evaluated at height $h(q_i = q_h)$.

Table G7-2 Velocity Pressures

	MWFRS		*C&C*	
	Exposure B		*Exposure B*	
Height (ft)	K_z	q_z *(psf)*	K_z	q_h *(psf)*
0 to 15	0.57	22.6		
h = 20	0.62	24.6*	0.70	27.8
25	0.66	26.2		

Note: *q_h = 24.6 psf for MWFRS.

Gust Effect Factor

The building can be classified as a low-rise building, so the Standard permits it to be a rigid building without determining fundamental frequency (Section 26.9.2)

The gust effect factor for nonflexible (rigid) buildings is given in Section 26.9.1 of the Standard as $G = 0.85$.

Wall External Pressure Coefficients

The coefficients for the windward and side walls in **Table G7-3** are given in Fig. 27.4-1 of the Standard as $C_p = +0.8$ and -0.7, respectively. The values for the leeward wall depend on L/B; they are different for the two directions: wind parallel to roof slope (normal to ridge), and wind normal to roof slope (parallel to ridge).

Roof External Pressure Coefficients

Since the building has a monoslope roof, the roof surface for wind directed parallel to the slope (normal to ridge) may be a windward or a leeward surface. The value of $h/L = 0.5$ in this case, and the proper coefficients are obtained from linear interpolation for $\theta = 14°$ (see **Table G7-4**). When wind is normal to the roof slope (parallel to ridge), angle $\theta = 0$ and $h/L = 0.25$.

For the overhang, Section 27.4.4 of the Standard requires $C_p = 0.8$ for wind directed normal to a 15-ft wall. The Standard does not address the leeward overhang for the case of wind directed toward a 25-ft wall and perpendicular to roof slope (parallel to ridge). A $C_p = -0.5$ could be used (coefficient for leeward wall), but the coefficient has been conservatively taken as 0.

The building is sited in a hurricane prone region less than 1 mi from the coastal mean high-water level. The basic wind speed is 135 mph, and the glazing must be designed to resist wind-borne debris impact (or some other method of protecting the glazing must be installed, such as shutters). Thus, as noted earlier, the building is classified as enclosed for this example. The internal pressure coefficients, from Table 26.11-1 of the Standard, are as follows:

$(GC_{pi}) = +0.18$ and
$(GC_{pi}) = -0.18$

Typical Calculations of Design Pressures for MWFRS

For cases with wind parallel to the slope with a 15-ft windward wall (see **Table G7-5**).

Table G7-3 Wall Pressure Coefficients

Surface	*Wind direction*	L/B	C_p
Leeward wall	‖ to roof slope	0.5	–0.5
Leeward wall	⊥ to roof slope	2.0	–0.3
Windward wall	—	—	0.8
Side walls	—	—	–0.7

Table G7-4 Roof Pressure Coefficients

Wind direction	h/L	θ°	C_p
|| to roof slope	0.5	14	–0.74, –0.18* as windward slope
|| to roof slope	0.5	14	–0.50 as leeward slope
⊥ to roof slope	0.25	0	–0.18* (0–80 ft from windward edge) –0.90 (0–20 ft from windward edge) –0.50 (20–40 ft) –0.30 (40–80 ft)

*The values of smaller uplift pressures on the roof can become critical when wind load is combined with roof live load or snow load; load combinations are given in Sections 2.3 and 2.4 of the Standard. For brevity, loading for this value is not shown here.

