2009 IBC ALTERNATE WIND DESIGN APPROACH

James S. Lai, S.E.
F. SEAOC, F. ACI, F. ASCE

OUTLINE

- Design Methods based on ASCE 7-05
- Development of Alternate Wind Design Approach
  - Design Equation
  - Derivation of C_{net} coefficients
    - Main Wind Force Resisting System
    - Components and Cladding
- Special Inspection Requirements
- Design Examples

Alternate Design Provisions

- Design Provisions are meant to
  - Satisfies ASCE 7 Method 2
  - Time saving - avoid interpretation of monographs
  - Simplification - combining K_d , G , C_p and GC_{pi} terms into a single parameter, C_{net}
  - Symbols and Notations in ASCE 7 plus specific ones defined in IBC 1609.6.2

Alternate Design Provisions - limitations

Ref. 2009 IBC 1609.6.1

- Aspect ratios
  - Height to width ratio ≤ 4
  - Height ≤ 75 feet, *OR*
  - Fundamental frequency ≥ 1 Hertz
- Flexibility
  - Building not sensitive to dynamic effects
- Site condition
  - No channeling effects
  - No buffeting in wake of upward obstruction

Alternate Design Provisions - limitations

- Building basic requirement
  - Simple diaphragm – transmits wind loads to MWFRS
- Building or structure <u>OTHER THAN</u>
  - Open building
  - Multi-span Gable Roof
  - Stepped Roof
  - Domed Roof
  - Roof slope > 45°
  - Free standing walls and solid signs (ASCE 7 Fig. 6-20)

Main-Wind-Force-Resisting System (MWFRS)

- Determination of K_z & K_{zt} : [Ref. 2009 IBC Sec. 1609.6.4.2]
  K_z - Velocity exposure coefficient, and
  K_{zt} - Topography Factor
  - For Windward side of structure :
    K_z and K_{zt} shall be based on height z
  - For Leeward and side walls :
    K_z and K_{zt} - based on mean roof height h
  - For windward and leeward roofs :
    K_z and K_{zt} - based on mean roof height h

Main-Wind-Force-Resisting System (MWFRS)

Ref. 2009 IBC Sec. 1609.6.4.3 and 1609.6.4.4

- Determination of Net Wind Pressure
  - Determine pressure coefficient , C_{net} for walls and roofs from Table 1609.6.2(2)
  - Where more than one value for C_{net} given in table, use the more severe wind load condition for design
- Application of Wind Pressure
  - Apply wind pressure simultaneously on, and in a direction normal to, all building envelope and roof surfaces, but no less than 10 lb/sq. ft. on projected surface
- Investigate Torsional Effect - Ref. IBC Sec. 1609.6.4.1

Derivation of Design Equations

- C_{net} values

Based on ASCE 7

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$ Eq. (6-15)

$p = qGC_p - q_i(GC_{pi})$ Eq. (6-17)

Combining above equations, rearranging terms and substituting $q_s = 0.00256\, V^2$:

$$p = [0.00256V^2 K_h K_d GC_p - 0.00256V^2 K_z K_d (GC_{pi})][IK_{zt}]$$

$$= q_s K_d [K_h GC_p - K_z (GC_{pi})][IK_{zt}]$$ Eq. (A-1)

Derivation of Design Equations

- For Leeward Wall and Roof Elements

$K_h = K_z$

- For Windward Roof Elements

$K_h \approx K_z$

Re-writing Eq. (A1)

$$p = q_s K_z [K_d (GC_p - (GC_{pi}))][IK_{zt}] \quad \text{Eq. (A-2)}$$

Substitute into Eq. (A-2)

$$C_{net} = K_d (GC_p - (GC_{pi})) \quad \text{Eq. (A-3)}$$

Design wind pressure:

$$\mathbf{p = q_s K_z C_{net} [IK_{zt}]} \quad \textbf{Eq. (A-4)}$$

IBC 2009 Eq. (16-34)

Wind Stagnation Pressure

Reference IBC 2009 Table 1609.6.2 (1)

Table 1609.6.2(1)

