# HH Gregg Building <br> Northgate Mall 

Cincinnati, Ohio
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## Structural Reinforcement Modification <br> Carbon Fiber Reinforcement

Of
Concrete Masonry Unit (CMU) Wall
Adjacent to Loading Dock


Frederick J. Sambor, P.E.
Project Engineer


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## BASIC ASSUMPTIONS:

- The Architect for this project is Herschman Architects of Cleveland, Ohio.
- The Structural Engineer for this project is Thorson Baker \& Associates of Richfield, Ohio.
- The steel reinforcement in the wall of concern is assumed to be non functional for the purpose of a tensile member for the reinforced CMU wall.
- The area of concern does have grout filling the cavities per original blueprint requirements.
- The shear load carrying capacity of the CMU wall is per blueprint.
- The focus of this modification is to ensure that the bending capacity of the CMU wall with is sufficient to carry the load, assuming the steel reinforcement is not functional.
- The Carbon Fiber Reinforcements are continuously adhered to the CMU with Epoxy adhesive. The adhesive encapsulates the carbon fiber.
- The design criteria and these calculations have been modified as directed by Nathaniel D. Roop, Structural Engineering Project Manager.
- Per ACl 318 requirements for tensile reinforcement splices, the actual applied moment is to be $.80 \times$ Moment allowable for given location.


## Design Criteria

Building Code: OBC 2011

1. Design live loads
A. Floor loads
1.1. Retail

$$
\text { 1.1. First floor }=100 \mathrm{psf}
$$

1.2. Stairs and exits $\quad=100 \mathrm{psf}$
B. Roof loads
1.1. Minimum roof live load by code $=20 \mathrm{psf}$
1.2. Ground snow load $=20 \mathrm{psf}$
1.2.a. Snow exposure factor (ce) $\quad=1.0$
12.a. Snow importance factor (Is) $\quad=1.0$
12. b . Thermal Factor ( Ct ) $\quad=1.0$
1.3. Flat roof snow load (Pf) $=14 \mathrm{psf}$
1.4. Rainon snow $=5 \mathrm{psf}$
1.5. Total design snow load $\quad=20 \mathrm{psf}+$ drifting
1.6. Roof design is governed by the minimum roof live load or total design snow load + drifting whichever is more stringent.
2. Design wind loads
A. Basic wind speed ( 3 second gust)

$$
\begin{aligned}
& =90 \mathrm{mph} \\
& =\mathrm{C} \\
& =1.0
\end{aligned}
$$

2.1. Exposure
2.2. Importance factor (lw)
B. Components and Cladding Wind Loads (PSF) for Walls

| Effective Area <br> (sq. ft.) | 10 | 20 | 50 | 100 | 0 | 20 | 50 | 100 |  |  |  |  |  |  |
| :--- | :---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Height | Interior Zone |  |  |  |  |  |  |  |  |  | Exterior Zone |  |  |  |
| $0-15$ | 19.5 | 18.5 | 17.5 | 16.5 | 24.0 | 22.0 | 20.0 | 18.5 |  |  |  |  |  |  |
| 20 | 20.5 | 19.5 | 18.5 | 18.0 | 25.5 | 23.5 | 21.5 | 19.5 |  |  |  |  |  |  |
| 25 | 21.5 | 20.5 | 19.5 | 18.5 | 26.5 | 25.0 | 22.5 | 20.5 |  |  |  |  |  |  |
| 30 | 22.5 | 21.5 | 20.5 | 19.5 | 27.5 | 25.5 | 23.5 | 21.5 |  |  |  |  |  |  |
| 35 | 24.0 | 22.0 | 21.0 | 20.0 | 28.5 | 26.5 | 24.0 | 22.0 |  |  |  |  |  |  |

C. Components and cladding: use the most stringent wind load obtained from code, underwriter criteria (Factory Mutual, etc.), and the project specifications. Cladding manufacturer shall consider increased pressure coefficients at building perimeter, corners, eaves, and rakes. Loads noted in general notes are obtained from code.
D. Roof uplift

Typical bay
Perimeter bay ( $10.0^{\prime}$ wide)
Corner bay ( $10.0^{\prime} \times 10.0^{\prime}$ wide)
gross 18.0 psf net 13.0 psf gross 21.5 psf net 16.5 psf gross 21.5 psf net 16.5 psf

## Drawing Notes:

REFER TO BUILDING DRAWINGS PREPARED BY HERSCHMAN ARCHITECTS INC, 25001 EMERY ROAD, SUITE 400, CLEVELAND, OHIO 44126 AND STRUCTURAL DRAWING PREPARED BY THORSON BAKER \& ASSOCIATES, INC. CONSULTING ENGINERS, 3030 WEST STREETBORO ROAD, RICHFIELD, OHIO 44286 FOR DESIGN LOAD CRITERIA AND REQUIREMENTS.

ALL CONSTRUCTION SHALL MEET 2011 OHIO BUILDING CODE (OBS), LOCAL CODE REQUIREMENTS, AS WELL AS REQUIREMENTS CALLED FOR IN THIS DRAWING.

CONTRACTOR/OWNER TO VERIFY ALL FIELD CONDITIONS PRIOR TO CONSTRUCTION. IF CONDITIONS OTHER THAN THOSE SHOWN IN DRAWING SET ARE FOUND, CONTRACTOR/OWNER SHALL NOTIFY PROJECT ENGINEER/DESIGNER IMMEDIATELY.

CONTRACTOR SHALL FURNISH ALL MATERIALS, LABOR AND EQUIPMENT TO COMPLETE ALL HIS WORK AND FURNISH A COMPLETED JOB ALL IN ACCORDANCE WITH LOCAL AND STATE GOVERNING AUTHORITIES AND AITHORITIES HAVING LAWFUL JURISDICTION OVER THE WORK.

DRAWINGS INDICATE THE MINIMUM STANDARDS BUT, IF ANY WORK SHOULD BE INDICATED TO BE SUBSTANDARD TO ANY ORDINANCES, LAWS, CODES, RULES, OR REGULATIONS BEARING ON THE WORK, THE CONTRACTOR SHALL INCLUDE IN HIS WORK, AND SHALL EXECUTE THE WORK CORRECTLY IN ACCORDANCE WITH SUCH ORDINANCES, LAWS, CODES, OR REGULATIONS WITH NO INCREASE OR COST.

FIBER-REINFORECE POLYMER SUPPORTS SHALL BE INSTALLED BY EXPERIENCED INSTALLERS.

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## WIND LOADS:

70 mph wind field
Reference:
Importance Factor = 1.0
Exposure C
ASCE 7-10 Chap 26 \& 27

WIND VELOCITY PRESSURE:

$$
\begin{aligned}
& \mathrm{q}_{\mathrm{z}}=0.00256 \times \mathrm{K}_{\mathrm{z}} \times \mathrm{K}_{\mathrm{zT}} \times \mathrm{K}_{\mathrm{d}} \times \mathrm{V}^{2} \times \mathrm{I} \\
& \mathrm{~K}_{\mathrm{z}}=0.98 \quad \text { ASCE } 7-\text { Table } 27.3 \\
& \mathrm{~K}_{\mathrm{zT}}=0.85 \\
& \mathrm{~K}_{\mathrm{d}}=0.85 \quad \text { ASCE } 7-\text { Table } 26.8 \\
& \mathrm{~V}=90 \mathrm{mph} \\
& \mathrm{I}=\text { Importance Factor }=1.0 \\
& \mathrm{q}_{\mathrm{z}}=14.68 \text { pounds per square foot }
\end{aligned}
$$

Use 20.9 psf at height of 27 ft as directed by Nathaniel D. Roop of Thorson Baker Engineers.

Assume analysis of wall using 4 foot wide sections of typical CMU wall.


FREE BODY
DIAGRAM


BENDING MOMENT DIAGRAM

Analyze wall as a simple beam with uniformly applied load rotated to vertical position.
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## Figure 1 Simple Beam - Uniformly Distributed Load



$$
\begin{aligned}
& R=V \ldots . . . . . . . \\
& v_{x} \quad \ldots \ldots \ldots . . . w^{2}\left(\frac{\ell}{2}-x\right) \\
& M_{\max } \text { (at center) } \ldots . . . .=\frac{w \ell^{2}}{8} \\
& M_{x} \ldots \ldots . . . . . .{ }^{\prime}=\frac{w x}{2}(\ell-x) \\
& \Delta_{\max } \text { (at center) } \quad \cdots . . .=\frac{5 w \ell^{4}}{384 E I} \\
& \Delta_{x} \quad \cdots \ldots . . . . .=\frac{w x}{24 E I}\left(\ell^{3}-2 \ell x^{2}+x^{3}\right)
\end{aligned}
$$

Assuming Shear is per blueprint and not a concern for this analysis.
Calculation will focus on the bending moment applied to the CMU wall by the uniformly applied wind pressure velocity load
$\mathrm{M} \max ($ at center $)=\mathrm{wl} / 8=7,563 \mathrm{ft}-\mathrm{lb}$.
$\mathrm{w}=$ uniformly applied load $=20.9 \mathrm{psf} \times 4 \mathrm{ft}$ wide section $=84 \mathrm{lb} / \mathrm{ft}$.

Bending Moment resisting reaction
(Ref: National Concrete Masonry Association TEK 14-48 report)
The CMU wall will react the bending moment with a tensile load [T] and a compressive load [C]


Modulus of rupture for CMU is an average of filled and unfilled CMU
Modulus of rupture $=(63+173) / 2=148$ pounds per square inch $(p s i)$.

Resisting moment

$$
\begin{aligned}
& \mathrm{C}=148 \mathrm{psi} \times 1.5 " \times 48^{\prime \prime} \text { wide section }=10,656 \mathrm{lb} \\
& \mathrm{~T}=\text { Tensile allowable of carbon fiber at } 48 \text { " on center. } \\
& =(.050 " \times 4 ") \times 51,571 \mathrm{psi} \text { (see test results for ultimate tensile) }=10,324 \mathrm{lb} .
\end{aligned}
$$

Bending resisting moment of a single laminate of carbon fiber $T=10,324$

## Using a 3X safety factor (concervative)

Bending allowable $=10,324 / 3=3,441 \mathrm{lb}-\mathrm{ft}$.
Since the CMU wall is 1 ft ( 12 ") thick limit the allowable for carbon fiber laminate $=3,441 \mathrm{lb} /$ laminate.

Using multiple laminate at 48" on center the moment resisting allowable would be as Follows:

1 laminate resists $=3,441 \mathrm{lb}-\mathrm{ft}$
2 laminate resists $=6,882 \mathrm{lb}-\mathrm{ft}$
3 laminate resists $=10,324 \mathrm{lb}-\mathrm{ft}$
Using a margin of safety for each lap splice of the carbon fiber as prescribed in the ACl 318

Moment applied $=.80$ Moment allowable per ACI 318

Using this margin of safety:
Start of second laminate - Max moment applied is limited to $2,750 \mathrm{lb}-\mathrm{ft}$.
Start of third laminate - Max moment applied is limited to $5,500 \mathrm{lb}-\mathrm{ft}$.

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Referring back to the Simple Beam Uniformily loaded diagram (Figure 1)

$$
M x=\left(w^{*} x\right) / 2^{*}(L-x)
$$

Using this moment applied at a distance x from the finished floor

Second laminate to start 2.5 ft above finished floor (aff)

Third laminate to start 6.5 ft above finished floor.

Since moment is symmetrical. The x also applies from the top of the wall.

## BENDING MOMENT

 DIAGRAMFinal Result


TYPICAL

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R RHINO CARBON FIBER WALL SUPPORTS
adHERED TO CMU WALL PER MANUFACTURERS REQUIREMENTS.
SUPPORTS SHALL EXTEND THE ENTIRE HEIGHT
OF WALL FROM FINISHED TO TOP OF CMU
WALL. SEE DETAIL. 1
FIBER-REINFORCED POLYMERS (FRPs) TO MEET ACI 440.3R-04 REQUIREMENTS.


CLOSER VIEW OF INSTALLATION
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TYPICAL INSTALLATION IN PROGRESS


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## Chapter 26 WIND LOADS: GENERAL REQUIREMENTS

### 26.1 PROCEDURES

### 26.1.1 Scope

Buildings and other structures, including the Main Wind-Force Resisting System (MWFRS) and all components and cladding (C\&C) thereof, shall be designed and constructed to resist the wind loads determined in accordance with Chapters 26 through 31. The provisions of this chapter define basic wind parameters for use with other provisions contained in this standard.

### 26.1.2 Permitted Procedures

The design wind loads for buildings and other structures, including the MWFRS and component and cladding elements thereof, shall be determined using one of the procedures as specified in this section. An outline of the overall process for the determination of the wind loads, including section references, is provided in Fig. 26.1-1.

### 26.1.2.1 Main Wind-Force Resisting System (MWFRS)

Wind loads for MWFRS shall be determined using one of the following procedures:
(1) Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
(2) Envelope Procedure for low-rise buildings as specified in Chapter 28 for buildings meeting the requirements specified therein;
(3) Directional Procedure for Building Appurtenances (rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in Chapter 29;
(4) Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31.

### 26.1.2.2 Components and Cladding

Wind loads on components and cladding on all buildings and other structures shall be designed using one of the following procedures:
(1) Analytical Procedures provided in Parts 1 through 6, as appropriate, of Chapter 30;
(2) Wind Tunnel Procedure as specified in Chapter 31.

### 26.2 DEFINITIONS

The following definitions apply to the provisions of Chapters 26 through 31:

APPROVED: Acceptable to the authority having jurisdiction.

BASIC WIND SPEED, $\boldsymbol{V}$ : Three-second gust speed at $33 \mathrm{ft}(10 \mathrm{~m})$ above the ground in Exposure C (see Section 26.7.3) as determined in accordance with Section 26.5.1.

BUILDING, ENCLOSED: A building that does not comply with the requirements for open or partially enclosed buildings.

BUILDING ENVELOPE: Cladding, roofing, exterior walls, glazing, door assemblies, window assemblies, skylight assemblies, and other components enclosing the building.

BUILDING AND OTHER STRUCTURE, FLEXIBLE: Slender buildings and other structures that have a fundamental natural frequency less than 1 Hz .

BUILDING, LOW-RISE: Enclosed or partially enclosed buildings that comply with the following conditions:

1. Mean roof height $h$ less than or equal to 60 ft ( 18 m ).
2. Mean roof height $h$ does not exceed least horizontal dimension.

BUILDING, OPEN: A building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_{o} \geq 0.8 A_{g}$ where
$A_{o}=$ total area of openings in a wall that receives positive external pressure, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{g}=$ the gross area of that wall in which $A_{o}$ is identified, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$

BUILDING, PARTIALLY ENCLOSED: A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives 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.
2. The total area of openings in a wall that receives positive external pressure exceeds $4 \mathrm{ft}^{2}\left(0.37 \mathrm{~m}^{2}\right)$


FIGURE 26.1-1 Outline of Process for Determining Wind Loads. Additional outlines and User Notes are provided at the beginning of each chapter for more detailed step-by-step procedures for determining the wind loads.
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.

These conditions are expressed by the following equations:

1. $A_{o}>1.10 A_{o i}$
2. $A_{o}>4 \mathrm{ft}^{2}\left(0.37 \mathrm{~m}^{2}\right)$ or $>0.01 A_{g}$, whichever is smaller, and $A_{o i} / A_{g i} \leq 0.20$
where
$A_{o}, A_{g}$ are as defined for Open Building
$A_{o i}=$ the sum of the areas of openings in the building envelope (walls and roof) not including $A_{o}$, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{g i}=$ the sum of the gross surface areas of the building envelope (walls and roof) not including $A_{g}$, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$

## BUILDING OR OTHER STRUCTURE,

 REGULAR-SHAPED: A building or other structure having no unusual geometrical irregularity in spatial form.BUILDING OR OTHER STRUCTURES, RIGID: A building or other structure whose fundamental frequency is greater than or equal to 1 Hz .

BUILDING, SIMPLE DIAPHRAGM: A building in which both windward and leeward wind loads are transmitted by roof and vertically spanning wall assemblies, through continuous floor and roof diaphragms, to the MWFRS.

BUILDING, TORSIONALLY REGULAR
UNDER WIND LOAD: A building with the MWFRS about each principal axis proportioned so that the maximum displacement at each story under Case 2, the torsional wind load case, of Fig. 27.4-8, does not exceed the maximum displacement at the same location under Case 1 of Fig. 27.4-8, the basic wind load case.

COMPONENTS AND CLADDING (C\&C):
Elements of the building envelope that do not qualify as part of the MWFRS.

DESIGN FORCE, $\boldsymbol{F}$ : Equivalent static force to be used in the determination of wind loads for other structures.

DESIGN PRESSURE, $\boldsymbol{p}$ : Equivalent static pressure to be used in the determination of wind loads for buildings.

DIAPHRAGM: Roof, floor, or other membrane or bracing system acting to transfer lateral forces to the vertical Main Wind-Force Resisting System. For analysis under wind loads, diaphragms constructed of untopped steel decks, concrete filled steel decks, and concrete slabs, each having a span-to-depth ratio of two or less, shall be permitted to be idealized as rigid. Diaphragms constructed of wood structural panels are permitted to be idealized as flexible.

DIRECTIONAL PROCEDURE: A procedure for determining wind loads on buildings and other structures for specific wind directions, in which the external pressure coefficients utilized are based on past wind tunnel testing of prototypical building models for the corresponding direction of wind.

EAVE HEIGHT, $\boldsymbol{h}_{\boldsymbol{e}}$ : The distance from the ground surface adjacent to the building to the roof eave line at a particular wall. If the height of the eave varies along the wall, the average height shall be used.

EFFECTIVE WIND AREA, $\boldsymbol{A}$ : The area used to determine $\left(G C_{p}\right)$. For component and cladding elements, the effective wind area in Figs. 30.4-1 through 30.4-7, 30.5-1. 30.6-1, and 30.8-1 through $30.8-3$ is the span length multiplied by an effective width that need not be less than one-third the span length. For cladding fasteners, the effective wind area shall not be greater than the area that is tributary to an individual fastener.

ENVELOPE PROCEDURE: A procedure for determining wind load cases on buildings, in which pseudo-external pressure coefficients are derived from past wind tunnel testing of prototypical building models successively rotated through 360 degrees, such that the pseudo-pressure cases produce key structural actions (uplift, horizontal shear, bending moments, etc.) that envelop their maximum values among all possible wind directions.

ESCARPMENT: Also known as scarp, with respect to topographic effects in Section 26.8, a cliff or steep slope generally separating two levels or gently sloping areas (see Fig. 26.8-1).

FREE ROOF: Roof with a configuration generally conforming to those shown in Figs. 27.4-4
through 27.4-6 (monoslope, pitched, or troughed) in an open building with no enclosing walls underneath the roof surface.

GLAZING: Glass or transparent or translucent plastic sheet used in windows, doors, skylights, or curtain walls.

GLAZING, IMPACT RESISTANT: Glazing that has been shown by testing to withstand the impact of test missiles. See Section 26.10.3.2.

HILL: With respect to topographic effects in Section 26.8, a land surface characterized by strong relief in any horizontal direction (see Fig. 26.8-1).

HURRICANE PRONE REGIONS: Areas vulnerable to hurricanes; in the United States and its territories defined as

1. The U.S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed for Risk Category II buildings is greater than $115 \mathrm{mi} / \mathrm{h}$, and
2. Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa.
IMPACT PROTECTIVE SYSTEM: Construction that has been shown by testing to withstand the impact of test missiles and that is applied, attached, or locked over exterior glazing. See Section 26.10.3.2.

MAIN WIND-FORCE RESISTING SYSTEM
(MWFRS): An assemblage of structural elements assigned to provide support and stability for the overall structure. The system generally receives wind loading from more than one surface.

MEAN ROOF HEIGHT, $\boldsymbol{h}$ : The average of the roof eave height and the height to the highest point on the roof surface, except that, for roof angles of less than or equal to $10^{\circ}$, the mean roof height is permitted to be taken as the roof eave height.

OPENINGS: Apertures or holes in the building envelope that allow air to flow through the building envelope and that are designed as "open" during design winds as defined by these provisions.

RECOGNIZED LITERATURE: Published research findings and technical papers that are approved.

RIDGE: With respect to topographic effects in Section 26.8 an elongated crest of a hill characterized by strong relief in two directions (see Fig. 26.8-1).

WIND TUNNEL PROCEDURE: A procedure for determining wind loads on buildings and other structures, in which pressures and/or forces and moments are determined for each wind direction considered, from a model of the building or other structure and its surroundings, in accordance with Chapter 31.

WIND-BORNE DEBRIS REGIONS: Areas
within hurricane prone regions where impact protection is required for glazed openings, see Section 26.10.3.

### 26.3 SYMBOLS AND NOTATION

The following symbols and notation apply only to the provisions of Chapters 26 through 31:
$A=$ effective wind area, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{f}=$ area of open buildings and other structures either normal to the wind direction or projected on a plane normal to the wind direction, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{g}=$ the gross area of that wall in which $A_{o}$ is identified, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{g i}=$ the sum of the gross surface areas of the building envelope (walls and roof) not including $A_{g}$, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{o}=$ total area of openings in a wall that receives positive external pressure, in $\mathrm{ft}^{2}$ ( $\mathrm{m}^{2}$ )
$A_{o i}=$ the sum of the areas of openings in the building envelope (walls and roof) not including $A_{o}$, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{o g}=$ total area of openings in the building envelope in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$A_{s}=$ gross area of the solid freestanding wall or solid sign, in $\mathrm{ft}^{2}\left(\mathrm{~m}^{2}\right)$
$a=$ width of pressure coefficient zone, in ft (m)
$B=$ horizontal dimension of building measured normal to wind direction, in $\mathrm{ft}(\mathrm{m})$
$\bar{b}=$ mean hourly wind speed factor in Eq. 26.9-16 from Table 26.9-1
$\hat{b}=3$-s gust speed factor from Table 26.9-1
$C_{f}=$ force coefficient to be used in determination of wind loads for other structures
$C_{N}=$ net pressure coefficient to be used in determination of wind loads for open buildings
$C_{p}=$ external pressure coefficient to be used in determination of wind loads for buildings
$c=$ turbulence intensity factor in Eq. 26.9-7 from Table 26.9-1
$D=$ diameter of a circular structure or member, in ft (m)
$D^{\prime}=$ depth of protruding elements such as ribs and spoilers, in $\mathrm{ft}(\mathrm{m})$
$F=$ design wind force for other structures, in lb (N)
$G=$ gust-effect factor
$G_{f}=$ gust-effect factor for MWFRS of flexible buildings and other structures
$\left(G C_{p n}\right)=$ combined net pressure coefficient for a parapet
$\left(G C_{p}\right)=$ product of external pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings
$\left(G C_{p f}\right)=$ product of the equivalent external pressure coefficient and gust-effect factor to be used in determination of wind loads for MWFRS of low-rise buildings
$\left(G C_{p i}\right)=$ product of internal pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings
$\left(G C_{r}\right)=$ product of external pressure coefficient and gust-effect factor to be used in determination of wind loads for rooftop structures
$g_{Q}=$ peak factor for background response in Eqs. 26.9-6 and 26.9-10
$g_{R}=$ peak factor for resonant response in Eq. 26.9-10
$g_{v}=$ peak factor for wind response in Eqs. 26.9-6 and 26.9-10
$H=$ height of hill or escarpment in Fig. 26.8-1, in ft (m)
$h=$ mean roof height of a building or height of other structure, except that eave height shall be used for roof angle $\theta$ less than or equal to $10^{\circ}$, in $\mathrm{ft}(\mathrm{m})$
$h_{e}=$ roof eave height at a particular wall, or the average height if the eave varies along the wall
$h_{p}=$ height to top of parapet in Fig. 27.6-4 and 30.7-1
$I_{\bar{z}}=$ intensity of turbulence from Eq. 26.9-7
$K_{1}, K_{2}, K_{3}=$ multipliers in Fig. 26.8-1 to obtain $K_{z t}$
$K_{d}=$ wind directionality factor in Table 26.6-1
$K_{h}=$ velocity pressure exposure coefficient evaluated at height $z=h$
$K_{z}=$ velocity pressure exposure coefficient evaluated at height $z$
$K_{z t}=$ topographic factor as defined in Section 26.8
$L=$ horizontal dimension of a building measured parallel to the wind direction, in ft (m)
$L_{h}=$ distance upwind of crest of hill or escarpment in Fig. 26.8-1 to where the difference in ground elevation is half the height of the hill or escarpment, in ft (m)
$L_{z}=$ integral length scale of turbulence, in ft (m)
$L_{r}=$ horizontal dimension of return corner for a solid freestanding wall or solid sign from Fig. 29.4-1, in ft (m)
$\ell=$ integral length scale factor from Table 26.9-1, ft (m)
$N_{1}=$ reduced frequency from Eq. 26.9-14
$n_{a}=$ approximate lower bound natural frequency (Hz) from Section 26.9.2
$n_{1}=$ fundamental natural frequency, Hz
$p=$ design pressure to be used in determination of wind loads for buildings, in $\mathrm{lb} / \mathrm{ft}^{2}$ ( $\mathrm{N} / \mathrm{m}^{2}$ )
$P_{L}=$ wind pressure acting on leeward face in Fig. 27.4-8, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$p_{\text {net }}=$ net design wind pressure from Eq. $30.5-1$, in lb/ft ${ }^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$p_{\text {net } 30}=$ net design wind pressure for Exposure B at $h=30 \mathrm{ft}$ and $I=1.0$ from Fig. 30.5-1, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$p_{p}=$ combined net pressure on a parapet from Eq. 27.4-5, in lb/ft ${ }^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$p_{s}=$ net design wind pressure from Eq. 28.6-1, in lb/ft ${ }^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$p_{s 30}=$ simplified design wind pressure for Exposure B at $h=30 \mathrm{ft}$ and $I=1.0$ from Fig. 28.6-1, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$P_{W}=$ wind pressure acting on windward face in Fig. 27.4-8, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$Q=$ background response factor from Eq. 26.9-8
$q=$ velocity pressure, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$q_{h}=$ velocity pressure evaluated at height $z=h$, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$q_{i}=$ velocity pressure for internal pressure determination, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$q_{p}=$ velocity pressure at top of parapet, in $\mathrm{lb} /$ $\mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$q_{z}=$ velocity pressure evaluated at height $z$ above ground, in $\mathrm{lb} / \mathrm{ft}^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right)$
$R=$ resonant response factor from Eq. 26.9-12
$R_{B}, R_{h}, R_{L}=$ values from Eqs. 26.9-15
$R_{i}=$ reduction factor from Eq. 26.11-1
$R_{n}=$ value from Eq. 26.9-13
$s=$ vertical dimension of the solid freestanding wall or solid sign from Fig. 29.4-1, in ft (m)
$r=$ rise-to-span ratio for arched roofs
$V=$ basic wind speed obtained from Fig. $26.5-1 \mathrm{~A}$ through $26.5-1 \mathrm{C}$, in $\mathrm{mi} / \mathrm{h}(\mathrm{m} / \mathrm{s})$. The basic wind speed corresponds to a

3-sec gust speed at $33 \mathrm{ft}(10 \mathrm{~m})$ above the ground in Exposure Category C
$V_{i}=$ unpartitioned internal volume, $\mathrm{ft}^{3}\left(\mathrm{~m}^{3}\right)$
$\bar{V}_{\bar{z}}=$ mean hourly wind speed at height $\overline{\mathrm{z}}, \mathrm{ft} / \mathrm{s}$ ( $\mathrm{m} / \mathrm{s}$ )
$W=$ width of building in Figs. 30.4-3 and
$30.4-5 \mathrm{~A}$ and $30.4-5 \mathrm{~B}$ and width of span
in Figs. 30.4-4 and 30.4-6, in ft (m)
$x=$ distance upwind or downwind of crest in
Fig. 26.8-1, in ft (m)
$z=$ height above ground level, in $\mathrm{ft}(\mathrm{m})$
$\bar{z}=$ equivalent height of structure, in $\mathrm{ft}(\mathrm{m})$
$z_{g}=$ nominal height of the atmospheric
boundary layer used in this standard.
Values appear in Table 26.9-1
$z_{\text {min }}=$ exposure constant from Table 26.9-1
$\alpha=3$-sec gust-speed power law exponent
from Table 26.9-1
$\hat{\alpha}=$ reciprocal of $\alpha$ from Table 26.9-1
$\bar{\alpha}=$ mean hourly wind-speed power law exponent in Eq. 26.9-16 from Table 26.9-1
$\beta=$ damping ratio, percent critical for
buildings or other structures
$\epsilon=$ ratio of solid area to gross area for solid freestanding wall, solid sign, open sign,
face of a trussed tower, or lattice structure
$\lambda=$ adjustment factor for building height and exposure from Figs. 28.6-1 and 30.5-1
$\bar{\epsilon}=$ integral length scale power law exponent in Eq. 26.9-9 from Table 26.9-1
$\eta=$ value used in Eq. 26.9-15 (see Section 26.9.4)
$\theta=$ angle of plane of roof from horizontal, in degrees
$v=$ height-to-width ratio for solid sign

### 26.4 GENERAL

### 26.4.1 Sign Convention

Positive pressure acts toward the surface and negative pressure acts away from the surface.

### 26.4.2 Critical Load Condition

Values of external and internal pressures shall be combined algebraically to determine the most critical load.

### 26.4.3 Wind Pressures Acting on Opposite Faces of Each Building Surface

In the calculation of design wind loads for the MWFRS and for components and cladding for
buildings, the algebraic sum of the pressures acting on opposite faces of each building surface shall be taken into account.

### 26.5 WIND HAZARD MAP

### 26.5.1 Basic Wind Speed

The basic wind speed, $V$, used in the determination of design wind loads on buildings and other structures shall be determined from Fig. 26.5-1 as follows, except as provided in Section 26.5.2 and 26.5.3:

For Risk Category II buildings and structures - use Fig. 26.5-1A.
For Risk Category III and IV buildings and structures - use Fig. 26.5-1B.

For Risk Category I buildings and structures - use Fig. 26.5-1C.

The wind shall be assumed to come from any horizontal direction. The basic wind speed shall be increased where records or experience indicate that the wind speeds are higher than those reflected in Fig. 26.5-1.

### 26.5.2 Special Wind Regions

Mountainous terrain, gorges, and special wind regions shown in Fig. 26.5-1 shall be examined for unusual wind conditions. The authority having jurisdiction shall, if necessary, adjust the values given in Fig. 26.5-1 to account for higher local wind speeds. Such adjustment shall be based on meteorological information and an estimate of the basic wind speed obtained in accordance with the provisions of Section 26.5.3.

### 26.5.3 Estimation of Basic Wind Speeds from Regional Climatic Data

In areas outside hurricane-prone regions, regional climatic data shall only be used in lieu of the basic wind speeds given in Fig. 26.5-1 when (1) approved extreme-value statistical-analysis procedures have been employed in reducing the data; and (2) the length of record, sampling error, averaging time, anemometer height, data quality, and terrain exposure of the anemometer have been taken into account. Reduction in basic wind speed below that of Fig. 26.5-1 shall be permitted.

In hurricane-prone regions, wind speeds derived from simulation techniques shall only be used in lieu of the basic wind speeds given in Fig. 26.5-1 when approved simulation and extreme value statistical analysis procedures are used. The use of regional wind speed data obtained from anemometers is not permit-
ted to define the hurricane wind-speed risk along the Gulf and Atlantic coasts, the Caribbean, or Hawaii.

In areas outside hurricane-prone regions, when the basic wind speed is estimated from regional climatic data, the basic wind speed shall not be less than the wind speed associated with the specified mean recurrence interval, and the estimate shall be adjusted for equivalence to a $3-\mathrm{sec}$ gust wind speed at 33 ft ( 10 m ) above ground in Exposure C. The data analysis shall be performed in accordance with this chapter.

### 26.5.4 Limitation

Tornadoes have not been considered in developing the basic wind-speed distributions.

### 26.6 WIND DIRECTIONALITY

The wind directionality factor, $K_{d}$, shall be determined from Table 26.6-1. This directionality factor shall only be included in determining wind loads when the load combinations specified in Sections 2.3 and 2.4 are used for the design. The effect of wind directionality in determining wind loads in accordance with Chapter 31 shall be based on an analysis for wind speeds that conforms to the requirements of Section 26.5.3.

### 26.7 EXPOSURE

For each wind direction considered, the upwind exposure shall be based on ground surface roughness that is determined from natural topography, vegetation, and constructed facilities.

### 26.7.1 Wind Directions and Sectors

For each selected wind direction at which the wind loads are to be determined, the exposure of the building or structure shall be determined for the two upwind sectors extending $45^{\circ}$ either side of the selected wind direction. The exposure in these two sectors shall be determined in accordance with Sections 26.7.2 and 26.7.3, and the exposure whose use would result in the highest wind loads shall be used to represent the winds from that direction.

### 26.7.2 Surface Roughness Categories

A ground Surface Roughness within each $45^{\circ}$ sector shall be determined for a distance upwind of the site as defined in Section 26.7.3 from the categories defined in the following text, for the purpose of assigning an exposure category as defined in Section 26.7.3.

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Figure 26.5-1A Basic Wind Speeds for Occupancy Category II Buildings and Other Structures.
Notes:

1. Values are nominal design 3 -second gust wind speeds in miles per hour ( $\mathrm{m} / \mathrm{s}$ ) at $33 \mathrm{ft}(10 \mathrm{~m})$ above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a $7 \%$ probability of exceedance in 50 years (Annual Exceedance Probability $=0.00143$, MRI $=700$ Years) .


Figure 26.5-1A (Continued)


Figure 26.5-1B Basic Wind Speeds for Occupancy Category III and IV Buildings and Other Structures. Notes:

1. Values are nominal design 3-second gust wind speeds in miles per hour ( $\mathrm{m} / \mathrm{s}$ ) at $33 \mathrm{ft}(10 \mathrm{~m})$ above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a $3 \%$ probability of exceedance in 50 years (Annual Exceedance Probability $=0.000588$, MRI $=1700$ Years $)$.


