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, \( V \): Three-second gust speed at 33 ft (10 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
\[
A_o = \text{total area of openings in a wall that receives positive external pressure, in ft}^2 (\text{m}^2)
\]
\[
A_g = \text{the gross area of that wall in which } A_o \text{ is identified, in ft}^2 (\text{m}^2)
\]

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 ft\(^2\) (0.37 m\(^2\))
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. \( Ao > 1.10A_{oi} \)
2. \( Ao > 4 \text{ ft}^2 (0.37 \text{ m}^2) \) or \( > 0.01A_{gi} \), whichever is smaller, and \( A_{oi}/A_{gi} \leq 0.20 \)

where

\( A_{oi}, A_{gi} \) are as defined for Open Building

\( A_{oi} = \) the sum of the areas of openings in the building envelope (walls and roof) not including \( A_{oi} \), in \( \text{ft}^2 (\text{m}^2) \)

\( A_{gi} = \) the sum of the gross surface areas of the building envelope (walls and roof) not including \( A_{oi} \), in \( \text{ft}^2 (\text{m}^2) \)

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, \( F \):** Equivalent static force to be used in the determination of wind loads for other structures.

**DESIGN PRESSURE, \( p \):** 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, \( h_e \):** 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, \( A \):** The area used to determine \((GC_p)\). 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 under 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 mi/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, \( h \):** 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°, 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 ft$^2$ (m$^2$)
- $A_f$ = area of open buildings and other structures either normal to the wind direction or projected on a plane normal to the wind direction, in ft$^2$ (m$^2$)
- $A_g$ = the gross area of that wall in which $A_o$ is identified, in ft$^2$ (m$^2$)
- $A_{gi}$ = the sum of the gross surface areas of the building envelope (walls and roof) not including $A_g$, in ft$^2$ (m$^2$)
- $A_o$ = total area of openings in a wall that receives positive external pressure, in ft$^2$ (m$^2$)
- $A_{oi}$ = the sum of the areas of openings in the building envelope (walls and roof) not including $A_o$, in ft$^2$ (m$^2$)
- $A_{og}$ = total area of openings in the building envelope in ft$^2$ (m$^2$)
- $A_s$ = gross area of the solid freestanding wall or solid sign, in ft$^2$ (m$^2$)
- $a$ = width of pressure coefficient zone, in ft (m)
- $B$ = horizontal dimension of building measured normal to wind direction, in ft (m)
- $\bar{b}$ = mean hourly wind speed factor in Eq. 26.9-16 from Table 26.9-1
- $\dot{b}$ = 3-s gust speed factor from Table 26.9-1
- $C_f$ = force 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)
- $D'$ = depth of protruding elements such as ribs and spoilers, in ft (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
- $(GC_{nu})$ = combined net pressure coefficient for a parapet
- $(GC_{pf})$ = product of external pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings
- $(GC_{pf})$ = 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
- $(GC_{pi})$ = product of internal pressure coefficient and gust-effect factor to be used in determination of wind loads for MWFRS of low-rise buildings
- $(GC_{pi})$ = product of internal pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings
- $g_Q$ = 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
- $h$ = 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°, in ft (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
- $I_t$ = intensity of turbulence from Eq. 26.9-7
- $K_1$, $K_2$, $K_3$ = multipliers in Fig. 26.8-1 to obtain $K_t$
- $K_a$ = wind directionality factor in Table 26.6-1
- $K_b$ = velocity pressure exposure coefficient evaluated at height $z = h$
- $K_c$ = velocity pressure exposure coefficient evaluated at height $z$
- $K_t$ = 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)
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 permitted 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-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° 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° 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.
This page intentionally left blank.
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 (m/s) at 33 ft (10m) 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 (m/s) at 33 ft (10m) 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 (m/s) at 33 ft (10m) 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, $K_d$

<table>
<thead>
<tr>
<th>Structure Type</th>
<th>Directionality Factor $K_d^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td></td>
</tr>
<tr>
<td>Main Wind Force Resisting System</td>
<td>0.85</td>
</tr>
<tr>
<td>Components and Cladding</td>
<td>0.85</td>
</tr>
<tr>
<td>Arched Roofs</td>
<td>0.85</td>
</tr>
<tr>
<td>Chimneys, Tanks, and Similar Structures</td>
<td></td>
</tr>
<tr>
<td>Square</td>
<td>0.90</td>
</tr>
<tr>
<td>Hexagonal</td>
<td>0.95</td>
</tr>
<tr>
<td>Round</td>
<td>0.95</td>
</tr>
<tr>
<td>Solid Freestanding Walls and Solid Freestanding and Attached Signs</td>
<td>0.85</td>
</tr>
<tr>
<td>Open Signs and Lattice Framework</td>
<td>0.85</td>
</tr>
<tr>
<td>Trussed Towers</td>
<td></td>
</tr>
<tr>
<td>Triangular, square, rectangular</td>
<td>0.85</td>
</tr>
<tr>
<td>All other cross sections</td>
<td>0.95</td>
</tr>
</tbody>
</table>