Wind Stagnation Pressure (q_s) at Standard Height of 33 Feet [a, b, c]

BASIC WIND SPEED, V (mph)[b]	85	90	100	105	110	120	125	130
PRESSURE, q_s (psf)[c]	18.5	20.7	25.6	28.2	31.0	56.9	40.0	43.3

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 0.048 to convert to kN/m^2

$$q_s = 0.00256V^2$$

Derivation of Design Equations

- Gust Effect Factor, G

  Reference ASCE 7 Sec. 6.5.8.1

  G = 0.85 for rigid structures

  - used in development of T-1609.6.2(2)

  – ASCE 7 Eq. (6-4) will give values slightly lower than 0.85

  Example:

	Height, h	Width, B	Gust factor, G
Bldg 1	50 ft.	200 ft.	0.85
Bldg 2	50 ft.	500 ft.	0.81

Derivation of Design Equations

- Directional factor, K_d

  Reference ASCE 7 Table 6-4

  For Buildings $K_d = 0.85$

  Other structures affected by shape $K_d \geq 0.85$

- $C_{net} = K_d\,(GC_p - (GC_{pi}))$ Eq. (A-3)

  Re-write equation (A-3) for C_{net}

  Substituting K_d and G

  $C_{net} = 0.85\,(0.85C_p - (GC_{pi}))$ Eq. (A-5)

  Eq. (A-5) is used to develop C_{net} in Table 1609.6.2(2)

Derivation of Design Equations

Determination of Velocity Pressure Coef., K_z — ASCE Table 6-3

Height above ground level, z		Exposure			
		B	B	C	D
ft	m	Case 1	Case 2	Cases 1 & 2	
0 -15	0 – 4.6	0.70	0.57	0.85	1.03
20	6.1	0.70	0.62	0.90	1.08
25	7.6	0.70	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	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