Figure 26.5-1B (Continued)


Figure 26.5-1C Basic Wind Speeds for Occupancy Category I Buildings and Other Structures.
Notes:

1. Values are nominal design 3-second gust wind speeds in miles per hour $(\mathrm{m} / \mathrm{s})$ at $33 \mathrm{ft}(10 \mathrm{~m})$ above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a $15 \%$ probability of exceedance in 50 years (Annual Exceedance Probability $=0.00333$, MRI $=300$ Years $)$.


Figure 26.5-1c (Continued)

Wind Directionality Factor, $\mathbf{K}_{\mathbf{d}}$
Table 26.6-1

| Structure Type | Directionality Factor $\mathbf{K}_{\mathrm{d}}{ }^{*}$ |
| :--- | :---: |
| Buildings <br> Main Wind Force Resisting System <br> Components and Cladding | 0.85 |
| Arched Roofs | 0.85 |
| Chimneys, Tanks, and Similar Structures <br> Square <br> Hexagonal <br> Round | 0.85 |
| Solid Freestanding Walls and Solid <br> Freestanding and Attached Signs | 0.90 |
| Open Signs and Lattice Framework | 0.95 |
| Trussed Towers <br> Triangular, square, rectangular <br> All other cross sections | 0.85 |

*Directionality Factor $K_{d}$ has been calibrated with combinations of loads specified in Chapter 2. This factor shall only be applied when used in conjunction with load combinations specified in Sections 2.3 and 2.4.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 30 ft ( 9.1 m ). This category includes flat open country and grasslands.

Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

### 26.7.3 Exposure Categories

Exposure B: For buildings with a mean roof height of less than or equal to $30 \mathrm{ft}(9.1 \mathrm{~m})$, Exposure B shall apply where the ground surface roughness, as defined by Surface Roughness B, prevails in the upwind direction for a distance greater than 1,500 ft ( 457 m ). For buildings with a mean roof height greater than $30 \mathrm{ft}(9.1 \mathrm{~m})$, Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than $2,600 \mathrm{ft}(792 \mathrm{~m})$ or 20 times the height of the building, whichever is greater.

Exposure C: Exposure C shall apply for all cases where Exposures B or D do not apply.

Exposure D: Exposure D shall apply where the ground surface roughness, as defined by Surface Roughness D, prevails in the upwind direction for a distance greater than $5,000 \mathrm{ft}(1,524 \mathrm{~m})$ or 20 times the building height, whichever is greater. Exposure D shall also apply where the ground surface roughness immediately upwind of the site is B or C , and the site is within a distance of $600 \mathrm{ft}(183 \mathrm{~m})$ or 20 times the building height, whichever is greater, from an Exposure D condition as defined in the previous sentence.

For a site located in the transition zone between exposure categories, the category resulting in the largest wind forces shall be used.

EXCEPTION: An intermediate exposure between the preceding categories is permitted in a transition zone provided that it is determined by a rational analysis method defined in the recognized literature.

### 26.7.4 Exposure Requirements.

### 26.7.4.1 Directional Procedure (Chapter 27)

For each wind direction considered, wind loads for the design of the MWFRS of enclosed and partially enclosed buildings using the Directional Procedure of Chapter 27 shall be based on the exposures as defined in Section 26.7.3. Wind loads for the design of open buildings with monoslope, pitched, or troughed free roofs shall be based on the expo-
sures, as defined in Section 26.7.3, resulting in the highest wind loads for any wind direction at the site.

### 26.7.4.2 Envelope Procedure (Chapter 28)

Wind loads for the design of the MWFRS for all low-rise buildings designed using the Envelope Procedure of Chapter 28 shall be based on the exposure category resulting in the highest wind loads for any wind direction at the site.

### 26.7.4.3 Directional Procedure for Building Appurtenances and Other Structures (Chapter 29)

Wind loads for the design of building appurtenances (such as rooftop structures and equipment) and other structures (such as solid freestanding walls and freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in Chapter 29 shall be based on the appropriate exposure for each wind direction considered.

### 26.7.4.4 Components and Cladding (Chapter 30)

Design wind pressures for components and cladding shall be based on the exposure category resulting in the highest wind loads for any wind direction at the site.

### 26.8 TOPOGRAPHIC EFFECTS

### 26.8.1 Wind Speed-Up over Hills, Ridges, and Escarpments

Wind speed-up effects at isolated hills, ridges, and escarpments constituting abrupt changes in the general topography, located in any exposure category, shall be included in the design when buildings and other site conditions and locations of structures meet all of the following conditions:

1. The hill, ridge, or escarpment is isolated and unobstructed upwind by other similar topographic features of comparable height for 100 times the height of the topographic feature $(100 \mathrm{H})$ or 2 mi ( 3.22 km ), whichever is less. This distance shall be measured horizontally from the point at which the height $H$ of the hill, ridge, or escarpment is determined.
2. The hill, ridge, or escarpment protrudes above the height of upwind terrain features within a 2-mi $(3.22-\mathrm{km})$ radius in any quadrant by a factor of two or more.
3. The structure is located as shown in Fig. 26.8-1 in the upper one-half of a hill or ridge or near the crest of an escarpment.


Topographic Factor, $\mathbf{K}_{\mathbf{z t}}$
Figure 26.8-1 (cont'd)

## Equations:

$$
\mathrm{K}_{\mathrm{zt}}=\left(1+\mathrm{K}_{1} \mathrm{~K}_{2} \mathrm{~K}_{3}\right)^{2}
$$

$\mathrm{K}_{1}$ determined from table below
$K_{2}=\left(1-\frac{|\mathrm{x}|}{\mu \mathrm{L}_{\mathrm{h}}}\right)$
$K_{3}=e^{-\gamma z / L_{h}}$

| Parameters for Speed-Up Over Hills and Escarpments |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Hill Shape | $K_{1} /\left(\mathbf{H} / L_{h}\right)$ |  |  | $\gamma$ | $\mu$ |  |
|  | Exposure |  |  |  | Upwind of Crest | Downwind of Crest |
|  | B | C | D |  |  |  |
| 2-dimensional ridges (or valleys with negative Hin $\mathrm{K}_{1} /\left(\mathrm{H} / \mathrm{L}_{\mathrm{h}}\right)$ | 1.30 | 1.45 | 1.55 | 3 | 1.5 | 1.5 |
| 2-dimensional escarpments | 0.75 | 0.85 | 0.95 | 2.5 | 1.5 | 4 |
| 3-dimensional axisym. hill | 0.95 | 1.05 | 1.15 | 4 | 1.5 | 1.5 |

4. $H / L_{h} \geq 0.2$.
5. $H$ is greater than or equal to $15 \mathrm{ft}(4.5 \mathrm{~m})$ for Exposure C and D and $60 \mathrm{ft}(18 \mathrm{~m})$ for Exposure B.

### 26.8.2 Topographic Factor

The wind speed-up effect shall be included in the calculation of design wind loads by using the factor $K_{z t}$ :

$$
\begin{equation*}
K_{z t}=\left(1+K_{1} K_{2} K_{3}\right)^{2} \tag{26.8-1}
\end{equation*}
$$

where $K_{1}, K_{2}$, and $K_{3}$ are given in Fig. 26.8-1.
If site conditions and locations of structures do not meet all the conditions specified in Section 26.8.1 then $K_{z t}=1.0$.

### 26.9 GUST-EFFECTS

26.9.1 Gust-Effect Factor: The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85 .

### 26.9.2 Frequency Determination

To determine whether a building or structure is rigid or flexible as defined in Section 26.2, the fundamental natural frequency, $n_{1}$, shall be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. Low-Rise Buildings, as defined in 26.2, are permitted to be considered rigid.

### 26.9.2.1 Limitations for Approximate Natural Frequency

As an alternative to performing an analysis to determine $n_{1}$, the approximate building natural frequency, $n_{a}$, shall be permitted to be calculated in accordance with Section 26.9.3 for structural steel, concrete, or masonry buildings meeting the following requirements:

1. The building height is less than or equal to 300 ft (91 m), and
2. The building height is less than 4 times its effective length, $L_{\text {eff. }}$.

The effective length, $L_{\text {eff }}$, in the direction under consideration shall be determined from the following equation:

$$
\begin{equation*}
L_{e f f}=\frac{\sum_{i=1}^{n} h_{i} L_{i}}{\sum_{i=1}^{n} h_{i}} \tag{26.9-1}
\end{equation*}
$$

The summations are over the height of the building where
$h_{i}$ is the height above grade of level $i$
$L_{i}$ is the building length at level $i$ parallel to the wind direction

### 26.9.3 Approximate Natural Frequency

The approximate lower-bound natural frequency $\left(n_{a}\right)$, in Hertz, of concrete or structural steel buildings meeting the conditions of Section 26.9.2.1, is permitted to be determined from one of the following equations:

For structural steel moment-resisting-frame buildings:

$$
\begin{equation*}
n_{a}=22.2 / h^{0.8} \tag{26.9-2}
\end{equation*}
$$

For concrete moment-resisting frame buildings:

$$
\begin{equation*}
n_{a}=43.5 / h^{0.9} \tag{26.9-3}
\end{equation*}
$$

For structural steel and concrete buildings with other lateral-force-resisting systems:

$$
\begin{equation*}
n_{a}=75 / h \tag{26.9-4}
\end{equation*}
$$

For concrete or masonry shear wall buildings, it is also permitted to use

$$
\begin{equation*}
n_{a}=385\left(\mathrm{C}_{w}\right)^{0.5} / h \tag{26.9-5}
\end{equation*}
$$

where

$$
C_{w}=\frac{100}{A_{B}} \sum_{i=1}^{n}\left(\frac{h}{h_{i}}\right)^{2} \frac{A_{i}}{\left[1+0.83\left(\frac{h_{i}}{D_{i}}\right)^{2}\right]}
$$

where
$h=$ mean roof height (ft)
$n=$ number of shear walls in the building effective in resisting lateral forces in the direction under consideration
$A_{B}=$ base area of the structure ( $\mathrm{ft}^{2}$ )
$A_{i}=$ horizontal cross-section area of shear wall " $i$ " $\left(\mathrm{ft}^{2}\right)$
$D_{i}=$ length of shear wall " $i$ " (ft)
$h_{i}=$ height of shear wall " $i$ " (ft)

### 26.9.4 Rigid Buildings or Other Structures

For rigid buildings or other structures as defined in Section 26.2, the gust-effect factor shall be taken as 0.85 or calculated by the formula:

$$
\begin{gather*}
G=0.925\left(\frac{1+1.7 g_{Q} I_{\bar{z}} Q}{1+1.7 g_{v} I_{\bar{z}}}\right)  \tag{26.9-6}\\
I_{\bar{z}}=c\left(\frac{33}{\bar{z}}\right)^{1 / 6} \tag{26.9-7}
\end{gather*}
$$

In SI: $I_{\bar{z}}=c\left(\frac{10}{\bar{z}}\right)^{1 / 6}$
where $I_{\bar{z}}$ is the intensity of turbulence at height $\overline{\mathrm{z}}$ where $\overline{\mathrm{z}}$ is the equivalent height of the structure defined as $0.6 h$, but not less than $z_{\text {min }}$ for all building heights $h . z_{\text {min }}$ and $c$ are listed for each exposure in Table 26.9-1; $g_{Q}$ and $g_{v}$ shall be taken as 3.4. The background response $Q$ is given by

$$
\begin{equation*}
Q=\sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}} \tag{26.9-8}
\end{equation*}
$$

where $B$ and $h$ are defined in Section 26.3 and $L_{\bar{z}}$ is the integral length scale of turbulence at the equivalent height given by

$$
\begin{equation*}
L_{\bar{z}}=\ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} \tag{26.9-9}
\end{equation*}
$$

In SI: $L_{\bar{z}}=\ell\left(\frac{\bar{z}}{10}\right)^{\bar{\epsilon}}$
in which $\ell$ and $\bar{\epsilon}$ are constants listed in Table 26.9-1.

### 26.9.5 Flexible or Dynamically Sensitive Buildings or Other Structures

For flexible or dynamically sensitive buildings or other structures as defined in Section 26.2, the gust-effect factor shall be calculated by

$$
\begin{equation*}
G_{f}=0.925\left(\frac{1+1.7 I_{\bar{z}} \sqrt{g_{Q}^{2} Q^{2}+g_{R}^{2} R^{2}}}{1+1.7 g_{v} I_{\bar{z}}}\right) \tag{26.9-10}
\end{equation*}
$$

$g_{Q}$ and $g_{v}$ shall be taken as 3.4 and $g_{R}$ is given by

$$
\begin{equation*}
g_{R}=\sqrt{2 \ln \left(3,600 n_{1}\right)}+\frac{0.577}{\sqrt{2 \ln \left(3,600 n_{1}\right)}} \tag{26.9-11}
\end{equation*}
$$

$R$, the resonant response factor, is given by

$$
\begin{gather*}
R=\sqrt{\frac{1}{\beta} R_{n} R_{h} R_{B}\left(0.53+0.47 R_{L}\right)}  \tag{26.9-12}\\
R_{n}=\frac{7.47 N_{1}}{\left(1+10.3 N_{1}\right)^{5 / 3}}  \tag{26.9-13}\\
N_{1}=\frac{n_{1} L_{\bar{z}}}{\bar{V}_{\bar{z}}}  \tag{26.9-14}\\
R_{\ell}=\frac{1}{\eta}-\frac{1}{2 \eta^{2}}\left(1-e^{-2 \eta}\right) \text { for } \eta>0  \tag{26.9-15a}\\
R_{\ell}=1 \text { for } \eta=0 \tag{26.9-15b}
\end{gather*}
$$

where the subscript $\ell$ in Eqs. $26.9-15$ shall be taken as $h, B$, and $L$, respectively, where $h, B$, and $L$ are defined in Section 26.3.
$n_{1}=$ fundamental natural frequency
$R_{\ell}=R_{h}$ setting $\eta=4.6 n_{1} h / \overline{\bar{V}}_{\bar{z}}$
$R_{\ell}=R_{B}$ setting $\eta=4.6 n_{1} B / \bar{V}_{\bar{z}}$
$R_{\ell}=R_{L}$ setting $\eta=15.4 n_{1} L / \bar{V}_{\bar{z}}$
$\beta=$ damping ratio, percent of critical (i.e. for $2 \%$ use 0.02 in the equation)
$\bar{V}_{\bar{z}}=$ mean hourly wind speed (ft/s) at height $\overline{\mathrm{Z}}$ determined from Eq. 26.9-16:

$$
\begin{equation*}
\bar{V}_{\bar{z}}=\bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}}\left(\frac{88}{60}\right) V \tag{26.9-16}
\end{equation*}
$$

In SI: $\bar{V}_{\bar{z}}=\bar{b}\left(\frac{\bar{z}}{10}\right)^{\bar{\alpha}} V$
where $\bar{b}$ and $\bar{\alpha}$ are constants listed in Table 26.9-1 and $V$ is the basic wind speed in $\mathrm{mi} / \mathrm{h}$.

### 26.9.6 Rational Analysis

In lieu of the procedure defined in Sections 26.9.3 and 26.9.4, determination of the gust-effect factor by any rational analysis defined in the recognized literature is permitted.

### 26.9.7 Limitations

Where combined gust-effect factors and pressure coefficients $\left(G C_{p}\right),\left(G C_{p i}\right)$, and $\left(G C_{p f}\right)$ are given in figures and tables, the gust-effect factor shall not be determined separately.

### 26.10 ENCLOSURE CLASSIFICATION

### 26.10.1 General

For the purpose of determining internal pressure coefficients, all buildings shall be classified as enclosed, partially enclosed, or open as defined in Section 26.2.

### 26.10.2 Openings

A determination shall be made of the amount of openings in the building envelope for use in determining the enclosure classification.

### 26.10.3 Protection of Glazed Openings

Glazed openings in Risk Category II, III or IV buildings located in hurricane-prone regions shall be protected as specified in this Section.

### 26.10.3.1 Wind-borne Debris Regions

Glazed openings shall be protected in accordance with Section 26.10.3.2 in the following locations:

Terrain Exposure Constants
Table 26.9-1

| Exposure | $\boldsymbol{\alpha}$ | $\mathbf{z}_{\mathrm{g}}(\mathbf{f t})$ | $\hat{\boldsymbol{a}}$ | $\hat{\boldsymbol{b}}$ | $\overline{\boldsymbol{\alpha}}$ | $\overline{\boldsymbol{b}}$ | $\mathbf{c}$ | $\ell(\mathbf{f t})$ | $\bar{\epsilon}$ | $\mathbf{z}_{\min }(\mathbf{f t})^{*}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{B}$ | 7.0 | 1200 | $1 / 7$ | 0.84 | $1 / 4.0$ | 0.45 | 0.30 | 320 | $1 / 3.0$ | 30 |
| $\mathbf{C}$ | 9.5 | 900 | $1 / 9.5$ | 1.00 | $1 / 6.5$ | 0.65 | 0.20 | 500 | $1 / 5.0$ | 15 |
| $\mathbf{D}$ | 11.5 | 700 | $1 / 11.5$ | 1.07 | $1 / 9.0$ | 0.80 | 0.15 | 650 | $1 / 8.0$ | 7 |

${ }^{*} \mathrm{Z}_{\text {min }}=$ minimum height used to ensure that the equivalent height $\overline{\mathrm{Z}}$ is greater of $0.6 h$ or $\mathrm{Z}_{\text {min }}$.
For buildings with $h \leq \mathrm{z}_{\text {min }}, \overline{\mathrm{Z}}$ shall be taken as $\mathrm{z}_{\min }$.

In metric

| Exposure | $\boldsymbol{\alpha}$ | $\mathbf{z}_{\mathrm{g}}(\mathbf{m})$ | $\hat{\boldsymbol{a}}$ | $\hat{\boldsymbol{b}}$ | $\overline{\boldsymbol{\alpha}}$ | $\overline{\boldsymbol{b}}$ | $\mathbf{c}$ | $\ell(\mathbf{m})$ | $\bar{\epsilon}$ | $\mathbf{z}_{\min }(\mathbf{m})^{*}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{B}$ | 7.0 | 365.76 | $1 / 7$ | 0.84 | $1 / 4.0$ | 0.45 | 0.30 | 97.54 | $1 / 3.0$ | 9.14 |
| $\mathbf{C}$ | 9.5 | 274.32 | $1 / 9.5$ | 1.00 | $1 / 6.5$ | 0.65 | 0.20 | 152.4 | $1 / 5.0$ | 4.57 |
| $\mathbf{D}$ | 11.5 | 213.36 | $1 / 11.5$ | 1.07 | $1 / 9.0$ | 0.80 | 0.15 | 198.12 | $1 / 8.0$ | 2.13 |

${ }^{Z_{\text {min }}}{ }=$ minimum height used to ensure that the equivalent height $\overline{\mathrm{Z}}$ is greater of $0.6 h$ or $\mathrm{Z}_{\text {min }}$.
For buildings with $h \leq \mathrm{z}_{\min }, \overline{\mathrm{Z}}$ shall be taken as $\mathrm{z}_{\min }$.

1. Within 1 mi of the coastal mean high water line where the basic wind speed is equal to or greater than $130 \mathrm{mi} / \mathrm{h}(58 \mathrm{~m} / \mathrm{s})$, or
2. In areas where the basic wind speed is equal to or greater than $140 \mathrm{mi} / \mathrm{h}(63 \mathrm{~m} / \mathrm{s})$.

For Risk Category II buildings and structures and Risk Category III buildings and structures, except health care facilities, the wind-borne debris region shall be based on Fig. 26.5-1A. For Risk Category III health care facilities and Risk Category IV buildings and structures, the wind-borne debris region shall be based on Fig. 26.5-1B. Risk Categories shall be determined in accordance with Section 1.5.

EXCEPTION: Glazing located over 60 ft $(18.3 \mathrm{~m})$ above the ground and over $30 \mathrm{ft}(9.2 \mathrm{~m})$ above aggregate-surfaced-roofs, including roofs with gravel or stone ballast, located within 1,500 $\mathrm{ft}(458 \mathrm{~m})$ of the building shall be permitted to be unprotected.

### 26.10.3.2 Protection Requirements for Glazed Openings

Glazing in buildings requiring protection shall be protected with an impact-protective system or shall be impact-resistant glazing.

Impact-protective systems and impact-resistant glazing shall be subjected to missile test and cyclic pressure differential tests in accordance with ASTM E1996 as applicable. Testing to demonstrate compliance with ASTM E1996 shall be in accordance with ASTM E1886. Impact-resistant glazing and impactprotective systems shall comply with the pass/fail criteria of Section 7 of ASTM E1996 based on the missile required by Table 3 or Table 4 of ASTM E1996.

EXCEPTION: Other testing methods and/or performance criteria are permitted to be used when approved.

Glazing and impact-protective systems in buildings and structures classified as Risk Category IV in accordance with Section 1.5 shall comply with the "enhanced protection" requirements of Table 3 of ASTM E1996. Glazing and impact-protective systems
in all other structures shall comply with the "basic protection" requirements of Table 3 of ASTM E1996.

User Note: The wind zones that are specified in ASTM E1996 for use in determining the applicable missile size for the impact test, have to be adjusted for use with the wind speed maps of ASCE 7-10 and the corresponding wind borne debris regions, see Section C26.10.3.2.

### 26.10.4 Multiple Classifications

If a building by definition complies with both the "open" and "partially enclosed" definitions, it shall be classified as an "open" building. A building that does not comply with either the "open" or "partially enclosed" definitions shall be classified as an "enclosed" building.

### 26.11 INTERNAL PRESSURE COEFFICIENT

### 26.11.1 Internal Pressure Coefficients

Internal pressure coefficients, $\left(G C_{p i}\right)$, shall be determined from Table 26.11-1 based on building enclosure classifications determined from Section 26.10.

### 26.11.1.1 Reduction Factor for Large Volume Buildings, $\mathbf{R}_{\mathrm{i}}$

For a partially enclosed building containing a single, unpartitioned large volume, the internal pressure coefficient, $\left(G C_{p i}\right)$, shall be multiplied by the following reduction factor, $R_{i}$ :

$$
\begin{align*}
& R_{i}=1.0 \text { or } \\
& \qquad R_{i}=0.5\left(1+\frac{1}{\sqrt{1+\frac{V_{i}}{22.800 A_{o g}}}}\right)<1.0 \tag{26.11-1}
\end{align*}
$$

where

[^0]| Main Wind Force Resisting System and Components and Cladding |  |  |
| :---: | :---: | :---: |
| Table 26.11-1 | Internal Pressure Coefficient, ( C $_{p i}$ ) |  |
| Enclosed, Partially Enclosed, and Open Buildings |  |  |
|  |  |  |
|  | Open Buildings | 0.00 |
|  | Partially Enclosed Buildings | $\begin{gathered} +0.55 \\ -0.55 \end{gathered}$ |
|  | Enclosed Buildings | $\begin{gathered} +0.18 \\ -0.18 \end{gathered}$ |

Notes:

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of $\left(G C_{p i}\right)$ shall be used with $q_{z}$ or $q_{h}$ as specified.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:
(i) a positive value of $\left(G C_{p i}\right)$ applied to all internal surfaces
(ii) a negative value of $\left(G C_{p i}\right)$ applied to all internal surfaces

# Chapter 27 <br> WIND LOADS ON BUILDINGS—MWFRS (DIRECTIONAL PROCEDURE) 

### 27.1 SCOPE

### 27.1.1 Building Types

This chapter applies to the determination of MWFRS wind loads on enclosed, partially enclosed, and open buildings of all heights using the Directional Procedure.

1) Part 1 applies to buildings of all heights where it is necessary to separate applied wind loads onto the windward, leeward, and side walls of the building to properly assess the internal forces in the MWFRS members.
2) Part 2 applies to a special class of buildings designated as enclosed simple diaphragm buildings, as defined in Section 26.2, with $h \leq 160 \mathrm{ft}$ (48.8 m).

### 27.1.2 Conditions

A building whose design wind loads are determined in accordance with this chapter shall comply with all of the following conditions:

1. The building is a regular-shaped building or structure as defined in Section 26.2.
2. The building does not have response characteristics making it subject to across-wind loading, vortex shedding, instability due to galloping or flutter; or it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

### 27.1.3 Limitations

The provisions of this chapter take into consideration the load magnification effect caused by gusts in resonance with along-wind vibrations of flexible buildings. Buildings not meeting the requirements of Section 27.1.2, or having unusual shapes or response characteristics shall be designed using recognized literature documenting such wind load effects or shall use the wind tunnel procedure specified in Chapter 31.

### 27.1.4 Shielding

There shall be no reductions in velocity pressure due to apparent shielding afforded by buildings and other structures or terrain features.

## PART 1: ENCLOSED, PARTIALLY ENCLOSED, AND OPEN BUILDINGS OF ALL HEIGHTS

### 27.2 GENERAL REQUIREMENTS

The steps to determine the wind loads on the MWFRS for enclosed, partially enclosed and open buildings of all heights are provided in Table 27.2-1.

> User Note: Use Part 1 of Chapter 27 to determine wind pressures on the MWFRS of enclosed, partially enclosed or an open building with any general plan shape, building height or roof geometry that matches the figures provided. These provisions utilize the traditional "all heights" method (Directional Procedure) by calculating wind pressures using specific wind pressure equations applicable to each building surface.

### 27.2.1 Wind Load Parameters Specified in Chapter 26

The following wind load parameters shall be determined in accordance with Chapter 26:

- Basic Wind Speed, V (Section 26.5)
- Wind directionality factor, $K_{d}$ (Section 26.6)
- Exposure category (Section 26.7)
- Topographic factor, $K_{z t}$ (Section 26.8)
- Gust-effect factor (Section 26.9)
- Enclosure classification (Section 26.10)
- Internal pressure coefficient, $\left(G C_{p i}\right)$ (Section 26-11).


### 27.3 VELOCITY PRESSURE

### 27.3.1 Velocity Pressure Exposure Coefficient

Based on the exposure category determined in Section 26.7.3, a velocity pressure exposure coefficient $K_{z}$ or $K_{h}$, as applicable, shall be determined from Table 27.3-1. For a site located in a transition zone between exposure categories that is near to a change in ground surface roughness, intermediate values of $K_{z}$ or $K_{h}$, between those shown in Table 27.3-1 are permitted provided that they are determined by a rational analysis method defined in the recognized literature.

Table 27.2-1 Steps to Determine MWFRS Wind Loads for Enclosed, Partially Enclosed and Open Buildings of All Heights

Step 1: Determine risk category of building or other structure, see Table 1.4-1

Step 2: Determine the basic wind speed, $V$, for the applicable risk category, see Figure $26.5-1 \mathrm{~A}$, B or C

Step 3: Determine wind load parameters:
$>$ Wind directionality factor, $K_{d}$, see Section 26.6 and Table 26.6-1
> Exposure category, see Section 26.7
$>$ Topographic factor, $K_{z z}$, see Section 26.8 and Table 26.8-1
> Gust Effect Factor, G, see Section 26.9
$>$ Enclosure classification, see Section 26.10
$>$ Internal pressure coefficient, $\left(G C_{p i}\right)$, see Section 26.11 and Table 26.11-1

Step 4: Determine velocity pressure exposure coefficient, $K_{z}$ or $K_{h}$, see Table 27.3-1
Step 5: Determine velocity pressure $q_{z}$ or $q_{h}$ Eq. 27.3-1
Step 6: Determine external pressure coefficient, $C_{p}$ or $C_{N}$
$>$ Fig. 27.4-1 for walls and flat, gable, hip, monoslope or mansard roofs
$>$ Fig. 27.4-2 for domed roofs
$>$ Fig. 27.4-3 for arched roofs
$>$ Fig. 27.4-4 for monoslope roof, open building
$>$ Fig. 27.4-5 for pitched roof, open building
$>$ Fig. 27.4-6 for troughed roof, open building
$>$ Fig. 27.4-7 for along-ridge/valley wind load case for monoslope, pitched or troughed roof, open building
Step 7: Calculate wind pressure, $p$, on each building surface
$>$ Eq. 27.4-1 for rigid buildings
$>$ Eq. 27.4-2 for flexible buildings
$>$ Eq. 27.4-3 for open buildings

### 27.3.2 Velocity Pressure

Velocity pressure, $q_{z}$, evaluated at height $z$ shall be calculated by the following equation:

$$
\begin{equation*}
q_{\mathrm{z}}=0.00256 K_{z} K_{z t} K_{d} V^{2}\left(\mathrm{lb} / \mathrm{ft}^{2}\right) \tag{27.3-1}
\end{equation*}
$$

[In SI: $q_{z}=0.613 K_{z} K_{z t} K_{d} V^{2}\left(\mathrm{~N} / \mathrm{m}^{2}\right) ; V$ in $\mathrm{m} / \mathrm{s}$ ] where
$K_{d}=$ wind directionality factor, see Section 26.6
$K_{z}=$ velocity pressure exposure coefficient, see
Section 27.3.1
$K_{z t}=$ topographic factor defined, see Section 26.8.2
$V=$ basic wind speed, see Section 26.5
$q_{\mathrm{z}}=$ velocity pressure calculated using Eq. 27.3-1 at height $z$
$q_{h}=$ velocity pressure calculated using Eq. 27.3-1 at mean roof height $h$.

The numerical coefficient 0.00256 ( 0.613 in SI) shall be used except where sufficient climatic data are available to justify the selection of a different value of this coefficient for a design application.

### 27.4 WIND LOADS—MAIN WIND FORCE-RESISTING SYSTEM

### 27.4.1 Enclosed and Partially Enclosed Rigid Buildings

Design wind pressures for the MWFRS of buildings of all heights shall be determined by the following equation:

$$
\begin{equation*}
p=q G C_{p}-q_{i}\left(G C_{p i}\right)\left(\mathrm{lb} / \mathrm{ft}^{2}\right)\left(\mathrm{N} / \mathrm{m}^{2}\right) \tag{27.4-1}
\end{equation*}
$$

where
$q=q_{z}$ for windward walls evaluated at height $z$ above the ground
$q=q_{h}$ for leeward walls, side walls, and roofs, evaluated at height $h$
$q_{i}=q_{h}$ for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings
$q_{i}=q_{z}$ for positive internal pressure evaluation in partially enclosed buildings where height $z$ is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind-borne debris regions, glazing that is not impact resistant or protected with an impact resistant covering shall be treated as an opening in accordance with Section 26.10.3. For positive internal pressure evaluation, $q_{i}$ may conservatively be evaluated at height $h\left(q_{i}=q_{h}\right)$
$G=$ gust-effect factor, see Section 26.9
$C_{p}=$ external pressure coefficient from Figs. 27.4-1, 27.4-2 and 27.4-3
$\left(G C_{p i}\right)=$ internal pressure coefficient from Table 26.11-1
$q$ and $q_{i}$ shall be evaluated using exposure defined in Section 26.7.3. Pressure shall be applied simultaneously on windward and leeward walls and on roof surfaces as defined in Figs. 27.4-1, 27.4-2 and 27.4-3.

| Main Wind Force Resisting System - Part 1 |  |  |  | All Heights |
| :---: | :---: | :---: | :---: | :---: |
| Velocity Pressure Exposure Coefficients, $K_{h}$ and $K_{z}$ |  |  |  |  |
| Table 27.3-1 |  |  |  |  |
|  |  |  | Expos |  |
|  |  |  |  |  |
| ft | (m) |  |  |  |
| 0-15 | (0-4.6) | 0.57 | 0.85 | 1.03 |
| 20 | (6.1) | 0.62 | 0.90 | 1.08 |
| 25 | (7.6) | 0.66 | 0.94 | 1.12 |
| 30 | (9.1) | 0.70 | 0.98 | 1.16 |
| 40 | (12.2) | 0.76 | 1.04 | 1.22 |
| 50 | (15.2) | 0.81 | 1.09 | 1.27 |
| 60 | (18) | 0.85 | 1.13 | 1.31 |
| 70 | (21.3) | 0.89 | 1.17 | 1.34 |
| 80 | (24.4) | 0.93 | 1.21 | 1.38 |
| 90 | (27.4) | 0.96 | 1.24 | 1.40 |
| 100 | (30.5) | 0.99 | 1.26 | 1.43 |
| 120 | (36.6) | 1.04 | 1.31 | 1.48 |
| 140 | (42.7) | 1.09 | 1.36 | 1.52 |
| 160 | (48.8) | 1.13 | 1.39 | 1.55 |
| 180 | (54.9) | 1.17 | 1.43 | 1.58 |
| 200 | (61.0) | 1.20 | 1.46 | 1.61 |
| 250 | (76.2) | 1.28 | 1.53 | 1.68 |
| 300 | (91.4) | 1.35 | 1.59 | 1.73 |
| 350 | (106.7) | 1.41 | 1.64 | 1.78 |
| 400 | (121.9) | 1.47 | 1.69 | 1.82 |
| 450 | (137.2) | 1.52 | 1.73 | 1.86 |
| 500 | (152.4) | 1.56 | 1.77 | 1.89 |

## Notes:

1. The velocity pressure exposure coefficient $\mathrm{K}_{\mathrm{z}}$ may be determined from the following formula:

$$
\begin{array}{ll}
\text { For } 15 \mathrm{ft} . \leq \mathrm{z} \leq \mathrm{z}_{\mathrm{g}} & \text { For } \mathrm{z}<15 \mathrm{ft} . \\
\mathrm{K}_{\mathrm{z}}=2.01\left(\mathrm{z} / \mathrm{z}_{\mathrm{g}}\right)^{2 / \alpha} & \mathrm{K}_{\mathrm{z}}=2.01\left(15 / \mathrm{z}_{\mathrm{g}}\right)^{2 / \alpha}
\end{array}
$$

2. $\quad \alpha$ and $\mathrm{z}_{\mathrm{g}}$ are tabulated in Table 26.9.1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 26.7.

### 27.4.2 Enclosed and Partially Enclosed Flexible Buildings

Design wind pressures for the MWFRS of flexible buildings shall be determined from the following equation:

$$
\begin{equation*}
p=q G_{f} \mathrm{C}_{p}-q_{i}\left(G C_{p i}\right)\left(\mathrm{lb} / \mathrm{ft}^{2}\right)\left(\mathrm{N} / \mathrm{m}^{2}\right) \tag{27.4-2}
\end{equation*}
$$

where $q, q_{i}, C_{p}$, and $\left(G C_{p i}\right)$ are as defined in Section 27.4.1 and $G_{f}$ (gust-effect factor) is determined in accordance with Section 26.9.5.

