# CHAPTER 2

# Design for Wind Loads

**Nomenclature**

| | | |
|---|---|---|
| $a$ | width of pressure coefficient zone | ft |
| $A$ | effective wind area | ft$^2$ |
| $A_g$ | gross area of wall in which $A_o$ is identified | ft$^2$ |
| $A_{gi}$ | sum of gross surface areas of building envelope (walls and roof), excluding $A_g$ | ft$^2$ |
| $A_o$ | total area of openings in a wall receiving positive external pressure | ft$^2$ |
| $A_{oi}$ | sum of areas of all openings in building envelope (walls and roof), excluding $A_o$ | ft$^2$ |
| $b_e$ | effective joist spacing | ft |
| $B$ | horizontal dimension of building measured normal to wind direction | ft |
| $C_p$ | external pressure coefficient | – |
| $C_{pi}$ | internal pressure coefficient | – |
| $G$ | gust effect factor | – |
| $(GC_p)$ | product of gust effect factor and external pressure coefficient | – |
| $(GC_{pf})$ | product of gust effect factor and equivalent external pressure coefficient for determining wind loads in MWFRS of low-rise buildings | – |
| $(GC_{pi})$ | product of internal pressure coefficient and gust effect factor | – |
| $h$ | mean roof or eave height | ft |
| $h$ | eave height for roof angle, θ, less than or equal to 10° | ft |
| $K_1$, $K_2$, $K_3$ | multipliers from ASCE 7 Figure 26.8-1 used to obtain $K_{zt}$ | – |
| $K_d$ | wind directionality factor given in ASCE 7 Table 26.6-1 | – |
| $K_e$ | ground elevation factor given in ASCE 7 Table 26.9-1 | – |
| $K_h$ | velocity pressure exposure coefficient evaluated at height $z = h$ | – |
| $K_z$ | velocity pressure exposure coefficient evaluated at height $z$ | – |
| $K_{zt}$ | topographic factor as defined in ASCE 7 Section 26.8.1 | – |

| | | |
|---|---|---|
| $l$ | span of joist | ft |
| $L$ | horizontal dimension of building measured parallel to wind direction | ft |
| MWFRS | main windforce-resisting system | – |
| $p$ | design pressure for determining wind loads | lb/ft$^2$ |
| $p_e$ | external wind pressure given by ASCE 7 Equation (27.3-1) | lb/ft$^2$ |
| $p_i$ | internal wind pressure given by ASCE 7 Equation (27.3-1) | lb/ft$^2$ |
| $q$ | velocity pressure given by ASCE 7 Equation (26.10-1) | lb/ft$^2$ |
| $q_h$ | velocity pressure evaluated at height $z = h$ | lb/ft$^2$ |
| $q_s$ | wind stagnation pressure | lb/ft$^2$ |
| $q_z$ | velocity pressure evaluated at height $z$ above ground | lb/ft$^2$ |
| $s$ | joist spacing | ft |
| $V$ | basic wind speed | mph |
| $w$ | distributed load | lb/ft |
| $z$ | height above ground | ft |
| $z_g$ | gradient height | ft |
| **Symbols** | | |
| $\gamma$ | exposure adjustment factor | – |
| $\theta$ | angle of plane of roof from horizontal | degree |
| $\lambda$ | adjustment factor for building height and exposure | – |

## 2.1 Wind effects

On striking an enclosed building, wind flows around the sides and over the roof and produces either a pressure or a suction on the external surfaces of the building. As shown in Figure 2-1, the windward wall that is perpendicular to the wind direction experiences an inward, positive pressure. As wind flows around the corners of the windward wall, the turbulence produced separates the airflow from the walls and causes an outward, negative pressure or suction on the sidewalls and the leeward wall. As wind flows over a high-sloping gable roof, a positive pressure is produced on the windward side of the ridge and a suction on the leeward side of the ridge. However, for gable roofs with shallow slopes, suction also develops on the windward side of the ridge and for flat roofs, suction develops over the whole roof.

