2007 CBC STRUCTURAL PROVISIONS - WIND

Wind loads are addressed in ASCE 7 Chapter 6 and CBC Section 1609. The IBC refers the user to ASCE 7 provisions for determination of wind loads.

ASCE 7-05: WIND LOAD PROVISIONS

ASCE 7 presents 3 methods:

1. ***Method 1**: "**Simplified Design**" method for low-rise buildings (ASCE Section 6.4*
    a. *MWFRS*
    b. *C&C*

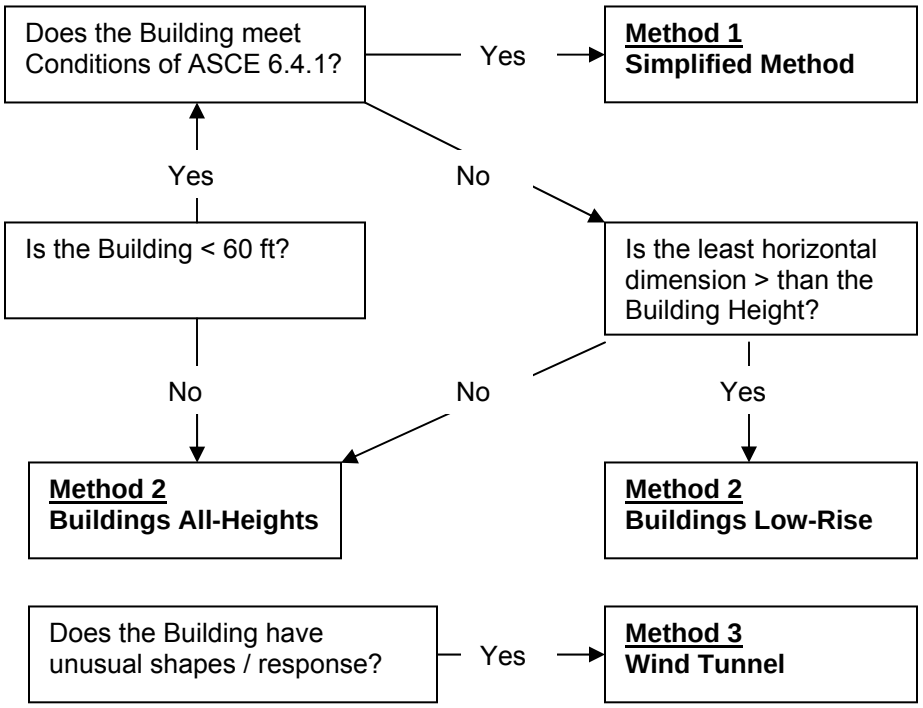
2. ***Method 2**: "**Analytical Design**" method generally applicable to regular buildings (ASCE Section 6.5)*
    a. *All Heights*
        i. *MWFRS*
        ii. *C&C*
    b. *Low-rise*
        i. *MWFRS*
        ii. *C&C*

3. ***Method 3**: "**Wind Tunnel**" procedure (ASCE Section 6.6)*

In addition, CBC Section 1609.1.1 allows additional design methods:

4. *A prescriptive method, developed by the Southern Building Code Congress International, (SBCCI SSTD 10) for Groups R-2 & R-3, with some restrictions per Section 1609.1.1.1*
5. *A prescriptive method, developed by the American Forest & Paper Association (AF&PA WFCM) for residential structures, with some restrictions per CBC Section 1609.1.1.1*

<u>NOTE:</u> Lateral-force-resisting system shall meet seismic detailing requirements and limitations prescribed in ASCE 7… **even when wind load effects are greater than seismic load effects** (seismic detailing does not "go away" if wind governs!).