### 27.4.3 Open Buildings with Monoslope, Pitched, or Troughed Free Roofs

The net design pressure for the MWFRS of open buildings with monoslope, pitched, or troughed roofs shall be determined by the following equation:

$$
\begin{equation*}
p=q_{h} G C_{N} \tag{27.4-3}
\end{equation*}
$$

where
$q_{h}=$ velocity pressure evaluated at mean roof height $h$ using the exposure as defined in Section 26.7.3 that results in the highest wind loads for any wind direction at the site
$G=$ gust-effect factor from Section 26.9
$C_{N}=$ net pressure coefficient determined from Figs.
27.4-4 through 27.4-7

Net pressure coefficients, $C_{N}$, include contributions from top and bottom surfaces. All load cases shown for each roof angle shall be investigated. Plus and minus signs signify pressure acting toward and away from the top surface of the roof, respectively.

For free roofs with an angle of plane of roof from horizontal $\theta$ less than or equal to $5^{\circ}$ and containing fascia panels, the fascia panel shall be considered an inverted parapet. The contribution of loads on the fascia to the MWFRS loads shall be determined using Section 27.4.5 with $q_{p}$ equal to $q_{h}$.

### 27.4.4 Roof Overhangs

The positive external pressure on the bottom surface of windward roof overhangs shall be determined using $C_{p}=0.8$ and combined with the top surface pressures determined using Fig. 27.4-1.

### 27.4.5 Parapets

The design wind pressure for the effect of parapets on MWFRS of rigid or flexible buildings with flat, gable, or hip roofs shall be determined by the following equation:

$$
\begin{equation*}
p_{p}=q_{p}\left(G C_{p n}\right)\left(\mathrm{lb} / \mathrm{ft}^{2}\right) \tag{27.4-4}
\end{equation*}
$$

where
$p_{p}=$ combined net pressure on the parapet due to the combination of the net pressures from the front and back parapet surfaces. Plus (and minus) signs signify net pressure acting toward (and away from) the front (exterior) side of the parapet
$q_{p}=$ velocity pressure evaluated at the top of the parapet
$\left(G C_{p n}\right)=$ combined net pressure coefficient
$=+1.5$ for windward parapet
$=-1.0$ for leeward parapet

### 27.4.6 Design Wind Load Cases

The MWFRS of buildings of all heights, whose wind loads have been determined under the provisions of this chapter, shall be designed for the wind load cases as defined in Fig. 27.4-8.

EXCEPTION: 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.
The eccentricity $e$ for rigid structures shall be measured from the geometric center of the building face and shall be considered for each principal axis ( $e_{X}, e_{Y}$ ). The eccentricity $e$ for flexible structures shall be determined from the following equation and shall be considered for each principal axis $\left(e_{X}, e_{Y}\right)$ :

$$
\begin{equation*}
e=\frac{e_{Q}+1.7 I_{\bar{z}} \sqrt{\left(g_{Q} Q e_{Q}\right)^{2}+\left(g_{R} R e_{R}\right)^{2}}}{1+1.7 I_{\bar{z}} \sqrt{\left(g_{Q} Q\right)^{2}+\left(g_{R} R\right)^{2}}} \tag{27.4-5}
\end{equation*}
$$

where
$e_{Q}=$ eccentricity $e$ as determined for rigid structures in Fig. 27.4-8
$e_{R}=$ distance between the elastic shear center and center of mass of each floor
$I_{\bar{z}}, g_{Q}, Q, g_{R}$, and $R$ shall be as defined in Section 26.9
The sign of the eccentricity $e$ shall be plus or minus, whichever causes the more severe load effect.

### 27.4.7 Minimum Design Wind Loads

The wind load to be used in the design of the MWFRS for an enclosed or partially enclosed building shall not be less than $16 \mathrm{lb} / \mathrm{ft}^{2}\left(0.77 \mathrm{kN} / \mathrm{m}^{2}\right)$ multiplied by the wall area of the building and $8 \mathrm{lb} / \mathrm{ft}^{2}$ ( $0.38 \mathrm{kN} / \mathrm{m}^{2}$ ) multiplied by the roof area of the building projected onto a vertical plane normal to the assumed wind direction. Wall and roof loads shall be applied simultaneously. The design wind force for open buildings shall be not less than $16 \mathrm{lb} / \mathrm{ft}^{2}$ $\left(0.77 \mathrm{kN} / \mathrm{m}^{2}\right)$ multiplied by the area $A_{f}$.



## Notes:

1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. Linear interpolation is permitted for values of $L / B, h / L$ and $\theta$ other than shown. Interpolation shall only be carried out between values of the same sign. Where no value of the same sign is given, assume 0.0 for interpolation purposes.
3. Where two values of $C_{p}$ are listed, this indicates that the windward roof slope is subjected to either positive or negative pressures and the roof structure shall be designed for both conditions. Interpolation for intermediate ratios of $\mathrm{h} / \mathrm{L}$ in this case shall only be carried out between $C_{p}$ values of like sign.
4. For monoslope roofs, entire roof surface is either a windward or leeward surface.
5. For flexible buildings use appropriate $G_{f}$ as determined by Section 26.9.4.
6. Refer to Figure 27.4-2 for domes and Figure 27.4-3 for arched roofs.
7. Notation:

B: Horizontal dimension of building, in feet (meter), measured normal to wind direction.
$L$ : Horizontal dimension of building, in feet (meter), measured parallel to wind direction.
$h$ : Mean roof height in feet (meters), except that eave height shall be used for $\theta \leq 10$ degrees.
z: Height above ground, in feet (meters).
$G$ : Gust effect factor.
$q_{z}, q_{h}$ : Velocity pressure, in pounds per square foot $\left(\mathrm{N} / \mathrm{m}^{2}\right)$, evaluated at respective height. $\theta$ : Angle of plane of roof from horizontal, in degrees.
8. For mansard roofs, the top horizontal surface and leeward inclined surface shall be treated as leeward surfaces from the table.
9. Except for MWFRS's at the roof consisting of moment resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
\#For roof slopes greater than $80^{\circ}$, use $C_{p}=0.8$

| Main Wind Force Resisting System - Part 1 |  | All Heights |
| :--- | :---: | :---: |
| Figure 27.4-2 | External Pressure Coefficients, $\mathrm{C}_{\mathrm{p}}$ | Domed Roofs |
| Enclosed, Partially Enclosed Buildings and Structures |  |  |



## Notes:

(Adapted from Eurocode, 1995)

1. Two load cases shall be considered:

Case A. $\quad C_{p}$ values between $A$ and $B$ and between $B$ and $C$ shall be determined by linear interpolation along arcs on the dome parallel to the wind direction;
Case B. $\quad C_{p}$ shall be the constant value of $A$ for $\theta \leq 25$ degrees, and shall be determined by linear interpolation from 25 degrees to B and from B to C .
2. Values denote $C_{p}$ to be used with $q_{(h b+f)}$ where $h_{D}+f$ is the height at the top of the dome.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. $\mathrm{C}_{\mathrm{p}}$ is constant on the dome surface for arcs of circles perpendicular to the wind direction; for example, the arc passing through $\mathrm{B}-\mathrm{B}-\mathrm{B}$ and all arcs parallel to $\mathrm{B}-\mathrm{B}-\mathrm{B}$.
5. For values of $h_{D} / D$ between those listed on the graph curves, linear interpolation shall be permitted.
6. $\theta=0$ degrees on dome springline, $\theta=90$ degrees at dome center top point. f is measured from springline to top.
7. The total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
8. For f/D values less than 0.05, use Figure 27.4-1.

| Main Wind Force Resisting System and Components and <br> Cladding - Part 1 |  | All Heights |
| :--- | :---: | :---: |
| Figure 27.4-3 | External Pressure Coefficients, $\mathrm{C}_{\mathrm{p}}$ |  |
| Enclosed, Partially Enclosed Buildings and Structures | Arched Roofs |  |


| Conditions | Rise-to-span <br> ratio, $r$ | $\mathbf{C}_{\mathbf{p}}$ |  |  |
| :--- | :--- | :--- | :--- | :---: |
|  |  | Windward <br> quarter | Center <br> half | Leeward <br> quarter |
| Roof on elevated structure | $0<\mathrm{r}<0.2$ | -0.9 | $-0.7-r$ | -0.5 |
|  | $0.2 \leq r<0.3^{*}$ | $1.5 r-0.3$ | $-0.7-r$ | -0.5 |
|  | $0.3 \leq r \leq 0.6$ | $2.75 r-0.7$ | $-0.7-r$ | -0.5 |
| Roof springing from ground level | $0<r \leq 0.6$ | $1.4 r$ | $-0.7-r$ | -0.5 |

*When the rise-to-span ratio is $0.2 \leq \mathrm{r} \leq 0.3$, alternate coefficients given by $6 \mathrm{r}-2.1$ shall also be used for the windward quarter.

## Notes:

1. Values listed are for the determination of average loads on main wind force resisting systems.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. For wind directed parallel to the axis of the arch, use pressure coefficients from Fig. 27.4-1 with wind directed parallel to ridge.
4. For components and cladding: (1) At roof perimeter, use the external pressure coefficients in Fig. 30.4$2 \mathrm{~A}, \mathrm{~B}$ and C with $\theta$ based on spring-line slope and (2) for remaining roof areas, use external pressure coefficients of this table multiplied by 0.87 .

| Main Wind Force Resisting System - Part 1 |  |  |  |  | $0.25 \leq h / L \leq 1.0$ |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Figure 27.4-4 |  | Net Pressure Coefficient, $\mathrm{C}_{\mathrm{N}}$ |  |  | Monoslope Free Roofs$\theta \leq 45^{\circ}, \gamma=0^{\circ}, 180^{\circ}$ |  |  |  |  |
| Open Buildings |  |  |  |  |  |  |  |  |  |
| Wind Direction | h <br> 171 | L $\rightarrow$ v <br> $\theta$ $\downarrow$ <br> 171 | 17 |  | h <br> /717 | L $\rightarrow \mid \leftarrow$ <br>  ? <br> 17 | $\xrightarrow{\rightarrow}$ |  |  |
| Roof | Load | Wind Direction, $\gamma=0$ |  |  |  | Wind Direction, $\gamma=180^{\circ}$ |  |  |  |
| Angle | Case | Clear Wind Flow |  | Obstructed Wind Flow |  | Clear Wind Flow |  | Obstructed Wind Flow |  |
| $\theta$ |  | $\mathrm{C}_{\mathrm{NW}}$ | $\mathrm{C}_{\mathrm{NL}}$ | $\mathrm{C}_{\text {NW }}$ | $\mathrm{C}_{\mathrm{NL}}$ | $\mathrm{C}_{\mathrm{NW}}$ | $\mathrm{C}_{\mathrm{NL}}$ | $\mathrm{C}_{\mathrm{NW}}$ | $\mathrm{C}_{\mathrm{NL}}$ |
| $0^{\circ}$ | A | 1.2 | 0.3 | -0.5 | -1.2 | 1.2 | 0.3 | -0.5 | -1.2 |
|  | B | -1.1 | -0.1 | -1.1 | -0.6 | -1.1 | -0.1 | -1.1 | -0.6 |
| $7.5{ }^{0}$ | A | -0.6 | -1 | -1 | -1.5 | 0.9 | 1.5 | -0.2 | -1.2 |
|  | B | -1.4 | 0 | -1.7 | -0.8 | 1.6 | 0.3 | 0.8 | -0.3 |
| $15^{0}$ | A | -0.9 | -1.3 | -1.1 | -1.5 | 1.3 | 1.6 | 0.4 | -1.1 |
|  | B | -1.9 | 0 | -2.1 | -0.6 | 1.8 | 0.6 | 1.2 | -0.3 |
| $22.5{ }^{\circ}$ | A | -1.5 | -1.6 | -1.5 | -1.7 | 1.7 | 1.8 | 0.5 | -1 |
|  | B | -2.4 | -0.3 | -2.3 | -0.9 | 2.2 | 0.7 | 1.3 | 0 |
| $30^{\circ}$ | A | -1.8 | -1.8 | -1.5 | -1.8 | 2.1 | 2.1 | 0.6 | -1 |
|  | B | -2.5 | -0.5 | -2.3 | -1.1 | 2.6 | 1 | 1.6 | 0.1 |
| $37.5^{\circ}$ | A | -1.8 | -1.8 | -1.5 | -1.8 | 2.1 | 2.2 | 0.7 | -0.9 |
|  | B | -2.4 | -0.6 | -2.2 | -1.1 | 2.7 | 1.1 | 1.9 | 0.3 |
| $45^{\circ}$ | A | -1.6 | -1.8 | -1.3 | -1.8 | 2.2 | 2.5 | 0.8 | -0.9 |
|  | B | -2.3 | -0.7 | -1.9 | -1.2 | 2.6 | 1.4 | 2.1 | 0.4 |
| Notes: <br> 1. $\quad \mathrm{C}_{\mathrm{NW}}$ and $\mathrm{C}_{\mathrm{NL}}$ denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively. <br> 2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to $50 \%$. Obstructed wind flow denotes objects below roof inhibiting wind flow ( $>50 \%$ blockage). <br> 3. For values of $\theta$ between $7.5^{\circ}$ and $45^{\circ}$, linear interpolation is permitted. For values of $\theta$ less than $7.5^{\circ}$, use load coefficients for $0^{\circ}$. <br> 4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively. <br> 5. All load cases shown for each roof angle shall be investigated. <br> 6. Notation: <br> L : horizontal dimension of roof, measured in the along wind direction, ft. (m) <br> h : mean roof height, ft. (m) <br> $\gamma \quad$ : direction of wind, degrees <br> $\theta \quad$ : angle of plane of roof from horizontal, degrees |  |  |  |  |  |  |  |  |  |


| Main Wind Force Resisting System - Part 1 |  | $0.25 \leq \mathrm{h} / \mathrm{L} \leq 1.0$ |
| :---: | :---: | :---: |
| Figure 27.4-5 | Net Pressure Coefficient, $\mathrm{C}_{\mathrm{N}}$ | Pitched Free Roofs |
| Open Buildings |  | $\theta \leq 45^{\circ}, \gamma=0^{\circ}, 180^{\circ}$ |



| Roof Angle, $\theta$ | Load Case | Wind Direction, $\gamma=0^{\circ}$, $180^{\circ}$ |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Clear Wind Flow |  | Obstructed Wind Flow |  |
|  |  | $\mathrm{C}_{\mathrm{NW}}$ | $\mathrm{C}_{\mathrm{NL}}$ | $\mathrm{C}_{\mathrm{NW}}$ | $\mathrm{C}_{\mathrm{NL}}$ |
| $7.5^{\circ}$ | A | 1.1 | -0.3 | -1.6 | -1 |
|  | B | 0.2 | -1.2 | -0.9 | -1.7 |
| $15^{\circ}$ | A | 1.1 | -0.4 | -1.2 | -1 |
|  | B | 0.1 | -1.1 | -0.6 | -1.6 |
| $22.5{ }^{\circ}$ | A | 1.1 | 0.1 | -1.2 | -1.2 |
|  | B | -0.1 | -0.8 | -0.8 | -1.7 |
| $30^{\circ}$ | A | 1.3 | 0.3 | -0.7 | -0.7 |
|  | B | -0.1 | -0.9 | -0.2 | -1.1 |
| $37.5^{\circ}$ | A | 1.3 | 0.6 | -0.6 | -0.6 |
|  | B | -0.2 | -0.6 | -0.3 | -0.9 |
| $45^{\circ}$ | A | 1.1 | 0.9 | -0.5 | -0.5 |
|  | B | -0.3 | -0.5 | -0.3 | -0.7 |

[^1]

Notes:

1. $\quad \mathrm{C}_{\mathrm{NW}}$ and $\mathrm{C}_{\mathrm{NL}}$ denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to $50 \%$. Obstructed wind flow denotes objects below roof inhibiting wind flow ( $>50 \%$ blockage).
3. For values of $\theta$ between $7.5^{\circ}$ and $45^{\circ}$, linear interpolation is permitted. For values of $\theta$ less than $7.5^{\circ}$, use monoslope roof load coefficients.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. All load cases shown for each roof angle shall be investigated.
6. Notation:

L : horizontal dimension of roof, measured in the along wind direction, ft. (m)
: mean roof height, ft. (m)
direction of wind, degrees
angle of plane of roof from horizontal, degrees



## CASE 2

## CASE 4

Case 1. Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.

Case 2. Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at $75 \%$ of the specified value.

Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at $75 \%$ of the specified value.

## Notes:

1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 27.4.1 and 27.4.2 as applicable for building of all heights.
2. Diagrams show plan views of building.
3. Notation:
$P_{W X}, P_{W Y}$ : Windward face design pressure acting in the $\mathrm{x}, \mathrm{y}$ principal axis, respectively.
$P_{L X}, P_{L Y}$ : Leeward face design pressure acting in the $\mathrm{x}, \mathrm{y}$ principal axis, respectively.
$e\left(e_{X} \cdot e_{Y}\right):$ Eccentricity for the $\mathrm{x}, \mathrm{y}$ principal axis of the structure, respectively.
$M_{T}$ : Torsional moment per unit height acting about a vertical axis of the building.

## PART 2: ENCLOSED SIMPLE DIAPHRAGM BUILDINGS WITH $h \leq 160 \mathrm{ft}(\mathbf{4 8 . 8} \mathbf{~ m})$

### 27.5 GENERAL REQUIREMENTS

### 27.5.1 Design Procedure

The procedure specified herein applies to the determination of MWFRS wind loads of enclosed simple diaphragm buildings, as defined in Section 26.2, with a mean roof height $h \leq 160 \mathrm{ft}(48.8 \mathrm{~m})$. The steps required for the determination of MWFRS wind loads on enclosed simple diaphragm buildings are shown in Table 27.5-1.

User Note: Part 2 of Chapter 27 is a simplified method for determining the wind pressures for the MWFRS of enclosed, simple diaphragm buildings whose height $h$ is $\leq 160 \mathrm{ft}(48.8 \mathrm{~m})$. The wind pressures are obtained directly from a table. The building may be of any general plan shape and roof geometry that matches the specified figures. This method is a simplification of the traditional "all heights" method (Directional Procedure) contained in Part 1 of Chapter 27.

Table 27.5-1 Steps to Determine MWFRS Wind Loads Enclosed Simple Diaphragm Buildings ( $h \leq 160 \mathrm{ft}$. $\mathbf{( 4 8 . 8 \mathrm { m } \text { ) ) } ) ~}$

Step 1: Determine risk category of building or other structure, see Table 1.5-1

Step 2: Determine the basic wind speed, $V$, for applicable risk category, see Figure $26.5-1 \mathrm{~A}$, B or C

Step 3: Determine wind load parameters:
$>$ Wind directionality factor, $K_{d}$, see Section 26.6 and Table 26.6-1
$>$ Exposure category $\mathrm{B}, \mathrm{C}$ or D, see Section 26.7
> Topographic factor, $K_{z z}$, see Section 26.8 and Figure 26.8-1
$>$ Enclosure classification, see Section 26.10
Step 4: Enter table to determine net pressures on walls at top and base of building respectively, $\mathrm{p}_{\mathrm{h}}, \mathrm{p}_{0}$, Table 27.6-1

Step 5: Enter table to determine net roof pressures, $p_{z}$, Table 27.6-2

Step 6: Determine topographic factor, $K_{z}$, and apply factor to wall and roof pressures (if applicable), see Section 26.8

Step 7: Apply loads to walls and roofs simultaneously.

### 27.5.2 Conditions

In addition to the requirements in Section 27.1.2, a building whose design wind loads are determined in accordance with this section shall meet all of the following conditions for either a Class 1 or Class 2 building (see Fig. 27.5-1):

## Class 1 Buildings:

1. The building shall be an enclosed simple diaphragm building as defined in Section 26.2.
2. The building shall have a mean roof height $h \leq 60$ $\mathrm{ft}(18.3 \mathrm{~m})$.
3. The ratio of $L / B$ shall not be less than 0.2 nor more than $5.0(0.2 \leq L / B \leq 5.0)$.
4. The topographic effect factor $K_{z t}=1.0$ or the wind pressures determined from this section shall be multiplied by $K_{z t}$ at each height $z$ as determined from Section 26.8. It shall be permitted to use one value of $K_{z t}$ for the building calculated at 0.33 h . Alternatively it shall be permitted to enter the pressure table with a wind velocity equal to $V$ $\sqrt{K_{z t}}$ where $K_{z t}$ is determined at a height of $0.33 h$.

## Class 2 Buildings:

1. The building shall be an enclosed simple diaphragm building as defined in Section 26.2.
2. The building shall have a mean roof height $60 \mathrm{ft}<$ $h \leq 160 \mathrm{ft}(18.3 \mathrm{~m}<\mathrm{h} \leq 48.8 \mathrm{~m})$.
3. The ratio of $L / B$ shall not be less than 0.5 nor more than $2.0(0.5 \leq L / B \leq 2.0)$.
4. The fundamental natural frequency (Hertz) of the building shall not be less $75 / h$ where $h$ is in feet.
5. The topographic effect factor $K_{z t}=1.0$ or the wind pressures determined from this section shall be multiplied by $K_{z t}$ at each height $z$ as determined from Section 26.8. It shall be permitted to use one value of $K_{z t}$ for the building calculated at 0.33 h . Alternatively it shall be permitted to enter the pressure table with a wind velocity equal to $V$ $\sqrt{K_{z t}}$ where $K_{z t}$ is determined at a height of $0.33 h$.

### 27.5.3 Wind Load Parameters Specified in Chapter 26

Refer to Chapter 26 for determination of Basic Wind Speed $V$ (Section 26.5) and exposure category (Section 26.7) and topographic factor $K_{z t}$ (Section 26.8).

### 27.5.4 Diaphragm Flexibility

The design procedure specified herein applies to buildings having either rigid or flexible diaphragms. The structural analysis shall consider the relative
stiffness of diaphragms and the vertical elements of the MWFRS.

Diaphragms constructed of wood panels can be idealized as flexible. Diaphragms constructed of untopped metal decks, concrete filled metal decks, and concrete slabs, each having a span-to-depth ratio of 2 or less, are permitted to be idealized as rigid for consideration of wind loading.

### 27.6 WIND LOADS—MAIN WIND FORCE-RESISTING SYSTEM

### 27.6.1 Wall and Roof Surfaces-Class 1 and 2 Buildings

Net wind pressures for the walls and roof surfaces shall be determined from Tables 27.6-1 and 27.6-2, respectively, for the applicable exposure category as determined by Section 26.7.

For Class 1 building with $L / B$ values less than 0.5 , use wind pressures tabulated for $L / B=0.5$. For Class 1 building with $L / B$ values greater than 2.0, use wind pressures tabulated for $L / B=2.0$.

Net wall pressures shall be applied to the projected area of the building walls in the direction of the wind, and exterior side wall pressures shall be applied to the projected area of the building walls normal to the direction of the wind acting outward according to Note 3 of Table 27.6-1, simultaneously with the roof pressures from Table 27.6-2 as shown in Fig. 27.6-1.

Where two load cases are shown in the table of roof pressures, the effects of each load case shall be investigated separately. The MWFRS in each direc-
tion shall be designed for the wind load cases as defined in Fig. 27.4-8.

EXCEPTION: The torsional load cases in Fig. 27.4-8 (Case 2 and Case 4) need not be considered for buildings which meet the requirements of Appendix D.

### 27.6.2 Parapets

The effect of horizontal wind loads applied to all vertical surfaces of roof parapets for the design of the MWFRS shall be based on the application of an additional net horizontal wind pressure applied to the projected area of the parapet surface equal to 2.25 times the wall pressures tabulated in Table 27.6-1 for $L / B=1.0$. The net pressure specified accounts for both the windward and leeward parapet loading on both the windward and leeward building surface. The parapet pressure shall be applied simultaneously with the specified wall and roof pressures shown in the table as shown in Fig. 27.6-2. The height $h$ used to enter Table 27.6-1 to determine the parapet pressure shall be the height to the top of the parapet as shown in Fig. 27.6-2 (use $h=h_{p}$ ).

### 27.6.3 Roof Overhangs

The effect of vertical wind loads on any roof overhangs shall be based on the application of a positive wind pressure on the underside of the windward overhang equal to $75 \%$ of the roof edge pressure from Table 27.6-2 for Zone 1 or Zone 3 as applicable. This pressure shall be applied to the windward roof overhang only and shall be applied simultaneously with other tabulated wall and roof pressures as shown in Fig. 27.6-3.



| Main Wind Force Resisting System - Part 2 | $\mathrm{h} \leq 160 \mathrm{ft}$. <br> Application of Parapet Wind Loads - See <br> Table 27.6-1 |  |
| :--- | :---: | :---: |
| Figure 27.6-2 | Parapet Wind Loads |  |
| Enclosed Simple Diaphragm Buildings |  |  |



| Main Wind Force Resisting System - Part 2 |  | h $\leq 160 \mathrm{ft}$. |
| :--- | :---: | :---: |
| Figure 27.6-3 | Roof Overhang Wind Loads | Application of Roof Overhang |
| Enclosed Simple Diaphragm Buildings | Wind Loads - See Table 27.6-2 |  |




Notes to Wall Pressure Table 27.6-1:

1. From table for each Exposure ( $B, C$ or $D$ ), $V, L / B$ and $h$, determine $p_{h}$ (top number) and $p_{0}$ (bottom number) horizontal along-wind net wall pressures.
2. Side wall external pressures shall be uniform over the wall surface acting outward and shall be taken as $54 \%$ of the tabulated $p_{h}$ pressure for $0.2 \leq L / B \leq 1.0$ and $64 \%$ of the tabulated $p_{h}$ pressure for $2.0 \leq L / B \leq 5.0$. Linear interpolation shall apply for $1.0<\mathrm{L} / \mathrm{B}<2.0$. Side wall external pressures do not include effect of internal pressure.
3. Apply along-wind net wall pressures as shown above to the projected area of the building walls in the direction of the wind and apply external side wall pressures to the projected area of the building walls normal to the direction wind, simultaneously with the roof pressures from Table 27.6-2.
4. Distribution of tabulated net wall pressures between windward and leeward wall faces shall be based on the linear distribution of total net pressure with building height as shown above and the leeward external wall pressures assumed uniformly distributed over the leeward wall surface acting outward at $38 \%$ of $\mathrm{p}_{\mathrm{h}}$ for $0.2 \leq \mathrm{L} / \mathrm{B} \leq 1.0$ and $27 \%$ of $\mathrm{p}_{\mathrm{h}}$ for $2.0 \leq \mathrm{L} / \mathrm{B} \leq 5.0$. Linear interpolation shall be used for $1.0<\mathrm{L} / \mathrm{B}<2.0$. The remaining net pressure shall be applied to the windward walls as an external wall pressure acting towards the wall surface. Windward and leeward wall pressures so determined do not include effect of internal pressure.
5. Interpolation between values of $\mathrm{V}, \mathrm{h}$ and $\mathrm{L} / \mathrm{B}$ is permitted.

## Notation:

$\mathrm{L}=$ building plan dimension parallel to wind direction (ft.)
$\mathrm{B}=$ building plan dimension perpendicular to wind direction ( ft )
$\mathrm{h}=$ mean roof height (ft.)
$\mathrm{p}_{\mathrm{h}}, \mathrm{p}_{0}=$ along-wind net wall pressure at top and base of building respectively (psf)
Table 27．6－1
MWFRS－Part 2：Wind Loads－Walls

