Building and Safety Division • Public Information

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WIND LOAD DETERMINATION – ALTERNATE METHOD

Policy: The following Alternate Wind Design procedure is not mandatory, but will be accepted by the Building and Safety Division as an alternate to Section 1609.1 of the 2007 CBC for projects under the jurisdiction of the County of Ventura.

Background: A Tri-State Wind Code Committee consisting of delegates from the Structural Engineering Associations of California, Oregon and Washington developed the following alternate wind design procedure. This alternate procedure is formatted similar to the 1997 UBC, but includes the basic approach, nomenclature and latest wind design knowledge of the ASCE 7 Standard. This procedure combines the internal and external pressures on each external surface of a building into a single Net Pressure Coefficient, Cnet. The Cnet coefficients are used in the equation for obtaining the design wind pressure, Pnet, for each external surface of the building.

1. Alternate Wind Design Procedure: The following wind load provisions are permitted by the Building and Safety Division as an alternative to Section 6.5 Method 2 – Analytical Procedure of ASCE 7, as mandated in Section 1609.1 of the 2007 (CBC).

2. Limitations: Buildings or other structures whose design wind forces are allowed to be determined in accordance with this method shall meet the following requirements:

2.1 The building or other structure shall have no unusual geometric irregularity or spatial form.

2.2 The building or other structure does not have response characteristics 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.

2.3 A building or other structure greater than 100 feet (30480 mm) in height shall be limited to a height-to-least-width ratio of 4 or less, and with a fundamental natural period less than or equal to one second.

Commentary: The starting assumption of the procedure is that the structures are "rigid," which is defined as having a fundamental natural period of at least one Hz (period of less than one second). Item 2.3 is intended to define that item. Structures less than 100 ft can generally be considered rigid, at least for the approximate period in ASCE Section 12.8.2.1 (these are similar period calculations as 2001 CBC Section 16302.2) Thus the flexible structure requirements in ASCE 7 Chapter 6 can be ignored.

3. Modifications to ASCE 7: The text of ASCE 7 shall be modified as follows:

3.1 Symbols and notations: Symbols and notations are specific to this section in conjunction with Symbols and notations in ASCE 7, Section 6.3.

B = Horizontal dimension of building measured normal to wind direction

B_{MWFRS} = Maximum horizontal distance between vertical elements of MWFRS resisting wind forces in any given direction.

C_{net} = Net-pressure coefficient based on K_d $[GC_p - (GC_{pi})]$, see Table 2

G = Gust effect factor equal to 0.85 for rigid buildings as defined in ASCE 7, Section 6.5.8.1

I = Importance factor in ASCE 7 Table 6-1

K_d = Wind directionality factor as defined in ASCE 7, Section 6.5.4.4.

P_{net} = Design wind pressure used to determine wind loads on buildings or other structures, or their components and cladding, in lb/ft^2 (N/m^2)

q_s = Wind velocity pressure in lb/ft^2 (N/m^2), Table 1

3.2 Design wind pressures: When using the Alternate Wind Design Procedure, the Main-Wind-Force-Resisting System, (MWFRS) and Components and Cladding of every building or structure shall be designed to resist the effects of wind pressures on the building envelope. The net pressure on exterior building surfaces shall be determined as follows:

$$P_{net} = q_s K_z C_{net} [I K_{zt}]$$ **(Equation 1)**

Design wind forces for the MWFRS shall not be less than 10 lb/ft^2 (0.48 kN/m^2) multiplied by the area of the building or structure projected on a plane normal to the wind direction under consideration. See ASCE 7 Section 6.1.4 for criteria. Design wind pressure for components and cladding shall not be less than 10 lb/ft^2 (0.48 kN/m^2) acting in either direction normal to the surface.

3.3 Design procedure: The MWFRS of every building or other structure shall be designed for the combination of the windward and leeward net pressure, P_{net}, using Equation 1. Components and claddings of every building or structure shall be designed for the critical net pressure, P_{net}, using Equation 1.

3.3.1 Main wind force resisting systems: The MWFRS shall be designed for the wind load cases as defined in ASCE 7 Figure 6-9.