Method 1: *Simplified Procedure* – ASCE 7-05 Section 6.4

Limitations on ***MWFRS*** (Main Wind-Force Resisting System):

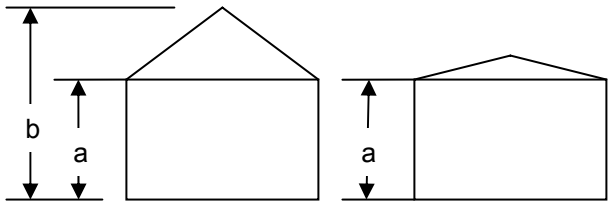
ASCE 6.4.1.1
ASCE 6.2

1. Building is a **simple diaphragm** building – a building in which both the windward and leeward loads are transmitted through the floor and roof diaphragms to the same MWFRS.

2. The building is **low-rise** – it has a mean roof height h < 60 ft, and has at least horizontal dimension not less than the mean roof height.

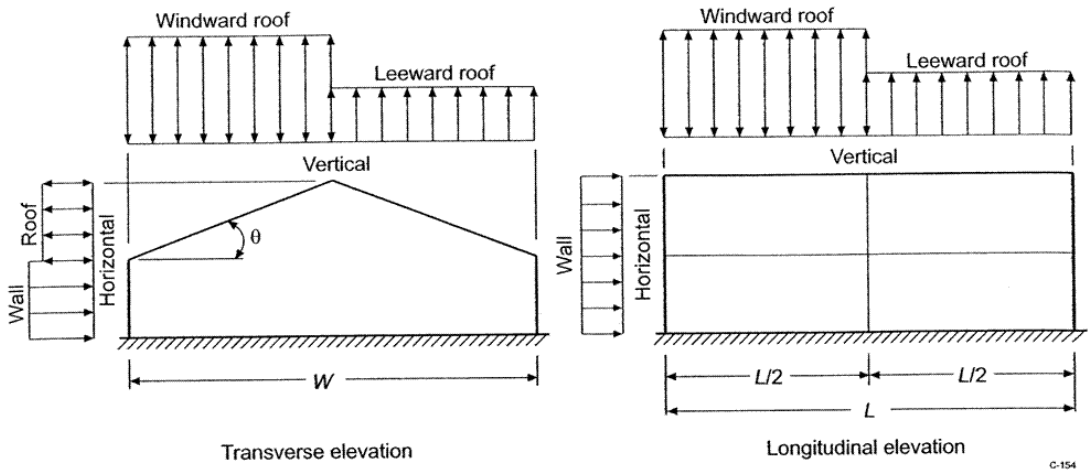
3. The building is "**enclosed**" and meets requirements for wind-borne

debris protection (if applicable). 4. The building is **regular** – has no unusual geometric irregularity is special form. 5. The building is not classified as flexible building (slender buildings with fundamental frequency < 1 Hz). *Note:* General rule-of-thumb for Rigid vs. Flexible buildings: Height to minimum Width < 4 (ASCE 7-05 Section 6 Commentary) 6. The building does not have response characteristics that create unusual loading (such as galloping or vortex shedding) and is not sited in a location where unusual wind load effects might occur (this is an effect for tall buildings > 60 ft). 7. The building has an approximate symmetrical cross section in each direction, and has a flat roof or gable or hip roof with slope θ ≤ 45 degrees (12:12 pitch). 8. The building is exempted from torsional load cases of ASCE 7 Figures 6-10, or the torsional cases do not control design. *Exceptions:* One- and two-story wood-framed construction is exempted per footnote 5.	
Components & Cladding, C&C are members making up the exterior envelope of the building, including wall and roof framing, sheathing, and finish material. For the design of the ***C&C***, the building must meet all of the following conditions: 1. The mean roof height $h \leq 60$ ft. 2. The building is "enclosed" as defined in ASCE Section 6.2. 3. The building is a regular-shaped building or structure as defined in ASCE Section 6.2. 4. The building does not have response characteristic making it subject to across wind loading, vortex shedding, instability due to galloping or flutter; and does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration. 5. The building has either flat roof, a gable roof with θ ≤ 45°, or a hip roof with θ ≤ 27°.	ASCE 6.4.1.2
Design Wind Pressure: Design Wind Pressure for ***MWFRS***: ASCE Formula (6-1) $P_S = \lambda K_{zt} I_w P_{S30}$	ASCE 6.4.2