| 읏 | $\sim$ | 0  <br> 0  | ｜rc｜c | $\begin{array}{\|cc}  & 0 \\ \underset{\sim}{2} & \text { N } \end{array}$ | $\begin{array}{cc} \infty \\ \underset{\sim}{\infty} & \infty \\ \underset{\sim}{\circ} \end{array}$ | $\begin{array}{ll} 0 & \underset{\infty}{\infty} \\ \stackrel{i}{\top} & \underset{N}{\mathrm{~N}} \end{array}$ | $\begin{array}{ll} \overline{\mathrm{N}} & 0 \\ \underset{\mathrm{~N}}{2} \end{array}$ |  | $\begin{array}{lll} \infty & 0 \\ \dot{8} & 0 \\ 8 \end{array}$ | $$ |  |  | $\left\lvert\,\right.$ |  | $\begin{array}{ll} \infty & - \\ \infty & \underset{\sim}{n} \\ \infty & i \end{array}$ |  | へ－ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  | $\begin{aligned} & \stackrel{L}{n} \\ & \dot{0} \\ & \underset{\sim}{\circ} \\ & \hline \end{aligned}$ | $\begin{array}{ll} 10 \\ 0 & \wedge \\ \dot{y} & 8 \\ \hline \end{array}$ | $\begin{array}{ll} \substack{n} \\ \underset{\sim}{2} & \grave{j} \end{array}$ | $\begin{array}{ll} 0 & 0 \\ \underset{\sim}{c} & 0 \\ \underset{\sim}{2} \end{array}$ | $$ |  |  | $\begin{array}{lc} \stackrel{N}{\dot{C}} \\ \stackrel{\rightharpoonup}{\mathrm{~N}} \end{array}$ |  | $\begin{array}{ll} 0 & 0 \\ \infty & 0 \\ \infty & 0 \end{array}$ |  | $$ | $\left\lvert\, \begin{array}{ll} \dot{+} & m \\ \dot{c} & \dot{\epsilon} \end{array}\right.$ | $$ |  |
|  | $10$ |  |  | $\begin{array}{ll} \infty \\ \stackrel{\infty}{\infty} & \infty \\ \underset{\sim}{2} & \infty \\ \hline \end{array}$ |  | $\begin{aligned} & N \\ & \underset{\sim}{c} \\ & \text { Ni } \\ & \text { N } \end{aligned}$ | $\left\|\begin{array}{ll} \infty & \infty \\ \underset{\sim}{N} & \infty \\ \sim \end{array}\right\|$ |  | $\begin{array}{ll} \hline 0 \\ \stackrel{\infty}{\infty} & \infty \\ \vdots \\ \hline \end{array}$ |  |  | $\begin{array}{ll} n & \cdots \\ \infty \\ \infty \\ \end{array}$ |  |  |  |  | $\left\|\begin{array}{cc} 0 & 0 \\ 1 & 0 \\ 10 & 1 \\ 10 & 1 \end{array}\right\|$ |
| $\underset{\sim}{\infty}$ | N |  |  |  | $\begin{array}{ll} \text { N } & 0 \\ \dot{O} & \text { in } \end{array}$ | $\left\lvert\, \begin{array}{ll} \infty & N \\ \dot{\sigma} & \vdots \\ \hline \end{array}\right.$ |  | $\left\lvert\, \begin{array}{ll} \infty & 0 \\ & \dot{0} \\ \infty & 1 \end{array}\right.$ | $\left\lvert\, \begin{array}{ll} 0 & 0 \\ \infty & \dot{N} \\ & 1 \end{array}\right.$ | $\begin{array}{cc} \overline{-} & 0 \\ & \underset{N}{n} \end{array}$ |  | $\begin{array}{lll} \infty & 0 \\ \dot{\sim} & \infty \\ 0 \\ \hline \end{array}$ |  |  | $$ |  |  |
|  |  |  |  |  |  | $\begin{aligned} & \text { B N } \\ & \dot{\beta} \end{aligned}$ |  |  | $\left\lvert\, \begin{array}{ll} \infty & 6 \\ \infty & 1 \\ \infty & 6 \end{array}\right.$ | $\left\lvert\, \begin{array}{lc} \infty & N \\ \infty & \bar{o} \end{array}\right.$ |  | $\left\|\begin{array}{ll} \infty & 0 \\ 0 & 6 \\ 0 & i \end{array}\right\|$ |  |  |  |  | $\left\|\begin{array}{ll} G & 0 \\ \dot{G} & \dot{寸} \end{array}\right\|$ |
|  | $\begin{aligned} & 10 \\ & 0 \\ & 0 \end{aligned}$ |  |  | $\begin{array}{ll} \underset{N}{N} & 0 \\ \stackrel{\rightharpoonup}{\tau} & \stackrel{\ominus}{N} \end{array}$ |  |  | $\begin{array}{\|cc\|} \hline & N \\ 6 & 0 \\ 6 & 0 \end{array}$ | $\left\|\begin{array}{l} N \\ \bar{\sigma} \\ \bar{o} \end{array}\right\|$ | $\left\lvert\, \begin{array}{ll} 0 & N \\ 0 & \dot{~} \\ \infty & 0 \end{array}\right.$ | $\begin{array}{lc} \infty & 0 \\ \infty & \frac{1}{6} \end{array}$ |  | $\left\lvert\, \begin{array}{ll} \bar{r} & 0 \\ \underset{\sim}{c} & 0 \\ \hline \end{array}\right.$ |  | $\left\lvert\, \begin{array}{cc} \text { N } & \text { N } \\ \dot{\sim} & \overline{5} \end{array}\right.$ | $\begin{array}{ll} \dot{y} & \text { n } \\ \text { in } \\ \hline \end{array}$ |  | $\left\lvert\, \begin{array}{ll} \sigma & 0 \\ \dot{\forall} & \dot{寸} \end{array}\right.$ |
|  | N |  |  |  |  |  | $\begin{array}{ll} \hline & 寸 \\ e & \underset{\sim}{*} \end{array}$ |  |  | $\left\lvert\, \begin{array}{ll} 0 & 3 \\ 10 & 0 \\ 1 & \circ \end{array}\right.$ |  |  |  | $\left\|\begin{array}{ll} \hat{y} & 0 \\ \underset{子}{\circ} & \dot{j} \end{array}\right\|$ | $\begin{array}{ll} \hline \cdots & N \\ \dot{e} & \underset{\sim}{m} \end{array}$ | $\begin{array}{ll} \underset{\sim}{N} \\ \underset{m}{j} \end{array}$ |  |
|  | F | $\begin{array}{ll} + & \bar{\circ} \\ \infty \\ \infty & \dot{O} \end{array}$ |  | $\begin{array}{ll} \infty & 0 \\ \text { Ni } \\ \infty & \stackrel{1}{n} \end{array}$ |  |  | $\left\|\right\|$ |  | $\left\lvert\, \begin{array}{lll} 10 & 0 \\ \stackrel{0}{\circ} & \infty \\ 0 \\ \hline \end{array}\right.$ |  |  |  |  | $\left\|\begin{array}{ll} n & z \\ \hdashline & o \\ \vdots & q \end{array}\right\|$ | $\left\lvert\, \begin{array}{ll} 9 & \underset{\sim}{\circ} \\ \stackrel{-}{\prime} & \infty \\ \hline \end{array}\right.$ | $\stackrel{M}{N}$ | ¢ |
|  | $\begin{aligned} & n \\ & 0 \\ & 0 \end{aligned}$ |  |  |  |  |  | $\begin{array}{cc} \cdots \\ & \underset{N}{n} \end{array}$ |  |  |  |  |  | $\begin{array}{cc} \text { M } & 0 \\ \dot{i} & \underset{y}{*} \end{array}$ |  |  |  |  |
| $\stackrel{1}{2}$ | N |  | $\left\|\begin{array}{ll} 0 & 0 \\ i & 0 \\ i & 0 \end{array}\right\|$ | $\left\lvert\, \begin{array}{ll} 1 \\ 10 & 0 \\ 10 & 0 \end{array}\right.$ |  | $\left\lvert\, \begin{array}{ll} 0 & 0 \\ \dot{B} & \mathrm{~m} \end{array}\right.$ | $\left\|\begin{array}{ll} \infty & 0 \\ \infty & \dot{j} \\ \underset{\sim}{2} & \text { en } \end{array}\right\|$ |  | $\left\|\begin{array}{ll} 0 & \infty \\ \dot{寸} & \dot{N} \end{array}\right\|$ | $\left\lvert\, \begin{array}{ll} \stackrel{\circ}{\dot{\sigma}} \\ \dot{\sim} \\ \text { N } \end{array}\right.$ |  | $\begin{array}{ll} \mathrm{N} & 0 \\ \dot{e} \\ & \mathrm{~N} \end{array}$ |  | $\left\|\begin{array}{cc} \hat{c} & \underset{\sim}{0} \\ \underset{\sim}{c} \end{array}\right\|$ | $\underset{\sim}{N} \stackrel{N}{N}$ |  | ¢ |
|  |  |  |  | $\begin{array}{ll} \infty & 0 \\ 0 & \dot{子} \\ 0 & \dot{\sigma} \end{array}$ |  |  | $\left\|\begin{array}{ll} \infty & 1 \\ & \infty \\ & \infty \end{array}\right\|$ | $\begin{array}{ll} m & 0 \\ \stackrel{n}{n} & \underset{m}{2} \end{array}$ | $\left.\begin{array}{ll} \infty & \underset{\sim}{\infty} \\ \infty & \dot{\sim} \end{array} \right\rvert\,$ | $\begin{array}{ll} m & m \\ \dot{c} & 1 \\ q & m \end{array}$ |  |  | $\begin{array}{lll} \hline 0 & \infty \\ \infty \\ \underset{\sim}{c} \\ \hline \end{array}$ |  |  |  | $\stackrel{\rightharpoonup}{N} \underset{N}{N}$ |
|  | $\left\|\begin{array}{l} n \\ 0 \end{array}\right\|$ |  |  |  | $\underset{\sim}{\circ} \stackrel{N}{\underset{\sigma}{*}}$ | $\begin{array}{ll} 0 & \overleftarrow{0} \\ 0 \\ 0 & 0 \\ \hline \end{array}$ | $\begin{array}{ll} \Gamma & \infty \\ \dot{\sim} & \infty \\ \hline 0 \end{array}$ | $\begin{array}{ll} 0 & \infty \\ \stackrel{\infty}{n} & \underset{\mathrm{~m}}{2} \end{array}$ |  |  |  | $\begin{array}{ll} 0 & 0 \\ \dot{+} & \mathbf{m} \end{array}$ | $\begin{array}{lll} 0 & \infty \\ \infty \\ \infty \\ \hline \end{array}$ |  |  |  | $\stackrel{\rightharpoonup}{\mathrm{N}}$ |
| ¢ | N |  |  | $$ |  | $\left\|\begin{array}{cc} \underset{\sim}{\infty} & \infty \\ \underset{\sim}{\infty} \\ \sim \end{array}\right\|$ | $\left\|\begin{array}{cc} \underset{\sim}{c} & 0 \\ \stackrel{\rightharpoonup}{\sim} \end{array}\right\|$ |  | $\begin{array}{lc} m & \underset{\sim}{i} \\ \underset{\sim}{c} \end{array}$ |  |  | $\left\lvert\, \begin{array}{ll} \hline 0 & 0 \\ 0 & \text { n } \end{array}\right.$ |  |  | $\begin{array}{ll} \infty & 0 \\ & \stackrel{i}{N} \end{array}$ |  | $\begin{array}{ll} m & m \\ \stackrel{y}{c} & 0 \\ \end{array}$ |
|  |  |  |  | $$ |  | $\begin{array}{ll} \bullet & N \\ \underset{\sim}{\prime} & \end{array}$ | $\left\|\right\|$ |  | $\left\|\begin{array}{cc} 0 & 0 \\ \dot{子} & \dot{c} \end{array}\right\|$ | か্ల প্ল |  | $\stackrel{\infty}{\infty}$ |  |  | $\stackrel{\sim}{\sim}$ | $\underset{\sim}{\text { ホ }}$ | $\begin{array}{cc} \infty & n \\ & \stackrel{\sim}{n} \end{array}$ |
|  | $\left\|\begin{array}{l} 0 \\ 0 \end{array}\right\|$ |  |  | $\left\lvert\, \begin{array}{ll} 9 & N \\ \dot{N} & \stackrel{N}{\mathrm{~N}} \end{array}\right.$ |  |  | $\begin{array}{lll} 0 & 0 \\ \omega_{0} & \mathbf{m} \end{array}$ | $\left\lvert\, \begin{array}{cc} \infty & \underset{\sim}{\mathrm{j}} \\ \text { - } \end{array}\right.$ | $\stackrel{N}{\dot{f}} \underset{\mathrm{j}}{\mathrm{j}}$ |  |  | $\stackrel{\infty}{\infty}$ |  |  |  |  | $\begin{array}{ll} n & n \\ \underset{\sim}{n} & \stackrel{n}{n} \end{array}$ |
| $\stackrel{\text { 글 }}{ }$ | N | $\stackrel{\sim}{\dot{\square}} \stackrel{\sim}{\sim}$ |  | $\begin{array}{ll} \infty & 0 \\ \infty & \dot{\sim} \\ \underset{\sim}{c} \end{array}$ | $\underset{\sim}{N}$ | $\begin{array}{ll} \infty & 0 \\ \stackrel{N}{N} & \\ \hline \end{array}$ | $$ |  | $\begin{array}{ll} N \\ \stackrel{N}{N} & \vdots \\ \hline \end{array}$ | ọ M |  | $\stackrel{\rightharpoonup}{\dot{N}} \stackrel{\rightharpoonup}{\dot{N}}$ |  | $\begin{gathered} \text { N } \\ \underset{\sim}{\infty} \\ \infty \end{gathered}$ | N | $\underset{\sim}{\sim}$ | $\stackrel{\sim}{\sim}$ |
|  |  |  |  | $\left\lvert\, \begin{array}{ll} \underset{\sim}{\mathrm{j}} & \bullet \\ \underset{\sim}{\mathrm{~N}} \end{array}\right.$ | $\begin{array}{cc} \dot{\sim} & \infty \\ \dot{\star} & \infty \\ \hline \end{array}$ | $\begin{aligned} & \infty \\ & \underset{\sim}{\infty} \\ & \underset{\sim}{\infty} \\ & \hline \end{aligned}$ | $\begin{array}{lll} \infty & 0 \\ \infty & n \\ m & N \end{array}$ |  |  | $\mathfrak{m}$ | $\left\{\begin{array}{l} n \\ \stackrel{n}{\mathrm{~N}} \\ \stackrel{y}{c} \end{array}\right.$ | © ণ ল্jী | N N | $\left\|\begin{array}{ll} 6 & \underset{\sim}{n} \\ \underset{N}{*} & \underset{N}{2} \end{array}\right\|$ | $\begin{array}{lll} m & \llcorner \\ \underset{N}{N} & \dot{\Sigma} \end{array}$ |  |  |
|  | $\left\|\begin{array}{l} 0 \\ 0 \end{array}\right\|$ |  |  |  | ¢ | $\underset{\sim}{\infty}$ | $\begin{array}{ll} \infty \\ \infty \\ \infty & N \\ \end{array}$ |  |  |  |  | $\underset{\sim}{N} \underset{\sim}{N}$ | $\stackrel{N}{N}$ | $\underset{N}{C} \underset{\sim}{N}$ |  |  |  |
| $\stackrel{10}{7}$ | N |  | $\left\lvert\, \begin{array}{ll} \infty & \infty \\ \dot{e} & \underset{N}{N} \end{array}\right.$ |  | $\begin{array}{ll} \hline 0 & \text { g } \\ \dot{\sim} & \vdots \end{array}$ | $\underset{\sim}{N} \stackrel{\underset{N}{N}}{\stackrel{\rightharpoonup}{N}}$ | $\begin{array}{lll} m & 0 \\ \stackrel{y}{m} & \grave{N} \end{array}$ |  |  |  |  | $\begin{array}{cc}\infty & + \\ \sim \\ \sim\end{array}$ | 두N | $\stackrel{\star}{\underset{N}{N}}$ | $\stackrel{\sim}{\infty} \times \infty$ | $\stackrel{\bullet}{\bullet} \stackrel{+}{\bullet}$ |  |
|  |  | $\underset{\sim}{\stackrel{\infty}{\sim}}$ |  | $\begin{array}{\|cc\|} \hline- & 0 \\ \underset{\sim}{j} & \stackrel{0}{N} \end{array}$ |  | $\begin{aligned} & m \\ & \underset{\sim}{n} \\ & \end{aligned}$ | $\left\lvert\, \begin{array}{lc} \underset{\sim}{c} \\ \dot{m} & \underset{\sim}{n} \end{array}\right.$ |  | $\begin{array}{ll} 0 \\ \underset{\sim}{\mathrm{~N}} & \text { ले } \\ \text { N. } \end{array}$ |  | $\begin{array}{lc} \infty & 0 \\ \infty \\ N \end{array}$ | 둧 | ¢ | $\begin{array}{ll} n & 0 \\ & 0 \\ N & 0 \end{array}$ | $\begin{array}{ll} +\infty \\ \stackrel{\infty}{\sim} & \dot{\sim} \end{array}$ | ¢ ${ }_{\sim}^{\sim}$ | $\stackrel{\sim}{\sim} \sim$ |
|  | $\left\|\begin{array}{l} 0 \\ 0 \end{array}\right\|$ | $\underset{\sim}{\sim} \stackrel{\infty}{\infty}$ | $\underset{\substack{N}}{\stackrel{N}{\mathrm{~N}}}$ | $\underset{\sim}{m} \underset{\sim}{\infty}$ |  | $\begin{cases}\infty & \infty \\ 0 & 1 \\ & \multirow{2}{*}{}\end{cases}$ | $\left\|\begin{array}{cc} \underset{\sim}{c} \\ \underset{\sim}{n} \end{array}\right\|$ | $\left\|\begin{array}{cc} 0 & 0 \\ \underset{\sim}{c} & \underset{\sim}{N} \end{array}\right\|$ |  |  | $\underset{\sim}{\infty} \underset{\sim}{\infty} \underset{\sim}{N}$ | $\stackrel{\rightharpoonup}{N} \underset{\sim}{N}$ | $\stackrel{N}{N}$ | $\left\lvert\, \begin{array}{ll} 1 & 0 \\ \underset{N}{n} & \vdots \\ \text { Non } \end{array}\right.$ | $\begin{array}{ll} \dot{\sim} \\ \stackrel{\infty}{\sim} \\ \stackrel{j}{2} \end{array}$ | $\stackrel{\sim}{\sim} \stackrel{\infty}{\sim}$ | $\stackrel{\sim}{\sim} \stackrel{\sim}{\sim}$ |
| $\frac{ㅇ}{7}$ | N | $\underset{\dot{j}}{\stackrel{\rightharpoonup}{\grave{N}}}$ | $\begin{array}{ll} \hline 0 & 0 \\ & \stackrel{\rightharpoonup}{N} \end{array}$ | $\begin{array}{ll} \hline 9 & N \\ \stackrel{i}{m} & \stackrel{i}{2} \end{array}$ | $\begin{array}{ll} \infty & \infty \\ \dot{c} & \dot{\sim} \\ \Gamma \end{array}$ | $\stackrel{+}{\circ} \stackrel{+}{\sim}$ | $\begin{array}{cc} \underset{0}{0} & 0 \\ \infty & 0 \\ \hline \end{array}$ | $\stackrel{\Gamma}{\stackrel{\rightharpoonup}{N}} \stackrel{\infty}{\infty} \underset{\sim}{\infty}$ | $$ | $\stackrel{\infty}{\infty} \underset{\sim}{N}$ | $\stackrel{\underset{N}{N}}{\stackrel{N}{\sim}}$ | N |  | $\left\lvert\, \begin{array}{cc} 0 & \infty \\ \infty & \stackrel{N}{\square} \end{array}\right.$ | ¢ | $\stackrel{\sim}{\sim}$ |  |
|  |  | $\underset{\sim}{N}$ | $\begin{array}{ll} \bullet & 0 \\ \dot{e} & \dot{\sim} \end{array}$ |  | $\begin{array}{ll} \mathrm{N} & 0 \\ \dot{m} & \text { Ni } \end{array}$ | OM | $\begin{array}{\|cc} \stackrel{\infty}{\mathrm{N}} \\ \stackrel{\infty}{\mathrm{~N}} \end{array}$ | $\left\lvert\, \begin{gathered} \underset{\sim}{\mathrm{N}} \\ \underset{N}{\prime} \end{gathered}\right.$ | $\stackrel{\rightharpoonup}{\sim} \stackrel{N}{\stackrel{ }{N}}$ | $\stackrel{N}{N} \stackrel{N}{N}$ | $\begin{array}{ll} m & 0 \\ \dot{N} & 0 \end{array}$ | $\begin{array}{ll} \infty & 0 \\ \underset{\sim}{j} & \dot{N} \end{array}$ |  | $\begin{aligned} & \infty \stackrel{N}{\sim} \\ & \stackrel{+}{\sim} \stackrel{1}{\circ} \end{aligned}$ | $\stackrel{\bullet}{\circ} \stackrel{\square}{\square} \stackrel{+}{\square}$ | $\stackrel{\sim}{\sim}$ | $\stackrel{N}{*}$ |
|  | $\left\|\begin{array}{c} 10 \\ 0 \end{array}\right\|$ | $\underset{\sim}{\infty} \stackrel{\bullet}{\infty}$ |  |  | $\begin{array}{ll} \dot{+} & 0 \\ \dot{j} & \dot{\sim} \end{array}$ | $\underset{\sim}{\underset{\sim}{N}}$ | $\begin{array}{ll} \infty & 0 \\ \stackrel{\rightharpoonup}{m} & \underset{N}{2} \end{array}$ | $\left\lvert\, \begin{array}{ll} \infty \\ \underset{\sim}{n} \\ \underset{N}{2} \end{array}\right.$ | $\begin{array}{ll} N \\ \underset{N}{N} \\ \underset{N}{\prime} \\ \hline \end{array}$ | $\begin{array}{lc} \infty & \underset{N}{N} \\ \end{array}$ | $\begin{array}{ll} \infty & 0 \\ \dot{N} \text { N } \end{array}$ | $\begin{array}{ll} \infty & 0 \\ \underset{\sim}{*} & \vdots \\ \text { N } \end{array}$ | $\stackrel{\Gamma}{\sim}$ | $\begin{array}{ll} \infty & \infty \\ \stackrel{\infty}{\sim} & \infty \\ \square \end{array}$ | $\stackrel{\odot}{\circ} \stackrel{\Gamma}{\square}$ | $\stackrel{\sim}{\sim}$ | 年 |
| 읕 |  | $10$ | $\stackrel{10}{2}$ | 안 | Mr | 슨 | 운 | 은 | 8 | $\varnothing$ | ㅇ | 8 | $\bigcirc$ | \％ | － | N | $\stackrel{\sim}{\square}$ |



| Main Wind Force Resisting System - Part 2 | h $\leq 160 \mathrm{ft}$. |
| :--- | :---: |
| Table 27.6-2 | Wind Pressures - Roof |
| Enclosed Simple Diaphragm Buildings | Application of Roof Pressures |

Notes to Roof Pressure Table 27.6-2:

1. From table for Exposure C, V, h and roof slope, determine roof pressure $\mathrm{p}_{\mathrm{h}}$ for each roof zone shown in the figures for the applicable roof form. For other exposures B or D, multiply pressures from table by appropriate exposure adjustment factor as determined from figure below.
2. Where two load cases are shown, both load cases shall be investigated. Load case 2 is required to investigate maximum overturning on the building from roof pressures shown.
3. Apply along-wind net wall pressures to the projected area of the building walls in the direction of the wind and apply exterior side wall pressures to the projected area of the building walls normal to the direction of the wind acting outward, simultaneously with the roof pressures from Table 27.6-2.
4. Where a value of zero is shown in the tables for the flat roof case, it is provided for the purpose of interpolation.
5. Interpolation between $\mathrm{V}, \mathrm{h}$ and roof slope is permitted.



Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

## MWFRS - Roof $\mathrm{V}=\mathbf{1 1 0}-\mathbf{1 2 0} \mathbf{m p h}$ $h=15-40 \mathrm{ft}$.

|  | V (MPH) |  | 110 |  |  |  |  | 115 |  |  |  |  | 120 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \end{gathered}$ |  |  | Zone |  |  |  |  | Zone |  |  | Zone |  |  |  |  |
| h (ft) |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 40 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -29.1 | -26.0 | -21.3 | NA | NA | -31.8 | -28.4 | -23.3 | NA | NA | -34.7 | -30.9 | -25.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -28.6 | -19.4 | -29.1 | -26.0 | -21.3 | -31.2 | -22.5 | -31.8 | -28.4 | -23.3 | -34.0 | -23.1 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 4.1 | -5.8 | 0.0 | 0.0 | 0.0 | 4.5 | -6.3 | 0.0 | 0.0 | 0.0 | 4.9 | -6.9 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -23.5 | -19.0 | -29.1 | -26.0 | -21.3 | -25.7 | -20.7 | -31.8 | -28.4 | -23.3 | -28.0 | -22.6 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 8.1 | -8.3 | 0.0 | 0.0 | 0.0 | 8.9 | -9.1 | 0.0 | 0.0 | 0.0 | 9.7 | -9.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -18.8 | -19.0 | -29.1 | -26.0 | -21.3 | -20.6 | -20.7 | -31.8 | -28.4 | -23.3 | -22.4 | -22.6 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 10.8 | -9.1 | 0.0 | 0.0 | 0.0 | 11.8 | -9.9 | 0.0 | 0.0 | 0.0 | 12.9 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -15.1 | -19.0 | -29.1 | -26.0 | -21.3 | -16.5 | -20.7 | -31.8 | -28.4 | -23.3 | -18.0 | -22.6 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 12.0 | -9.1 | 0.0 | 0.0 | 0.0 | 13.1 | -9.9 | 0.0 | 0.0 | 0.0 | 14.2 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -8.8 | -19.0 | -29.1 | -26.0 | -21.3 | -9.6 | -20.7 | -31.8 | -28.4 | -23.3 | -10.4 | -22.6 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 14.3 | -9.1 | 0.0 | 0.0 | 0.0 | 15.6 | -9.9 | 0.0 | 0.0 | 0.0 | 17.0 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -4.9 | -19.0 | -29.1 | -26.0 | -21.3 | -5.4 | -20.7 | -31.8 | -28.4 | -23.3 | -5.9 | -22.6 | -34.7 | -30.9 | -25.3 |
|  |  | 2 | 14.3 | -9.1 | 0.0 | 0.0 | 0.0 | 15.6 | -9.9 | 0.0 | 0.0 | 0.0 | 17.0 | -10.8 | 0.0 | 0.0 | 0.0 |
| 30 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -27.4 | -24.4 | -20.0 | NA | NA | -30.0 | -26.7 | -21.9 | NA | NA | -32.6 | -29.1 | -23.9 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -26.9 | -18.3 | -27.4 | -24.4 | -20.0 | -29.4 | -21.2 | -30.0 | -26.7 | -21.9 | -32.0 | -21.8 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 3.9 | -5.5 | 0.0 | 0.0 | 0.0 | 4.2 | -6.0 | 0.0 | 0.0 | 0.0 | 4.6 | -6.5 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -22.1 | -17.8 | -27.4 | -24.4 | -20.0 | -24.2 | -19.5 | -30.0 | -26.7 | -21.9 | -26.3 | -21.2 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 7.7 | -7.8 | 0.0 | 0.0 | 0.0 | 8.4 | -8.6 | 0.0 | 0.0 | 0.0 | 9.1 | -9.3 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -17.7 | -17.8 | -27.4 | -24.4 | -20.0 | -19.4 | -19.5 | -30.0 | -26.7 | -21.9 | -21.1 | -21.2 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 10.2 | -8.5 | 0.0 | 0.0 | 0.0 | 11.1 | -9.3 | 0.0 | 0.0 | 0.0 | 12.1 | -10.2 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -14.3 | -17.8 | -27.4 | -24.4 | -20.0 | -15.6 | -19.5 | -30.0 | -26.7 | -21.9 | -17.0 | -21.2 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 11.3 | -8.5 | 0.0 | 0.0 | 0.0 | 12.3 | -9.3 | 0.0 | 0.0 | 0.0 | 13.4 | -10.2 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -8.3 | -17.8 | -27.4 | -24.4 | -20.0 | -9.0 | -19.5 | -30.0 | -26.7 | -21.9 | -9.8 | -21.2 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 13.4 | -8.5 | 0.0 | 0.0 | 0.0 | 14.7 | -9.3 | 0.0 | 0.0 | 0.0 | 16.0 | -10.2 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -4.7 | -17.8 | -27.4 | -24.4 | -20.0 | -5.1 | -19.5 | -30.0 | -26.7 | -21.9 | -5.5 | -21.2 | -32.6 | -29.1 | -23.9 |
|  |  | 2 | 13.4 | -8.5 | 0.0 | 0.0 | 0.0 | 14.7 | -9.3 | 0.0 | 0.0 | 0.0 | 16.0 | -10.2 | 0.0 | 0.0 | 0.0 |
| 20 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -25.2 | -22.4 | -18.4 | NA | NA | -27.5 | -24.5 | -20.1 | NA | NA | -30.0 | -26.7 | -21.9 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -24.7 | -16.8 | -25.2 | -22.4 | -18.4 | -27.0 | -19.4 | -27.5 | -24.5 | -20.1 | -29.4 | -20.0 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 3.6 | -5.0 | 0.0 | 0.0 | 0.0 | 3.9 | -5.5 | 0.0 | 0.0 | 0.0 | 4.2 | -6.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -20.3 | -16.4 | -25.2 | -22.4 | -18.4 | -22.2 | -17.9 | -27.5 | -24.5 | -20.1 | -24.2 | -19.5 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 7.0 | -7.2 | 0.0 | 0.0 | 0.0 | 7.7 | -7.9 | 0.0 | 0.0 | 0.0 | 8.4 | -8.6 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -16.3 | -16.4 | -25.2 | -22.4 | -18.4 | -17.8 | -17.9 | -27.5 | -24.5 | -20.1 | -19.4 | -19.5 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 9.4 | -7.8 | 0.0 | 0.0 | 0.0 | 10.2 | -8.6 | 0.0 | 0.0 | 0.0 | 11.1 | -9.3 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -13.1 | -16.4 | -25.2 | -22.4 | -18.4 | -14.3 | -17.9 | -27.5 | -24.5 | -20.1 | -15.6 | -19.5 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 10.3 | -7.8 | 0.0 | 0.0 | 0.0 | 11.3 | -8.6 | 0.0 | 0.0 | 0.0 | 12.3 | -9.3 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -7.6 | -16.4 | -25.2 | -22.4 | -18.4 | -8.3 | -17.9 | -27.5 | -24.5 | -20.1 | -9.0 | -19.5 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 12.3 | -7.8 | 0.0 | 0.0 | 0.0 | 13.5 | -8.6 | 0.0 | 0.0 | 0.0 | 14.7 | -9.3 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -4.3 | -16.4 | -25.2 | -22.4 | -18.4 | -4.7 | -17.9 | -27.5 | -24.5 | -20.1 | -5.1 | -19.5 | -30.0 | -26.7 | -21.9 |
|  |  | 2 | 12.3 | -7.8 | 0.0 | 0.0 | 0.0 | 13.5 | -8.6 | 0.0 | 0.0 | 0.0 | 14.7 | -9.3 | 0.0 | 0.0 | 0.0 |
| 15 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -23.7 | -21.1 | -17.3 | NA | NA | -25.9 | -23.1 | -18.9 | NA | NA | -28.2 | -25.1 | -20.6 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -23.2 | -15.8 | -23.7 | -21.1 | -17.3 | -25.4 | -18.3 | -25.9 | -23.1 | -18.9 | -27.7 | -18.8 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 3.4 | -4.7 | 0.0 | 0.0 | 0.0 | 3.7 | -5.2 | 0.0 | 0.0 | 0.0 | 4.0 | -5.6 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -19.1 | -15.4 | -23.7 | -21.1 | -17.3 | -20.9 | -16.9 | -25.9 | -23.1 | -18.9 | -22.7 | -18.4 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 6.6 | -6.8 | 0.0 | 0.0 | 0.0 | 7.2 | -7.4 | 0.0 | 0.0 | 0.0 | 7.9 | -8.1 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -15.3 | -15.4 | -23.7 | -21.1 | -17.3 | -16.8 | -16.9 | -25.9 | -23.1 | -18.9 | -18.2 | -18.4 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 8.8 | -7.4 | 0.0 | 0.0 | 0.0 | 9.6 | -8.1 | 0.0 | 0.0 | 0.0 | 10.5 | -8.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -12.3 | -15.4 | -23.7 | -21.1 | -17.3 | -13.5 | -16.9 | -25.9 | -23.1 | -18.9 | -14.7 | -18.4 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 9.7 | -7.4 | 0.0 | 0.0 | 0.0 | 10.6 | -8.1 | 0.0 | 0.0 | 0.0 | 11.6 | -8.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -7.1 | -15.4 | -23.7 | -21.1 | -17.3 | -7.8 | -16.9 | -25.9 | -23.1 | -18.9 | -8.5 | -18.4 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 11.6 | -7.4 | 0.0 | 0.0 | 0.0 | 12.7 | -8.1 | 0.0 | 0.0 | 0.0 | 13.8 | -8.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -4.0 | -15.4 | -23.7 | -21.1 | -17.3 | -4.4 | -16.9 | -25.9 | -23.1 | -18.9 | -4.8 | -18.4 | -28.2 | -25.1 | -20.6 |
|  |  | 2 | 11.6 | -7.4 | 0.0 | 0.0 | 0.0 | 12.7 | -8.1 | 0.0 | 0.0 | 0.0 | 13.8 | -8.8 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof
Exposure C

$$
\begin{aligned}
& \text { MWFRS }- \text { Roof } \\
& V=130-150 \mathrm{mph} \\
& \mathrm{~h}=15-40 \mathrm{ft} .
\end{aligned}
$$

|  | V (MPH) |  | 130 |  |  |  |  | 140 |  |  |  |  | 150 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \end{gathered}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 40 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -40.7 | -36.3 | -29.7 | NA | NA | -47.2 | -42.1 | -34.5 | NA | NA | -54.2 | -48.3 | -39.6 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -39.9 | -27.1 | -40.7 | -36.3 | -29.7 | -46.3 | -31.5 | -47.2 | -42.1 | -34.5 | -53.1 | -36.1 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 5.8 | -8.1 | 0.0 | 0.0 | 0.0 | 6.7 | -9.4 | 0.0 | 0.0 | 0.0 | 7.7 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -32.8 | -26.5 | -40.7 | -36.3 | -29.7 | -38.1 | -30.7 | -47.2 | -42.1 | -34.5 | -43.7 | -35.3 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 11.4 | -11.6 | 0.0 | 0.0 | 0.0 | 13.2 | -13.5 | 0.0 | 0.0 | 0.0 | 15.1 | -15.5 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -26.3 | -26.5 | -40.7 | -36.3 | -29.7 | -30.5 | -30.7 | -47.2 | -42.1 | -34.5 | -35.1 | -35.3 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 15.1 | -12.7 | 0.0 | 0.0 | 0.0 | 17.5 | -14.7 | 0.0 | 0.0 | 0.0 | 20.1 | -16.9 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -21.1 | -26.5 | -40.7 | -36.3 | -29.7 | -24.5 | -30.7 | -47.2 | -42.1 | -34.5 | -28.2 | -35.3 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 16.7 | -12.7 | 0.0 | 0.0 | 0.0 | 19.4 | -14.7 | 0.0 | 0.0 | 0.0 | 22.2 | -16.9 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -12.2 | -26.5 | -40.7 | -36.3 | -29.7 | -14.2 | -30.7 | -47.2 | -42.1 | -34.5 | -16.3 | -35.3 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 23.1 | -14.7 | 0.0 | 0.0 | 0.0 | 8.5 | -16.9 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.9 | -26.5 | -40.7 | -36.3 | -29.7 | -8.0 | -30.7 | -47.2 | -42.1 | -34.5 | -9.2 | -35.3 | -54.2 | -48.3 | -39.6 |
|  |  | 2 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 23.1 | -14.7 | 0.0 | 0.0 | 0.0 | 26.6 | -16.9 | 0.0 | 0.0 | 0.0 |
| 30 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -38.3 | -34.1 | -28.0 | NA | NA | -44.4 | -39.6 | -32.5 | NA | NA | -51.0 | -45.4 | -37.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -37.6 | -25.5 | -38.3 | -34.1 | -28.0 | -43.6 | -29.6 | -44.4 | -39.6 | -32.5 | -50.0 | -34.0 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 5.4 | -7.6 | 0.0 | 0.0 | 0.0 | 6.3 | -8.8 | 0.0 | 0.0 | 0.0 | 7.2 | -10.1 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -30.9 | -24.9 | -38.3 | -34.1 | -28.0 | -35.8 | -28.9 | -44.4 | -39.6 | -32.5 | -41.1 | -33.2 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 10.7 | -10.9 | 0.0 | 0.0 | 0.0 | 12.4 | -12.7 | 0.0 | 0.0 | 0.0 | 14.2 | -14.6 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -24.8 | -24.9 | -38.3 | -34.1 | -28.0 | -28.7 | -28.9 | -44.4 | -39.6 | -32.5 | -33.0 | -33.2 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 14.2 | -11.9 | 0.0 | 0.0 | 0.0 | 16.5 | -13.8 | 0.0 | 0.0 | 0.0 | 18.9 | -15.9 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -19.9 | -24.9 | -38.3 | -34.1 | -28.0 | -23.1 | -28.9 | -44.4 | -39.6 | -32.5 | -26.5 | -33.2 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 15.7 | -11.9 | 0.0 | 0.0 | 0.0 | 18.2 | -13.8 | 0.0 | 0.0 | 0.0 | 20.9 | -15.9 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.5 | -24.9 | -38.3 | -34.1 | -28.0 | -13.4 | -28.9 | -44.4 | -39.6 | -32.5 | -15.3 | -33.2 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 18.8 | -11.9 | 0.0 | 0.0 | 0.0 | 21.8 | -13.8 | 0.0 | 0.0 | 0.0 | 8.0 | -15.9 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.5 | -24.9 | -38.3 | -34.1 | -28.0 | -7.5 | -28.9 | -44.4 | -39.6 | -32.5 | -8.7 | -33.2 | -51.0 | -45.4 | -37.3 |
|  |  | 2 | 18.8 | -11.9 | 0.0 | 0.0 | 0.0 | 21.8 | -13.8 | 0.0 | 0.0 | 0.0 | 25.0 | -15.9 | 0.0 | 0.0 | 0.0 |
| 20 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -35.2 | -31.3 | -25.7 | NA | NA | -40.8 | -36.3 | -29.8 | NA | NA | -46.8 | -41.7 | -34.2 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -34.5 | -23.4 | -35.2 | -31.3 | -25.7 | -40.0 | -27.2 | -40.8 | -36.3 | -29.8 | -45.9 | -31.2 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 5.0 | -7.0 | 0.0 | 0.0 | 0.0 | 5.8 | -8.1 | 0.0 | 0.0 | 0.0 | 6.6 | -9.3 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -28.4 | -22.9 | -35.2 | -31.3 | -25.7 | -32.9 | -26.5 | -40.8 | -36.3 | -29.8 | -37.8 | -30.5 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 9.8 | -10.0 | 0.0 | 0.0 | 0.0 | 11.4 | -11.7 | 0.0 | 0.0 | 0.0 | 13.1 | -13.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -22.8 | -22.9 | -35.2 | -31.3 | -25.7 | -26.4 | -26.5 | -40.8 | -36.3 | -29.8 | -30.3 | -30.5 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 13.1 | -10.9 | 0.0 | 0.0 | 0.0 | 15.2 | -12.7 | 0.0 | 0.0 | 0.0 | 17.4 | -14.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -18.3 | -22.9 | -35.2 | -31.3 | -25.7 | -21.2 | -26.5 | -40.8 | -36.3 | -29.8 | -24.3 | -30.5 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 14.4 | -10.9 | 0.0 | 0.0 | 0.0 | 16.7 | -12.7 | 0.0 | 0.0 | 0.0 | 19.2 | -14.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.6 | -22.9 | -35.2 | -31.3 | -25.7 | -12.3 | -26.5 | -40.8 | -36.3 | -29.8 | -14.1 | -30.5 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 17.2 | -10.9 | 0.0 | 0.0 | 0.0 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 7.4 | -14.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.0 | -22.9 | -35.2 | -31.3 | -25.7 | -6.9 | -26.5 | -40.8 | -36.3 | -29.8 | -7.9 | -30.5 | -46.8 | -41.7 | -34.2 |
|  |  | 2 | 17.2 | -10.9 | 0.0 | 0.0 | 0.0 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 23.0 | -14.6 | 0.0 | 0.0 | 0.0 |
| 15 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -33.1 | -29.5 | -24.2 | NA | NA | -38.4 | -34.2 | -28.1 | NA | NA | -44.1 | -39.3 | -32.2 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -32.5 | -22.1 | -33.1 | -29.5 | -24.2 | -37.7 | -25.6 | -38.4 | -34.2 | -28.1 | -43.2 | -29.4 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 4.7 | -6.6 | 0.0 | 0.0 | 0.0 | 5.4 | -7.6 | 0.0 | 0.0 | 0.0 | 6.2 | -8.8 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -26.7 | -21.5 | -33.1 | -29.5 | -24.2 | -31.0 | -25.0 | -38.4 | -34.2 | -28.1 | -35.5 | -28.7 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 9.2 | -9.5 | 0.0 | 0.0 | 0.0 | 10.7 | -11.0 | 0.0 | 0.0 | 0.0 | 12.3 | -12.6 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -21.4 | -21.5 | -33.1 | -29.5 | -24.2 | -24.8 | -25.0 | -38.4 | -34.2 | -28.1 | -28.5 | -28.7 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 12.3 | -10.3 | 0.0 | 0.0 | 0.0 | 14.3 | -11.9 | 0.0 | 0.0 | 0.0 | 16.4 | -13.7 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -17.2 | -21.5 | -33.1 | -29.5 | -24.2 | -19.9 | -25.0 | -38.4 | -34.2 | -28.1 | -22.9 | -28.7 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 13.6 | -10.3 | 0.0 | 0.0 | 0.0 | 15.7 | -11.9 | 0.0 | 0.0 | 0.0 | 18.1 | -13.7 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.0 | -21.5 | -33.1 | -29.5 | -24.2 | -11.5 | -25.0 | -38.4 | -34.2 | -28.1 | -13.3 | -28.7 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 16.2 | -10.3 | 0.0 | 0.0 | 0.0 | 18.8 | -11.9 | 0.0 | 0.0 | 0.0 | 6.9 | -13.7 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -5.6 | -21.5 | -33.1 | -29.5 | -24.2 | -6.5 | -25.0 | -38.4 | -34.2 | -28.1 | -7.5 | -28.7 | -44.1 | -39.3 | -32.2 |
|  |  | 2 | 16.2 | -10.3 | 0.0 | 0.0 | 0.0 | 18.8 | -11.9 | 0.0 | 0.0 | 0.0 | 21.6 | -13.7 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