$$K_z = 2.01(z/z_g)^{2/\alpha}$$

for $15 \leq z \leq z_g$

Where

$\alpha = 7.0$, $z_g = 1200$ for Exp. B

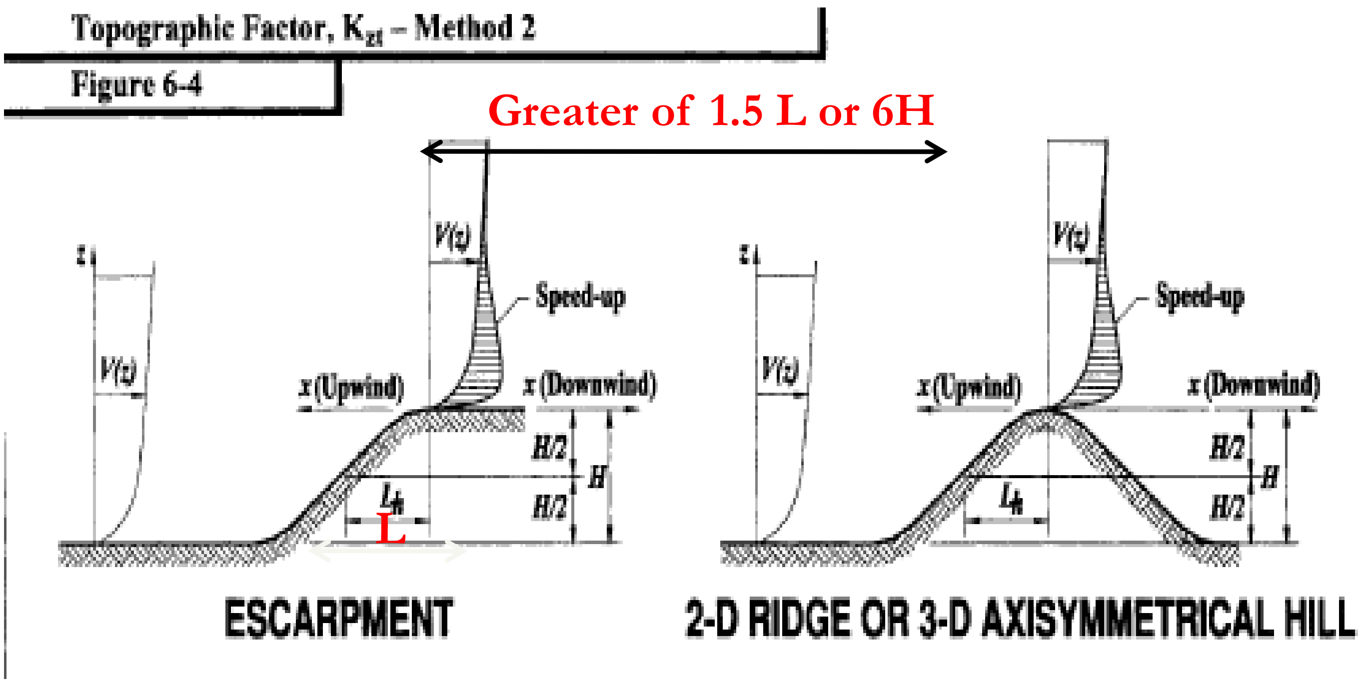
$\alpha = 9.5$, $z_g = 900$ for Exp. C

$\alpha = 11.5$, $z_g = 700$ for Exp. D

Note:
Case 1: MWFRS low rise & CC of all heights
Case 2: All MWFRS other than low-rise buildings

Derivation of Design Equations

- Determination of Topography Factor, K_{zt} refer to ASCE 7 Sec. 6.5.7 and coefficients in Fig. 6 - 4
- Site not impacted by hills, ridges and escarpment listed under 6.5.7.1 – $K_{zt} = 1.0$



ASCE 7 Fig. 6-4

Helpful Guideline: (Ref 2009 IRC)

Ave slope Top half	Wind speed
Flat	85 mph
0.10 to 0.15	100 mph
0.175 to 0.23	110 mph
≥ 0.25	120 mph

Derivation of C_{net} Coefficient

- Internal pressure coefficient, GC_{pi}
  - Enclosed buildings GC_{pi} = +0.18 or - 0.18
  - Partially Enclosed GC_{pi} = +0.55 or - 0.55

Exposure Classification	GC_{pi}
Open Buildings	**0.00**
Partially Enclosed Buildings	**+0.55** **- 0.55**
Enclosed Buildings	**+0.18** **- 0.18**

ASCE 7 Fig. 6-5

Derivation of C_{net} Coefficient (MWFRS)

– Windward Wall external pressure coefficient

Cp = + 0.8 for all L/B

– Leeward Wall external pressure coefficient

Cp = - 0.5 for L/B ≤ 1

ASCE 7 Fig. 6-6

Main Wind Force Resisting System			All Height
Enclosed, Partially Enclosed Buildings			Walls & Roofs
External Wind Pressure Coefficient, C_p			
Surface	L/B	Cp	Use With
Windward Wall	All Values	+ 0.8	q_z
Leeward Wall	0 - 1	- 0.5	q_h
	2	- 0.3	
	≥ 4	- 0.2	
Side Wall	All Values	- 0.7	q_h

Derivation of C_{net} Coefficient (MWFRS)

$C_{net} = 0.85\,(0.85C_p - (GC_{pi}))$ Eq. (A-5)

- For positive internal pressure in enclosed building
  - Windward wall

    $C_{net} = 0.85(0.85 \times 0.80 - 0.18)$ $= 0.43$
  - Leeward wall

    $C_{net} = 0.85(0.85 \times (-0.50) - 0.18)$ $= -\,0.51$
- For negative internal pressure in enclosed building
  - Windward wall

    $C_{net} = 0.85(0.85 \times 0.80 - (-\,0.18))$ $= 0.73$
  - Leeward wall

    $C_{net} = 0.85(0.85 \times (-0.50) - (-\,0.18))$ $= -\,0.21$
- Σ Windward and Leeward wall pressure coefficients

  $= 0.43 - (-0.51) = 0.94$

Net Pressure Coefficient – Wall (MWFRS)

Reference IBC 2009 Table 1609.6.2 (2)