Table G7-5 Design Pressures for MWFRS for Wind Parallel to Roof Slope, Normal to Ridge Line

Wind direction	*Surface*	z *(ft)*	q_z *(psf)*	*Gust effect*	*External* C_p	*Design pressure (psf)** $(+GC_{pi})$	*Design pressure (psf)** $(-GC_{pi})$
Windward wall (15 ft)	Windward wall	0 to 15	22.6	0.85	0.80	10.9	19.8
	Leeward wall	0 to 25	24.6	0.85	–0.50	–14.9	–6.0
	Side wall	All	24.6	0.85	–0.70	–19.1	–10.2
	Roof	—	24.6	0.85	–0.74	–19.9	–11.0
	Overhang top	—	24.6	0.85	–0.74	–15.5**	–15.5**
	Overhang bottom	—	22.6	0.85	0.80	15.4**	15.4**
Windward wall (25 ft)	Windward wall	0 to 15	22.6	0.85	0.80	10.9	19.8
		15 to 20	24.6	0.85	0.80	16.7	21.2
		20 to 25	26.2	0.85	0.80	17.8	22.2
	Leeward wall	All	24.6	0.85	–0.50	–14.9	–6.0
	Side wall	All	24.6	0.85	–0.70	–19.1	–10.2
	Roof	—	24.6	0.85	–0.50	–14.9	–6.0
	Overhang top	—	24.6	0.85	–0.50	–10.4**	–10.4**
	Overhang bottom	—	—		—	0.0**	0.0**

*External pressure calculations include $G = 0.85$.

**Overhang pressures are not affected by internal pressures. The Standard does not address bottom surface pressures for leeward overhang. It could be argued that leeward wall pressure coefficients can be applied, but note that neglecting the bottom overhang pressures would be conservative in this application.

Pressure on Leeward Wall

$$\begin{aligned} p &= q_h GC_p - q_h(\pm GC_{pi}) \\ &= 24.6(0.85)(-0.5) - (24.6)(+0.18) = -14.9 \text{ psf with positive internal pressure} \\ \text{and } &= 24.6(0.85)(-0.5) - (24.6)(-0.18) = -6.0 \text{ psf with negative internal pressure} \end{aligned}$$

Pressure on Overhang Top Surface

$$p = q_h GC_p = 24.6(0.85)(-0.74) = -15.5 \text{ psf}$$

Pressure on Overhang Bottom Surface

This is the same as windward wall external pressure.

$$p = q_z GC_p = 22.6(0.85)(0.8) = 15.4 \text{ psf}$$

Note that q_z was evaluated for $z = 15$ ft for bottom surface of overhang as C_p coefficient is based on induced pressures at top of wall.

Figures G7-2 and G7-3 illustrate the external, internal, and combined pressure for wind directed normal to the 15-ft wall. **Figures G7-4 and G7-5** illustrate combined pressure for wind directed normal to the 25-ft wall and perpendicular to slope (parallel to ridge line), respectively (see **Table G7-6**).

Design Wind Load Cases

Section 27.4.6 of the Standard requires that any building whose wind loads have been determined under the provisions of chapter 27 shall be designed for wind load cases as defined in Fig. 27.4-8 of the Standard. Case 1 includes the loadings shown in **Fig. G7-2 through Fig. G7-5**. The exception in Section 27.4.6 of the Standard indicates that buildings meeting the requirements of Section D1.1 of Appendix D need only be designed for Case 1 and Case 3 of Fig. 27.4-8.

Design Pressures for Components and Cladding

The design pressure equation for components and cladding (C&C) for a building with mean roof height $h \leq 60$ ft is given in Section 30.4.2 of the Standard:

$$P = q_h[(GC_p) - (GC_{pi})] \qquad \text{(Eq. 30.4-1)}$$

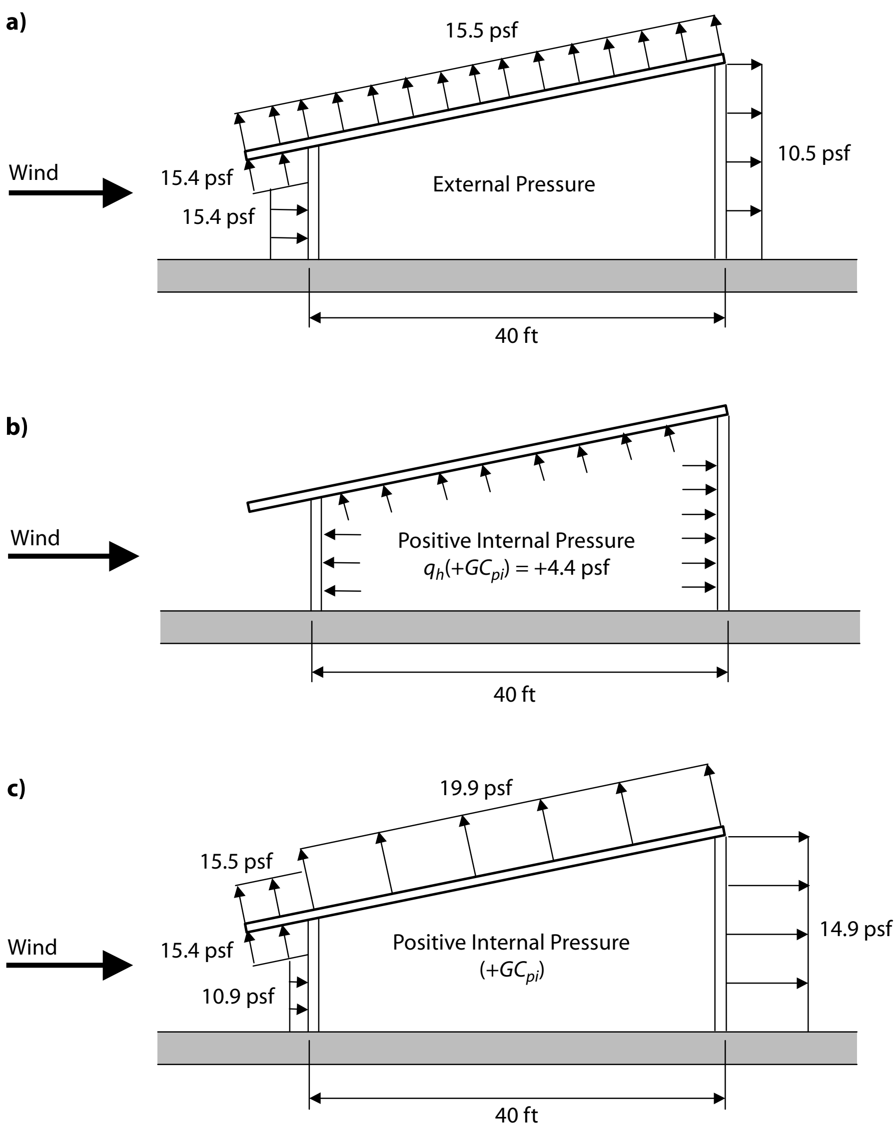
where

q_h = velocity pressure at mean roof height associated with Exposure B ($q_h = 27.8$ psf, previously determined)

(GC_p) = external pressure coefficients from Figs. 30.4-2A, 30.4-2B, and 30.4-2C of the Standard

(GC_{pi}) = +0.18 and −0.18, previously determined from Table 26.11-1 of the Standard

Fig. G7-2
Design pressures for MWFRS for wind parallel to roof slope, normal to 15-ft wall, and positive internal pressure: a) external pressures, b) positive internal pressure, and c) combined external and positive internal pressure



Wall Design Pressures

Wall external pressure coefficients are presented in **Table G7-7**. Since the CMU walls are supported at the top and bottom, the effective wind area will depend on the span length.