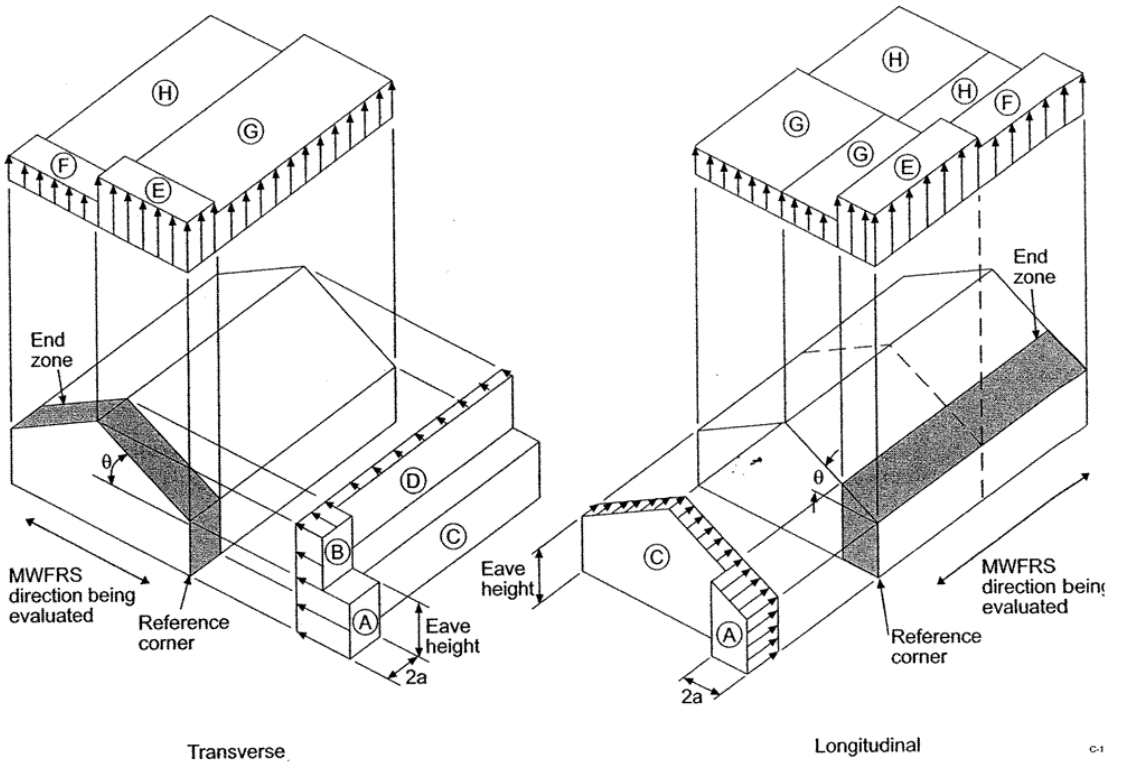
Design of the ***Components & Cladding (C&C)*** : ASCE Formula (6-2) $P_{net} = \lambda K_{zt} Iw P_{net30}$ Where…		
P_{S30}:	*Simplified Design Wind Pressure* for ***MWFRS*** from Fig. 6-2 Once the basic wind speed (from ASCE 7 – Figure 6-1, or from local building official) is determined, the simplified design wind pressure, P_{S30}, can be read from ASCE & Figure 6-2. *Wind Exposure Categories*: **Exposure B**… applies to Surface Roughness B in upwind direction for distance of 2,600 feet or 20 times height of building, whichever is greater. Exception: For buildings with mean roof height not greater than 30 feet, upwind distance may be reduced to 1,500 feet. **Exposure D**… applies to Surface Roughness D in upwind direction for a distance of 5,000 feet or 20 times height of building, whichever is greater. Exposure D shall extend inland from shoreline for a distance of 600 feet or 20 times height of building, whichever is greater. **Exposure C**… **applies when B or D do not apply**. Applicable to open terrain with scattered obstruction having heights generally less than 30 feet. This category includes flat open country, grasslands, and direct coastal exposure in hurricane-prone regions.	ASCE Fig. 6-1 & 2 CBC Fig. 1609 Guidance given in ASCE Commentary C6.5.6.
P_{net30}:	*Net design wind pressure* for ***Components & Cladding (C&C)*** P_{net30} = ± 10 psf - minimum (+) & maximum (-) net design	ASCE Fig. 6-3 ASCE 6.4.2.2.1
λ:	*Height & Exposure Factor:* Mean roof Height, h = For roof angles > 10° For roof angles < 10°  **h = (a + b) / 2** **h = a**	ASCE 7-05 Figure 6-2 or 6-3
K_{zt}:	*Topographical Factor:*	ASCE Sec. 6.5.7