Structure or Part thereof	DESCRIPTION		C_{net} FACTOR			
1. MWFRS	WALLS:		Enclosed		Part. Enclosed	
			+ ve	- ve	+ ve	- ve
			Int. Pressure		Int. Pressure	
	Windward Wall		0.43	0.73	0.11	1.05
	Leeward Wall		-0.51	-0.21	-0.83	0.11
	Side Wall		-0.66	-0.35	-0.97	-0.04
	Parapet Wall	Windward	1.28		1.28	
		Leeward	- 0.85		- 0.85	

Derivation of C_{net} Coefficient (MWFRS)

- Windward Roof external pressure coefficient normal to ridge for roof slope ≤ 2:12 or 10°
  Cp = -1.3 , -0.18 for h/L ≤ 0.5
- Leeward Wall external pressure coefficient
  Cp = -0.7 for h/L ≥ 1

ASCE 7 Fig. 6-6

Roof Pressure Coefficients, C_p, for use with q_h

Wind Direction	h/L	Windward Angle, Θ° 10	15	20	30	Leeward Θ° 10	15	≥20
Normal to ridge for Θ≥ 10°	≤.25	-0.7, -0.18	-0.5, 0.0	-0.3, 0.2	-0.2, 0.3	-0.3	-0.5	-0.6
	0.50	-0.9, -0.18	-0.7, -0.18	-0.4, 0.0	-0.2, 0.2	-0.5	-0.5	-0.6
	≥1.0	-1.3, -0.18	-1.0, -0.18	-0.7, -0.18	-0.3, 0.2	-0.7	-0.6	-0.6
Normal to ridge for Θ< 10° & Parallel to ridge for all Θ		Horiz. Dist. from Windward edge			C_p			
	≤0.5	0 to h/2 and h/2 to h			-0.9, -0.18	Note: reduction for increase area not taken		
		h to 2h			-0.5, -0.18			
	≥1.0	0 to h/2			-1.3, -0.18			
		> h/2			-0.7, -0.18			

Derivation of C_{net} Coefficient (MWFRS)

$C_{net} = 0.85\,(0.85C_p - (GC_{pi}))$ Eq. (A-7)

- For +ve or -ve internal pressure in enclosed building
  - Leeward roof normal to ridge for slope ≤ 2:12 or 10°

$C_{net} = 0.85(0.85 \times (-0.70) - 0.18) = -0.66$ *OR*

$C_{net} = 0.85(0.85 \times (-0.70) + 0.18) = -0.35$

  - Windward roof normal to ridge for slope ≤ 2:12 or 10°

$C_{net} = 0.85(0.85 \times (-1.30) - 0.18) = -1.09$ *OR*

$C_{net} = 0.85(0.85 \times (-1.30) + 0.18) = -0.79$

$C_{net} = 0.85(0.85 \times (-0.18) - 0.18) = -0.28$ *OR*

$C_{net} = 0.85(0.85 \times (-0.18) + 0.18) = +0.02$

  - For Parallel to ridge – same as for normal to ridge w/o slope

Net Pressure Coefficient – Roof (MWFRS)

Reference IBC 2009 Table 1609.6.2 (2)

Structure or Part thereof	DESCRIPTION		C_{net} FACTOR			
1. MWFRS	ROOFS:		Enclosed		Partially Encl.	
			+ ve	- ve	+ ve	- ve
			Int. Pressure		Int. Pressure	
	Wind ⊥ to Ridge					
	Leeward or Flat Roof		-0.66	-0.35	-0.97	-0.04
	Windward Roof Slope					
	Slope < 2:12 (10°)	Condition 1	-1.09	-0.79	-1.41	-0.47
		Condition 2	-0.28	0.02	-0.60	0.34
	Slope = 4:12 (18°)	Condition 1	-0.73	-0.42	-1.04	-0.11
		Condition 2	-0.58	0.25	-0.37	0.57
	Slope 12:12 (45°)		0.14	0.44	-0.18	0.76
	Wind ‖ Ridge and Flat Roof		-1.09	-0.79	-1.41	-0.49

Derivation of C_{net} Coefficient (C & C)

- For components and Cladding – apply internal pressure (positive or negative) that result in the largest total pressure on element
- ASCE 7 Figures 6-11A through 6-11D, 6-14A, 6-14B, 6-17 give zones of discontinuity and external pressure coefficient, GC_p
- $p = q_h[(GC_p) - (GC_{pi})]$ for $h \leq 60$ ft.