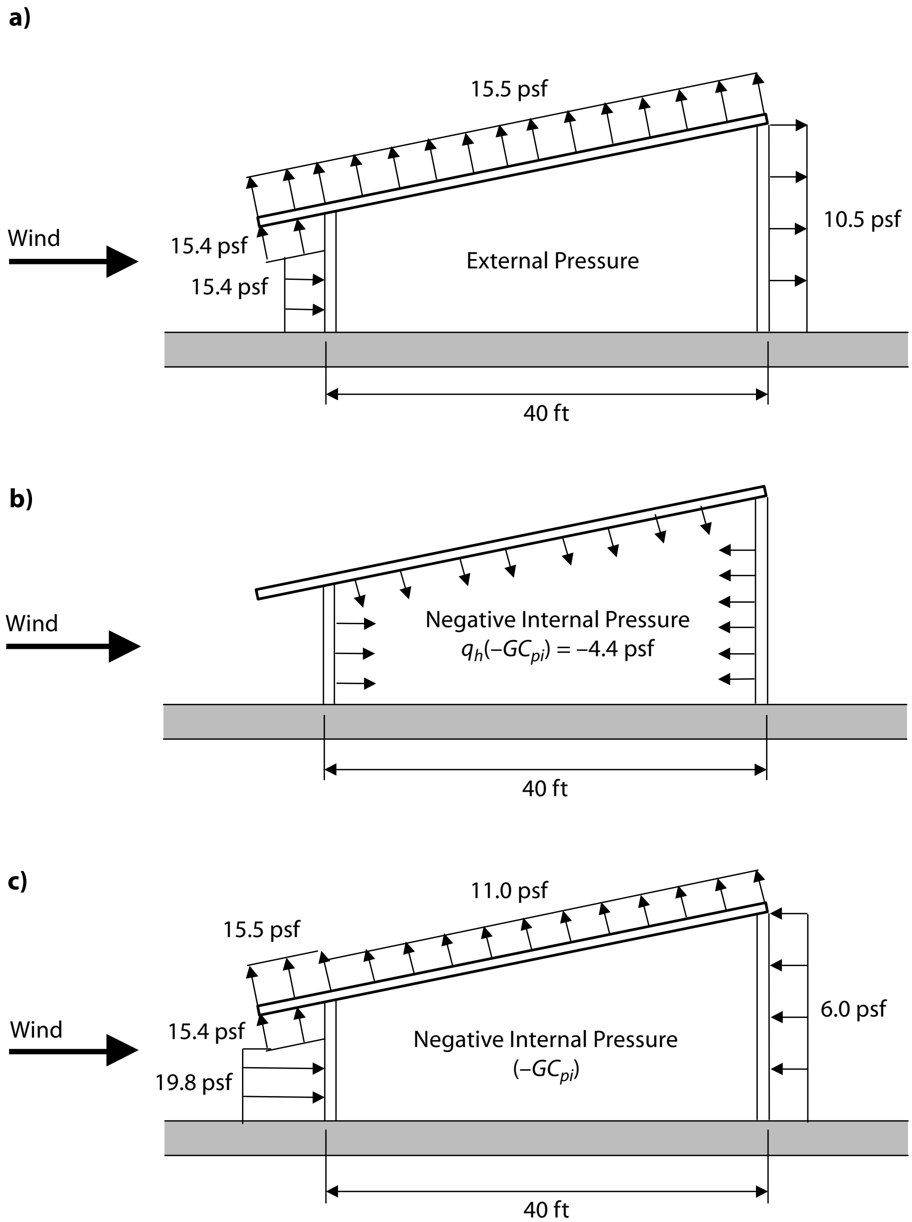
Effective wind area

For span of 15 ft, $A = 15(15/3) = 75\ \text{ft}^2$
For span of 20 ft, $A = 20(20/3) = 133\ \text{ft}^2$
For span of 25 ft, $A = 25(25/3) = 208\ \text{ft}^2$

Width of Zone 5 (Fig. 30.4-1)

smaller of	$a = 0.1(40) = 4$ ft (controls)
or	$a = 0.4(20) = 8$ ft
but not less than	$a = 0.4(40) = 1.6$ ft
or	$a = 3$ ft

Fig. G7-3
Design pressures for MWFRS for wind parallel to roof slope, normal to 15-ft wall, and negative internal pressure: a) external pressures, b) negative internal pressure, and c) combined external and negative internal pressure



Design pressures are the critical combinations when the algebraic sum of the external and internal pressures is a maximum.