*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 ft (9.1 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 ft (9.1 m), Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 2,600 ft (792 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 ft (1,524 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 ft (183 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 exposures, 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 ($100H$) 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-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.
### Chapter 26: Wind Loads: General Requirements

#### Topographic Factor, $K_{zt}$

**Figure 26.8-1**

<table>
<thead>
<tr>
<th>$H/L_h$</th>
<th>$K_1$ Multiplier</th>
<th>$K_2$ Multiplier</th>
<th>$K_3$ Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-D Ridge</td>
<td>2-D Escarp.</td>
<td>3-D Axisym. Hill</td>
</tr>
<tr>
<td>0.20</td>
<td>0.29</td>
<td>0.17</td>
<td>0.21</td>
</tr>
<tr>
<td>0.25</td>
<td>0.36</td>
<td>0.21</td>
<td>0.26</td>
</tr>
<tr>
<td>0.30</td>
<td>0.43</td>
<td>0.26</td>
<td>0.32</td>
</tr>
<tr>
<td>0.35</td>
<td>0.51</td>
<td>0.30</td>
<td>0.37</td>
</tr>
<tr>
<td>0.40</td>
<td>0.58</td>
<td>0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>0.45</td>
<td>0.65</td>
<td>0.38</td>
<td>0.47</td>
</tr>
<tr>
<td>0.50</td>
<td>0.72</td>
<td>0.43</td>
<td>0.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$x/L_h$</th>
<th>2-D Escarp.</th>
<th>All Other Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.50</td>
<td>0.88</td>
<td>0.67</td>
</tr>
<tr>
<td>1.00</td>
<td>0.75</td>
<td>0.33</td>
</tr>
<tr>
<td>1.50</td>
<td>0.63</td>
<td>0.00</td>
</tr>
<tr>
<td>2.00</td>
<td>0.50</td>
<td>0.00</td>
</tr>
<tr>
<td>2.50</td>
<td>0.38</td>
<td>0.00</td>
</tr>
<tr>
<td>3.00</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>3.50</td>
<td>0.13</td>
<td>0.00</td>
</tr>
<tr>
<td>4.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$z/L_h$</th>
<th>2-D Escarp.</th>
<th>All Other Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>0.10</td>
<td>0.74</td>
<td>0.78</td>
</tr>
<tr>
<td>0.20</td>
<td>0.55</td>
<td>0.61</td>
</tr>
<tr>
<td>0.30</td>
<td>0.41</td>
<td>0.47</td>
</tr>
<tr>
<td>0.40</td>
<td>0.30</td>
<td>0.37</td>
</tr>
<tr>
<td>0.50</td>
<td>0.22</td>
<td>0.29</td>
</tr>
<tr>
<td>0.60</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>0.70</td>
<td>0.12</td>
<td>0.17</td>
</tr>
<tr>
<td>0.80</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>0.90</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>1.00</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>1.50</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Notes:**

1. For values of $H/L_h$, $x/L_h$, and $z/L_h$ other than those shown, linear interpolation is permitted.
2. For $H/L_h > 0.5$, assume $H/L_h = 0.5$ for evaluating $K_1$ and substitute $2H$ for $L_h$ for evaluating $K_2$ and $K_3$.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:
   - $H$: Height of hill or escarpment relative to the upwind terrain, in feet (meters).
   - $L_h$: Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in feet (meters).
   - $K_1$: Factor to account for shape of topographic feature and maximum speed-up effect.
   - $K_2$: Factor to account for reduction in speed-up with distance upwind or downwind of crest.
   - $K_3$: Factor to account for reduction in speed-up with height above local terrain.
   - $x$: Distance (upwind or downwind) from the crest to the building site, in feet (meters).
   - $z$: Height above ground surface at building site, in feet (meters).
   - $\mu$: Horizontal attenuation factor.
   - $\gamma$: Height attenuation factor.
Equations:

\[ K_{zt} = (1 + K_1 K_2 K_3)^2 \]

\[ K_1 \text{ determined from table below} \]

\[ K_2 = (1 - \frac{|x|}{\mu L_h}) \]

\[ K_3 = e^{-\gamma z/L_h} \]