	Accounts for higher wind speeds experienced by buildings sited on or adjacent to an abrupt change in topography such as isolated hill, ridge, or escarpment. $K_{zt} = (1 + K_1K_2K_3)^2$ » For Hillside Sites $K_{zt} = 1.0$ » No topographic effect; for applications see the 5 items below K_1: Factor that accounts for the gradient of the slope. It is related to the shape of the topographic feature and the maximum speed-up near the crest (H/Ln). K_2: Factor that accounts for the distance of the building from the crest. Accounts for the reduction in speed-up with distance upwind or downwind of the crest (x/Ln). K_3: Factor that accounts for the gradient of the slope. Accounts for the reduction in speed-up with height above the local ground surface (Z/Ln). *Note:* Factors from ASCE Figure 6-4 The Topographic Factor is applicable, provided that: 1. The hill, ridge, or escarpment is unobstructed upwind by similar features for a distance given by the lesser of 100 times the height of the topographic feature or 2 miles. 2. The topographic feature protrudes above the height of the upwind terrain, within a radius of 2 miles, by a factor of not less than 2. 3. The building is located on the upper one half of a hill or ridge or near the crest of an escarpment. 4. $H / L_h \geq 0.2$ 5. H > 15 ft (Exposure C & D) and 60 ft (Exposure B)	ASCE 6.5.7.1.5 ASCE 6.5.7.1
Iw:	*Importance Factor:* **ASCE Table 6-1** **Occupancy** | **Iw** I | 0.87 II | 1.0 III (Assembly with O.L. > 300) | 1.15 IV (Essential Facilities) | 1.15 *Notes:* 1. For change in use to an Assembly (with O.L. > 300), the structure has to be rechecked for wind loads & I = 1.15 2. Use IBC Table 1604.5 for Occupancy Category, not ASCE Table 1-1. They are not the same!	ASCE Section 2.4 IBC Table 1604.5

Main Wind-Force-Resisting System (*MWFRS*) – Loading Diagrams:

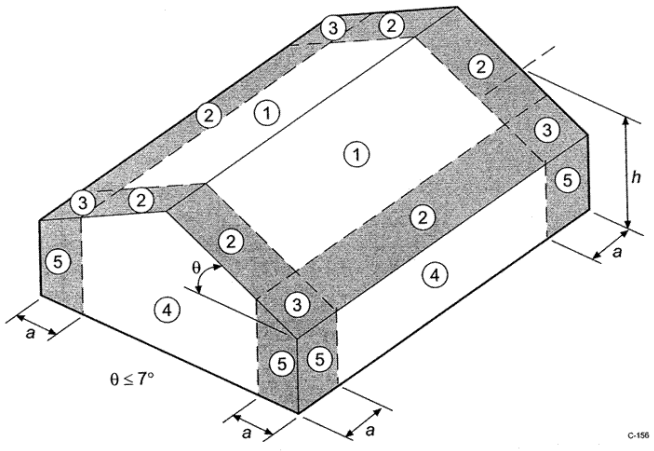


Design wind pressures are assumed to act normal to the projected wall and roof areas. The values given for the walls in the Tables represent the sum of the positive pressure on the windward face of the building and the negative pressure on the leeward face and are applied to the windward projection of the building of the building.