Typical Calculations for Design Pressures for 15-ft Wall, Zone 4

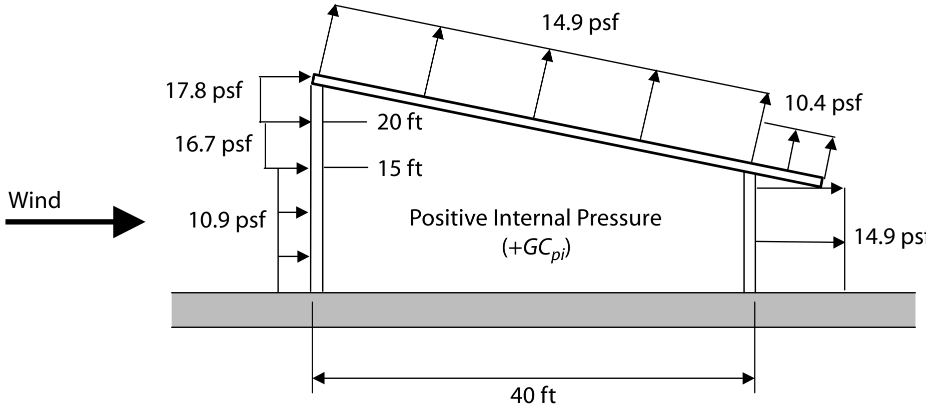
Wall design pressures are presented in **Table G7-8**.

$$
\begin{aligned}
p &= q_h[(GC_p) - (\pm GC_{pi})] \\
&= 27.8[(0.85) - (-0.18)] = 28.6 \text{ psf} \\
\text{and } &= 27.8[(-0.95) - (0.18)] = -31.4 \text{ psf}
\end{aligned}
$$

The CMU walls are designed for pressures determined for Zones 4 and 5 using appropriate tributary areas.

The design pressures for doors and glazing can be assessed by using appropriate pressure coefficients associated with their effective wind areas.

Fig. G7-4
Combined design pressures for MWFRS for wind parallel to roof slope, normal to 25-ft wall



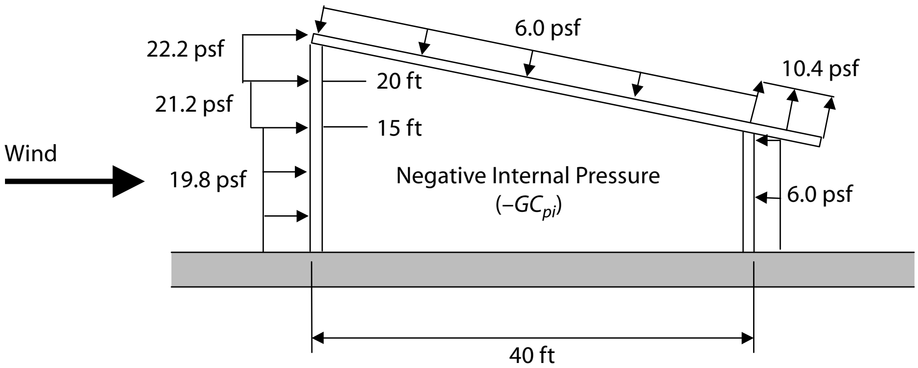
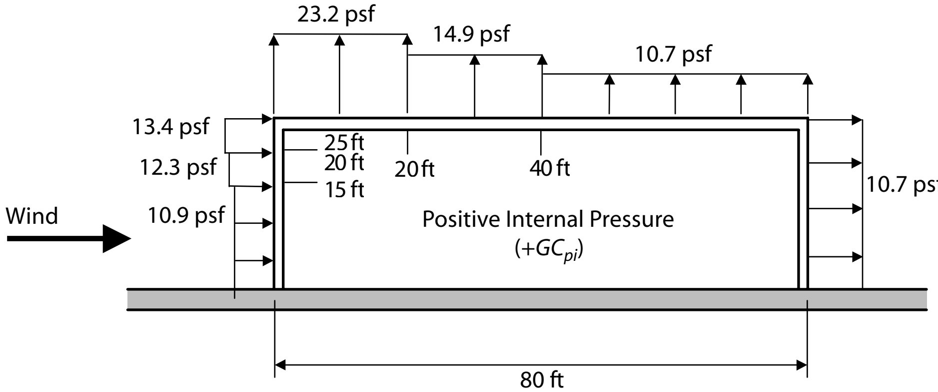