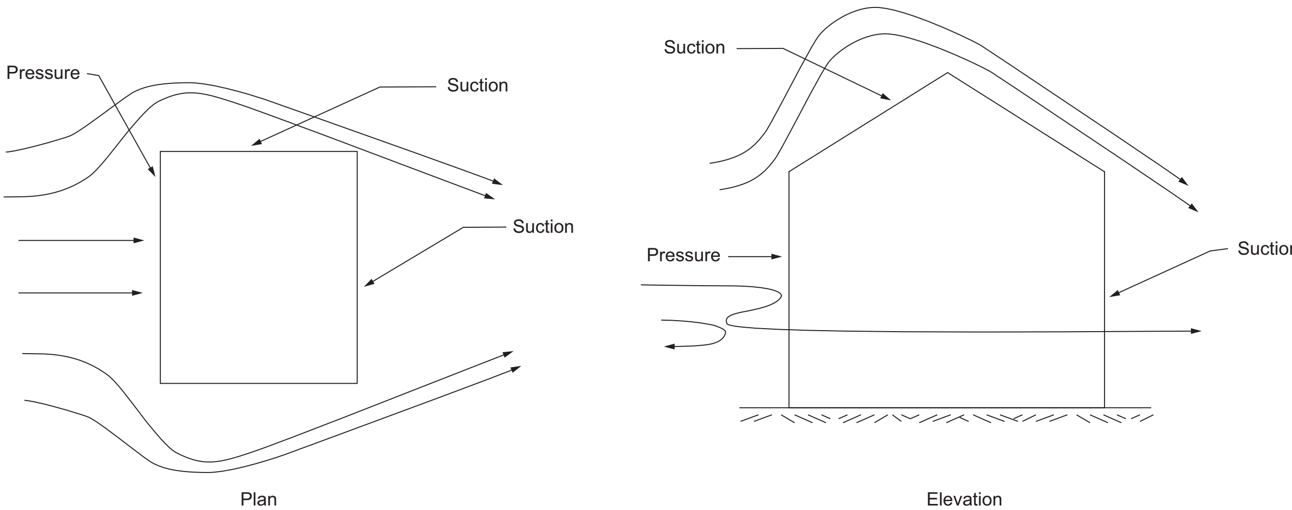


**Figure 2-1 Wind pressure effects**

Procedures are available for determining pressures on the main windforce-resisting system (MWFRS) and on components and cladding. The main windforce-resisting system is defined in the *International Building Code*® (IBC®)[1] Section 202 as the structural elements assigned to provide support and stability for the overall structure. Components and cladding are defined in ASCE 7[2] Section 26.2 as elements of the building envelope that do not qualify as part of the main windforce-resisting system. The cladding of a building receives wind loading directly. Examples of cladding include wall and roof sheathing, windows, and doors. Components receive wind loading from the cladding and transfer the load to the main windforce-resisting system. Components include purlins, studs, girts, fasteners, and roof trusses. Some elements, such as roof trusses and sheathing, may also form part of the main windforce-resisting system and must be designed for both conditions. Because of local turbulence, which may occur over small areas at ridges and corners of buildings, components and cladding are designed for higher wind pressures than the main windforce-resisting system.

The design procedures consist of two basic approaches:

- the directional procedure determines the wind loads on buildings for specific wind directions, in which the external pressure coefficients are based on wind tunnel testing of prototypical building models for the corresponding direction of wind
- the envelope procedure determines the wind load cases on buildings, in which pseudo external pressure coefficients are derived from 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, and so on) that envelope their maximum values among all possible wind directions

## 2.2 Analysis procedures

Several analysis procedures are permitted by IBC Section 1609.1.1 for determining the wind loads on buildings. For determining wind loads on the main windforce-resisting system of buildings, the permitted procedures are:

- the analytical directional design method of ASCE 7 Chapter 27 Part 1 Section 27.3. This is applicable to enclosed, partially enclosed, and open buildings of all heights and roof geometry. Wind pressure is calculated using specific wind pressure equations applicable to each building surface. The method uses the directional procedure to separate applied wind loads onto the windward walls, leeward walls, and sidewalls of the building to correctly assess the forces in the members.

- the simplified directional method of ASCE 7 Chapter 27 Part 2 Section 27.5. This is based on the analytical method of ASCE 7 Chapter 27 Part 1, and wind pressures are obtained directly from a table. The method is applicable to enclosed, simple diaphragm buildings of any roof geometry complying with the requirements of either Class 1 or Class 2 buildings. For a Class 1 building, the dimensions must be such that

  $$h \leq 60 \text{ ft}$$

  $$0.2 \leq L/B \leq 5.0$$

  where:
  $h$ = mean roof height
  $L$ = horizontal dimension of building parallel to the wind direction
  $B$ = horizontal dimension of building normal to the wind direction

  For a Class 2 building, the dimensions must be such that

  $$60 \text{ ft} < h \leq 160 \text{ ft}$$

  $$0.5 \leq L/B \leq 2.0$$

  In addition, the fundamental natural frequency of the building shall be not less than $75/h$ where $h$ is in feet.