> MWFRS - Roof $V=160-200 \mathrm{mph}$ $\mathrm{h}=15-40 \mathrm{ft}$.

| V (MPH) |  | Load Case | 160 |  |  |  |  | 180 |  |  |  |  | 200 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope |  |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 40 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -61.6 | -54.9 | -45.1 | NA | NA | -78.0 | -69.5 | -57.0 | NA | NA | -96.3 | -85.8 | -70.4 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -60.5 | -43.5 | -61.6 | -54.9 | -45.1 | -76.5 | -52.0 | -78.0 | -69.5 | -57.0 | -94.5 | -64.2 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 8.7 | -12.3 | 0.0 | 0.0 | 0.0 | 11.0 | -15.5 | 0.0 | 0.0 | 0.0 | 13.6 | -19.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -49.7 | -40.1 | -61.6 | -54.9 | -45.1 | -62.9 | -50.8 | -78.0 | -69.5 | -57.0 | -77.7 | -62.7 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 17.2 | -17.6 | 0.0 | 0.0 | 0.0 | 21.8 | -22.3 | 0.0 | 0.0 | 0.0 | 26.9 | -27.5 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -39.9 | -40.1 | -61.6 | -54.9 | -45.1 | -50.5 | -50.8 | -78.0 | -69.5 | -57.0 | -62.3 | -62.7 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 22.9 | -19.2 | 0.0 | 0.0 | 0.0 | 29.0 | -24.3 | 0.0 | 0.0 | 0.0 | 35.8 | -30.0 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -32.0 | -40.1 | -61.6 | -54.9 | -45.1 | -40.5 | -50.8 | -78.0 | -69.5 | -57.0 | -50.0 | -62.7 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 25.3 | -19.2 | 0.0 | 0.0 | 0.0 | 32.0 | -24.3 | 0.0 | 0.0 | 0.0 | 39.5 | -30.0 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -18.5 | -40.1 | -61.6 | -54.9 | -45.1 | -23.5 | -50.8 | -78.0 | -69.5 | -57.0 | -29.0 | -62.7 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 30.2 | -19.2 | 0.0 | 0.0 | 0.0 | 38.3 | -24.3 | 0.0 | 0.0 | 0.0 | 47.2 | -30.0 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -10.5 | -40.1 | -61.6 | -54.9 | -45.1 | -13.2 | -50.8 | -78.0 | -69.5 | -57.0 | -16.3 | -62.7 | -96.3 | -85.8 | -70.4 |
|  |  | 2 | 30.2 | -19.2 | 0.0 | 0.0 | 0.0 | 38.3 | -24.3 | 0.0 | 0.0 | 0.0 | 47.2 | -30.0 | 0.0 | 0.0 | 0.0 |
| 30 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -58.0 | -51.7 | -42.4 | NA | NA | -73.4 | -65.4 | -53.7 | NA | NA | -90.6 | -80.8 | -66.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -56.9 | -41.0 | -58.0 | -51.7 | -42.4 | -72.0 | -49.0 | -73.4 | -65.4 | -53.7 | -88.9 | -60.4 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 8.2 | -11.5 | 0.0 | 0.0 | 0.0 | 10.4 | -14.6 | 0.0 | 0.0 | 0.0 | 12.8 | -18.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -46.8 | -37.8 | -58.0 | -51.7 | -42.4 | -59.2 | -47.8 | -73.4 | -65.4 | -53.7 | -73.1 | -59.0 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 16.2 | -16.6 | 0.0 | 0.0 | 0.0 | 20.5 | -21.0 | 0.0 | 0.0 | 0.0 | 25.3 | -25.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -37.5 | -37.8 | -58.0 | -51.7 | -42.4 | -47.5 | -47.8 | -73.4 | -65.4 | -53.7 | -58.6 | -59.0 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 21.6 | -18.1 | 0.0 | 0.0 | 0.0 | 27.3 | -22.9 | 0.0 | 0.0 | 0.0 | 33.7 | -28.2 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -30.1 | -37.8 | -58.0 | -51.7 | -42.4 | -38.2 | -47.8 | -73.4 | -65.4 | -53.7 | -47.1 | -59.0 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 23.8 | -18.1 | 0.0 | 0.0 | 0.0 | 30.1 | -22.9 | 0.0 | 0.0 | 0.0 | 37.2 | -28.2 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -17.5 | -37.8 | -58.0 | -51.7 | -42.4 | -22.1 | -47.8 | -73.4 | -65.4 | -53.7 | -27.3 | -59.0 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 28.5 | -18.1 | 0.0 | 0.0 | 0.0 | 36.0 | -22.9 | 0.0 | 0.0 | 0.0 | 44.5 | -28.2 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -9.8 | -37.8 | -58.0 | -51.7 | -42.4 | -12.5 | -47.8 | -73.4 | -65.4 | -53.7 | -15.4 | -59.0 | -90.6 | -80.8 | -66.3 |
|  |  | 2 | 28.5 | -18.1 | 0.0 | 0.0 | 0.0 | 36.0 | -22.9 | 0.0 | 0.0 | 0.0 | 44.5 | -28.2 | 0.0 | 0.0 | 0.0 |
| 20 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -53.3 | -47.5 | -38.9 | NA | NA | -67.4 | -60.1 | -49.3 | NA | NA | -83.2 | -74.2 | -60.8 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -52.2 | -37.6 | -53.3 | -47.5 | -38.9 | -66.1 | -45.0 | -67.4 | -60.1 | -49.3 | -81.6 | -55.5 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 7.5 | -10.6 | 0.0 | 0.0 | 0.0 | 9.5 | -13.4 | 0.0 | 0.0 | 0.0 | 11.8 | -16.6 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -43.0 | -34.7 | -53.3 | -47.5 | -38.9 | -54.4 | -43.9 | -67.4 | -60.1 | -49.3 | -67.1 | -54.2 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 14.9 | -15.2 | 0.0 | 0.0 | 0.0 | 18.8 | -19.3 | 0.0 | 0.0 | 0.0 | 23.2 | -23.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -34.5 | -34.7 | -53.3 | -47.5 | -38.9 | -43.6 | -43.9 | -67.4 | -60.1 | -49.3 | -53.9 | -54.2 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 19.8 | -16.6 | 0.0 | 0.0 | 0.0 | 25.1 | -21.0 | 0.0 | 0.0 | 0.0 | 30.9 | -25.9 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -27.7 | -34.7 | -53.3 | -47.5 | -38.9 | -35.0 | -43.9 | -67.4 | -60.1 | -49.3 | -43.3 | -54.2 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 21.9 | -16.6 | 0.0 | 0.0 | 0.0 | 27.7 | -21.0 | 0.0 | 0.0 | 0.0 | 34.1 | -25.9 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -16.0 | -34.7 | -53.3 | -47.5 | -38.9 | -20.3 | -43.9 | -67.4 | -60.1 | -49.3 | -25.0 | -54.2 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 26.1 | -16.6 | 0.0 | 0.0 | 0.0 | 33.1 | -21.0 | 0.0 | 0.0 | 0.0 | 40.8 | -25.9 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -9.0 | -34.7 | -53.3 | -47.5 | -38.9 | -11.4 | -43.9 | -67.4 | -60.1 | -49.3 | -14.1 | -54.2 | -83.2 | -74.2 | -60.8 |
|  |  | 2 | 26.1 | -16.6 | 0.0 | 0.0 | 0.0 | 33.1 | -21.0 | 0.0 | 0.0 | 0.0 | 40.8 | -25.9 | 0.0 | 0.0 | 0.0 |
| 15 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -50.1 | -44.7 | -36.6 | NA | NA | -63.4 | -56.6 | -46.4 | NA | NA | -78.3 | -69.8 | -57.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -49.2 | -35.4 | -50.1 | -44.7 | -36.6 | -62.2 | -42.3 | -63.4 | -56.6 | -46.4 | -76.8 | -52.2 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 7.1 | -10.0 | 0.0 | 0.0 | 0.0 | 9.0 | -12.6 | 0.0 | 0.0 | 0.0 | 11.1 | -15.6 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -40.4 | -32.6 | -50.1 | -44.7 | -36.6 | -51.2 | -41.3 | -63.4 | -56.6 | -46.4 | -63.2 | -51.0 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 14.0 | -14.3 | 0.0 | 0.0 | 0.0 | 17.7 | -18.1 | 0.0 | 0.0 | 0.0 | 21.9 | -22.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -32.4 | -32.6 | -50.1 | -44.7 | -36.6 | -41.1 | -41.3 | -63.4 | -56.6 | -46.4 | -50.7 | -51.0 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 18.6 | -15.6 | 0.0 | 0.0 | 0.0 | 23.6 | -19.7 | 0.0 | 0.0 | 0.0 | 29.1 | -24.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -26.1 | -32.6 | -50.1 | -44.7 | -36.6 | -33.0 | -41.3 | -63.4 | -56.6 | -46.4 | -40.7 | -51.0 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 20.6 | -15.6 | 0.0 | 0.0 | 0.0 | 26.0 | -19.7 | 0.0 | 0.0 | 0.0 | 32.1 | -24.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -15.1 | -32.6 | -50.1 | -44.7 | -36.6 | -19.1 | -41.3 | -63.4 | -56.6 | -46.4 | -23.6 | -51.0 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 24.6 | -15.6 | 0.0 | 0.0 | 0.0 | 31.1 | -19.7 | 0.0 | 0.0 | 0.0 | 38.4 | -24.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.5 | -32.6 | -50.1 | -44.7 | -36.6 | -10.8 | -41.3 | -63.4 | -56.6 | -46.4 | -13.3 | -51.0 | -78.3 | -69.8 | -57.3 |
|  |  | 2 | 24.6 | -15.6 | 0.0 | 0.0 | 0.0 | 31.1 | -19.7 | 0.0 | 0.0 | 0.0 | 38.4 | -24.4 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

MWFRS - Roof $\mathrm{V}=\mathbf{1 1 0}-\mathbf{1 2 0} \mathbf{m p h}$ $\mathrm{h}=50-\mathbf{8 0} \mathrm{ft}$.

|  | V (MPH) |  | 110 |  |  |  |  | 115 |  |  |  |  | 120 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \end{gathered}$ | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |  |  |
| h (ft) |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 80 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -33.7 | -30.0 | -24.6 | NA | NA | -36.8 | -32.8 | -26.9 | NA | NA | -40.1 | -35.8 | -29.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -33.1 | -22.5 | -33.7 | -30.0 | -24.6 | -36.1 | -26.0 | -36.8 | -32.8 | -26.9 | -39.4 | -26.8 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 4.8 | -6.7 | 0.0 | 0.0 | 0.0 | 5.2 | -7.3 | 0.0 | 0.0 | 0.0 | 5.7 | -8.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -27.2 | -21.9 | -33.7 | -30.0 | -24.6 | -29.7 | -24.0 | -36.8 | -32.8 | -26.9 | -32.4 | -26.1 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 9.4 | -9.6 | 0.0 | 0.0 | 0.0 | 10.3 | -10.5 | 0.0 | 0.0 | 0.0 | 11.2 | -11.5 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -21.8 | -21.9 | -33.7 | -30.0 | -24.6 | -23.8 | -24.0 | -36.8 | -32.8 | -26.9 | -26.0 | -26.1 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 12.5 | -10.5 | 0.0 | 0.0 | 0.0 | 13.7 | -11.5 | 0.0 | 0.0 | 0.0 | 14.9 | -12.5 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -17.5 | -21.9 | -33.7 | -30.0 | -24.6 | -19.1 | -24.0 | -36.8 | -32.8 | -26.9 | -20.8 | -26.1 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 13.8 | -10.5 | 0.0 | 0.0 | 0.0 | 15.1 | -11.5 | 0.0 | 0.0 | 0.0 | 16.5 | -12.5 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.1 | -21.9 | -33.7 | -30.0 | -24.6 | -11.1 | -24.0 | -36.8 | -32.8 | -26.9 | -12.1 | -26.1 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 16.5 | -10.5 | 0.0 | 0.0 | 0.0 | 18.1 | -11.5 | 0.0 | 0.0 | 0.0 | 19.7 | -12.5 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -5.7 | -21.9 | -33.7 | -30.0 | -24.6 | -6.3 | -24.0 | -36.8 | -32.8 | -26.9 | -6.8 | -26.1 | -40.1 | -35.8 | -29.3 |
|  |  | 2 | 16.5 | -10.5 | 0.0 | 0.0 | 0.0 | 18.1 | -11.5 | 0.0 | 0.0 | 0.0 | 19.7 | -12.5 | 0.0 | 0.0 | 0.0 |
| 70 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -32.8 | -29.2 | -24.0 | NA | NA | -35.8 | -31.9 | -26.2 | NA | NA | -39.0 | -34.8 | -28.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -32.1 | -21.9 | -32.8 | -29.2 | -24.0 | -35.1 | -25.3 | -35.8 | -31.9 | -26.2 | -38.3 | -26.0 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 4.6 | -6.5 | 0.0 | 0.0 | 0.0 | 5.1 | -7.1 | 0.0 | 0.0 | 0.0 | 5.5 | -7.8 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -26.4 | -21.3 | -32.8 | -29.2 | -24.0 | -28.9 | -23.3 | -35.8 | -31.9 | -26.2 | -31.5 | -25.4 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 9.2 | -9.4 | 0.0 | 0.0 | 0.0 | 10.0 | -10.2 | 0.0 | 0.0 | 0.0 | 10.9 | -11.1 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -21.2 | -21.3 | -32.8 | -29.2 | -24.0 | -23.2 | -23.3 | -35.8 | -31.9 | -26.2 | -25.2 | -25.4 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 12.2 | -10.2 | 0.0 | 0.0 | 0.0 | 13.3 | -11.1 | 0.0 | 0.0 | 0.0 | 14.5 | -12.1 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -17.0 | -21.3 | -32.8 | -29.2 | -24.0 | -18.6 | -23.3 | -35.8 | -31.9 | -26.2 | -20.3 | -25.4 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 13.4 | -10.2 | 0.0 | 0.0 | 0.0 | 14.7 | -11.1 | 0.0 | 0.0 | 0.0 | 16.0 | -12.1 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -9.9 | -21.3 | -32.8 | -29.2 | -24.0 | -10.8 | -23.3 | -35.8 | -31.9 | -26.2 | -11.7 | -25.4 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 16.1 | -10.2 | 0.0 | 0.0 | 0.0 | 17.6 | -11.1 | 0.0 | 0.0 | 0.0 | 19.1 | -12.1 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -5.6 | -21.3 | -32.8 | -29.2 | -24.0 | -6.1 | -23.3 | -35.8 | -31.9 | -26.2 | -6.6 | -25.4 | -39.0 | -34.8 | -28.5 |
|  |  | 2 | 16.1 | -10.2 | 0.0 | 0.0 | 0.0 | 17.6 | -11.1 | 0.0 | 0.0 | 0.0 | 19.1 | -12.1 | 0.0 | 0.0 | 0.0 |
| 60 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -31.7 | -28.3 | -23.2 | NA | NA | -34.7 | -30.9 | -25.3 | NA | NA | -37.8 | -33.7 | -27.6 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -31.1 | -21.2 | -31.7 | -28.3 | -23.2 | -34.0 | -24.5 | -34.7 | -30.9 | -25.3 | -37.0 | -25.2 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 4.5 | -6.3 | 0.0 | 0.0 | 0.0 | 4.9 | -6.9 | 0.0 | 0.0 | 0.0 | 5.3 | -7.5 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -25.6 | -20.6 | -31.7 | -28.3 | -23.2 | -28.0 | -22.6 | -34.7 | -30.9 | -25.3 | -30.4 | -24.6 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 8.9 | -9.1 | 0.0 | 0.0 | 0.0 | 9.7 | -9.9 | 0.0 | 0.0 | 0.0 | 10.5 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -20.5 | -20.6 | -31.7 | -28.3 | -23.2 | -22.4 | -22.6 | -34.7 | -30.9 | -25.3 | -24.4 | -24.6 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 11.8 | -9.9 | 0.0 | 0.0 | 0.0 | 12.9 | -10.8 | 0.0 | 0.0 | 0.0 | 14.0 | -11.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -16.5 | -20.6 | -31.7 | -28.3 | -23.2 | -18.0 | -22.6 | -34.7 | -30.9 | -25.3 | -19.6 | -24.6 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 13.0 | -9.9 | 0.0 | 0.0 | 0.0 | 14.2 | -10.8 | 0.0 | 0.0 | 0.0 | 15.5 | -11.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -9.5 | -20.6 | -31.7 | -28.3 | -23.2 | -10.4 | -22.6 | -34.7 | -30.9 | -25.3 | -11.4 | -24.6 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 15.6 | -9.9 | 0.0 | 0.0 | 0.0 | 17.0 | -10.8 | 0.0 | 0.0 | 0.0 | 18.5 | -11.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -5.4 | -20.6 | -31.7 | -28.3 | -23.2 | -5.9 | -22.6 | -34.7 | -30.9 | -25.3 | -6.4 | -24.6 | -37.8 | -33.7 | -27.6 |
|  |  | 2 | 15.6 | -9.9 | 0.0 | 0.0 | 0.0 | 17.0 | -10.8 | 0.0 | 0.0 | 0.0 | 18.5 | -11.8 | 0.0 | 0.0 | 0.0 |
| 50 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -30.5 | -27.2 | -22.3 | NA | NA | -33.4 | -29.7 | -24.4 | NA | NA | -36.3 | -32.4 | -26.6 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -30.0 | -20.4 | -30.5 | -27.2 | -22.3 | -32.7 | -23.6 | -33.4 | -29.7 | -24.4 | -35.6 | -24.2 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 4.3 | -6.1 | 0.0 | 0.0 | 0.0 | 4.7 | -6.6 | 0.0 | 0.0 | 0.0 | 5.1 | -7.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -24.6 | -19.9 | -30.5 | -27.2 | -22.3 | -26.9 | -21.7 | -33.4 | -29.7 | -24.4 | -29.3 | -23.6 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 8.5 | -8.7 | 0.0 | 0.0 | 0.0 | 9.3 | -9.5 | 0.0 | 0.0 | 0.0 | 10.1 | -10.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -19.8 | -19.9 | -30.5 | -27.2 | -22.3 | -21.6 | -21.7 | -33.4 | -29.7 | -24.4 | -23.5 | -23.6 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 11.3 | -9.5 | 0.0 | 0.0 | 0.0 | 12.4 | -10.4 | 0.0 | 0.0 | 0.0 | 13.5 | -11.3 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -15.9 | -19.9 | -30.5 | -27.2 | -22.3 | -17.3 | -21.7 | -33.4 | -29.7 | -24.4 | -18.9 | -23.6 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 12.5 | -9.5 | 0.0 | 0.0 | 0.0 | 13.7 | -10.4 | 0.0 | 0.0 | 0.0 | 14.9 | -11.3 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -9.2 | -19.9 | -30.5 | -27.2 | -22.3 | -10.0 | -21.7 | -33.4 | -29.7 | -24.4 | -10.9 | -23.6 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 15.0 | -9.5 | 0.0 | 0.0 | 0.0 | 16.4 | -10.4 | 0.0 | 0.0 | 0.0 | 17.8 | -11.3 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) |  | -5.2 | -19.9 | -30.5 | -27.2 | -22.3 | -5.7 | -21.7 | -33.4 | -29.7 | -24.4 | -6.2 | -23.6 | -36.3 | -32.4 | -26.6 |
|  |  | 2 | 15.0 | -9.5 | 0.0 | 0.0 | 0.0 | 16.4 | -10.4 | 0.0 | 0.0 | 0.0 | 17.8 | -11.3 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

$$
\begin{aligned}
& \text { MWFRS - Roof } \\
& \text { V = 130-150 } \mathbf{~ m p h} \\
& \mathrm{h}=50-80 \mathrm{ft} .
\end{aligned}
$$

|  | V (MPH) |  | 130 |  |  |  |  | 140 |  |  |  |  | 150 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Roof Slope | Load Case | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |  |  |
| h (ft) |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 80 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -47.1 | -42.0 | -34.4 | NA | NA | -54.6 | -48.7 | -39.9 | NA | NA | -62.7 | -55.9 | -45.8 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -46.2 | -31.4 | -47.1 | -42.0 | -34.4 | -53.6 | -36.4 | -54.6 | -48.7 | -39.9 | -61.5 | -41.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 6.7 | -9.4 | 0.0 | 0.0 | 0.0 | 7.7 | -10.9 | 0.0 | 0.0 | 0.0 | 8.9 | -12.5 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -38.0 | -30.6 | -47.1 | -42.0 | -34.4 | -44.0 | -35.5 | -54.6 | -48.7 | -39.9 | -50.5 | -40.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 13.1 | -13.5 | 0.0 | 0.0 | 0.0 | 15.2 | -15.6 | 0.0 | 0.0 | 0.0 | 17.5 | -17.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -30.5 | -30.6 | -47.1 | -42.0 | -34.4 | -35.3 | -35.5 | -54.6 | -48.7 | -39.9 | -40.6 | -40.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 17.5 | -14.7 | 0.0 | 0.0 | 0.0 | 20.3 | -17.0 | 0.0 | 0.0 | 0.0 | 23.3 | -19.5 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -24.5 | -30.6 | -47.1 | -42.0 | -34.4 | -28.4 | -35.5 | -54.6 | -48.7 | -39.9 | -32.6 | -40.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 19.3 | -14.7 | 0.0 | 0.0 | 0.0 | 22.4 | -17.0 | 0.0 | 0.0 | 0.0 | 25.7 | -19.5 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -14.2 | -30.6 | -47.1 | -42.0 | -34.4 | -16.4 | -35.5 | -54.6 | -48.7 | -39.9 | -18.9 | -40.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 23.1 | -14.7 | 0.0 | 0.0 | 0.0 | 26.8 | -17.0 | 0.0 | 0.0 | 0.0 | 9.9 | -19.5 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.0 | -30.6 | -47.1 | -42.0 | -34.4 | -9.3 | -35.5 | -54.6 | -48.7 | -39.9 | -10.6 | -40.8 | -62.7 | -55.9 | -45.8 |
|  |  | 2 | 23.1 | -14.7 | 0.0 | 0.0 | 0.0 | 26.8 | -17.0 | 0.0 | 0.0 | 0.0 | 30.7 | -19.5 | 0.0 | 0.0 | 0.0 |
| 70 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -45.8 | -40.8 | -33.5 | NA | NA | -53.1 | -47.3 | -38.8 | NA | NA | -60.9 | -54.3 | -44.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -44.9 | -30.5 | -45.8 | -40.8 | -33.5 | -52.1 | -35.4 | -53.1 | -47.3 | -38.8 | -59.8 | -40.6 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 6.5 | -9.1 | 0.0 | 0.0 | 0.0 | 7.5 | -10.6 | 0.0 | 0.0 | 0.0 | 8.6 | -12.1 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -36.9 | -29.8 | -45.8 | -40.8 | -33.5 | -42.8 | -34.6 | -53.1 | -47.3 | -38.8 | -49.1 | -39.7 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 12.8 | -13.1 | 0.0 | 0.0 | 0.0 | 14.8 | -15.2 | 0.0 | 0.0 | 0.0 | 17.0 | -17.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -29.6 | -29.8 | -45.8 | -40.8 | -33.5 | -34.4 | -34.6 | -53.1 | -47.3 | -38.8 | -39.4 | -39.7 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 17.0 | -14.2 | 0.0 | 0.0 | 0.0 | 19.7 | -16.5 | 0.0 | 0.0 | 0.0 | 22.6 | -19.0 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -23.8 | -29.8 | -45.8 | -40.8 | -33.5 | -27.6 | -34.6 | -53.1 | -47.3 | -38.8 | -31.7 | -39.7 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 18.8 | -14.2 | 0.0 | 0.0 | 0.0 | 21.8 | -16.5 | 0.0 | 0.0 | 0.0 | 25.0 | -19.0 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -13.8 | -29.8 | -45.8 | -40.8 | -33.5 | -16.0 | -34.6 | -53.1 | -47.3 | -38.8 | -18.3 | -39.7 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 22.5 | -14.2 | 0.0 | 0.0 | 0.0 | 26.0 | -16.5 | 0.0 | 0.0 | 0.0 | 9.6 | -19.0 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -7.8 | -29.8 | -45.8 | -40.8 | -33.5 | -9.0 | -34.6 | -53.1 | -47.3 | -38.8 | -10.3 | -39.7 | -60.9 | -54.3 | -44.5 |
|  |  | 2 | 22.5 | -14.2 | 0.0 | 0.0 | 0.0 | 26.0 | -16.5 | 0.0 | 0.0 | 0.0 | 29.9 | -19.0 | 0.0 | 0.0 | 0.0 |
| 60 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -44.3 | -39.5 | -32.4 | NA | NA | -51.4 | -45.8 | -37.6 | NA | NA | -59.0 | -52.6 | -43.1 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -43.5 | -29.6 | -44.3 | -39.5 | -32.4 | -50.4 | -34.3 | -51.4 | -45.8 | -37.6 | -57.9 | -39.3 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 6.3 | -8.8 | 0.0 | 0.0 | 0.0 | 7.3 | -10.2 | 0.0 | 0.0 | 0.0 | 8.3 | -11.7 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -35.7 | -28.8 | -44.3 | -39.5 | -32.4 | -41.4 | -33.4 | -51.4 | -45.8 | -37.6 | -47.6 | -38.4 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 12.4 | -12.7 | 0.0 | 0.0 | 0.0 | 14.3 | -14.7 | 0.0 | 0.0 | 0.0 | 16.5 | -16.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -28.7 | -28.8 | -44.3 | -39.5 | -32.4 | -33.3 | -33.4 | -51.4 | -45.8 | -37.6 | -38.2 | -38.4 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 16.5 | -13.8 | 0.0 | 0.0 | 0.0 | 19.1 | -16.0 | 0.0 | 0.0 | 0.0 | 21.9 | -18.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -23.0 | -28.8 | -44.3 | -39.5 | -32.4 | -26.7 | -33.4 | -51.4 | -45.8 | -37.6 | -30.7 | -38.4 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 18.2 | -13.8 | 0.0 | 0.0 | 0.0 | 21.1 | -16.0 | 0.0 | 0.0 | 0.0 | 24.2 | -18.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -13.3 | -28.8 | -44.3 | -39.5 | -32.4 | -15.5 | -33.4 | -51.4 | -45.8 | -37.6 | -17.8 | -38.4 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 21.7 | -13.8 | 0.0 | 0.0 | 0.0 | 25.2 | -16.0 | 0.0 | 0.0 | 0.0 | 9.3 | -18.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -7.5 | -28.8 | -44.3 | -39.5 | -32.4 | -8.7 | -33.4 | -51.4 | -45.8 | -37.6 | -10.0 | -38.4 | -59.0 | -52.6 | -43.1 |
|  |  | 2 | 21.7 | -13.8 | 0.0 | 0.0 | 0.0 | 25.2 | -16.0 | 0.0 | 0.0 | 0.0 | 28.9 | -18.4 | 0.0 | 0.0 | 0.0 |
| 50 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -42.6 | -38.0 | -31.2 | NA | NA | -49.4 | -44.1 | -36.2 | NA | NA | -56.8 | -50.6 | -41.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -41.8 | -28.4 | -42.6 | -38.0 | -31.2 | -48.5 | -33.0 | -49.4 | -44.1 | -36.2 | -55.7 | -37.9 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 6.0 | -8.5 | 0.0 | 0.0 | 0.0 | 7.0 | -9.8 | 0.0 | 0.0 | 0.0 | 8.0 | -11.3 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -34.4 | -27.8 | -42.6 | -38.0 | -31.2 | -39.9 | -32.2 | -49.4 | -44.1 | -36.2 | -45.8 | -37.0 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 11.9 | -12.2 | 0.0 | 0.0 | 0.0 | 13.8 | -14.1 | 0.0 | 0.0 | 0.0 | 15.9 | -16.2 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -27.6 | -27.8 | -42.6 | -38.0 | -31.2 | -32.0 | -32.2 | -49.4 | -44.1 | -36.2 | -36.7 | -37.0 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 15.8 | -13.3 | 0.0 | 0.0 | 0.0 | 18.4 | -15.4 | 0.0 | 0.0 | 0.0 | 21.1 | -17.7 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -22.2 | -27.8 | -42.6 | -38.0 | -31.2 | -25.7 | -32.2 | -49.4 | -44.1 | -36.2 | -29.5 | -37.0 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 17.5 | -13.3 | 0.0 | 0.0 | 0.0 | 20.3 | -15.4 | 0.0 | 0.0 | 0.0 | 23.3 | -17.7 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -12.8 | -27.8 | -42.6 | -38.0 | -31.2 | -14.9 | -32.2 | -49.4 | -44.1 | -36.2 | -17.1 | -37.0 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 20.9 | -13.3 | 0.0 | 0.0 | 0.0 | 24.3 | -15.4 | 0.0 | 0.0 | 0.0 | 8.9 | -17.7 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -7.2 | -27.8 | -42.6 | -38.0 | -31.2 | -8.4 | -32.2 | -49.4 | -44.1 | -36.2 | -9.6 | -37.0 | -56.8 | -50.6 | -41.5 |
|  |  | 2 | 20.9 | -13.3 | 0.0 | 0.0 | 0.0 | 24.3 | -15.4 | 0.0 | 0.0 | 0.0 | 27.8 | -17.7 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

$$
\begin{aligned}
& \text { MWFRS }- \text { Roof } \\
& V=160-200 \mathrm{mph} \\
& \mathrm{~h}=50-80 \mathrm{ft} .
\end{aligned}
$$