Exceptions:

1. One-story buildings with *h* less than or equal to 30 ft, buildings two stories or less framed with light-frame construction, and buildings two stories or less designed with flexible diaphragms need only be designed for Load Case 1 and Load Case 3 in Fig. 6-9.
2. Where the ratio B_{MWFRS}/B exceeds 0.7, only Load Case 1 and Load Case 3 in Fig. 6-9 need be considered, provided the design wind load is increased 20% for the vertical elements of the MWFRS closest to the perimeter, for those lateral lines which resist less than 50% of the total wind force at that story.

Commentary: Section 3.3.1 of the Building and Safety Division Policy is different than the code change proposal by SEA. The original ASCE 7 requirement to use the load cases in Figure 6-9 was put back into the procedure. Exception 1 is directly from ASCE 7. The proposal from SEA was to simplify the torsion was included as Exception 2. However, since there is an increase to some of the vertical elements in the MWFRS due to the torsion load case, the 20% increase was included for the perimeter lines of resistance. When using Exception 2, wall lines that resist more than 50% of the lateral load at that story will not see an increase due to the torsional load cases.

3.3.2 Determination of K_z and K_{zt}: Velocity pressure exposure coefficient, K_z, shall be determined in accordance with ASCE 7 Section 6.5.6.6; and Topography Factor, K_{zt}, shall be determined in accordance with ASCE 7 Section 6.5.7.

1. For windward side of a structure, K_z and K_{zt} shall be based on height z.
2. For leeward side and side walls, and for windward and leeward roofs, K_z and K_{zt} shall be based on mean roof height *h*.

K_z for exposure C = $2.01(z/900)^{0.21}$ where z is the height in ft and $z \geq 15$ ft. For other exposures, see ASCE 7 Table 6-3.

3.3.3 Determination of net pressure coefficient C_{net}: For the design of the main wind force resisting system and for components and cladding, the net pressure shall be as follows:

1. The net pressure coefficient, C_{net} for walls and roofs shall be determined from Table 2.
2. Where C_{net} may have more than one value, the more severe wind load combination shall be used for design.

3.4 Application of wind pressures: When using Alternate Wind Design Procedure, wind pressure shall be applied simultaneously on, and in a direction normal to, all building envelope wall and roof surfaces.

3.4.1 Components and cladding: Wind pressure for each component or cladding element is applied using C_{net} values based on the effective wind area, *A*, contained within the zones in areas of discontinuity of width and/ or length "a", "2a" or 4a" at: corners of roofs and walls; edge strips for ridges, rakes and eaves; or field areas on walls or roofs as indicated in Table 2, and shall meet the following requirements:

1. Calculated pressure at local discontinuities acting over specific edge strips or corner boundary areas.
2. Include "field" (Zones 1, 2 or 4 as applicable) pressures applied to areas beyond the boundaries of the areas of discontinuity.
3. Where applicable, calculated pressures at discontinuities (Zones 2 or 3) shall be combined with design pressures on rake or eave overhangs.

TABLE 1
WIND VELOCITY PRESSURE (q_s) AT STANDARD HEIGHT OF 33 FEET[a]

Basic Wind Speed, V (mph)[b]	85	90	95	100	110	120	130	140	150
Pressure, q_s (lb/ft^2) [c]	18.5	20.7	23.1	25.6	31.0	36.9	43.3	50.2	57.6