<table>
<thead>
<tr>
<th>Hill Shape</th>
<th>( K_1/(H/L_h) )</th>
<th>( \gamma )</th>
<th>( \mu )</th>
<th>Upwind of Crest</th>
<th>Downwind of Crest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-dimensional ridges (or valleys with negative ( H ) in ( K_1/(H/L_h) ))</td>
<td>1.30</td>
<td>1.45</td>
<td>1.55</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>2-dimensional escarpments</td>
<td>0.75</td>
<td>0.85</td>
<td>0.95</td>
<td>2.5</td>
<td>1.5</td>
</tr>
<tr>
<td>3-dimensional axisym. hill</td>
<td>0.95</td>
<td>1.05</td>
<td>1.15</td>
<td>4</td>
<td>1.5</td>
</tr>
</tbody>
</table>
4. $H/L_h \geq 0.2$.
5. $H$ is greater than or equal to 15 ft (4.5 m) for Exposure C and D and 60 ft (18 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 $K_{zt}$:

$$K_{zt} = (1 + K_1 K_2 K_3)^2 \quad (26.8-1)$$

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 $K_{zt} = 1.0$.

### 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, $L_{eff}$.

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

$$L_{eff} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} \quad (26.9-1)$$

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 ($n_a$), 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:

$$n_a = 22.2/h^{0.8} \quad (26.9-2)$$

For concrete moment-resisting frame buildings:

$$n_a = 43.5/h^{0.9} \quad (26.9-3)$$

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

$$n_a = 75/h \quad (26.9-4)$$

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

$$n_a = 385(C_w)^{0.5}/h \quad (26.9-5)$$

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 ($ft^2$)
$A_i$ = horizontal cross-section area of shear wall “$i$” ($ft^2$)
$D_i$ = 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:

$$G = 0.925 \left( \frac{1+1.7g_0 L_\tau Q}{1+1.7g_0 I_\tau} \right) \quad (26.9-6)$$

$$I_\tau = c \left( \frac{33}{\tau} \right)^{1/6} \quad (26.9-7)$$

254
In SI: \( L_z = \sqrt[1/6]{\frac{10}{c}} \)

where \( I_z \) is the intensity of turbulence at height \( z \)
where \( z \) is the equivalent height of the structure defined as \( 0.6h \), 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; \( g_0 \) and \( g_r \) shall be taken as 3.4. The background response \( Q \) is given by

\[
Q = \frac{1}{\sqrt{1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} \quad (26.9-8)
\]

where \( B \) and \( h \) are defined in Section 26.3 and \( L_z \) is the integral length scale of turbulence at the equivalent height given by

\[
L_z = \ell \left(\frac{\pi}{33}\right) \quad (26.9-9)
\]

In SI: \( L_z = \ell \left(\frac{\pi}{10}\right) \)

in which \( \ell \) and \( \varepsilon \) 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

\[
G_f = 0.925 \left(1 + 1.7I_\tau \sqrt{g_0 Q^2 + g_r^2 R^2}\right) \quad (26.9-10)
\]

\( g_0 \) and \( g_r \) shall be taken as 3.4 and \( g_r \) is given by

\[
g_r = \sqrt{2\ln(3600n_1)} + \frac{0.577}{\sqrt{2\ln(3600n_1)}} \quad (26.9-11)
\]

\( R \), the resonant response factor, is given by

\[
R = \frac{1}{\sqrt{\beta}} \left(\frac{R_s R_{\tau} N_1}{0.53 + 0.47R_{\tau}}\right) \quad (26.9-12)
\]

\[
R_s = \frac{7.47N_1}{(1 + 10.3N_1)^{3/3}} \quad (26.9-13)
\]

\[
N_1 = \frac{n_1 L_z}{\sqrt{\tau}} \quad (26.9-14)
\]

\[
R_{\tau} = \frac{1}{\eta} \left(1 - \frac{1}{2n_1^2(1 - e^{-2n})}\right) \quad \text{for} \quad \eta > 0 \quad (26.9-15a)
\]

\[
R_{\tau} = 1 \quad \text{for} \quad \eta = 0 \quad (26.9-15b)
\]

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
\( R_{\tau} = R_s \) setting \( \eta = 4.6n_1h/V_z \)
\( R_{\tau} = R_s \) setting \( \eta = 4.6n_1B/V_z \)
\( R_{\tau} = R_s \) setting \( \eta = 15.4n_1L/V_z \)
\( \beta \) = damping ratio, percent of critical (i.e. for 2% use 0.02 in the equation)
\( V_z \) = mean hourly wind speed (ft/s) at height \( z \) determined from Eq. 26.9-16:

\[
V_z = \beta \left(\frac{\pi}{33}\right) \left(\frac{88}{60}\right) V \quad (26.9-16)
\]