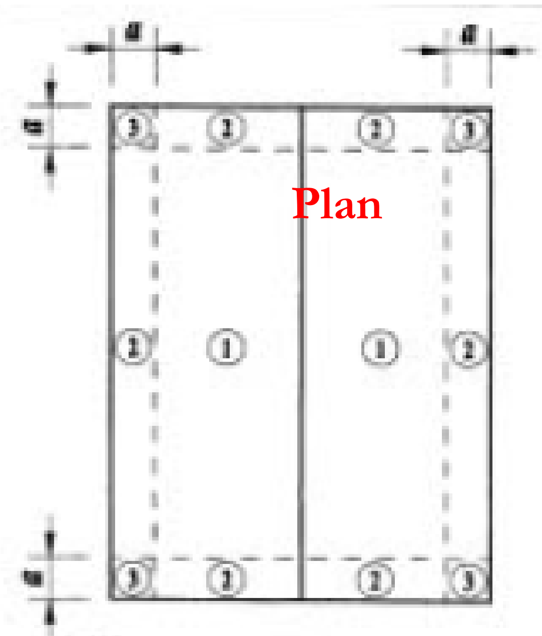
  $p = q(GC_p) - q_i(GC_{pi})$ for $h > 60$ ft.

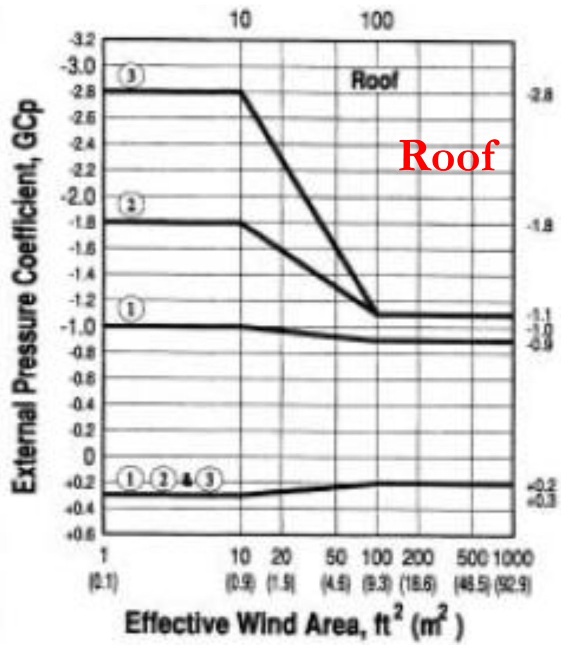
  $C_{net} = K_d(GC_p - (GC_{pi}))$ Eq. (A-3)

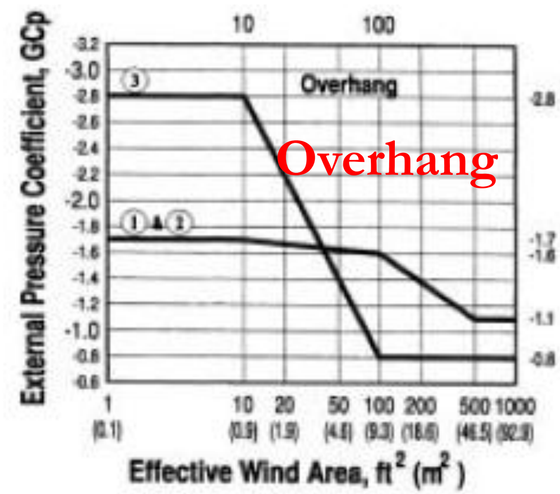
  $C_{net} = 0.85[(GC_p) - (GC_{pi})]$ Eq. (A- 5)
- Minimum design pressure = 10 psf