The Figure above shows the locations of end zones and interior zones of the MWFRS. The load patterns shown are applied to each corner of the building in turn as the reference corner. Wind pressures are positive when acting toward the projected surface and negative when acting away from the projected surface.

Components & Cladding (C&C) – Loading Diagrams:



The building surface is divided into interior zones, edge strips, and corner zones. The design wind pressures are assumed to act normal to the wall and roof areas. ASCE 7 Figure 6-3 give composite pressure values that include the internal pressures appropriate to an enclosed building condition.

Design Procedure:

Main Wind-Force-Resisting-System (*MWFRS*):

1. ASCE Fig. 6-2 provides MWFRS design loads (psf) for buildings with mean roof height of 30 ft and located in Exposure Category B, I_W = 1.0, and K_{ZT} = 1.0
2. Using height and exposure adjustment coefficient (λ) from ASCE Fig 6-2 for different heights & exposures.
3. Apply MWFRS loads in accordance with ASCE Fig 6-2.

Components & Cladding (*C&C*):

1. ASCE Fig. 6-3 provides Component & Cladding design loads (psf) for buildings with mean roof height of 30 ft and located in Exposure Category B, I_W = 1.0, and K_{ZT} = 1.0
2. Using height and exposure adjustment coefficient (λ) from ASCE Fig 6-3 for different heights & exposures.
3. Apply MWFRS loads in accordance with ASCE Fig 6-3.

Minimum Wind Loading:

1. ***Main Wind-Force-Force-Resisting System*** (***MWFRS***): Not less than **10 psf** multiplied by area of building projected on vertical plane normal to wind direction.

ASCE 6.1.4.1

ASCE 6.1.4.2

2. ***Components & Cladding*** (***C&C***): Not less than net pressure of **10 psf** acting in either direction normal to surface.	

Method 2: *Analytical Procedure* – ASCE 7-05 Section 6.5		
The *Design Load* due to wind can be calculated after determining the following:		ASCE 6.5.3
Step 1.	• The *Basic wind speed* V • A *Wind Directionality Factor* K_d (ASCE 6.5.4.4, Table 6-4)	ASCE Sec. 6.5.4 CBC Sec. 1609.3
Step 2.	An *Importance Factor*, I Using IBC Table 1604.5 for Occupancy Category	ASCE Sec. 6.5.5 IBC Table 1604.5
Step 3.	For each wind direction: • An *exposure category*, and • *Velocity Pressure Exposure Coefficient* K_z or K_h	ASCE Sec. 6.5.6 ASCE 6.5.6.6, Table 6-3
Step 4.	A *Topographic Factor,* K_{zt}	ASCE Sec. 6.5.7 Figure 6-4
Step 5.	A *Gust Effect Factor,* G or $G_{f;}$ 1. For "rigid" structures as defined in Section 6.2, G = 0.85, or calculated by Eqs. 604, 6-5, 6-6 and 6-7, using Table 6-2. 2. For "flexible" structures as defined in Section 6.2, Gf shall be calculated by Eqs. 6-8, 6-9, 6-10, 6-11, 6-12, 6-13a, 6-13b and 6-14, using Table 6-2.	ASCE Sec. 6.5.8
Step 6.	An "*Enclosure*" classification: 1. Buildings, **Open**: • A building having each wall at least 80% open Ao ≥ 0.8Ag, Where: Ao: Total area of openings in a wall that receives (+) external pressure, sq. ft Ag: Gross area of that wall in which Ao is identified, sq. ft 2. Buildings, **Partially Enclosed**: • Ao > 1.1 Aoi • Ao > 4 sq. ft or > 0.01 Ag, whichever is smaller, and Aoi ≤ 0.2 Agi Where: Aoi: The sum of areas of openings in the building envelope (walls & roof) not including Ao, in sq. ft Agi: The sum of the gross surface areas of the building envelope (walls & roof) not	ASCE Sec. 6.5.9

<table>
<tr><td></td><td>including Ag, in sq. ft

3. Buildings, Enclosed:
• A building that does not comply with the requirements for open or partially enclosed buildings.</td><td></td></tr>
<tr><td>Step 7.</td><td>Internal Pressure Coefficient, GC_{pi}