|  | V (MPH) |  | 160 |  |  |  |  | 180 |  |  |  |  | 200 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope | $\begin{array}{\|c} \hline \text { Load } \\ \text { Case } \\ \hline \end{array}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 80 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -71.3 | -63.6 | -52.1 | NA | NA | -90.2 | -80.5 | -66.0 | NA | NA | -111.4 | -99.3 | -81.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -70.0 | -50.4 | -71.3 | -63.6 | -52.1 | -88.5 | -60.2 | -90.2 | -80.5 | -66.0 | -109.3 | -74.3 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 10.1 | -14.2 | 0.0 | 0.0 | 0.0 | 12.8 | -18.0 | 0.0 | 0.0 | 0.0 | 15.8 | -22.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -57.5 | -46.4 | -71.3 | -63.6 | -52.1 | -72.8 | -58.7 | -90.2 | -80.5 | -66.0 | -89.9 | -72.5 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 19.9 | -20.4 | 0.0 | 0.0 | 0.0 | 25.2 | -25.8 | 0.0 | 0.0 | 0.0 | 31.1 | -31.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -46.1 | -46.4 | -71.3 | -63.6 | -52.1 | -58.4 | -58.7 | -90.2 | -80.5 | -66.0 | -72.1 | -72.5 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 26.5 | -22.2 | 0.0 | 0.0 | 0.0 | 33.5 | -28.1 | 0.0 | 0.0 | 0.0 | 41.4 | -34.7 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -37.1 | -46.4 | -71.3 | -63.6 | -52.1 | -46.9 | -58.7 | -90.2 | -80.5 | -66.0 | -57.9 | -72.5 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 29.3 | -22.2 | 0.0 | 0.0 | 0.0 | 37.0 | -28.1 | 0.0 | 0.0 | 0.0 | 45.7 | -34.7 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -21.5 | -46.4 | -71.3 | -63.6 | -52.1 | -27.2 | -58.7 | -90.2 | -80.5 | -66.0 | -33.5 | -72.5 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 35.0 | -22.2 | 0.0 | 0.0 | 0.0 | 44.3 | -28.1 | 0.0 | 0.0 | 0.0 | 54.7 | -34.7 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -12.1 | -46.4 | -71.3 | -63.6 | -52.1 | -15.3 | -58.7 | -90.2 | -80.5 | -66.0 | -18.9 | -72.5 | -111.4 | -99.3 | -81.5 |
|  |  | 2 | 35.0 | -22.2 | 0.0 | 0.0 | 0.0 | 44.3 | -28.1 | 0.0 | 0.0 | 0.0 | 54.7 | -34.7 | 0.0 | 0.0 | 0.0 |
| 70 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -69.3 | -61.8 | -50.7 | NA | NA | -87.7 | -78.2 | -64.2 | NA | NA | -108.3 | -96.6 | -79.2 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -68.0 | -49.0 | -69.3 | -61.8 | -50.7 | -86.1 | -58.5 | -87.7 | -78.2 | -64.2 | -106.3 | -72.2 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 9.8 | -13.8 | 0.0 | 0.0 | 0.0 | 12.4 | -17.5 | 0.0 | 0.0 | 0.0 | 15.3 | -21.6 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -55.9 | -45.1 | -69.3 | -61.8 | -50.7 | -70.8 | -57.1 | -87.7 | -78.2 | -64.2 | -87.4 | -70.5 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 19.4 | -19.8 | 0.0 | 0.0 | 0.0 | 24.5 | -25.1 | 0.0 | 0.0 | 0.0 | 30.2 | -31.0 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -44.9 | -45.1 | -69.3 | -61.8 | -50.7 | -56.8 | -57.1 | -87.7 | -78.2 | -64.2 | -70.1 | -70.5 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 25.8 | -21.6 | 0.0 | 0.0 | 0.0 | 32.6 | -27.3 | 0.0 | 0.0 | 0.0 | 40.3 | -33.7 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -36.0 | -45.1 | -69.3 | -61.8 | -50.7 | -45.6 | -57.1 | -87.7 | -78.2 | -64.2 | -56.3 | -70.5 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 28.4 | -21.6 | 0.0 | 0.0 | 0.0 | 36.0 | -27.3 | 0.0 | 0.0 | 0.0 | 44.5 | -33.7 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -20.9 | -45.1 | -69.3 | -61.8 | -50.7 | -26.4 | -57.1 | -87.7 | -78.2 | -64.2 | -32.6 | -70.5 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 34.0 | -21.6 | 0.0 | 0.0 | 0.0 | 43.0 | -27.3 | 0.0 | 0.0 | 0.0 | 53.1 | -33.7 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -11.8 | -45.1 | -69.3 | -61.8 | -50.7 | -14.9 | -57.1 | -87.7 | -78.2 | -64.2 | -18.4 | -70.5 | -108.3 | -96.6 | -79.2 |
|  |  | 2 | 34.0 | -21.6 | 0.0 | 0.0 | 0.0 | 43.0 | -27.3 | 0.0 | 0.0 | 0.0 | 53.1 | -33.7 | 0.0 | 0.0 | 0.0 |
| 60 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -67.1 | -59.8 | -49.1 | NA | NA | -84.9 | -75.7 | -62.1 | NA | NA | -104.9 | -93.5 | -76.7 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -65.8 | -47.4 | -67.1 | -59.8 | -49.1 | -83.3 | -56.7 | -84.9 | -75.7 | -62.1 | -102.9 | -69.9 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 9.5 | -13.4 | 0.0 | 0.0 | 0.0 | 12.0 | -16.9 | 0.0 | 0.0 | 0.0 | 14.8 | -20.9 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -54.1 | -43.7 | -67.1 | -59.8 | -49.1 | -68.5 | -55.3 | -84.9 | -75.7 | -62.1 | -84.6 | -68.3 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 18.7 | -19.2 | 0.0 | 0.0 | 0.0 | 23.7 | -24.3 | 0.0 | 0.0 | 0.0 | 29.3 | -30.0 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -43.4 | -43.7 | -67.1 | -59.8 | -49.1 | -55.0 | -55.3 | -84.9 | -75.7 | -62.1 | -67.9 | -68.3 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 24.9 | -20.9 | 0.0 | 0.0 | 0.0 | 31.6 | -26.4 | 0.0 | 0.0 | 0.0 | 39.0 | -32.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -34.9 | -43.7 | -67.1 | -59.8 | -49.1 | -44.2 | -55.3 | -84.9 | -75.7 | -62.1 | -54.5 | -68.3 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 27.5 | -20.9 | 0.0 | 0.0 | 0.0 | 34.9 | -26.4 | 0.0 | 0.0 | 0.0 | 43.0 | -32.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -20.2 | -43.7 | -67.1 | -59.8 | -49.1 | -25.6 | -55.3 | -84.9 | -75.7 | -62.1 | -31.6 | -68.3 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 32.9 | -20.9 | 0.0 | 0.0 | 0.0 | 41.7 | -26.4 | 0.0 | 0.0 | 0.0 | 51.4 | -32.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -11.4 | -43.7 | -67.1 | -59.8 | -49.1 | -14.4 | -55.3 | -84.9 | -75.7 | -62.1 | -17.8 | -68.3 | -104.9 | -93.5 | -76.7 |
|  |  | 2 | 32.9 | -20.9 | 0.0 | 0.0 | 0.0 | 41.7 | -26.4 | 0.0 | 0.0 | 0.0 | 51.4 | -32.6 | 0.0 | 0.0 | 0.0 |
| 50 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -64.6 | -57.6 | -47.2 | NA | NA | -81.7 | -72.9 | -59.8 | NA | NA | -100.9 | -90.0 | -73.8 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -63.4 | -45.6 | -64.6 | -57.6 | -47.2 | -80.2 | -54.5 | -81.7 | -72.9 | -59.8 | -99.0 | -67.3 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 9.1 | -12.9 | 0.0 | 0.0 | 0.0 | 11.6 | -16.3 | 0.0 | 0.0 | 0.0 | 14.3 | -20.1 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -52.1 | -42.0 | -64.6 | -57.6 | -47.2 | -65.9 | -53.2 | -81.7 | -72.9 | -59.8 | -81.4 | -65.7 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 18.0 | -18.5 | 0.0 | 0.0 | 0.0 | 22.8 | -23.4 | 0.0 | 0.0 | 0.0 | 28.2 | -28.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -41.8 | -42.0 | -64.6 | -57.6 | -47.2 | -52.9 | -53.2 | -81.7 | -72.9 | -59.8 | -65.3 | -65.7 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 24.0 | -20.1 | 0.0 | 0.0 | 0.0 | 30.4 | -25.4 | 0.0 | 0.0 | 0.0 | 37.5 | -31.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -33.6 | -42.0 | -64.6 | -57.6 | -47.2 | -42.5 | -53.2 | -81.7 | -72.9 | -59.8 | -52.5 | -65.7 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 26.5 | -20.1 | 0.0 | 0.0 | 0.0 | 33.5 | -25.4 | 0.0 | 0.0 | 0.0 | 41.4 | -31.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -19.4 | -42.0 | -64.6 | -57.6 | -47.2 | -24.6 | -53.2 | -81.7 | -72.9 | -59.8 | -30.4 | -65.7 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 31.7 | -20.1 | 0.0 | 0.0 | 0.0 | 40.1 | -25.4 | 0.0 | 0.0 | 0.0 | 49.5 | -31.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -11.0 | -42.0 | -64.6 | -57.6 | -47.2 | -13.9 | -53.2 | -81.7 | -72.9 | -59.8 | -17.1 | -65.7 | -100.9 | -90.0 | -73.8 |
|  |  | 2 | 31.7 | -20.1 | 0.0 | 0.0 | 0.0 | 40.1 | -25.4 | 0.0 | 0.0 | 0.0 | 49.5 | -31.4 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

> MWFRS - Roof
> $V=110-120 \mathrm{mph}$ $\mathrm{h}=90-120 \mathrm{ft}$.

|  | V (MPH) |  | 110 |  |  |  |  | 115 |  |  |  |  | 120 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \\ \hline \end{gathered}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 120 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -36.7 | -32.7 | -26.8 | NA | NA | -40.1 | -35.8 | -29.3 | NA | NA | -43.7 | -38.9 | -31.9 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -36.0 | -24.5 | -36.7 | -32.7 | -26.8 | -39.4 | -28.3 | -40.1 | -35.8 | -29.3 | -42.9 | -29.1 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 5.2 | -7.3 | 0.0 | 0.0 | 0.0 | 5.7 | -8.0 | 0.0 | 0.0 | 0.0 | 6.2 | -8.7 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -29.6 | -23.9 | -36.7 | -32.7 | -26.8 | -32.4 | -26.1 | -40.1 | -35.8 | -29.3 | -35.2 | -28.4 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 10.2 | -10.5 | 0.0 | 0.0 | 0.0 | 11.2 | -11.5 | 0.0 | 0.0 | 0.0 | 12.2 | -12.5 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -23.8 | -23.9 | -36.7 | -32.7 | -26.8 | -26.0 | -26.1 | -40.1 | -35.8 | -29.3 | -28.3 | -28.4 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 13.6 | -11.4 | 0.0 | 0.0 | 0.0 | 14.9 | -12.5 | 0.0 | 0.0 | 0.0 | 16.2 | -13.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -19.1 | -23.9 | -36.7 | -32.7 | -26.8 | -20.9 | -26.1 | -40.1 | -35.8 | -29.3 | -22.7 | -28.4 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 15.1 | -11.4 | 0.0 | 0.0 | 0.0 | 16.5 | -12.5 | 0.0 | 0.0 | 0.0 | 17.9 | -13.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.0 | -23.9 | -36.7 | -32.7 | -26.8 | -12.1 | -26.1 | -40.1 | -35.8 | -29.3 | -13.1 | -28.4 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 18.0 | -11.4 | 0.0 | 0.0 | 0.0 | 19.7 | -12.5 | 0.0 | 0.0 | 0.0 | 21.4 | -13.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.2 | -23.9 | -36.7 | -32.7 | -26.8 | -6.8 | -26.1 | -40.1 | -35.8 | -29.3 | -7.4 | -28.4 | -43.7 | -38.9 | -31.9 |
|  |  | 2 | 18.0 | -11.4 | 0.0 | 0.0 | 0.0 | 19.7 | -12.5 | 0.0 | 0.0 | 0.0 | 21.4 | -13.6 | 0.0 | 0.0 | 0.0 |
| 110 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -36.0 | -32.1 | -26.3 | NA | NA | -39.4 | -35.1 | -28.8 | NA | NA | -42.9 | -38.2 | -31.4 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -35.4 | -24.0 | -36.0 | -32.1 | -26.3 | -38.6 | -27.8 | -39.4 | -35.1 | -28.8 | -42.1 | -28.6 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 5.1 | -7.2 | 0.0 | 0.0 | 0.0 | 5.6 | -7.8 | 0.0 | 0.0 | 0.0 | 6.1 | -8.5 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -29.1 | -23.5 | -36.0 | -32.1 | -26.3 | -31.8 | -25.6 | -39.4 | -35.1 | -28.8 | -34.6 | -27.9 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 10.1 | -10.3 | 0.0 | 0.0 | 0.0 | 11.0 | -11.3 | 0.0 | 0.0 | 0.0 | 12.0 | -12.3 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -23.3 | -23.5 | -36.0 | -32.1 | -26.3 | -25.5 | -25.6 | -39.4 | -35.1 | -28.8 | -27.8 | -27.9 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 13.4 | -11.2 | 0.0 | 0.0 | 0.0 | 14.6 | -12.3 | 0.0 | 0.0 | 0.0 | 15.9 | -13.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -18.7 | -23.5 | -36.0 | -32.1 | -26.3 | -20.5 | -25.6 | -39.4 | -35.1 | -28.8 | -22.3 | -27.9 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 14.8 | -11.2 | 0.0 | 0.0 | 0.0 | 16.2 | -12.3 | 0.0 | 0.0 | 0.0 | 17.6 | -13.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.8 | -23.5 | -36.0 | -32.1 | -26.3 | -11.9 | -25.6 | -39.4 | -35.1 | -28.8 | -12.9 | -27.9 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 17.7 | -11.2 | 0.0 | 0.0 | 0.0 | 19.3 | -12.3 | 0.0 | 0.0 | 0.0 | 21.0 | -13.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.1 | -23.5 | -36.0 | -32.1 | -26.3 | -6.7 | -25.6 | -39.4 | -35.1 | -28.8 | -7.3 | -27.9 | -42.9 | -38.2 | -31.4 |
|  |  | 2 | 17.7 | -11.2 | 0.0 | 0.0 | 0.0 | 19.3 | -12.3 | 0.0 | 0.0 | 0.0 | 21.0 | -13.4 | 0.0 | 0.0 | 0.0 |
| 100 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -35.3 | -31.5 | -25.8 | NA | NA | -38.6 | -34.4 | -28.2 | NA | NA | -42.0 | -37.5 | -30.7 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -34.7 | -23.6 | -35.3 | -31.5 | -25.8 | -37.9 | -27.3 | -38.6 | -34.4 | -28.2 | -41.2 | -28.0 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 5.0 | -7.0 | 0.0 | 0.0 | 0.0 | 5.5 | -7.7 | 0.0 | 0.0 | 0.0 | 5.9 | -8.4 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -28.5 | -23.0 | -35.3 | -31.5 | -25.8 | -31.1 | -25.1 | -38.6 | -34.4 | -28.2 | -33.9 | -27.4 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 9.9 | -10.1 | 0.0 | 0.0 | 0.0 | 10.8 | -11.0 | 0.0 | 0.0 | 0.0 | 11.7 | -12.0 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -22.9 | -23.0 | -35.3 | -31.5 | -25.8 | -25.0 | -25.1 | -38.6 | -34.4 | -28.2 | -27.2 | -27.4 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 13.1 | -11.0 | 0.0 | 0.0 | 0.0 | 14.4 | -12.0 | 0.0 | 0.0 | 0.0 | 15.6 | -13.1 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -18.4 | -23.0 | -35.3 | -31.5 | -25.8 | -20.1 | -25.1 | -38.6 | -34.4 | -28.2 | -21.9 | -27.4 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 14.5 | -11.0 | 0.0 | 0.0 | 0.0 | 15.8 | -12.0 | 0.0 | 0.0 | 0.0 | 17.3 | -13.1 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.6 | -23.0 | -35.3 | -31.5 | -25.8 | -11.6 | -25.1 | -38.6 | -34.4 | -28.2 | -12.7 | -27.4 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 17.3 | -11.0 | 0.0 | 0.0 | 0.0 | 18.9 | -12.0 | 0.0 | 0.0 | 0.0 | 20.6 | -13.1 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.0 | -23.0 | -35.3 | -31.5 | -25.8 | -6.6 | -25.1 | -38.6 | -34.4 | -28.2 | -7.1 | -27.4 | -42.0 | -37.5 | -30.7 |
|  |  | 2 | 17.3 | -11.0 | 0.0 | 0.0 | 0.0 | 18.9 | -12.0 | 0.0 | 0.0 | 0.0 | 20.6 | -13.1 | 0.0 | 0.0 | 0.0 |
| 90 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -34.5 | -30.8 | -25.3 | NA | NA | -37.8 | -33.7 | -27.6 | NA | NA | -41.1 | -36.7 | -30.1 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -33.9 | -23.0 | -34.5 | -30.8 | -25.3 | -37.0 | -26.7 | -37.8 | -33.7 | -27.6 | -40.3 | -27.4 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 4.9 | -6.9 | 0.0 | 0.0 | 0.0 | 5.3 | -7.5 | 0.0 | 0.0 | 0.0 | 5.8 | -8.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -27.9 | -22.5 | -34.5 | -30.8 | -25.3 | -30.5 | -24.6 | -37.8 | -33.7 | -27.6 | -33.2 | -26.8 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 9.6 | -9.9 | 0.0 | 0.0 | 0.0 | 10.5 | -10.8 | 0.0 | 0.0 | 0.0 | 11.5 | -11.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -22.4 | -22.5 | -34.5 | -30.8 | -25.3 | -24.4 | -24.6 | -37.8 | -33.7 | -27.6 | -26.6 | -26.8 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 12.8 | -10.8 | 0.0 | 0.0 | 0.0 | 14.0 | -11.8 | 0.0 | 0.0 | 0.0 | 15.3 | -12.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -18.0 | -22.5 | -34.5 | -30.8 | -25.3 | -19.6 | -24.6 | -37.8 | -33.7 | -27.6 | -21.4 | -26.8 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 14.2 | -10.8 | 0.0 | 0.0 | 0.0 | 15.5 | -11.8 | 0.0 | 0.0 | 0.0 | 16.9 | -12.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -10.4 | -22.5 | -34.5 | -30.8 | -25.3 | -11.4 | -24.6 | -37.8 | -33.7 | -27.6 | -12.4 | -26.8 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 16.9 | -10.8 | 0.0 | 0.0 | 0.0 | 18.5 | -11.8 | 0.0 | 0.0 | 0.0 | 20.2 | -12.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -5.9 | -22.5 | -34.5 | -30.8 | -25.3 | -6.4 | -24.6 | -37.8 | -33.7 | -27.6 | -7.0 | -26.8 | -41.1 | -36.7 | -30.1 |
|  |  | 2 | 16.9 | -10.8 | 0.0 | 0.0 | 0.0 | 18.5 | -11.8 | 0.0 | 0.0 | 0.0 | 20.2 | -12.8 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

$$
\begin{aligned}
& \text { MWFRS - Roof } \\
& V=130-150 \mathrm{mph} \\
& \mathrm{~h}=90-120 \mathrm{ft} .
\end{aligned}
$$

|  | V (MPH) |  | 130 |  |  |  |  | 140 |  |  |  |  | 150 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Roof Slope | $\begin{array}{c\|} \hline \text { Load } \\ \text { Case } \end{array}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
| h (ft) |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 120 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -51.3 | -45.7 | -37.5 | NA | NA | -59.5 | -53.0 | -43.5 | NA | NA | -36.7 | -32.7 | -26.8 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -50.3 | -34.2 | -51.3 | -45.7 | -37.5 | -58.3 | -39.7 | -59.5 | -53.0 | -43.5 | -36.0 | -24.5 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 7.3 | -10.2 | 0.0 | 0.0 | 0.0 | 8.4 | -11.8 | 0.0 | 0.0 | 0.0 | 5.2 | -7.3 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -41.4 | -33.4 | -51.3 | -45.7 | -37.5 | -48.0 | -38.7 | -59.5 | -53.0 | -43.5 | -29.6 | -23.9 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 14.3 | -14.7 | 0.0 | 0.0 | 0.0 | 16.6 | -17.0 | 0.0 | 0.0 | 0.0 | 10.2 | -10.5 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -33.2 | -33.4 | -51.3 | -45.7 | -37.5 | -38.5 | -38.7 | -59.5 | -53.0 | -43.5 | -23.8 | -23.9 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 19.1 | -16.0 | 0.0 | 0.0 | 0.0 | 22.1 | -18.5 | 0.0 | 0.0 | 0.0 | 13.6 | -11.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -26.6 | -33.4 | -51.3 | -45.7 | -37.5 | -30.9 | -38.7 | -59.5 | -53.0 | -43.5 | -19.1 | -23.9 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 21.0 | -16.0 | 0.0 | 0.0 | 0.0 | 24.4 | -18.5 | 0.0 | 0.0 | 0.0 | 15.1 | -11.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -15.4 | -33.4 | -51.3 | -45.7 | -37.5 | -17.9 | -38.7 | -59.5 | -53.0 | -43.5 | -11.0 | -23.9 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 25.1 | -16.0 | 0.0 | 0.0 | 0.0 | 29.2 | -18.5 | 0.0 | 0.0 | 0.0 | 18.0 | -11.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.7 | -33.4 | -51.3 | -45.7 | -37.5 | -10.1 | -38.7 | -59.5 | -53.0 | -43.5 | -6.2 | -23.9 | -36.7 | -32.7 | -26.8 |
|  |  | 2 | 25.1 | -16.0 | 0.0 | 0.0 | 0.0 | 29.2 | -18.5 | 0.0 | 0.0 | 0.0 | 18.0 | -11.4 | 0.0 | 0.0 | 0.0 |
| 110 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -50.3 | -44.9 | -36.8 | NA | NA | -58.4 | -52.0 | -42.7 | NA | NA | -36.0 | -32.1 | -26.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -49.4 | -33.6 | -50.3 | -44.9 | -36.8 | -57.3 | -38.9 | -58.4 | -52.0 | -42.7 | -35.4 | -24.0 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 7.1 | -10.0 | 0.0 | 0.0 | 0.0 | 8.3 | -11.6 | 0.0 | 0.0 | 0.0 | 5.1 | -7.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -40.6 | -32.8 | -50.3 | -44.9 | -36.8 | -47.1 | -38.0 | -58.4 | -52.0 | -42.7 | -29.1 | -23.5 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 14.1 | -14.4 | 0.0 | 0.0 | 0.0 | 16.3 | -16.7 | 0.0 | 0.0 | 0.0 | 10.1 | -10.3 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -32.6 | -32.8 | -50.3 | -44.9 | -36.8 | -37.8 | -38.0 | -58.4 | -52.0 | -42.7 | -23.3 | -23.5 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 18.7 | -15.7 | 0.0 | 0.0 | 0.0 | 21.7 | -18.2 | 0.0 | 0.0 | 0.0 | 13.4 | -11.2 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -26.2 | -32.8 | -50.3 | -44.9 | -36.8 | -30.3 | -38.0 | -58.4 | -52.0 | -42.7 | -18.7 | -23.5 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 20.7 | -15.7 | 0.0 | 0.0 | 0.0 | 24.0 | -18.2 | 0.0 | 0.0 | 0.0 | 14.8 | -11.2 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -15.1 | -32.8 | -50.3 | -44.9 | -36.8 | -17.6 | -38.0 | -58.4 | -52.0 | -42.7 | -10.8 | -23.5 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 24.7 | -15.7 | 0.0 | 0.0 | 0.0 | 28.6 | -18.2 | 0.0 | 0.0 | 0.0 | 17.7 | -11.2 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.5 | -32.8 | -50.3 | -44.9 | -36.8 | -9.9 | -38.0 | -58.4 | -52.0 | -42.7 | -6.1 | -23.5 | -36.0 | -32.1 | -26.3 |
|  |  | 2 | 24.7 | -15.7 | 0.0 | 0.0 | 0.0 | 28.6 | -18.2 | 0.0 | 0.0 | 0.0 | 17.7 | -11.2 | 0.0 | 0.0 | 0.0 |
| 100 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -49.3 | -44.0 | -36.1 | NA | NA | -57.2 | -51.0 | -41.8 | NA | NA | -35.3 | -31.5 | -25.8 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -48.4 | -32.9 | -49.3 | -44.0 | -36.1 | -56.1 | -38.2 | -57.2 | -51.0 | -41.8 | -34.7 | -23.6 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 7.0 | -9.8 | 0.0 | 0.0 | 0.0 | 8.1 | -11.4 | 0.0 | 0.0 | 0.0 | 5.0 | -7.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -39.8 | -32.1 | -49.3 | -44.0 | -36.1 | -46.2 | -37.2 | -57.2 | -51.0 | -41.8 | -28.5 | -23.0 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 13.8 | -14.1 | 0.0 | 0.0 | 0.0 | 16.0 | -16.4 | 0.0 | 0.0 | 0.0 | 9.9 | -10.1 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -31.9 | -32.1 | -49.3 | -44.0 | -36.1 | -37.0 | -37.2 | -57.2 | -51.0 | -41.8 | -22.9 | -23.0 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 18.3 | -15.4 | 0.0 | 0.0 | 0.0 | 21.3 | -17.8 | 0.0 | 0.0 | 0.0 | 13.1 | -11.0 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -25.6 | -32.1 | -49.3 | -44.0 | -36.1 | -29.7 | -37.2 | -57.2 | -51.0 | -41.8 | -18.4 | -23.0 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 20.2 | -15.4 | 0.0 | 0.0 | 0.0 | 23.5 | -17.8 | 0.0 | 0.0 | 0.0 | 14.5 | -11.0 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -14.8 | -32.1 | -49.3 | -44.0 | -36.1 | -17.2 | -37.2 | -57.2 | -51.0 | -41.8 | -10.6 | -23.0 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 24.2 | -15.4 | 0.0 | 0.0 | 0.0 | 28.1 | -17.8 | 0.0 | 0.0 | 0.0 | 17.3 | -11.0 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.4 | -32.1 | -49.3 | -44.0 | -36.1 | -9.7 | -37.2 | -57.2 | -51.0 | -41.8 | -6.0 | -23.0 | -35.3 | -31.5 | -25.8 |
|  |  | 2 | 24.2 | -15.4 | 0.0 | 0.0 | 0.0 | 28.1 | -17.8 | 0.0 | 0.0 | 0.0 | 17.3 | -11.0 | 0.0 | 0.0 | 0.0 |
| 90 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -48.3 | -43.0 | -35.3 | NA | NA | -56.0 | -49.9 | -40.9 | NA | NA | -34.5 | -30.8 | -25.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -47.3 | -32.2 | -48.3 | -43.0 | -35.3 | -54.9 | -37.3 | -56.0 | -49.9 | -40.9 | -33.9 | -23.0 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 6.8 | -9.6 | 0.0 | 0.0 | 0.0 | 7.9 | -11.1 | 0.0 | 0.0 | 0.0 | 4.9 | -6.9 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -38.9 | -31.4 | -48.3 | -43.0 | -35.3 | -45.1 | -36.4 | -56.0 | -49.9 | -40.9 | -27.9 | -22.5 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 13.5 | -13.8 | 0.0 | 0.0 | 0.0 | 15.6 | -16.0 | 0.0 | 0.0 | 0.0 | 9.6 | -9.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -31.2 | -31.4 | -48.3 | -43.0 | -35.3 | -36.2 | -36.4 | -56.0 | -49.9 | -40.9 | -22.4 | -22.5 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 17.9 | -15.0 | 0.0 | 0.0 | 0.0 | 20.8 | -17.4 | 0.0 | 0.0 | 0.0 | 12.8 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -25.1 | -31.4 | -48.3 | -43.0 | -35.3 | -29.1 | -36.4 | -56.0 | -49.9 | -40.9 | -18.0 | -22.5 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 19.8 | -15.0 | 0.0 | 0.0 | 0.0 | 23.0 | -17.4 | 0.0 | 0.0 | 0.0 | 14.2 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -14.5 | -31.4 | -48.3 | -43.0 | -35.3 | -16.8 | -36.4 | -56.0 | -49.9 | -40.9 | -10.4 | -22.5 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 23.7 | -15.0 | 0.0 | 0.0 | 0.0 | 27.5 | -17.4 | 0.0 | 0.0 | 0.0 | 16.9 | -10.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.2 | -31.4 | -48.3 | -43.0 | -35.3 | -9.5 | -36.4 | -56.0 | -49.9 | -40.9 | -5.9 | -22.5 | -34.5 | -30.8 | -25.3 |
|  |  | 2 | 23.7 | -15.0 | 0.0 | 0.0 | 0.0 | 27.5 | -17.4 | 0.0 | 0.0 | 0.0 | 16.9 | -10.8 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

$$
\begin{aligned}
& \text { MWFRS - Roof } \\
& V=160-200 \mathrm{mph} \\
& \mathrm{~h}=90-120 \mathrm{ft} .
\end{aligned}
$$

|  | V (MPH) |  | 160 |  |  |  |  | 180 |  |  |  |  | 200 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope | $\begin{aligned} & \hline \text { Load } \\ & \text { Case } \end{aligned}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 120 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -77.7 | -69.2 | -56.8 | NA | NA | -98.3 | -87.6 | -71.9 | NA | NA | -121.3 | -108.2 | -88.7 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -76.2 | -54.8 | -77.7 | -69.2 | -56.8 | -96.4 | -65.6 | -98.3 | -87.6 | -71.9 | -119.0 | -80.9 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 11.0 | -15.5 | 0.0 | 0.0 | 0.0 | 13.9 | -19.6 | 0.0 | 0.0 | 0.0 | 17.2 | -24.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -62.6 | -50.5 | -77.7 | -69.2 | -56.8 | -79.3 | -64.0 | -98.3 | -87.6 | -71.9 | -97.9 | -79.0 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 21.7 | -22.2 | 0.0 | 0.0 | 0.0 | 27.4 | -28.1 | 0.0 | 0.0 | 0.0 | 33.9 | -34.7 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -50.3 | -50.5 | -77.7 | -69.2 | -56.8 | -63.6 | -64.0 | -98.3 | -87.6 | -71.9 | -78.5 | -79.0 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 28.9 | -24.2 | 0.0 | 0.0 | 0.0 | 36.5 | -30.6 | 0.0 | 0.0 | 0.0 | 45.1 | -37.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -40.4 | -50.5 | -77.7 | -69.2 | -56.8 | -51.1 | -64.0 | -98.3 | -87.6 | -71.9 | -63.1 | -79.0 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 31.9 | -24.2 | 0.0 | 0.0 | 0.0 | 40.3 | -30.6 | 0.0 | 0.0 | 0.0 | 49.8 | -37.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -23.4 | -50.5 | -77.7 | -69.2 | -56.8 | -29.6 | -64.0 | -98.3 | -87.6 | -71.9 | -36.5 | -79.0 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 38.1 | -24.2 | 0.0 | 0.0 | 0.0 | 48.2 | -30.6 | 0.0 | 0.0 | 0.0 | 59.5 | -37.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -13.2 | -50.5 | -77.7 | -69.2 | -56.8 | -16.7 | -64.0 | -98.3 | -87.6 | -71.9 | -20.6 | -79.0 | -121.3 | -108.2 | -88.7 |
|  |  | 2 | 38.1 | -24.2 | 0.0 | 0.0 | 0.0 | 48.2 | -30.6 | 0.0 | 0.0 | 0.0 | 59.5 | -37.8 | 0.0 | 0.0 | 0.0 |
| 110 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -76.2 | -68.0 | -55.7 | NA | NA | -96.5 | -86.0 | -70.6 | NA | NA | -119.1 | -106.2 | -87.1 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -74.8 | -53.8 | -76.2 | -68.0 | -55.7 | -94.7 | -64.4 | -96.5 | -86.0 | -70.6 | -116.9 | -79.5 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 10.8 | -15.2 | 0.0 | 0.0 | 0.0 | 13.7 | -19.2 | 0.0 | 0.0 | 0.0 | 16.9 | -23.7 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -61.5 | -49.6 | -76.2 | -68.0 | -55.7 | -77.8 | -62.8 | -96.5 | -86.0 | -70.6 | -96.1 | -77.6 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 21.3 | -21.8 | 0.0 | 0.0 | 0.0 | 26.9 | -27.6 | 0.0 | 0.0 | 0.0 | 33.3 | -34.1 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -49.3 | -49.6 | -76.2 | -68.0 | -55.7 | -62.5 | -62.8 | -96.5 | -86.0 | -70.6 | -77.1 | -77.6 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 28.3 | -23.7 | 0.0 | 0.0 | 0.0 | 35.9 | -30.0 | 0.0 | 0.0 | 0.0 | 44.3 | -37.1 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -39.6 | -49.6 | -76.2 | -68.0 | -55.7 | -50.2 | -62.8 | -96.5 | -86.0 | -70.6 | -61.9 | -77.6 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 31.3 | -23.7 | 0.0 | 0.0 | 0.0 | 39.6 | -30.0 | 0.0 | 0.0 | 0.0 | 48.9 | -37.1 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -22.9 | -49.6 | -76.2 | -68.0 | -55.7 | -29.0 | -62.8 | -96.5 | -86.0 | -70.6 | -35.9 | -77.6 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 37.4 | -23.7 | 0.0 | 0.0 | 0.0 | 47.3 | -30.0 | 0.0 | 0.0 | 0.0 | 58.4 | -37.1 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -12.9 | -49.6 | -76.2 | -68.0 | -55.7 | -16.4 | -62.8 | -96.5 | -86.0 | -70.6 | -20.2 | -77.6 | -119.1 | -106.2 | -87.1 |
|  |  | 2 | 37.4 | -23.7 | 0.0 | 0.0 | 0.0 | 47.3 | -30.0 | 0.0 | 0.0 | 0.0 | 58.4 | -37.1 | 0.0 | 0.0 | 0.0 |
| 100 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -74.7 | -66.6 | -54.6 | NA | NA | -94.6 | -84.3 | -69.2 | NA | NA | -116.8 | -104.1 | -85.4 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -73.3 | -52.8 | -74.7 | -66.6 | -54.6 | -92.8 | -63.1 | -94.6 | -84.3 | -69.2 | -114.6 | -77.9 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 10.6 | -14.9 | 0.0 | 0.0 | 0.0 | 13.4 | -18.8 | 0.0 | 0.0 | 0.0 | 16.5 | -23.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -60.3 | -48.6 | -74.7 | -66.6 | -54.6 | -76.3 | -61.6 | -94.6 | -84.3 | -69.2 | -94.2 | -76.0 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 20.9 | -21.4 | 0.0 | 0.0 | 0.0 | 26.4 | -27.0 | 0.0 | 0.0 | 0.0 | 32.6 | -33.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -48.4 | -48.6 | -74.7 | -66.6 | -54.6 | -61.2 | -61.6 | -94.6 | -84.3 | -69.2 | -75.6 | -76.0 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 27.8 | -23.3 | 0.0 | 0.0 | 0.0 | 35.2 | -29.4 | 0.0 | 0.0 | 0.0 | 43.4 | -36.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -38.8 | -48.6 | -74.7 | -66.6 | -54.6 | -49.2 | -61.6 | -94.6 | -84.3 | -69.2 | -60.7 | -76.0 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 30.7 | -23.3 | 0.0 | 0.0 | 0.0 | 38.8 | -29.4 | 0.0 | 0.0 | 0.0 | 47.9 | -36.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -22.5 | -48.6 | -74.7 | -66.6 | -54.6 | -28.5 | -61.6 | -94.6 | -84.3 | -69.2 | -35.1 | -76.0 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 36.7 | -23.3 | 0.0 | 0.0 | 0.0 | 46.4 | -29.4 | 0.0 | 0.0 | 0.0 | 57.3 | -36.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -12.7 | -48.6 | -74.7 | -66.6 | -54.6 | -16.1 | -61.6 | -94.6 | -84.3 | -69.2 | -19.8 | -76.0 | -116.8 | -104.1 | -85.4 |
|  |  | 2 | 36.7 | -23.3 | 0.0 | 0.0 | 0.0 | 46.4 | -29.4 | 0.0 | 0.0 | 0.0 | 57.3 | -36.4 | 0.0 | 0.0 | 0.0 |
| 90 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -73.1 | -65.2 | -53.4 | NA | NA | -92.5 | -82.5 | -67.6 | NA | NA | -114.2 | -101.8 | -83.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -71.7 | -51.6 | -73.1 | -65.2 | -53.4 | -90.8 | -61.7 | -92.5 | -82.5 | -67.6 | -112.1 | -76.2 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 10.3 | -14.5 | 0.0 | 0.0 | 0.0 | 13.1 | -18.4 | 0.0 | 0.0 | 0.0 | 16.2 | -22.7 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -59.0 | -47.6 | -73.1 | -65.2 | -53.4 | -74.6 | -60.2 | -92.5 | -82.5 | -67.6 | -92.1 | -74.3 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 20.4 | -20.9 | 0.0 | 0.0 | 0.0 | 25.8 | -26.4 | 0.0 | 0.0 | 0.0 | 31.9 | -32.6 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -47.3 | -47.6 | -73.1 | -65.2 | -53.4 | -59.9 | -60.2 | -92.5 | -82.5 | -67.6 | -73.9 | -74.3 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 27.2 | -22.8 | 0.0 | 0.0 | 0.0 | 34.4 | -28.8 | 0.0 | 0.0 | 0.0 | 42.5 | -35.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -38.0 | -47.6 | -73.1 | -65.2 | -53.4 | -48.1 | -60.2 | -92.5 | -82.5 | -67.6 | -59.4 | -74.3 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 30.0 | -22.8 | 0.0 | 0.0 | 0.0 | 38.0 | -28.8 | 0.0 | 0.0 | 0.0 | 46.9 | -35.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -22.0 | -47.6 | -73.1 | -65.2 | -53.4 | -27.8 | -60.2 | -92.5 | -82.5 | -67.6 | -34.4 | -74.3 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 35.9 | -22.8 | 0.0 | 0.0 | 0.0 | 45.4 | -28.8 | 0.0 | 0.0 | 0.0 | 56.0 | -35.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -12.4 | -47.6 | -73.1 | -65.2 | -53.4 | -15.7 | -60.2 | -92.5 | -82.5 | -67.6 | -19.4 | -74.3 | -114.2 | -101.8 | -83.5 |
|  |  | 2 | 35.9 | -22.8 | 0.0 | 0.0 | 0.0 | 45.4 | -28.8 | 0.0 | 0.0 | 0.0 | 56.0 | -35.6 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