- the analytical envelope design method of ASCE 7 Chapter 28 Part 1 Section 28.3. This is applicable to enclosed, partially enclosed, and open low-rise buildings that have a flat, gable, or hip roof with a height not exceeding 60 feet and not exceeding the least horizontal dimension. Wind pressure is calculated using specific wind pressure equations applicable to each building surface. The method uses the envelope procedure to separate applied wind loads onto the windward walls, leeward walls, and sidewalls of the building to correctly assess the forces in the members.

- the simplified envelope method of ASCE 7 Chapter 28 Part 2 Section 28.5. This is based on the envelope procedure of ASCE 7 Chapter 28 Part 1 and is applicable to enclosed, simple diaphragm low-rise buildings that have a flat, gable, or hip roof with a height not exceeding 60 feet. Wind pressures are obtained directly from a table and applied to vertical and horizontal projected surfaces of the building.

- the wind tunnel procedure of ASCE 7 Chapter 31, which may be used for any structure. This is a procedure for determining wind loads, using a model of the building or other structure and its surroundings, in which pressures, forces, and moments may be determined for each wind direction considered. The wind tunnel procedure must be used when the limiting conditions of the previous methods are not satisfied. This method is considered to produce the most accurate wind pressure values.

- the prescriptive provisions of ICC 600: *Standard for Residential Construction in High-Wind Regions*[3] is permitted for applicable Group R-2 and R-3 buildings, subject to the limitations of IBC Section 1609.1.1.1.

- the prescriptive provisions of AWC *Wood Frame Construction Manual for One- and Two-Family Dwellings*[4], subject to the limitations of IBC Section 1609.1.1.1.

- the prescriptive provisions of AISI S230 *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings*[5], subject to the limitations of IBC Section 1609.1.1.1.

## 2.3 General requirements

To calculate the wind loads on a building, it is necessary to determine a number of prerequisites, including:

- the exposure category of the site
- wind speed at the location of the structure
- the velocity pressure exposure coefficient
- the topography at the location of the building
- the probable direction of the wind
- the building type

### 2.3.1 Exposure category

Exposure category accounts for the effect of terrain roughness on wind speed and is defined in ASCE 7 Section C26.7. The height and density of topographic features and buildings for a selected upwind fetch distance are considered. Three surface roughness categories are specified and listed in Table 2-1 and are illustrated in Figure 2-2.