Fig. G7-5
Combined design pressures for MWFRS for wind perpendicular to roof slope, parallel to ridge line



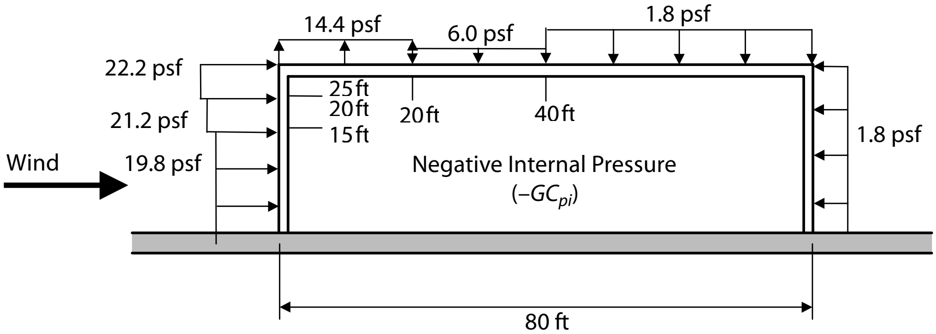


Table G7-6 Design Pressures for MWFRS for Wind Normal to Roof Slope, Parallel to Ridge Line

Surface	*z or distance (ft)*	q_z *(psf)*	*Gust effect, G*	C_p	*Design pressure (psf)* $+(GC_{pi})$	$-(GC_{pi})$
Windward wall	0–15	22.6	0.85	0.8	10.9	19.8
	15–20	24.6	0.85	0.8	12.3	21.2
	20–25	26.2	0.85	0.8	13.4	22.2
Leeward wall	All	24.6	0.85	–0.3	–10.7	–1.8
Side wall	All	24.6	0.85	–0.7	–19.1	–10.2
Roof	0–20	24.6	0.85	–0.9	–23.2	–14.4
	20–40	24.6	0.85	–0.5	–14.9	–6.0
	40–80	24.6	0.85	–0.3	–10.7	–1.8

Note: For design pressure, external pressure calculations include $G = 0.85$. Internal pressure, (GC_{pi}), is associated with $q_h = 24.6$ psf. For z, distance along roof is from leading windward edge. For the roof, pressure on the overhang is only external pressure (contribution on underside is conservatively neglected).

Table G7-7 Wall External Pressure Coefficients by Zone

A (ft^2)	*Pressure coefficients* Zones 4 and 5 $(+GC_p)$	Zone 4 $(-GC_p)$	Zone 5 $(-GC_p)$
75	0.85	–0.95	–1.09
133	0.80	–0.90	–1.00
208	0.77	–0.87	–0.93

Table G7-8 Wall Design Pressures by Zone

Wall height (ft)	*Design pressures (psf)* Zones 4 and 5 Positive	Zone 4 Negative	Zone 5 Negative
15	28.6	–31.4	–35.3
20	27.2	–30.0	–32.8
25	26.4	–29.2	–30.9

Note: $q_h = 27.8$ psf.

Roof Design Pressures

Roof external pressure coefficients are presented in **Table G7-9**; roof design pressures are presented in **Table G7-10**.

Effective wind area

Roof joist

$$A = (41.2)(5) = 206 \text{ ft}^2$$
$$\text{or} = (41.2)(41.2/3) = 566 \text{ ft}^2 \text{ (controls)}$$