a. For wind speeds not shown, use $q_s = 0.00256\ V^2$

b. Multiply by 1.61 to convert to km/h

c. Multiply by 0.0478 to convert to kN/m^2

TABLE 2
NET PRESSURE COEFFICIENT, C_{net}

STRUCTURE OR PART THEREOF	DESCRIPTION		C_{NET} FACTOR [a, f]			
			Enclosed		Partially enclosed	
1. Main Wind Force Resisting System	Walls:					
	Windward wall		0.43		0.11	
	Leeward wall		-0.51		-0.83	
	Side wall		-0.66		-0.97	
	Parapet wall	Windward	1.28		1.28	
		Leeward	-0.85		-0.85	
	Roofs:					
	Wind perpendicular to ridge					
	Leeward roof or flat roof		-0.66		-0.97	
	Windward roof slopes:					
	Slope ≤ 2:12 (or 10º)	Case 1	-1.09		-1.41	
		Case 2	-0.28		-0.60	
	Slope 4:12 (or 18º)	Case 1	-0.73		-1.05	
		Case 2	-0.05		-0.37	
	Slope 5:12 (or 22º)	Case 1	-0.59		-0.90	
		Case 2	0.03		-0.29	
	Slope 6:12 (or 27º)	Case 1	-0.47		-0.79	
		Case 2	0.06		-0.25	
	Slope 7:12 (or 30º)	Case 1	-0.37		-0.68	
		Case 2	0.06		-0.25	
	Slope 9:12 (or 37º)	Case 1	-0.27		-0.58	
		Case 2	0.14		-0.18	
	Slope 12:12 (or 45º)	Case 1	-0.15		-0.47	
		Case 2	0.14		-0.18	
	Slope 21:12 (or 60º)		0.28		-0.03	
	Slope > 21:12 (or 60º)		c		c	
	Wind parallel to ridge or flat roofs		-1.09		-1.41	
2. Components and cladding - Walls [b]	Affected zone [d]		4	4	5	5
	Wall elements h ≤ 60 ft.	≤ 10 sf	1.00	-1.09	1.00	-1.34
		≥ 500 sf	0.75	-0.83	0.75	-0.83
	Wall elements h > 60 ft.	≤ 20 sf	0.92	-0.92	0.92	-1.68
		≥ 500 sf	0.66	-0.75	0.66	-1.00
	Parapet walls h ≤ 60 ft		2.53	-1.94	3.38	-2.19
	Parapet walls h > 60 ft		2.87	-1.68	3.64	-2.45

3. Components and cladding - Roofs[b]	Affected zone[d]	1	1	2	2	3	3
	Roof for h > 60 ft[e]						
	Slope ≤ 2: 12 (or 10º) ≤ 10 sf	-	-1.34	-	-2.11	-	-2.87
	≥ 500 sf	-	-1.00	-	-1.51	-	-2.11
	Gable and Hipped Roof h ≤ 60 ft						
	Slope ≤ 6:12 (or 27º) ≤ 10 sf	0.58	-1.00	0.58	-1.68	0.58	-2.53
	≥ 100 sf	0.41	-0.92	0.41	-1.17	0.41	-1.85
	Overhang ≤ 10 sf	-	-1.45	-	-1.87	-	-3.15
	≥ 100 sf	-	-1.36	-	-1.87	-	-2.13
	Slope 6:12 to 12:12 ≤ 10 sf	0.92	-1.00	0.92	-1.17	0.92	-1.17
	(or 27º to 45º) ≥ 100 sf	0.83	-0.83	0.83	-1.00	0.83	-1.00
	Overhang ≤ 10 sf	-	-	-	-1.70	-	-1.70
	≥ 100 sf	-	-	-	-1.53	-	-1.53
	Monoslope Roof h ≤ 60 ft						
	Slope ≤ 7:12 (or 30º) ≤ 10 sf	0.49	-1.26	0.49	-1.51	0.49	-2.62
	≥ 100 sf	0.41	-1.09	0.41	-1.43	0.41	-1.85

4. Chimneys, tanks and solid towers[b]	**Height / depth or diameter (h/D)**	**1**	**7**	**25**
	Square (wind normal to face)	0.99	1.07	1.53
	Square (wind along diagonal)	0.77	0.84	1.15
	Hexagonal or Octagonal	0.81	0.97	1.13
	Round	0.65	0.81	0.97

5. Open sign and lattice frameworks	**Ratio of solid to gross area**	**< 0.1**	**0.1 to 0.29**	**0.3 to 0.7**
	Flat	1.45	1.30	1.16
	Round	0.87	0.94	1.08

6. Solid Freestanding Wall	**Horizontal to vertical dimension (B/s)**	**0 to s**	**s to 2s**	**≥ 3s**
	Case A and Case B (all B/s)	1.45	1.45	1.45
	Case C (2 ≤ B/s ≤ 5)	2.24	1.45	1.45
	Case C (B/s > 5)	3.10	1.88	1.45

a. Linear interpolation between tabulated C_{net} values and between tabulated slope or effective wind areas is acceptable.
b. Overhang values are for both enclosed and partially enclosed buildings. For other than overhangs, component and cladding values are for enclosed buildings. For partially enclosed buildings, algebraically add or subtract 0.32 to increase values on table.
c. Use wall element values for slopes greater than 21:12 (60º).
d. Refer to ASCE 7 Figure 6-11-A through Figure 6-17 for affected zone designations.
e. For roof slope > 2:12 (or 10º), use coefficients tabulated for gable and hipped roof h ≤ 60 ft.
f. Open structures can conservatively use the values for "enclosed structures" except for a MWFRS mono-slope windward roof, which must add +0.15 to the Case 2 C_{net} factor.