In SI: \( V_z = \beta \left(\frac{\pi}{10}\right) V \)

where \( \beta \) and \( \alpha \) are constants listed in Table 26.9-1 and \( V \) is the basic wind speed in mi/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 \( (GC_p), (GC_{pi}), \) and \( (GC_{pf}) \) 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**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>$\alpha$</th>
<th>$z_t$ (ft)</th>
<th>$\frac{\bar{a}}{a}$</th>
<th>$\frac{\bar{b}}{b}$</th>
<th>$\bar{a}$</th>
<th>$\bar{b}$</th>
<th>$c$</th>
<th>$\ell$ (ft)</th>
<th>$\bar{e}$</th>
<th>$z_{min}$ (ft)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7.0</td>
<td>1200</td>
<td>0.84</td>
<td>1/4.0</td>
<td>0.45</td>
<td>0.30</td>
<td>320</td>
<td>1/3.0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>9.5</td>
<td>900</td>
<td>1/9.5</td>
<td>1/6.5</td>
<td>0.65</td>
<td>0.20</td>
<td>500</td>
<td>1/5.0</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>11.5</td>
<td>700</td>
<td>1/11.5</td>
<td>1/9.0</td>
<td>0.80</td>
<td>0.15</td>
<td>650</td>
<td>1/8.0</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

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

**In metric**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>$\alpha$</th>
<th>$z_t$ (m)</th>
<th>$\frac{\bar{a}}{a}$</th>
<th>$\frac{\bar{b}}{b}$</th>
<th>$\bar{a}$</th>
<th>$\bar{b}$</th>
<th>$c$</th>
<th>$\ell$ (m)</th>
<th>$\bar{e}$</th>
<th>$z_{min}$ (m)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7.0</td>
<td>365.76</td>
<td>0.84</td>
<td>1/4.0</td>
<td>0.45</td>
<td>0.30</td>
<td>97.54</td>
<td>1/3.0</td>
<td>9.14</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>9.5</td>
<td>274.32</td>
<td>1/9.5</td>
<td>1/6.5</td>
<td>0.65</td>
<td>0.20</td>
<td>152.4</td>
<td>1/5.0</td>
<td>4.57</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>11.5</td>
<td>213.36</td>
<td>1/11.5</td>
<td>1/9.0</td>
<td>0.80</td>
<td>0.15</td>
<td>198.12</td>
<td>1/8.0</td>
<td>2.13</td>
<td></td>
</tr>
</tbody>
</table>

* $z_{min} = \text{minimum height used to ensure that the equivalent height } \bar{Z} \text{ is greater of 0.6}h \text{ or } z_{min}.$
  
  For buildings with $h \leq z_{min}$, $\bar{Z}$ shall be taken as $z_{min}$.
1. Within 1 mi of the coastal mean high water line where the basic wind speed is equal to or greater than 130 mi/h (58 m/s), or

2. In areas where the basic wind speed is equal to or greater than 140 mi/h (63 m/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 m) above the ground and over 30 ft (9.2 m) above aggregate-surfaced-roofs, including roofs with gravel or stone ballast, located within 1,500 ft (458 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 impact-protective 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, \( GC_{pi} \), 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, \( R_i \)

For a partially enclosed building containing a single, unpartitioned large volume, the internal pressure coefficient, \( GC_{pi} \), shall be multiplied by the following reduction factor, \( R_i \):

\[
R_i = 1.0 \text{ or } \frac{1}{\sqrt{1 + \frac{V_i}{22.800A_{og}}}} < 1.0 \quad (26.11-1)
\]

where

\( A_{og} \) = total area of openings in the building envelope (walls and roof, in ft²)

\( V_i \) = unpartitioned internal volume, in ft³
## Table 26.11-1 Internal Pressure Coefficient, \((GC_{pi})\)

<table>
<thead>
<tr>
<th>Enclosure Classification</th>
<th>((GC_{pi}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Buildings</td>
<td>0.00</td>
</tr>
<tr>
<td>Partially Enclosed Buildings</td>
<td>+0.55, -0.55</td>
</tr>
<tr>
<td>Enclosed Buildings</td>
<td>+0.18, -0.18</td>
</tr>
</tbody>
</table>

**Notes:**

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of \((GC_{pi})\) 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 \((GC_{pi})\) applied to all internal surfaces
   (ii) a negative value of \((GC_{pi})\) applied to all internal surfaces