Components and Cladding – Roof (C & C)

Reference ASCE 7 Fig.6-11B **$h \leq 60$ feet** **Slope $\leq 5/8{:}12$ or 7°**







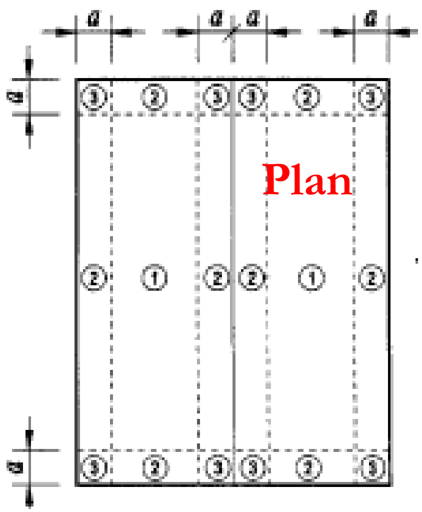
	ROOF						OVERHANG			
Zone	1	2	3	1	2, 3	1, 2, 3	1,2	1 ,2	3	3
A, s.f.	10	10	10	100	100	10	10	100	10	100
GC_p	-1.0	-1.8	-2.8	-0.9	-1.1	+0.3	-1.7	-0.8	-2.8	-1.1
C_{net}	-1.00	-1.68	-2.53	-0.92	-1.09	+0.41	-1.45	-0.68	-2.38	-0.95

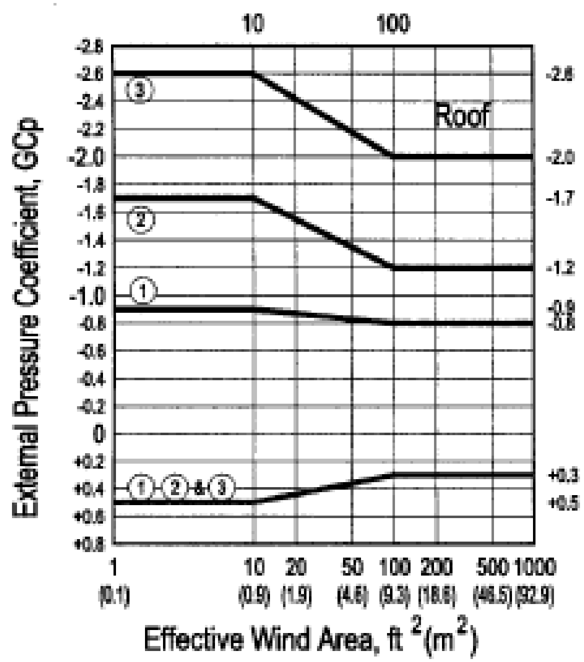
Note: $GC_{pi} = 0$ at overhang

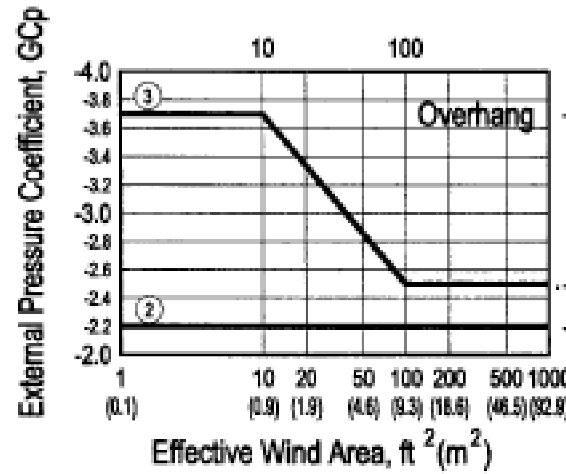
$$C_{net} = 0.85\,(GC_p - (GC_{pi})) \qquad \text{Eq. (A-5)}$$

Components and Cladding – Roof (C & C)