Commentary: Many of the Figures in ASCE include multiple C_p pressure values that are not included in Table 2. For example, in Figure 6-6, the wall pressure coefficient C_p varies depending on the L/B ratio. The L/B ratio with a C_p value that results in the largest C_{net} value was used in Table 2. The same logic was used for other ratios not included in Table 2, such as the h/L values for the MWFRS roof values. Also, the reduction factor for the MWFRS roof values based on area were ignored.

Appendix 1 – Additional Background and Commentary

Reason for Developing the Alternate Method: The following is an excerpt from the SEAOC presentation to the IBC requesting the addition of the Alternate Method into the IBC model code.

> In response to concerns from design engineers on the complexity of wind design procedures, this proposal provides for an alternate design procedure to Method 2 of ASCE 7.
>
> In using 2006 IBC and ASCE 7, engineers have found that, except for low rise light framed buildings, lateral force design of most structures tends to be controlled by seismic forces in the western states. While ASCE 7 includes a simplified procedure under Method 1 for buildings not greater than sixty feet in height, the procedure includes various limitations such as simple diaphragm, low rise building with no unusual geometrical irregularity, and requires an engineer to refer to numerous relatively complicated charts. The complexity of the detailed Analytical Procedure has daunted even the most experience engineers. The need for wind design procedure in the IBC similar to that which was in the 1997 UBC has been echoed throughout most of the United States.
>
> The Structural Engineers Association of California established a Wind *Ad Hoc* Committee in late 2006. The group was charged to develop alternate wind design procedures for all height buildings in conjunction with the Tri-state (California, Oregon and Washington) Wind Committee. The Tri-state Wind Committee, with representatives appointed by each of the three states' structural engineers' associations, all of whom are experienced structural engineers, was active in code development for the 1991 UBC using ASCE 7-88 standard as the source document, and also took a primary roll in developing the basic format of the wind design provisions in the 1997 Uniform Building Code, which is still being used in several states.
>
> This proposed alternate design procedure is developed for the most common type of buildings that are not subjected to dynamic response with further limitations for building or other structure over 100 feet. The alternate method follows closely with design requirements Chapter 6 of ASCE 7. Simplification is accomplished by generating a table of net pressure coefficients (C_{net}), combining a number of parameters in a simple and yet conservative manner. Application of the net pressure coefficients meets the intent to reduce the number of steps required for performing a wind loading analysis on buildings that satisfy the criteria prescribed under the limitations statement, resulting in net forces which meet or exceed those calculated based on Method 2. The reduction of design effort should be helpful in the determination of wind forces for the main wind force resisting system; and should be substantial for components and cladding. The procedure has been designed to give results equal to or more conservative than the present provisions in ASCE 7.
>
> While the proposed code change by SEAOC Wind *Ad Hoc* Committee has been developed in concert with the Tri-state Wind Committee proposed document, this proposal has some uniqueness in addressing buildings of all heights and the table developed for C_{net} coefficient has been arranged in a format similar to the 1997 Uniform Building Code, which most engineers preferred in the past. Given the substantial time savings using this proposed alternate design procedure, and given that the next edition of ASCE wind standard will not be published until after 2010, we respectfully request that this proposed change be adopted into the IBC as an alternative procedure until such time as the next edition of ASCE wind standard can incorporate this alternate design method.

Appendix 2 - Additional Commentary on Design Wind Pressure

The simplification of this procedure is to combine some of the factors in the wind equations to reduce the number of computations required.