MWFRS - Roof
$\mathrm{V}=110-120 \mathrm{mph}$
$h=130-160 \mathrm{ft}$.

|  | V (MPH) |  | 110 |  |  |  |  | 115 |  |  |  |  | 120 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \\ \hline \end{gathered}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
| h (ft) |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 160 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -39.0 | -34.8 | -28.5 | NA | NA | -42.6 | -38.0 | -31.2 | NA | NA | -46.4 | -41.4 | -33.9 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -38.3 | -26.0 | -39.0 | -34.8 | -28.5 | -41.8 | -30.1 | -42.6 | -38.0 | -31.2 | -45.5 | -31.0 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 5.5 | -7.8 | 0.0 | 0.0 | 0.0 | 6.0 | -8.5 | 0.0 | 0.0 | 0.0 | 6.6 | -9.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -31.5 | -25.4 | -39.0 | -34.8 | -28.5 | -34.4 | -27.7 | -42.6 | -38.0 | -31.2 | -37.4 | -30.2 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 10.9 | -11.1 | 0.0 | 0.0 | 0.0 | 11.9 | -12.2 | 0.0 | 0.0 | 0.0 | 13.0 | -13.3 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -25.2 | -25.4 | -39.0 | -34.8 | -28.5 | -27.6 | -27.7 | -42.6 | -38.0 | -31.2 | -30.0 | -30.2 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 14.5 | -12.1 | 0.0 | 0.0 | 0.0 | 15.8 | -13.3 | 0.0 | 0.0 | 0.0 | 17.3 | -14.4 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -20.3 | -25.4 | -39.0 | -34.8 | -28.5 | -22.2 | -27.7 | -42.6 | -38.0 | -31.2 | -24.1 | -30.2 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 16.0 | -12.1 | 0.0 | 0.0 | 0.0 | 17.5 | -13.3 | 0.0 | 0.0 | 0.0 | 19.0 | -14.4 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.7 | -25.4 | -39.0 | -34.8 | -28.5 | -12.8 | -27.7 | -42.6 | -38.0 | -31.2 | -14.0 | -30.2 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 19.1 | -12.1 | 0.0 | 0.0 | 0.0 | 20.9 | -13.3 | 0.0 | 0.0 | 0.0 | 22.8 | -14.4 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.6 | -25.4 | -39.0 | -34.8 | -28.5 | -7.2 | -27.7 | -42.6 | -38.0 | -31.2 | -7.9 | -30.2 | -46.4 | -41.4 | -33.9 |
|  |  | 2 | 19.1 | -12.1 | 0.0 | 0.0 | 0.0 | 20.9 | -13.3 | 0.0 | 0.0 | 0.0 | 22.8 | -14.4 | 0.0 | 0.0 | 0.0 |
| 150 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -38.5 | -34.3 | -28.1 | NA | NA | -42.0 | -37.5 | -30.7 | NA | NA | -45.8 | -40.8 | -33.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -37.7 | -25.7 | -38.5 | -34.3 | -28.1 | -41.3 | -29.7 | -42.0 | -37.5 | -30.7 | -44.9 | -30.5 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 5.4 | -7.7 | 0.0 | 0.0 | 0.0 | 6.0 | -8.4 | 0.0 | 0.0 | 0.0 | 6.5 | -9.1 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -31.0 | -25.0 | -38.5 | -34.3 | -28.1 | -33.9 | -27.4 | -42.0 | -37.5 | -30.7 | -36.9 | -29.8 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 10.7 | -11.0 | 0.0 | 0.0 | 0.0 | 11.7 | -12.0 | 0.0 | 0.0 | 0.0 | 12.8 | -13.1 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -24.9 | -25.0 | -38.5 | -34.3 | -28.1 | -27.2 | -27.4 | -42.0 | -37.5 | -30.7 | -29.6 | -29.8 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 14.3 | -12.0 | 0.0 | 0.0 | 0.0 | 15.6 | -13.1 | 0.0 | 0.0 | 0.0 | 17.0 | -14.3 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -20.0 | -25.0 | -38.5 | -34.3 | -28.1 | -21.9 | -27.4 | -42.0 | -37.5 | -30.7 | -23.8 | -29.8 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 15.8 | -12.0 | 0.0 | 0.0 | 0.0 | 17.3 | -13.1 | 0.0 | 0.0 | 0.0 | 18.8 | -14.3 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.6 | -25.0 | -38.5 | -34.3 | -28.1 | -12.7 | -27.4 | -42.0 | -37.5 | -30.7 | -13.8 | -29.8 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 18.9 | -12.0 | 0.0 | 0.0 | 0.0 | 20.6 | -13.1 | 0.0 | 0.0 | 0.0 | 22.5 | -14.3 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.5 | -25.0 | -38.5 | -34.3 | -28.1 | -7.1 | -27.4 | -42.0 | -37.5 | -30.7 | -7.8 | -29.8 | -45.8 | -40.8 | -33.5 |
|  |  | 2 | 18.9 | -12.0 | 0.0 | 0.0 | 0.0 | 20.6 | -13.1 | 0.0 | 0.0 | 0.0 | 22.5 | -14.3 | 0.0 | 0.0 | 0.0 |
| 140 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -37.9 | -33.8 | -27.7 | NA | NA | -41.4 | -36.9 | -30.3 | NA | NA | -45.1 | -40.2 | -33.0 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -37.2 | -25.3 | -37.9 | -33.8 | -27.7 | -40.7 | -29.3 | -41.4 | -36.9 | -30.3 | -44.3 | -30.1 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 5.4 | -7.5 | 0.0 | 0.0 | 0.0 | 5.9 | -8.2 | 0.0 | 0.0 | 0.0 | 6.4 | -9.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -30.6 | -24.7 | -37.9 | -33.8 | -27.7 | -33.4 | -27.0 | -41.4 | -36.9 | -30.3 | -36.4 | -29.4 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 10.6 | -10.8 | 0.0 | 0.0 | 0.0 | 11.6 | -11.8 | 0.0 | 0.0 | 0.0 | 12.6 | -12.9 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -24.5 | -24.7 | -37.9 | -33.8 | -27.7 | -26.8 | -27.0 | -41.4 | -36.9 | -30.3 | -29.2 | -29.4 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 14.1 | -11.8 | 0.0 | 0.0 | 0.0 | 15.4 | -12.9 | 0.0 | 0.0 | 0.0 | 16.8 | -14.0 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -19.7 | -24.7 | -37.9 | -33.8 | -27.7 | -21.5 | -27.0 | -41.4 | -36.9 | -30.3 | -23.5 | -29.4 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 15.6 | -11.8 | 0.0 | 0.0 | 0.0 | 17.0 | -12.9 | 0.0 | 0.0 | 0.0 | 18.5 | -14.0 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.4 | -24.7 | -37.9 | -33.8 | -27.7 | -12.5 | -27.0 | -41.4 | -36.9 | -30.3 | -13.6 | -29.4 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 18.6 | -11.8 | 0.0 | 0.0 | 0.0 | 20.3 | -12.9 | 0.0 | 0.0 | 0.0 | 22.1 | -14.0 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.4 | -24.7 | -37.9 | -33.8 | -27.7 | -7.0 | -27.0 | -41.4 | -36.9 | -30.3 | -7.7 | -29.4 | -45.1 | -40.2 | -33.0 |
|  |  | 2 | 18.6 | -11.8 | 0.0 | 0.0 | 0.0 | 20.3 | -12.9 | 0.0 | 0.0 | 0.0 | 22.1 | -14.0 | 0.0 | 0.0 | 0.0 |
| 130 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -37.3 | -33.3 | -27.3 | NA | NA | -40.8 | -36.4 | -29.8 | NA | NA | -44.4 | -39.6 | -32.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -36.6 | -24.9 | -37.3 | -33.3 | -27.3 | -40.0 | -28.8 | -40.8 | -36.4 | -29.8 | -43.6 | -29.6 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 5.3 | -7.4 | 0.0 | 0.0 | 0.0 | 5.8 | -8.1 | 0.0 | 0.0 | 0.0 | 6.3 | -8.8 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -30.1 | -24.3 | -37.3 | -33.3 | -27.3 | -32.9 | -26.6 | -40.8 | -36.4 | -29.8 | -35.8 | -28.9 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 10.4 | -10.7 | 0.0 | 0.0 | 0.0 | 11.4 | -11.7 | 0.0 | 0.0 | 0.0 | 12.4 | -12.7 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -24.2 | -24.3 | -37.3 | -33.3 | -27.3 | -26.4 | -26.6 | -40.8 | -36.4 | -29.8 | -28.7 | -28.9 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 13.9 | -11.6 | 0.0 | 0.0 | 0.0 | 15.2 | -12.7 | 0.0 | 0.0 | 0.0 | 16.5 | -13.8 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -19.4 | -24.3 | -37.3 | -33.3 | -27.3 | -21.2 | -26.6 | -40.8 | -36.4 | -29.8 | -23.1 | -28.9 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 15.3 | -11.6 | 0.0 | 0.0 | 0.0 | 16.7 | -12.7 | 0.0 | 0.0 | 0.0 | 18.2 | -13.8 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -11.2 | -24.3 | -37.3 | -33.3 | -27.3 | -12.3 | -26.6 | -40.8 | -36.4 | -29.8 | -13.4 | -28.9 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 18.3 | -11.6 | 0.0 | 0.0 | 0.0 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 21.8 | -13.8 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -6.3 | -24.3 | -37.3 | -33.3 | -27.3 | -6.9 | -26.6 | -40.8 | -36.4 | -29.8 | -7.5 | -28.9 | -44.4 | -39.6 | -32.5 |
|  |  | 2 | 18.3 | -11.6 | 0.0 | 0.0 | 0.0 | 20.0 | -12.7 | 0.0 | 0.0 | 0.0 | 21.8 | -13.8 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS- Part 2: Wind Loads - Roof Exposure C

MWFRS - Roof $\mathrm{V}=130-150 \mathrm{mph}$ $h=130-160 \mathrm{ft}$.

|  | V (MPH) |  | 130 |  |  |  |  | 140 |  |  |  |  | 150 |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| h (ft) | Roof Slope | $\begin{gathered} \hline \text { Load } \\ \text { Case } \end{gathered}$ |  |  | Zone |  |  |  |  | Zone |  |  |  |  | Zone |  |  |
|  |  |  | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 160 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -54.5 | -48.6 | -39.8 | NA | NA | -63.2 | -56.3 | -46.2 | NA | NA | -72.5 | -64.6 | -53.0 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -53.4 | -36.3 | -54.5 | -48.6 | -39.8 | -62.0 | -42.1 | -63.2 | -56.3 | -46.2 | -71.1 | -48.4 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 7.7 | -10.8 | 0.0 | 0.0 | 0.0 | 8.9 | -12.6 | 0.0 | 0.0 | 0.0 | 10.3 | -14.4 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -43.9 | -35.5 | -54.5 | -48.6 | -39.8 | -51.0 | -41.1 | -63.2 | -56.3 | -46.2 | -58.5 | -47.2 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 15.2 | -15.6 | 0.0 | 0.0 | 0.0 | 17.6 | -18.1 | 0.0 | 0.0 | 0.0 | 20.2 | -20.7 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -35.2 | -35.5 | -54.5 | -48.6 | -39.8 | -40.9 | -41.1 | -63.2 | -56.3 | -46.2 | -46.9 | -47.2 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 20.2 | -17.0 | 0.0 | 0.0 | 0.0 | 23.5 | -19.7 | 0.0 | 0.0 | 0.0 | 27.0 | -22.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -28.3 | -35.5 | -54.5 | -48.6 | -39.8 | -32.8 | -41.1 | -63.2 | -56.3 | -46.2 | -37.7 | -47.2 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 22.4 | -17.0 | 0.0 | 0.0 | 0.0 | 25.9 | -19.7 | 0.0 | 0.0 | 0.0 | 29.8 | -22.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -16.4 | -35.5 | -54.5 | -48.6 | -39.8 | -19.0 | -41.1 | -63.2 | -56.3 | -46.2 | -21.8 | -47.2 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 26.7 | -17.0 | 0.0 | 0.0 | 0.0 | 31.0 | -19.7 | 0.0 | 0.0 | 0.0 | 11.4 | -22.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -9.2 | -35.5 | -54.5 | -48.6 | -39.8 | -10.7 | -41.1 | -63.2 | -56.3 | -46.2 | -12.3 | -47.2 | -72.5 | -64.6 | -53.0 |
|  |  | 2 | 26.7 | -17.0 | 0.0 | 0.0 | 0.0 | 31.0 | -19.7 | 0.0 | 0.0 | 0.0 | 35.6 | -22.6 | 0.0 | 0.0 | 0.0 |
| 150 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -53.7 | -47.9 | -39.3 | NA | NA | -62.3 | -55.6 | -45.6 | NA | NA | -71.5 | -63.8 | -52.3 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -52.7 | -35.8 | -53.7 | -47.9 | -39.3 | -61.1 | -41.6 | -62.3 | -55.6 | -45.6 | -70.2 | -47.7 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 7.6 | -10.7 | 0.0 | 0.0 | 0.0 | 8.8 | -12.4 | 0.0 | 0.0 | 0.0 | 10.1 | -14.2 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -43.3 | -35.0 | -53.7 | -47.9 | -39.3 | -50.3 | -40.6 | -62.3 | -55.6 | -45.6 | -57.7 | -46.6 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 15.0 | -15.4 | 0.0 | 0.0 | 0.0 | 17.4 | -17.8 | 0.0 | 0.0 | 0.0 | 20.0 | -20.4 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -34.8 | -35.0 | -53.7 | -47.9 | -39.3 | -40.3 | -40.6 | -62.3 | -55.6 | -45.6 | -46.3 | -46.6 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 20.0 | -16.7 | 0.0 | 0.0 | 0.0 | 23.2 | -19.4 | 0.0 | 0.0 | 0.0 | 26.6 | -22.3 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -27.9 | -35.0 | -53.7 | -47.9 | -39.3 | -32.4 | -40.6 | -62.3 | -55.6 | -45.6 | -37.2 | -46.6 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 22.1 | -16.7 | 0.0 | 0.0 | 0.0 | 25.6 | -19.4 | 0.0 | 0.0 | 0.0 | 29.4 | -22.3 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -16.2 | -35.0 | -53.7 | -47.9 | -39.3 | -18.8 | -40.6 | -62.3 | -55.6 | -45.6 | -21.5 | -46.6 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 26.4 | -16.7 | 0.0 | 0.0 | 0.0 | 30.6 | -19.4 | 0.0 | 0.0 | 0.0 | 11.3 | -22.3 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -9.1 | -35.0 | -53.7 | -47.9 | -39.3 | -10.6 | -40.6 | -62.3 | -55.6 | -45.6 | -12.1 | -46.6 | -71.5 | -63.8 | -52.3 |
|  |  | 2 | 26.4 | -16.7 | 0.0 | 0.0 | 0.0 | 30.6 | -19.4 | 0.0 | 0.0 | 0.0 | 35.1 | -22.3 | 0.0 | 0.0 | 0.0 |
| 140 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -53.0 | -47.2 | -38.7 | NA | NA | -61.4 | -54.8 | -44.9 | NA | NA | -70.5 | -62.9 | -51.5 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -52.0 | -35.3 | -53.0 | -47.2 | -38.7 | -60.3 | -41.0 | -61.4 | -54.8 | -44.9 | -69.2 | -47.0 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 7.5 | -10.5 | 0.0 | 0.0 | 0.0 | 8.7 | -12.2 | 0.0 | 0.0 | 0.0 | 10.0 | -14.0 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -42.7 | -34.5 | -53.0 | -47.2 | -38.7 | -49.5 | -40.0 | -61.4 | -54.8 | -44.9 | -56.9 | -45.9 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 14.8 | -15.1 | 0.0 | 0.0 | 0.0 | 17.2 | -17.6 | 0.0 | 0.0 | 0.0 | 19.7 | -20.2 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -34.3 | -34.5 | -53.0 | -47.2 | -38.7 | -39.7 | -40.0 | -61.4 | -54.8 | -44.9 | -45.6 | -45.9 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 19.7 | -16.5 | 0.0 | 0.0 | 0.0 | 22.8 | -19.1 | 0.0 | 0.0 | 0.0 | 26.2 | -21.9 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -27.5 | -34.5 | -53.0 | -47.2 | -38.7 | -31.9 | -40.0 | -61.4 | -54.8 | -44.9 | -36.6 | -45.9 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 21.7 | -16.5 | 0.0 | 0.0 | 0.0 | 25.2 | -19.1 | 0.0 | 0.0 | 0.0 | 28.9 | -21.9 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -15.9 | -34.5 | -53.0 | -47.2 | -38.7 | -18.5 | -40.0 | -61.4 | -54.8 | -44.9 | -21.2 | -45.9 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 26.0 | -16.5 | 0.0 | 0.0 | 0.0 | 30.1 | -19.1 | 0.0 | 0.0 | 0.0 | 11.1 | -21.9 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -9.0 | -34.5 | -53.0 | -47.2 | -38.7 | -10.4 | -40.0 | -61.4 | -54.8 | -44.9 | -12.0 | -45.9 | -70.5 | -62.9 | -51.5 |
|  |  | 2 | 26.0 | -16.5 | 0.0 | 0.0 | 0.0 | 30.1 | -19.1 | 0.0 | 0.0 | 0.0 | 34.6 | -21.9 | 0.0 | 0.0 | 0.0 |
| 130 | Flat < 2:12 (9.46 deg) | 1 | NA | NA | -52.1 | -46.5 | -38.1 | NA | NA | -60.5 | -53.9 | -44.2 | NA | NA | -69.4 | -61.9 | -50.7 |
|  |  | 2 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 | NA | NA | 0.0 | 0.0 | 0.0 |
|  | 3:12 (14.0 deg) | 1 | -51.2 | -34.8 | -52.1 | -46.5 | -38.1 | -59.3 | -40.3 | -60.5 | -53.9 | -44.2 | -68.1 | -46.3 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 7.4 | -10.4 | 0.0 | 0.0 | 0.0 | 8.6 | -12.0 | 0.0 | 0.0 | 0.0 | 9.8 | -13.8 | 0.0 | 0.0 | 0.0 |
|  | 4:12 (18.4 deg) | 1 | -42.1 | -33.9 | -52.1 | -46.5 | -38.1 | -48.8 | -39.4 | -60.5 | -53.9 | -44.2 | -56.0 | -45.2 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 14.6 | -14.9 | 0.0 | 0.0 | 0.0 | 16.9 | -17.3 | 0.0 | 0.0 | 0.0 | 19.4 | -19.8 | 0.0 | 0.0 | 0.0 |
|  | 5:12 (22.6 deg) | 1 | -33.7 | -33.9 | -52.1 | -46.5 | -38.1 | -39.1 | -39.4 | -60.5 | -53.9 | -44.2 | -44.9 | -45.2 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 19.4 | -16.2 | 0.0 | 0.0 | 0.0 | 22.5 | -18.8 | 0.0 | 0.0 | 0.0 | 25.8 | -21.6 | 0.0 | 0.0 | 0.0 |
|  | 6:12 (26.6 deg) | 1 | -27.1 | -33.9 | -52.1 | -46.5 | -38.1 | -31.4 | -39.4 | -60.5 | -53.9 | -44.2 | -36.1 | -45.2 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 21.4 | -16.2 | 0.0 | 0.0 | 0.0 | 24.8 | -18.8 | 0.0 | 0.0 | 0.0 | 28.5 | -21.6 | 0.0 | 0.0 | 0.0 |
|  | 9:12 (36.9 deg) | 1 | -15.7 | -33.9 | -52.1 | -46.5 | -38.1 | -18.2 | -39.4 | -60.5 | -53.9 | -44.2 | -20.9 | -45.2 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 25.6 | -16.2 | 0.0 | 0.0 | 0.0 | 29.7 | -18.8 | 0.0 | 0.0 | 0.0 | 10.9 | -21.6 | 0.0 | 0.0 | 0.0 |
|  | 12:12 (45.0 deg) | 1 | -8.9 | -33.9 | -52.1 | -46.5 | -38.1 | -10.3 | -39.4 | -60.5 | -53.9 | -44.2 | -11.8 | -45.2 | -69.4 | -61.9 | -50.7 |
|  |  | 2 | 15.0 | -9.5 | 0.0 | 0.0 | 0.0 | 16.4 | -10.4 | 0.0 | 0.0 | 0.0 | 34.1 | -21.6 | 0.0 | 0.0 | 0.0 |

Table 27.6-2
MWFRS - Part 2: Wind Loads - Roof Exposure C

> MWFRS - Roof V = 160-200 mph $\mathrm{h}=130-160 \mathrm{ft}$.


# STRENGTH DESIGN PROVISIONS FOR CONCRETE MASONRY 

Keywords: axial strength, building code provisions, design strength, flexural strength, nominal strength, reinforced concrete masonry, shear strength, strength design, strength reduction factor, structural design, unreinforced concrete masonry

## INTRODUCTION

Concrete masonry elements can be designed using one of several methods in accordance with Building Code Requirements for Masonry Structures (ref. 1): empirical design, strength design or allowable stress design. This TEK provides a basic overview of design criteria and requirements for concrete masonry structures designed using the strength design provisions contained in Chapter 3 of the 2002 edition of Building Code Requirements for Masonry Structures (also referred to as the MSJC Code) (ref. 1) as referenced and modified in Section 2108 of the 2003 International Building Code (IBC) (ref. 2). In addition, changes to the strength design method incorporated into the 2005 edition of the MSJC Code (ref. 3) through Section 2108 of the 2006 International Building Code (ref. 4) are also reviewed, as are modifications included in the 2008 MSJC Code (ref. 5).

For empirical and allowable stress design requirements, the user is referred to TEK 14-8A, Empirical Design of Concrete Masonry Walls (ref. 6), and TEK 14-7A, Allowable Stress Design of Concrete Masonry (ref. 7), respectively. Tables, charts, and additional design aids specific to the design of various concrete masonry elements can be found in other related TEK.

Strength designis based on the following designassumptions in conjunction with basic principles of engineering mechanics (refs. 1, 3, 5), as shown in Figure 1 for a reinforced element:

- Plane sections before bending remain plane after bending. Therefore, strain in the masonry and in reinforcement, if present, is directly proportional to the distance from the neutral axis.
- For unreinforced masonry, the flexural stresses in the masonry are assumed to be directly proportional to strain. For reinforced masonry, the tensile strength of the masonry is neglected when calculating flexural strength, but considered when calculating deflection.
- The units, mortar, grout and reinforcement for reinforced
masonry act compositely to resist applied loads.
- The nominal strength of masonry cross-sections for combined flexure and axial load is based on applicable conditions of equilibrium.
- The maximum masonry compressive stress is $0.80 f^{\prime}{ }_{m}$ for both reinforced and unreinforced masonry.
- The maximum usable strain, $\varepsilon_{\mathrm{mu}}$, at the extreme compression fiber of concrete masonry is 0.0025 .
- For reinforced masonry, compression and tension stresses in the reinforcement below the specified yield strength, $f_{y}$, are taken equal to the modulus of elasticity of the reinforcement, $E_{\mathrm{s}}$, times the steel strain $\varepsilon_{\mathrm{s}}$. For strains greater than the yield strain corresponding to $f_{y}$, stress in the reinforcement is taken equal to $f_{y}$.
- For reinforced masonry, the compressive stress is rectangular and uniformly distributed over an equivalent compression zone, bounded by the compression face of the masonry with a depth of $a=0.80$ c.

Based on the prescribed design model outlined above, the internal distribution of stresses and strains is illustrated in Figure 1 for a reinforced masonry element. A more comprehensive review of the design model is provided in Masonry Structures, Behavior and Design (ref. 8).


Figure 1—Stress and Strain Distribution for Strength Design of Reinforced Masonry

## 2003 IBC STRENGTH DESIGN MODIFICATIONS

The 2003 IBC adopts the 2002 MSJC Code with two modifications specific to the strength design procedure in IBC Section 2108. The two modifications are as follows.

- Section 2108.2 introduces a maximum effective compression width for out-of-plane bending of six times the nominal wall thickness, not to exceed the reinforcement spacing. This is similar to limits historically used by the allowable stress design provisions in the MSJC Code as well as those adopted into the 2005 MSJC Code for strength design, as reviewed below.
- Welded and mechanical splices incorporated into masonry elements designed by the strength design method must also comply with Section 2108.3 of the 2003 IBC. For welded splices, the reinforcement to be welded must comply with ASTM A 706 (ref. 9). Splicing by mechanical connectors is classified as either Type 1 or Type 2 mechanical splices in accordance with ACI 318, Building Code Requirements for Structural Concrete (ref. 10). Type 1 mechanical splices are only required to develop 125 percent of the nominal yield strength of the reinforcement being spliced. Type 2 mechanical splices, conversely, must develop the full specified tensile strength of the reinforcement. Welded and Type 1 mechanical splices are not permitted to be used in the plastic hinge region of intermediate or special reinforced masonry shear walls.


## 2002 MSJC CODE STRENGTH DESIGN CRITERIA

Using strength design, the design strength of a masonry element is compared to the required (or factored) strength (indicated by the subscript $\underline{u}$ ), which includes load factors to account for the uncertainty in predicting design loads and the probability of more than one design load acting simultaneously. The required strength is based on the strength design load combinations as required by Section 1605 of the IBC. At the option of the designer, or when the MSJC Code is used in conjunction with another building code that does not contain load combinations, masonry structures are designed to resist the load combination specified in ASCE 7, Minimum Design Loads for Buildings and Other Structures (ref. 11). For strength design, these load combinations are effectively the same.

The design strength of masonry is the nominal strength (indicated by the subscriptn) multiplied by an appropriate strength reduction factor, $\phi$. The design is acceptable when the design strength equals or exceeds the factored strength (i.e., when $\phi M_{n}$ $\geq M_{u}$ ) for all prescribed load combinations. The following sections cover the general strength design requirements applicable to both unreinforced and reinforced masonry assemblies, with the exception of design requirements for anchor bolts and lap splices. For these topics, the user is referred to TEK 12-3A, Design of Anchor Bolts Embedded in Concrete Masonry (ref. 12) and TEK 12-6, Splices, Development and Standard Hooks for Concrete Masonry (ref. 13), respectively.

## Strength Reduction Factors

To account for uncertainties in construction, material properties, calculated versus actual strengths and anticipated failure modes, the nominal strength of a masonry element is multiplied by an appropriate strength reduction factor, $\phi$.

Strength reduction factors are used in conjunction with the load factors applied to the design loads. The values of the strength reduction factors for various types of loading conditions are:

- for reinforced masonry elements subjected to flexure or axial loads; $\phi=0.90$;
- for unreinforced masonry elements subjected to flexure or axial loads; $\phi=0.60$;
- for masonry elements subjected to shear loads; $\phi=0.80$;
- for bearing on masonry elements; $\phi=0.60$.


## Drift and Deflection

When designing for earthquakes, the story drift (the relative displacement of adjacent stories) must be checked against the IBC prescribed allowable story drifts. When the MSJC Code is used in conjunction with a building code that does not contain allowable story drifts, the provisions of ASCE 7 are used. For masonry buildings with cantilevered shear walls, the IBC limits the story drift to $0.01 h_{s x}$, where $h_{s x}$ is the height of the story below the level for which the drift is being calculated. For other types of masonry shear wall buildings, except masonry frames, the allowable story drift is limited to $0.007 h_{s x}$. While the IBC includes story drift limits for masonry frame wall buildings, such structural configurations are rarely used. When calculating story drift, the calculated elastic deflection is multiplied by the deflection amplification factor, $C_{d}$, as prescribed in the IBC for the type of structural system being designed. The deflection amplification factor approximates the additional deflection due to inelastic response (if applicable) of the system during an earthquake. Due to the inherent inplane stiffness of masonry assemblies, in-plane deflection and story drift are rarely a controlling limit unless a relatively large number of openings is incorporated that reduces the strength and stiffness along a line of lateral resistance.

Unlike allowable stress design, which permits deflections to be calculated assuming uncracked sections for both reinforced and unreinforced masonry, strength design requires that deflections of reinforced masonry elements be based on cracked section properties, which are limited to one-half of the gross section properties unless a rigorous cracked section analysis is performed. The deflection of unreinforced masonry elements, which are required to remain uncracked, use uncracked section properties.

Because unreinforced masonry elements must be designed to remain uncracked, deflection is rarely a controlling design limit for these systems. Reinforced masonry elements, however, particularly tall, slender walls bending in the out-of-plane direction, may exhibit excessive deflection even at relatively low applied loads. As such, the MSJC Code limits the mid-height deflection, $\delta_{s}$, of reinforced masonry elements bending in the out-of-plane direction due to service level lateral and axial loads to $0.007 h$. Second order effects due to $P$-delta contributions must also be taken into account, which is usually accomplished through iteration until convergence is achieved.

When the applied moment, $M_{\text {ser }}$, is less than the moment required to cause cracking, $M_{c r},\left(M_{s e r}<M_{c r}\right)$ then the mid-height deflection of a masonry element subjected to a uniform out-of-plane load can be determined using Equation 1.
$\delta_{s}=\frac{5 M_{\text {ser }} h^{2}}{48 E_{m} I_{g}}$
Eqn. 1

Conversely, when the applied moment, $M_{\text {ser }}$, is greater than the moment required to cause cracking, $M_{c}$, but less than the nominal moment strength of the assembly $\left(M_{c r}<M_{\text {ser }}<M_{n}\right)$ the mid-heightdeflection of a masonry elementsubjectedto auniform out-of-plane load can be determined using Equation 2.
$\delta_{s}=\frac{5 M_{c r} h^{2}}{48 E_{m} I_{g}}+\frac{5\left(M_{s e r}-M_{c r}\right) h^{2}}{48 E_{m} I_{c r}}$
The MSJC does not prescribe a method of determining the cracked moment of inertia, $I_{c r}$. As such, any rational method of determining cracked section properties is permitted. TEK 14-1B, Section Properties of Concrete Masonry Walls (ref. 14), provides typical section properties for various uncracked wall sections. For use in Equations 1 and 2, the cracking moment can be taken as:
$M_{c r}=S_{n} f_{r}$
Where the modulus of rupture, $f_{r}$, is obtained from Table 1 for the type of mortar and construction under consideration.

## Material Properties

Due to the lack of available research data substantiating its use, the specified compressive strength of concrete masonry, $f_{m}^{\prime}$, designed by the strength design method is required to be at least 1,500 psi ( 10.34 MPa ), but not larger than $4,000 \mathrm{psi}$ ( 27.58 MPa ). In addition, when used in a structural role, the specified compressive strength of grout is required to be at least equal to the specified compressive strength of concrete masonry, but not greater than 5,000 psi ( 34.47 MPa ). For each of these upper limits on masonry assembly or grout compressive strength, the actual tested strength is permitted to exceed these values: the restriction applies only to specified strengths upon which the design is based. Note that these provisions are included in the 2005 MSJC Code as well.

Strength design of reinforced masonry is based on the specified yield strength of reinforcement, $f_{y}$, which is limited to $60,000 \mathrm{psi}(413.7 \mathrm{MPa})$. The actual yield strength of the reinforcement is limited to 1.3 times the specified yield strength. The combination of these requirements effectively precludes the use of bed joint reinforcement to be used as primary structural steel in masonry designed by the strength design method, because the nominal yield strength of bed joint reinforcement exceeds these limits. The compressive resistance of steel reinforcement is not permitted to be used unless lateral reinforcement is provided in compliance with Chapter 2 of the MSJC Code, except as permitted when checking the maximum reinforcement limits as described later.