Reference ASCE 7 Fig.6-11C $h \le 60$ feet Slope ≤ 6:12 or 27°







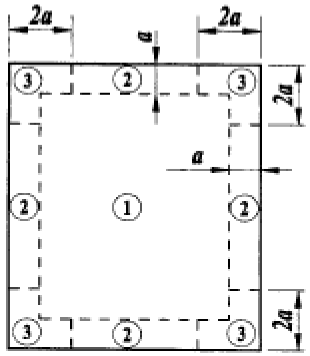
For hip roof see Fig. 6-11C

	ROOF							OVERHANG		
Zone	1	2	3	1	2	3	1, 2 ,3	1, 2	3	3
A, s.f.	10	10	10	100	100	10	100	≤100	10	100
GC_p	-0.9	-1.7	-2.8	-0.8	-1.2	-2.0	+0.5	-2.2	-3.7	-2.5
C_{net}	-0.92	-1.60	-2.53	-0.83	-1.17	-1.85	+0.58	-1.87	-3.15	-2.13

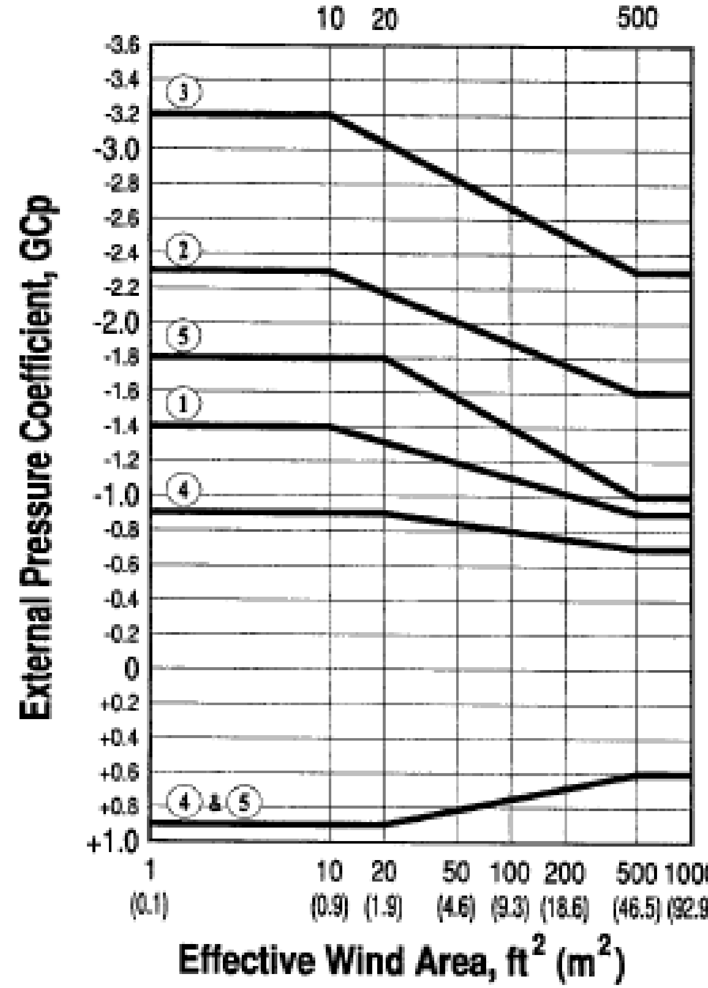
$C_{net} = 0.85\,(GC_p - (GC_{pi}))$ Eq. (A-5)

Components and Cladding – Roof (C & C)

Reference ASCE 7 Fig.6-17 **$h \geq 60$ feet**



ROOF PLAN



a: 10% of least horiz. dimension
or 0.4 h
≥ 4 % of least horiz. Dimension, or
≥ 3 feet

ROOF

Zone	1	2	3	1	2	3
A, s.f.	10	10	10	500	500	500
GC_p	-1.4	-2.3	-3.2	-1.0	-1.6	-2.3
C_{net}	-1.34	-2.11	-2.87	-1.00	-1.51	-2.11

No + ve pressure

$C_{net} = 0.85\,(GC_p - (GC_{pi}))$ Eq. (A-5)