For example, the ASCE 7 formulas for the MWFRS are:
$q_z = 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ I$ **Equation 6-15**
$p = q\ G\ C_p - q_i\ (GC_{pi})$ **Equation 6-17**

Combining the two above equations,
$p = 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ I\ G\ C_p - 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ I\ (GC_{pi})$
or
$p = (0.00256\ V^2)\ K_z\ K_d\ (G\ C_p - (GC_{pi}))[I\ K_{zt}]$

With the following new terms:

$q_s = 0.00256\ V^2$
$C_{net} = K_d\ [GC_p - (GC_{pi})]$,
Then the pressure $p = (0.00256\ V^2)\ K_z\ K_d\ (G\ C_p - (GC_{pi}))[I\ K_{zt}]$ can be rewritten as:
$P_{net} = q_s\ K_z\ C_{net}\ [I\ K_{zt}]$

Therefore, the simplification is in the C_{net} value combining the K_d, GC_p and GC_{pi} terms into a single value in Table 2.

Gust Effect Factor G: ASCE Section 6.5.8.1 allows the designer to use G = 0.85 or calculate G according to Formula 6-4. As the building projected wind area becomes very large, the G factor in Formula 6-4 is reduced. For example, a 50 foot high building that is 200 feet wide has a G just below 0.85, but a 50 foot high building that is 500 feet wide has a G of 0.81. The values in Table 2 are based on the maximum G = 0.85.

ASCE 7 Section 6.5.12.2.1: For the MWFRS, Equation 6-17 is permitted to be used for buildings of all heights per ASCE Section 6.5.12.2.1. Section 6.5.12.2.1 is the basis for Table 2 in this IR. ASCE Section 6.5.12.2.2 provides an alternate method for low rise buildings in Equation 6-18 and Figure 6-10, but this alternate was not used and therefore the load cases in Figure 6-10 are not required.

MWFRS Walls: ASCE Figure 6-5 for the GC_{pi} values requires that two load cases must be considered. Case 1 is positive internal pressure applied to all internal surfaces and Case 2 is negative internal pressure applied to all internal surfaces.

For the MWFRS, the authors used the positive internal pressures. This results in reducing the windward values and increasing the leeward values. It is more conservative to use the positive internal pressures because the leeward pressure is based on the full height of the building, where the windward pressure is based on the height going up the structure. At the top of the structure, you have maximum positive and maximum negative pressures. As you go down the structure, you continue to use the maximum negative pressure (leeward), but use a reduced positive pressure (reduced windward with respect to the maximum). Since positive internal pressure results in increased negative values, the resulting sum of the forces will be higher with positive internal pressures.

MWFRS Roof: For the MWFRS roof, there are two load cases in Figure 6-6.
Case 1 for the maximum wind uplift force occurs when the maximum negative windward pressure is combined with the maximum negative leeward pressure. The maximum

external negative pressures are increased with a positive internal pressure. Positive internal pressures were used for Table 2.
Case 2 for the maximum horizontal wind shear force occurs when the maximum positive windward pressure is combined with the maximum negative leeward pressure. However, when combining windward and leeward loads, the same internal pressure is used. The positive internal pressure is used in Table 2 to reduce the MWFRS windward pressure since the leeward roof and leeward walls are both based on positive internal pressure.

Components and Cladding: For components and cladding, the authors used the internal pressure (positive or negative) that would result in the greatest total pressure on the element.

Determination of q_i: In Section 6.5.12.2.1, $q = q_z$ for windward walls, $q = q_h$ for leeward and side walls. The simplified formula uses q_i based on the height used for the external pressure, which results in $q_i = q_z$ for windward walls and $q_i = q_h$ for leeward and side walls. The $q_i = q_z$ for windward walls is conservative since it results in a higher windward pressure by subtracting a smaller inward pressure. With $q_i = q_h$ for leeward and side walls, this matches the ASCE 7 language since windward and side walls are required to use q_h.

Open Structures were not included in Table 2. Open structures have no internal pressure so there is no simplification of combining external and internal pressures. Open structures can conservatively use the "enclosed structure" values, except for the MWFRS windward pressures on mono-slope roofs. The internal pressure cancels out when combining windward and leeward pressures on walls and roofs for the MWFRS. An open structure with only a mono-slope roof will not cancel out the internal pressure where there is no leeward wall.