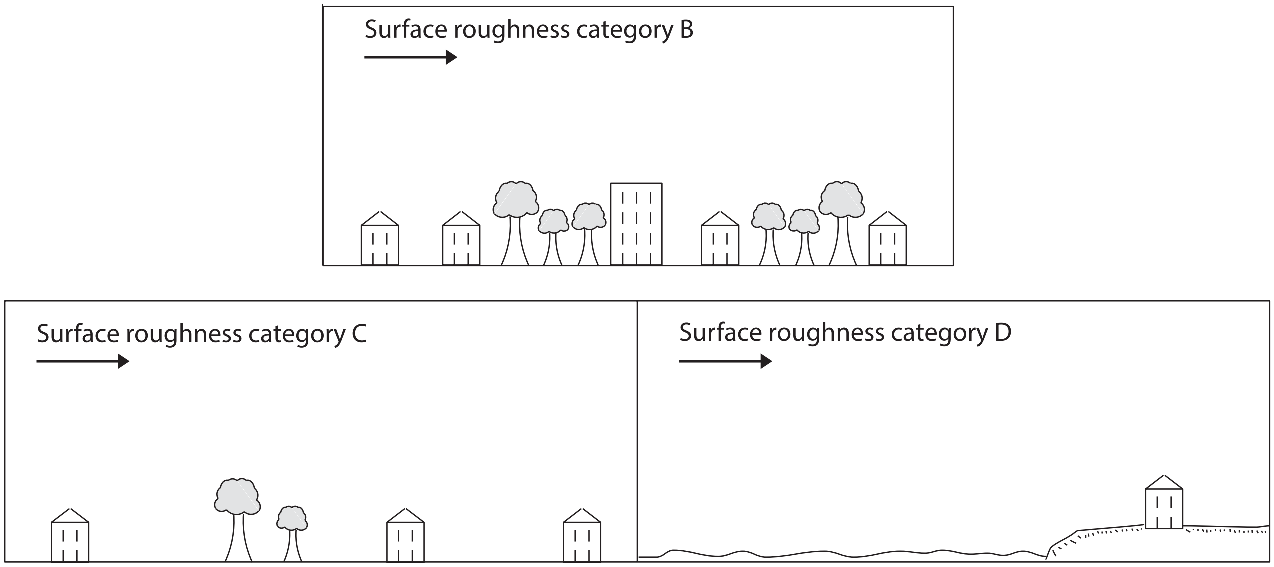


**Figure 2-2 Surface roughness categories**

The three exposure categories are listed in Table 2-1, and exposure categories B and D are illustrated in Figure 2-3.

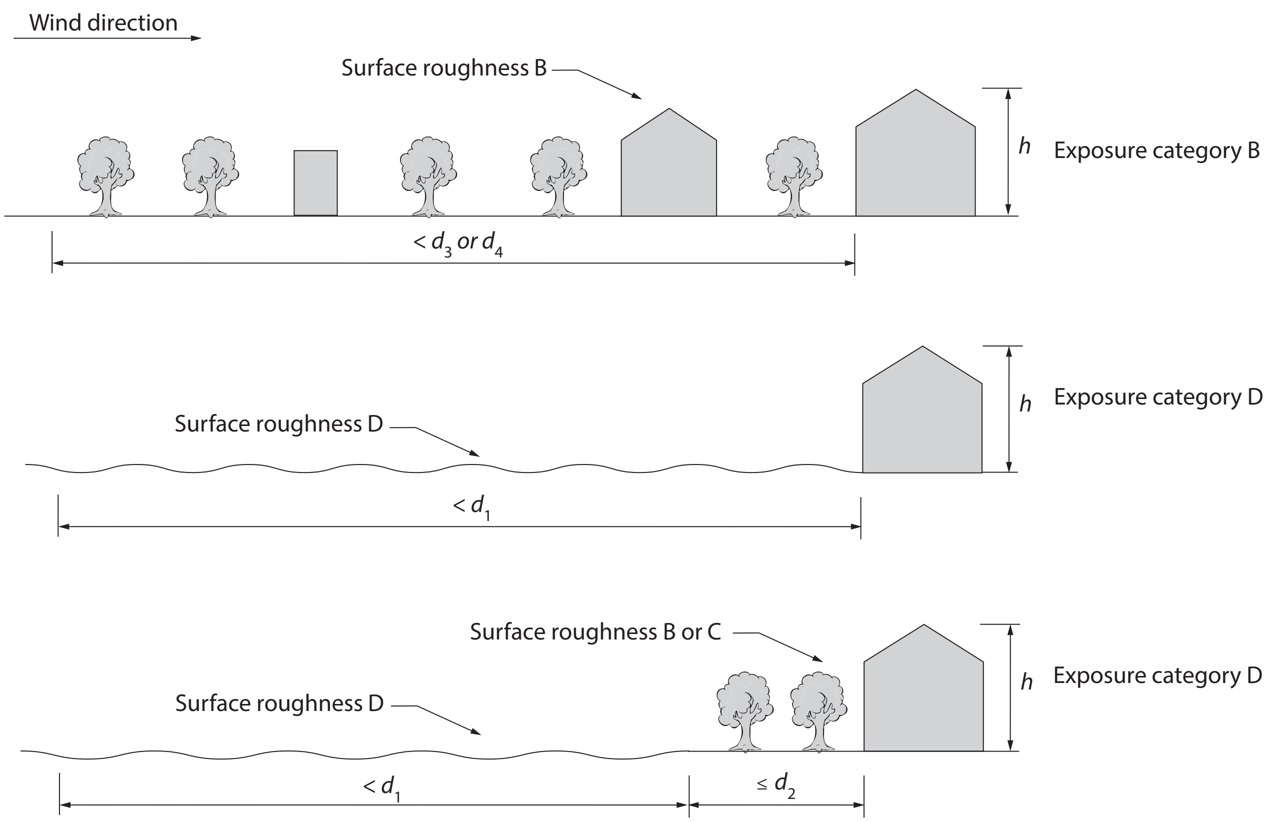


**Figure 2-3 Exposure categories (See Table 2-1 for notation)**