<table><tr><th>Enclosure Classification</th><th>GC_{pi}</th></tr><tr><td>Open Buildings</td><td>0.00</td></tr><tr><td>Partially Enclosed Buildings</td><td>±0.55</td></tr><tr><td>Enclosed Buildings</td><td>±0.18</td></tr></table></td><td>ASCE 6.5.11.1
Figure 6-5</td></tr>
<tr><td>Step 8.</td><td>External Pressure Coefficient, C_p or GC_{pf} (ASCE 6.5.11.2)
Or Force Coefficient, C_f (ASCE 6.5.11.2)

Cp: For main wind force resisting system — Fig. 6-6
GC_{pf}: For low-rise buildings — Fig. 6-10
GC_p: For components & cladding — Fig. 6-11 ~ 17
C_N: For main wind force resisting system — Fig. 6-18
C_N: For components & cladding — Fig. 6-19
C_f: — Fig. 6-20 ~ 23</td><td>ASCE 6.5.11.2
ASCE 6.5.11.3</td></tr>
<tr><td>Step 9.</td><td>Velocity Pressure, q_z or q_h:
$q_z = 0.00256\ K_Z\ K_{Zt}\ K_d\ V^2\ I$</td><td>ASCE Sec. 6.5.10
Equation 6-15</td></tr>
<tr><td>Step 10.</td><td>Design Wind Pressure (ASCE 6.5.12, 6.5.13) or Wind Force, F (ASCE 6.5.14, 6.5.15)

<table><tr><th colspan="3">Enclosed or Partially Enclosed Buildings, MWFRS</th></tr><tr><td>» Rigid, All heights:</td><td>$P = q\ GC_p - qi\ (GC_{pi})$</td><td>Eq. 6-17</td></tr><tr><td>» Low-Rise:</td><td>$P = q_h\ (GC_{pf} - GC_{pi})$</td><td>Eq. 6-18</td></tr><tr><td>» Flexible:</td><td>$P = q\ G_f C_p - qi\ (GC_{pi})$</td><td>Eq. 6-18</td></tr><tr><td>» Parapets:</td><td>$P = q\ GC_{pn}$</td><td>Eq. 6-20</td></tr><tr><th colspan="3">Enclosed or Partially Enclosed Buildings, C&C</th></tr><tr><td>» Low-Rise & Buildings with h ≤ 60 ft</td><td>$P = q_h\ (GC_p - GC_{pi})$</td><td>Eq. 6-22</td></tr><tr><td>» Buildings with h > 60 ft</td><td>$P = q\ GC_p - qi\ (GC_{pi})$</td><td>Eq. 6-23</td></tr><tr><td>» Parapets</td><td>$P = q_p\ (GC_p - GC_{pi})$</td><td>Eq. 6-24</td></tr><tr><th colspan="3">Open Buildings, MWFRS</th></tr><tr><td>» MWFRS</td><td>$P = q_h\ GC_N$
C_N from Figs. 6-18A ~ 6-18D</td><td>Eq. 6-25</td></tr><tr><td>» C & C</td><td>$P = q_h\ GC_N$
C_N from Figs. 6-19A ~ 6-19C</td><td>Eq. 6-26</td></tr><tr><th colspan="3">Solid Freestanding Walls & Solid Signs</th></tr><tr><td>» Solid Freestanding Walls & Signs</td><td>$F = q_h\ GC_f\ A_S$</td><td>Eq. 6-27</td></tr></table></td></tr>
</table>

Method 3: *Wind Tunnel Procedure* – ASCE 7-05 Section 6.6

References:

International Code Council: *2006 IBC & 2007 CBC*
American Society of Civil Engineers: *Minimum Design Loads for Buildings and Other Structures*
CALBO: "*2007 CBC – Structural Plans Examination*"
S. K. Ghosh Associates Inc.: "*Overview of the Wind Provisions of the 2006 IBC*"
Alan Williams: "*Seismic and Wind Forces – Structural Design Examples*"