## Unreinforced Masonry

For unreinforced masonry, the masonry assembly (units, mortar and grout, if used) is designed to carry all applied stresses. The additional capacity from the inclusion of reinforcing steel, if present (such as reinforcement added to control shrinkage cracking or prescriptively required by the code), is neglected when designing unreinforced masonry elements. Because the masonry resists both tension and compression stresses resulting from applied loads, the masonry must be designed to remain uncracked.

## Unreinforced Nominal Flexural Strength

The nominal flexural tensile strength of unreinforced concrete masonry is given by the modulus of rupture as prescribed
in the MSJC Code, which varies with the direction of span, mortar type, bond pattern and percentage of grouting as shown in Table 1. These values apply to masonry subject to out-of-plane bending. For walls spanning horizontally between supports, the code conservatively assumes that stack bond masonry has no flexural bond strength across the mortared head joints, thus only the grout area (for horizontally grouted sections) is used. For this case, the modulus of rupture of the grout is taken equal to 250 psi (1720 kPa). Likewise, for masonry subjected to in-plane bending, the modulus of rupture normal and parallel to the bed joints is taken as $250 \mathrm{psi}(1720 \mathrm{kPa})$.

For masonry elements subjected to a factored bending moment, $M_{u}$, and a compressive axial force, $P_{u}$, the resulting flexural bending stress is determined using Equation 4.

$$
\begin{equation*}
F_{u}=\frac{M_{u} t}{2 I_{n}}-\frac{P_{u}}{A_{n}} \tag{Eqn. 4}
\end{equation*}
$$

If the resulting value of $F_{u}$ is positive, then the masonry section is controlled by tension and the modulus of rupture values of Table 1, reduced by the appropriate strength reduction factor ( $\phi=0.60$ ), must be satisfied. Conversely, if $F_{u}$ as given by Equation 4 is negative, the masonry section is in compression and the design compressive stress of $0.80 f^{\prime}{ }_{m}$ applies. When using axial load to offset flexural bending stresses as described above, only dead loads or other permanent loads should be included in $P_{u}$.

## Unreinforced Nominal Axial Strength

When unreinforced masonry walls are subjected to compressive axial loads only, the nominal axial compressive strength, $P_{n}$, is determined using equation 5 or 6 , as appropriate. Unreinforced masonry is not permitted to carry net axial tension forces.
For elements with $h / r$ not greater than 99:

$$
\begin{equation*}
P_{n}=0.8\left[0.8 A_{n} f_{m}^{\prime}\left(1-\left(\frac{h}{140 r}\right)^{2}\right)\right] \tag{Eqn. 5}
\end{equation*}
$$

For elements with $h / r$ greater than 99:

$$
\begin{equation*}
P_{n}=0.8\left[0.8 A_{n} f_{m}^{\prime}\left(1-\left(\frac{70 r}{h}\right)^{2}\right)\right] \tag{Eqn. 6}
\end{equation*}
$$

## Unreinforced Nominal Shear Strength

Shear stresses on unreinforced masonry elements are calculated using the net cross-sectional properties of the masonry in the direction of the applied shear force using:

$$
\begin{equation*}
F_{v u}=\frac{V_{u} Q_{n}}{I_{n} b} \tag{Eqn. 7}
\end{equation*}
$$

Equation 7 is applicable to determining both in-plane and out-of-plane shear stresses. Because unreinforced masonry is designed to remain uncracked, it is not necessary to perform a cracked section analysis to determine the net section properties. In turn, the applied shear stresses (factored accordingly for the appropriate load combination) are compared to the nominal shear strength, $V_{n}$, of an unreinforced masonry section, which is the least of:

1. $3.8 A_{n} \sqrt{f_{m}^{\prime}} \mathrm{psi} \quad\left(3.8 A_{n} \sqrt{f_{m}^{\prime}} \mathrm{MPa}\right)$
2. $300 A_{n} \mathrm{psi}$
( $0.83 A_{n} \mathrm{MPa}$ )
3. a. For running bond not solidly grouted and for stack bond masonry with open end units and grouted solid,
$56 A_{n}+0.45 N_{v}$ psi $\left(0.26 A_{n}+0.3 N_{v} \mathrm{MPa}\right)$
b. For solidly grouted running bond masonry, $90 A_{n}+0.45 N_{v}$ psi $\left(0.414 A_{n}+0.3 N_{v} \mathrm{MPa}\right)$
c. For stack bond masonry with other than open end units grouted solid,

$$
23 A_{n} \mathrm{psi} \quad\left(0.103 A_{n} \mathrm{MPa}\right)
$$

## Reinforced Masonry

The design of reinforced masonry in accordance with the MSJC Code neglects the tensile resistance provided by the masonry units, mortar and grout in determining the strength of the masonry assemblage. (The tensile strength of the units, mortar, and grout is considered, however, in determining the stiffness and deflection of a reinforced masonry element.) Thus, for design purposes, the portion of masonry subject to net tensile stress is assumed to have cracked, transferring all tensile forces to the reinforcement.

Using strength design, reinforcing bars used in masonry may not be larger than No. 9 (M \#29) and bars may not be bundled. Further, the nominal bar diameter is not permitted to exceed one-eighth of the nominal member thickness or one-quarter of the least clear dimension of the cell, course or collar joint in which it is placed. The total area of reinforcing bars placed in a single cell or in a course of hollow unit construction may not exceed $4 \%$ of the cell area. Note that this limit does not apply at sections where lap splices occur. At lap splices, the maximum reinforcing bar area is increased to 8\%, in both the 2002 and 2005 editions of the MSJC Code.

## Maximum Flexural Reinforcement Ratio

To provide for a prescribed level of reinforced masonry ductility in the event of failure, the maximum reinforcement ratio, $\rho_{\max }$, is limited in accordance with Equation 8 or 9, as appropriate. Equation 8 applies to masonry cross sections that are fully grouted or where the neutral axis falls within the face shell of the masonry units in partially grouted construction. When the neutral axis falls within the cores of partially grouted construction, Equation 9 is used.
$\rho_{\max }=\frac{0.64 f_{m}^{\prime}\left(\frac{\varepsilon_{m u}}{\varepsilon_{m u}+\alpha \varepsilon_{y}}\right)-\frac{P}{b d}}{1.25 f_{y}}$
$\rho_{\max }=\frac{0.64 f_{m}^{\prime}\left(\frac{\varepsilon_{m u}}{\varepsilon_{m u}+\alpha \varepsilon_{y}}\right)\left(\frac{b_{w}}{b}\right)+0.80 f_{m}^{\prime} t_{f s}\left(\frac{b-b_{w}}{b d}\right)-\frac{P}{b d}}{1.25 f_{y}}$
Eqn. 8

The tension reinforcement yield strain factor, $\alpha$, varies with the seismic response modification factor, $R$, masonry element, and type of loading as follows:
(a) $\alpha=1.3$ for walls subjected to out-of-plane forces and designed using an $R$ value greater than 1.5,
(b) $\alpha=5.0$ for walls subjected to in-plane forces, for columns and for beams designed using an $R>1.5$,
(c) $\alpha=2.0$ for masonry structures designed using an $\mathrm{R} \leq 1.5$.

In the above set of requirements, $\alpha$ is larger for out-of-plane loads when $R$ is less than or equal to 1.5 , which is contrary to the underlying intent of providing increased ductility for systems and elements whose ductility demand may be relatively high. Several updates and revisions to the maximum have been incorporated into subsequent editions to the 2002 MSJC Code as reviewed below.

## Reinforced Nominal Axial Strength

The nominal axial strength, $P_{u}$, of masonry walls, piers and columns, modified to account for the effects of slenderness, is determined using equation 10 or 11 , as appropriate. The MSJC Code also limits the factored axial stress to $0.20 f^{\prime}{ }_{m}$.
For elements with $h / r$ not greater than 99:
$P_{n}=0.80\left(0.80 f_{m}^{\prime}\left(A_{n}-A_{s}\right)+f_{y} A_{s}\left[1-\left(\frac{h}{140 r}\right)^{2}\right]\right)$
Eqn. 10

For elements with $h / r$ greater than 99:
$P_{n}=0.80\left(0.80 f_{m}^{\prime}\left(A_{n}-A_{s}\right)+f_{y} A_{s}\left(\frac{70 r}{h}\right)^{2}\right)$
Eqn. 11

Note that the reinforcing steel area, $A_{s}$, is included in the nominal axial strength calculation only if it is laterally confined in accordance with Chapter 2 of the MSJC Code.

| Table 1—Modulus of Rupture Values, psi (kPa) |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Direction of flexural tensile stress and masonry type | Portland cement/lime or mortar cement mortar M or S $\qquad$ |  | Masonry cement or air-entrained portland cement/lime mortar M or S |  |
| Normal to bed joints |  |  |  |  |
| Solid units | 100 (689) | 75 (517) | 60 (413) | 38 (262) |
| Hollow units ${ }^{\text {A }}$ |  |  |  |  |
| Ungrouted | 63 (431) | 48 (331) | 38 (262) | 23 (158) |
| Fully grouted ${ }^{\text {B }}$ | $170(1,172)$ | 145 (999) | 103 (710) | 73 (503) |
| Parallel to bed joints in running bond |  |  |  |  |
| Solid units | $200(1,379)$ | $150(1,033)$ | 120 (827) | 75 (517) |
| Hollow units |  |  |  |  |
| Ungrouted and partially grouted | 125 (862) | 95 (655) | 75 (517) | 48 (331) |
| Fully grouted | $200(1,379)$ | $150(1,033)$ | 120 (827) | 75 (517) |
| Parallel to bed joints in stack bond | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

A For partially grouted masonry, allowable stresses shall be determined on the basis of linear interpolation between fully grouted hollow units and ungrouted hollow units based on amount (percentage) of grouting.
в $\quad$ These values have been modified in the 2005 MSJC: see Table 2.

## Reinforced Nominal Flexural Strength

The nominal flexural strength, $M_{n}$, of a reinforced masonry element is determined as outlined below. In addition, the nominal flexural strength at any section along a member must be at least one-fourth of the maximum nominal flexural strength at the critical section.

When there are no axial loads, or when axial loads are conservatively neglected as may be appropriate in some cases, there are several circumstances to consider when determining the nominal flexural strength of reinforced masonry walls. For a fully grouted element, the internal moment arm between the resulting compressive and tensile forces is resolved to determine the resisting capacity of the section. Partially grouted walls are analyzed in the same way, but with the additional consideration of the possible influence of the ungrouted cores on the strength of the section. For partially grouted masonry bending out-of-plane, there are two types of behavior to consider.

1. In the first case, when the neutral axis (the location of zero stress) lies within the compression face shell, the wall is analyzed and designed using the procedures for a fully grouted wall.
2. In the second case, when the neutral axis lies within the core area, the portion of the ungrouted cells must be deducted from the area of masonry capable of carrying compression stresses.
The neutral axis location depends on the reinforcement spacing as well as the reinforcement ratio, $\rho$, and the distance between the reinforcement and the extreme compression fiber, $d$.

When analyzing partially grouted walls, it is typically initially assumed that the neutral axis lies within the compression face shell, as the analysis is more straightforward. The value of $c$ is then calculated based on this assumption. If it is determined that the neutral axis lies outside the compression face shell, the more rigorous tee beam analysis is performed. Otherwise, the rectangular beam analysis is carried out.

## Rectangular Beam Analysis

For fully grouted masonry elements and for partially grouted masonry walls with the neutral axis in the compression face shell, the nominal flexural strength, $M_{n}$, is calculated using equations 12 and 13 as follows:
$M_{n}=\left(A_{s} f_{y}+P_{u}\right)\left(d-\frac{a}{2}\right)$
Eqn. 12
where: $a=\frac{P_{u}+A_{s} f_{y}}{0.80 f_{m}^{\prime} b}$
Eqn. 13

## Tee Beam Analysis

For partially grouted masonry walls where the neutral axis is located within the cores, the nominal flexural strength, $M_{n}$, is calculated using equations 14,15 , and 16 as follows:
$M_{n}=\left(A_{s} f_{y}+P_{u}\right)(d-X)$
Eqn. 14
$X=\frac{\frac{b\left(t_{f s}{ }^{2}\right)}{2}+b_{w}\left(a-t_{f s}\right)\left(t_{f s}+\frac{a-t_{f s}}{2}\right)}{b t_{f s}+b_{w}\left(a-t_{f s}\right)}$
$a=\frac{P_{u}+A_{s} f_{y}}{0.80 f_{m}^{\prime} b_{w}}-t_{f s}\left(\frac{b}{b_{w}}-1\right)$
Eqn. 15

Eqn. 16

To account for deflection resulting from out-of-plane loads and the additional bending moment due to eccentrically applied axial loads, the factored bending moment at the mid-height of a simply supported wall under uniform loading is required to be determined by Equation 17.
$M_{u}=\frac{w_{u} h^{2}}{8}+P_{u f} \frac{e_{u}}{2}+P_{u} \delta_{u}$
Eqn. 17
where: $P_{u}=P_{u w}+P_{u f}$
Eqn. 18
Multiple iterations may be necessary to determine the converging value of the resulting deflection.

## Reinforced Nominal Shear Strength

Shear acting on reinforced masonry members is resisted by the masonry and shear reinforcement, if provided, in accordance with the following:
$V_{n}=V_{m}+V_{s}$
Eqn. 19
Where $V_{n}$ may not exceed the values given by Equations 20 or 21 , as appropriate.
Where $M / V d_{v}$ is less than or equal to 0.25 :
$V_{n} \leq 6 A_{n} \sqrt{f_{m}^{\prime}}$
Eqn. 20
Where $M / V d_{v}$ is greater than 1.00:
$V_{n} \leq 4 A_{n} \sqrt{f_{m}^{\prime}}$
Eqn. 21
For values of $M / V d_{v}$ between 0.25 and 1.00 , the maximum value of $V_{n}$ may be linearly interpolated.

The nominal shear strength provided by the masonry is determined in accordance with the following.
$V_{m}=\left[4.0-1.75\left(\frac{M}{V d_{v}}\right)\right] A_{n} \sqrt{f_{m}^{\prime}}+0.25 P$
$\left(V_{m}=0.83\left[4.0-1.75\left(\frac{M}{V d_{v}}\right)\right] A_{n} \sqrt{f_{m}^{\prime}}+0.25 P\right)$
Where the value of $M / V d_{v}$ need not be taken greater than 1.0.
When shear reinforcement is incorporated into reinforced masonry construction, the shear strength provided by the reinforcement is calculated in accordance with the following.
$V_{s}=0.5\left(\frac{A_{v}}{s}\right) f_{y} d_{v}$
Eqn. 23

## 2006 IBC REQUIREMENTS

The following is a brief summary of the changes and modifications adopted into the 2005 MSJC Code as referenced in the 2006 IBC. The majority of the basic design provisions remain unchanged, with several notable exceptions as reviewed below.

## 2006 IBC Strength Design Modifications

The same modifications for welded and mechanical splices previously discussed in the 2003 IBC Strength Design Modifications section remain in the 2006 IBC. In addition, Section 2108 of the 2006 IBC has incorporated a limit of $72 d_{b}$ on the maximum required length of lap splices used in masonry designed by the strength design method as determined by the 2005 MSJC lap splice provisions. While this limit is typically not triggered for relatively small bar diameters, it can reduce the required lap length of large diameter reinforcing bars or in cases where small cover distances are used. Refer to TEK 12-6 (ref. 13) for detailed splice length requirements.

Other changes to Section 2108 of the 2006 IBC reflect updates and modifications to the 2005 MSJC Code to remove redundant or conflicting requirements.

## 2005 MSJC Code Strength Design Criteria

 Bearing StrengthDue primarily to oversight, the 2002 MSJC Code did not include explicit provisions for determining the bearing strength of masonry subjected to concentrated loads. The bearing strength requirements adopted into the 2005 MSJC Code are similar to those used for allowable stress design, modified as necessary for use in strength design. The nominal bearing strength of masonry is taken as the greater of Equations 24 and 25:
$C_{n}=0.6 f_{m}^{\prime} A_{1}$
Eqn. 24
$C_{n}=0.6 f_{m}^{\prime} A_{1} \sqrt{A_{2} / A_{1}}$
Eqn. 25
The value of 0.6 in Equations 24 and 25 is a design coefficient, not the strength reduction factor, $\phi$, which also happens to be equal to 0.6 for determining the design bearing strength. For use in Equation 25, the following expression must also be satisfied:
$A_{1} \sqrt{A_{2} / A_{1}} \leq 2 A_{1}$
Where $A_{1}$ is the actual bearing area directly under the bearing plate and $A_{2}$ is the effective bearing area, defined as a right pyramid having $A_{1}$ as a top plane and sloping at $45^{\circ}$. For walls laid in stack bond, the area defined by $A_{2}$ is terminated at head joints unless a bond beam or other means of distributing stresses is used. The concentrated stresses are distributed over a length equal to the width of the bearing area plus four times the thickness of the supporting element, but not to exceed the center-to-center distance between the concentrated loads.

## Modulus of Rupture

The 2005 MSJC Code incorporated a few modifications to the modulus of rupture values presented in Table 1 for flexural tension stresses normal to the bed joints of hollow, fully grouted assemblies, as shown in Table 2. These modifications recognize that the type of mortar has less of an influence on the modulus of rupture when the element is fully grouted.

In addition, instead of prescribing a single value of 250 psi (1.72 MPa) for masonry subjected to in-plane bending as in the 2002 MSJC Code, the 2005 MSJC Code requires the use of Table 1, as modified by Table 2, for all cases of in-plane and out-of-plane bending.

## Maximum Flexural Reinforcement Limits

The maximum flexural reinforcement requirements in the 2005 MSJC employ the same strain gradient approach as reviewed above, with several notable revisions.

- Reinforcement is permitted to carry compression stresses, with or without lateral confining reinforcement. Further, the 1.25 factor on the nominal yield stress of the reinforcement as been removed. The resulting equations for the maximum flexural reinforcement limits are given by Equation 26 for fully grouted members or members subjected to in-plane loads, and Equation 27 for partially grouted masonry assemblies subjected to out-of-plane loads where the neutral axis falls in an open cell.
$\rho_{\text {max }}=\frac{0.64 f_{m}^{\prime}\left(\frac{\varepsilon_{m u}}{\varepsilon_{m u}+\alpha \varepsilon_{y}}\right)-\frac{P}{b d}}{f_{y}-\varepsilon E_{s}}$
Eqn. 26
where $\varepsilon=$ the minimum of $\varepsilon_{y}$ and $\left[\varepsilon_{m u}-\frac{d^{\prime}}{d}\left(\varepsilon_{m u}+\alpha \varepsilon_{y}\right)\right]$
$\rho_{\max }=\frac{0.64 f_{m}^{\prime}\left(\frac{\varepsilon_{m u}}{\varepsilon_{m u}+\alpha \varepsilon_{y}}\right)\left(\frac{b_{w}}{b}\right)+0.80 f_{m}^{\prime} t_{s s}\left(\frac{b-b_{w}}{b d}\right)-\frac{P}{b d}}{f_{y}}$ Eqn. 27
- The tension reinforcement yield strain factor, $\alpha$, is taken equal to the following values when $M_{u} / V_{u} d_{v} \geq 1.0$ (indicating performance is dominated by flexure):
- for intermediate reinforced masonry shear walls subjected to in-plane loads: $\alpha=3.0$,
- for special reinforced masonry shear walls subjected to in-plane loads: $\alpha=4.0$,
- for other masonry elements and loading conditions: $\alpha=1.5$.
- For cases where $M_{u} / V_{u} d_{v} \leq 1.0$ (indicating shear dominated performance) and $R>1.5$ : $\alpha=1.5$.
- For masonry members where $M_{u} / V_{u} d_{v} \leq 1.0$ and $R \leq 1.5$, there is no limit on the amount of reinforcement permitted.
- The axial load, $P$, for use in Equations 26 and 27, is the gravity axial load component determined from the following load combination: $D+0.75 L+0.525 Q_{E}$.


## Effective Compression Width per Reinforcing Bar

Section 2108 of the 2003 IBC included limits on the effective compression width per reinforcing bar, which were subsequently removed from the 2006 IBC, as similar provisions were incorporated into the 2005 MSJC Code. For masonry construction in running bond, and for masonry in stack bond construction with bond beams space no further than 48 in. ( $1,219 \mathrm{~mm}$ ) on center, the maximum width of the compression area used is limited to the least of:

- the center-to-center spacing of the reinforcement;
- six times the nominal thickness of the element; or
- 72 in. (1,829 mm).


## Boundary Elements

New to the 2005 MSJC Code are design provisions for boundary elements incorporated into the end zones of masonry shear walls. Because the MSJC does not include minimum prescriptive reinforcement detailing requirements for boundary elements, it requires that when used, their performance be verified by testing. In addition, when meeting the requirements for geometrical symmetry, axial load and flexural performance, the MSJC Code permits the maximum reinforcement limits as reviewed above to be waived. This exception may or may not require the incorporation of special boundary elements, depending on the design circumstances.

## 2008 MSJC STRENGTH DESIGN REQUIREMENTS

At the time of publication, the 2008 edition of the MSJC Code had been finalized, but the 2009 edition of the IBC had not. In anticipation of the 2009 IBC adopting the 2008 MSJC by reference, following is a brief overview of changes to the strength design provisions of the 2008 MSJC Code. In addition to some reorganization, substantive revisions to the strength design method include:

Table 2—Modifications to Modulus of Rupture Values in Table 1, as Included in the 2005 MSJC Code, psi (kPa)

| Direction of flexural tensile stress and masonry type | Portland cement/lime or mortar cement mortar M or S <br> N | Masonry cement or air-entrained portland cement/lime mortar M or S <br> N |  |
| :---: | :---: | :---: | :---: |
| Normal to bed joints Fully grouted | $163(1,124) 158(1,089)$ | $153(1,055)$ | 145 (999) |

$E_{m}=$ modulus of elasticity of masonry, psi (MPa)
$E_{\mathrm{s}}=$ modulus of elasticity of reinforcement, psi (MPa)
$e_{u}=$ eccentricity of $P_{u f}$ in. (mm)
$F_{u}=$ net flexural bending stress due to factored loads, psi (MPa)
$F_{v u}=$ shear stress on unreinforced masonry elements, psi (MPa)
$f^{\prime}{ }_{m}=$ specified compressive strength of masonry, psi (MPa)

- The shear strength check to help preclude brittle failure of a masonry element during an earthquake was revised to apply only to special reinforced masonry shear walls. Previously, this check applied to both reinforced and unreinforced masonry elements regardless of seismic considerations.
- The requirement to provide at least 80 percent of the lateral stiffness through shear walls was revised to apply only to Seismic Design Categories C and higher.
- Instead of requiring that the deflection of all reinforced masonry elements be calculated on cracked section properties, the 2008 MSJC Code simply requires that the design "consider the effects of cracking and reinforcement on member stiffness," thereby permitting more flexibility in design application.
- A moment magnifier approach was incorporated for unreinforced masonry design in determining the influence of $P$-delta effects. The magnified moment, $M_{c}$, is determined either through a second-order analysis, or by the following:
$M_{c}=\delta M_{u}$
Eqn. 28
where: $\delta=\frac{1}{1-\frac{P_{u}}{A_{n} f_{m}^{\prime}\left(\frac{70 r}{h}\right)^{2}}}$
Eqn. 29

For members with $h / r \leq 45$, it is permitted to take $\delta=1.0$. For members with $45<h / r \leq 60$, it is permitted to take $\delta$ $=1.0$ provided that the maximum factored axial stress on the element does not exceed $0.72 f^{\prime}{ }_{m}$.

## NOTATIONS

$A_{n}=$ net cross-sectional area of masonry, in. ${ }^{2}\left(\mathrm{~mm}^{2}\right)$
$A_{s}=$ effective cross-sectional area of reinforcement, in. ${ }^{2}\left(\mathrm{~mm}^{2}\right)$
$A_{v}=$ cross-sectional area of shear reinforcement, in. ${ }^{2}\left(\mathrm{~mm}^{2}\right)$
$A_{1}=$ bearing area under bearing plate, in. ${ }^{2}\left(\mathrm{~mm}^{2}\right)$
$A_{2}=$ effective bearing area, in. ${ }^{2}\left(\mathrm{~mm}^{2}\right)$
$a=$ depth of an equivalent compression zone at nominal strength, in. (mm)
$b=$ width of section, in. (mm)
$b_{w}=$ for partially grouted walls, width of grouted cell plus each web thickness within the compression zone, in. (mm)
$C=$ resultant compressive force, $\mathrm{lb}(\mathrm{N})$
$c$ = distance from the fiber of maximum compressive strain to the neutral axis, in. (mm)
$C_{d}=$ seismic deflection amplification factor
$C_{n}=$ nominal bearing strength, $\mathrm{lb}(\mathrm{N})$
$D=$ dead load, lb (N)
$d=$ distance from the extreme compression fiber to centroid of tension reinforcement, in. (mm)
$d_{b}=$ nominal diameter of reinforcement, in. (mm)
$d_{v}=$ actual depth of masonry in direction of shear considered, in. (mm)
$d^{\prime}=$ distance from the extreme tension fiber to centroid of compression reinforcement, in. (mm)
$f_{r}=$ modulus of rupture, psi (MPa)
$f_{y}=$ specified yield strength of reinforcement, psi (MPa)
$h \quad=\quad$ effective height of masonry element, in. (mm)
$h_{\text {sx }}=$ effective height of masonry element below level x , in. (mm)
$I_{c r}=$ moment of inertia of cracked cross-sectional area of a member, in. ${ }^{4}\left(\mathrm{~mm}^{4}\right)$
$I_{g}=$ moment of inertia of gross cross-sectional area of a member, in. ${ }^{4}\left(\mathrm{~mm}^{4}\right)$
$I_{n}=$ moment of inertia of net cross-sectional area of a member, in. ${ }^{4}\left(\mathrm{~mm}^{4}\right)$
$L \quad=\quad$ live load, lb (N)
$M=$ unfactored maximum calculated bending moment at the section under consideration, in.-lb ( $\mathrm{N}-\mathrm{mm}$ )
$M_{c}=$ factored moment magnified for the effects of member curvature, in.-lb (N-mm)
$M_{\text {cr }}=$ cracking bending moment, in.-lb (N-mm)
$M_{n}=$ nominal moment strength, in.-lb (N-mm)
$M_{\text {ser }}=$ applied bending moment, in.-lb (N-mm)
$M_{u}=$ factored moment, in.-lb (N-mm)
$N_{v}=$ compressive force acting normal to the shear surface, $\mathrm{lb}(\mathrm{N})$
$P \quad=$ unfactored axial load, lb (N)
$P_{n}=$ nominal axial strength, $\mathrm{lb}(\mathrm{N})$
$P_{u} \quad=$ factored axial load, lb (N)
$P_{u f}=$ factored load from tributary floor or roof areas, $\mathrm{lb}(\mathrm{N})$
$P_{u w}=$ factored weight of wall area tributary to wall section under consideration, lb ( N )
$Q_{E} \quad=$ the effect of horizontal seismic forces, $\mathrm{lb}(\mathrm{N})$
$Q_{n}=$ first moment about the neutral axis of a section of that portion of the net cross section lying between the neutral axis and extreme fiber, in. ${ }^{3}\left(\mathrm{~mm}^{3}\right)$
$R \quad=$ seismic response modification factor
$r=$ radius of gyration, in. (mm)
$S_{n}=$ section modulus of cross-section, in. ${ }^{3}\left(\mathrm{~mm}^{3}\right)$
$s=$ spacing of shear reinforcement, in. (mm)
$T=$ tension in reinforcement, $\mathrm{lb}(\mathrm{N})$
$t=$ specified thickness of masonry element, in. (mm)
$t_{\text {ss }}=$ concrete masonry face shell thickness, in. (mm)
$V=$ unfactored shear force, $\mathrm{lb}(\mathrm{N})$
$V_{m}=$ shear strength provided by masonry, $\mathrm{lb}(\mathrm{N})$
$V_{n}=$ nominal shear strength, lb ( N )
$V_{s}=$ shear strength provided by shear reinforcement, lb (N)
$V_{u}=$ factored shear, lb (N)
$w_{u}=$ out-of-plane factored uniformly distributed load, lb/in. ( $\mathrm{N} / \mathrm{mm}$ )
$X \quad=$ forpartially grouted masonry, distance from extreme compression fiber to centroid of the compression resultant, in. (mm)
$\alpha=$ tension reinforcement yield strain factor
$\delta=$ moment magnification factor
$\delta_{s}=$ deflection due to service loads, in. (mm)
$\delta_{u}=$ deflection due to factored loads, in. (mm)
$\varepsilon_{m u}=$ maximum usable compressive strain of masonry
$\varepsilon_{s} \quad=$ steel strain
$\varepsilon_{y} \quad=$ yield strain of reinforcement
$\rho \quad=$ reinforcement ratio
$\rho_{\text {max }}=$ maximum reinforcement ratio
$\phi \quad=$ strength reduction factor

## REFERENCES

1. Building Code Requirements for Masonry Structures, ACI 530-02/ASCE 5-02/TMS 402-02. Reported by the Masonry Standards Joint Committee, 2002.
2. 2003 International Building Code. International Code Council, 2003.
3. Building Code Requirements for Masonry Structures, ACI 530-05/ASCE 5-05/TMS 402-05. Reported by the Masonry Standards Joint Committee, 2005.
4. 2006 International Building Code. International Code Council, 2006.
5. Building Code Requirements for Masonry Structures, ACI 530-08/ASCE 5-08/TMS 402-08. Reported by the Masonry Standards Joint Committee, 2008.
6. Empirical Design of Concrete Masonry Walls, TEK 14-8A. National Concrete Masonry Association, 2001.
7. Allowable Stress Design of Concrete Masonry, TEK 14-7A. National Concrete Masonry Association, 2004.
8. Drysdale, R. G., Hamid, A. A. and Baker L. R., Masonry Structures, Behavior and Design, Second Edition. The Masonry Society, 1999.
9. Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement, ASTM A 706/A 706M-01. ASTM International, 2001.
10. Building Code Requirements for Structural Concrete, ACI 318-02. American Concrete Institute, 2002.
11. Minimum Design Loads for Buildings and Other Structures, ASCE 7-02. Structural Engineering Institute of the American Society of Civil Engineers, 2002.
12. Design of Anchor Bolts Embedded in Concrete Masonry, TEK 12-3A. National Concrete Masonry Association, 2004.
13. Splices, Development and Standard Hooks for Concrete Masonry, TEK 12-6. National Concrete Masonry Association, 2007.
14. Section Properties of Concrete Masonry Walls, TEK 14-1B. National Concrete Masonry Association, 2007.

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## TENSION TESTING CARBON FIBER VERTICALS <br> 07/29/2010



## DESCRIPTION

One sets of carbon fiber samples were received for room temperature tension testing. They were identified as Rhino® Carbon Fiber Verticals.

## MECHANICAL

One set of tensile specimens, with a nominal gage width of 1.0 inches, were received already prepared by the client. Prior to testing it was noted that the specimens had uneven gage sections, jagged edges, areas of non-existent fibers (epoxy only), and uneven layering. Testing was performed at room temperature on a servo-hydraulic test stand withguidance from ASTM D3039-08. Specimens were loaded in displacement

## Case Studies

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06 POWER BEAM ANIMATION (coming soon)
07 REINFORCEMENT SYSTEM
control at a rate of $0.05 \mathrm{in} / \mathrm{min}$ until rupture.
The sample results are presented in Table 01.
Total results from test are presented in Table 02 with comparative results from Fortress Stabilization System's website (www.fortressstabilization.com/weavetest.php).

TABLE 01 (Carbon Fiber Verticals)

| Sample | Ultimate Tensile Strength* | Sample | Ultimate Tensile Strength* |
| :---: | :---: | :---: | :---: |
| 01 | 49,890 | 11 | 45,320 |
| 02 | 64,200 | 12 | 58,070 |
| 03 | 53,700 | 13 | 48,020 |
| 04 | 44,320 | 14 | 61,560 |
| 05 | 42,240 | 15 | 41,530 |
| 06 | 56,510 | 16 | 57,590 |
| 07 | 37,610 | 17 | 40,920 |
| 08 | 46,670 | 18 | 52,980 |
| 09 | 63,430 | 19 | 54,530 |
| 10 | 53,660 | 20 | 58,670 |

*Pounds per square inch (psi).

TABLE 02 (Carbon Fiber Verticals)


## RESULTS

The average ultimate tensile strength for Rhino Carbon Fiber equals 51,571 psi.
The average ultimate tensile strength for Fortress Carbon Fiber equals 18,136 psi.
Through tensile testing we were able to determine that Rhino Carbon Fiber Verticals are substantialy stronger than the competition.
*Results pulled from the Fortress Stabilization System's website
(fortressstabilization.com/weavetest.php).

## PRODUCT OVERVIEW

## INSTALLATION

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[^0]:    $A_{o g}=$ total area of openings in the building envelope (walls and roof, in $\mathrm{ft}^{2}$ )
    $V_{i}=$ unpartitioned internal volume, in $\mathrm{ft}^{3}$

[^1]:    Notes:

    1. $\quad \mathrm{C}_{\mathrm{NW}}$ and $\mathrm{C}_{\mathrm{NL}}$ denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
    2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to $50 \%$. Obstructed wind flow denotes objects below roof inhibiting wind flow ( $>50 \%$ blockage).
    3. For values of $\theta$ between $7.5^{\circ}$ and $45^{\circ}$, linear interpolation is permitted. For values of $\theta$ less than $7.5^{\circ}$, use monoslope roof load coefficients.
    Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
    4. All load cases shown for each roof angle shall be investigated.
    5. Notation:
    $\mathrm{L} \quad$ : horizontal dimension of roof, measured in the along wind direction, $\mathrm{ft} .(\mathrm{m})$
    h : mean roof height, ft. (m)
    $\gamma \quad$ : direction of wind, degrees
    $\theta$ : angle of plane of roof from horizontal, degrees