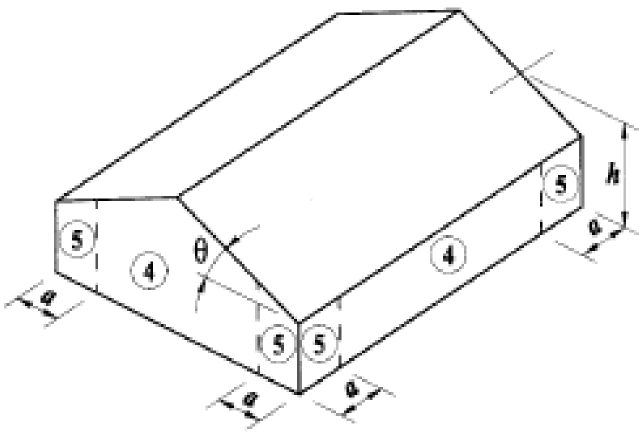
Net Pressure Coefficient – Roof (C & C)

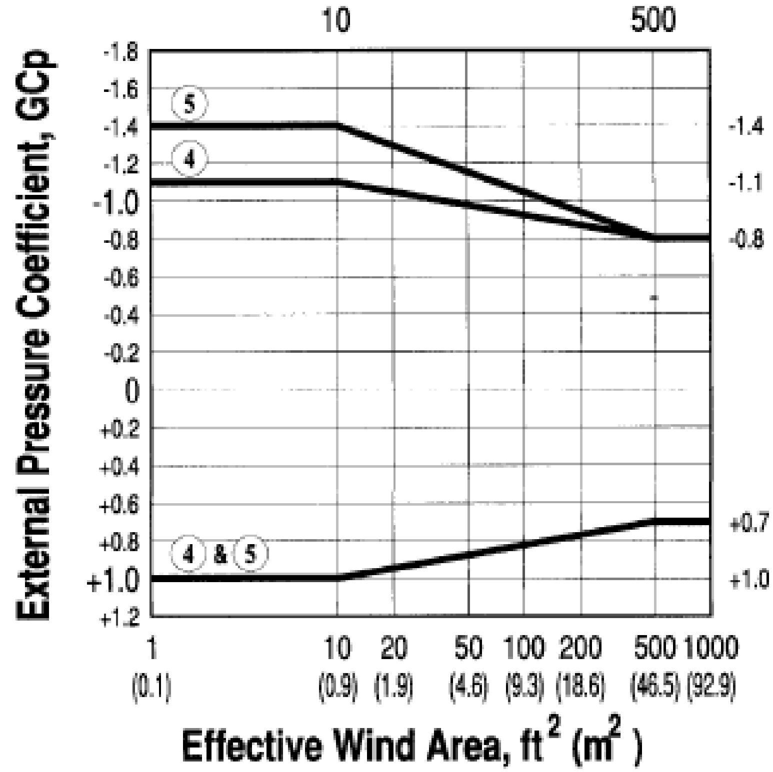
Reference IBC 2009 Table 1609.6.2 (2)

Structure or Part thereof	DESCRIPTION		C_{net} FACTOR	
3. C & C in areas of discontinuities – Roofs and Overhangs	**Roof Elements & Slopes**		**Enclosed**	**Partially Encl.**
	Gable or Hipped Config. at Ridges, Eaves and Rakes (Zone 2)			
	Flat < Slope < 6:12 (27°) – See ASCE 7 Fig. 6-11C Zone 2			
	Positive	**≤ 10 SF**	**0.58**	**0.89**
		≥ 100 SF	**0.41**	**0.72**
	Negative	**≤ 10 SF**	**- 1.68**	**- 2.00**
		≥ 100 SF	**- 1.17**	**- 1.49**
	Overhang for Flat < Slope < 6:12 (27°)			
	Negative	**≤ 10 SF**	**- 1.87**	
		≥ 100 SF	**- 1.87**	
	Monosloped Config. at Ridges, Eaves, and Rakes (Zone 2)			
	Negative	**≤ 10 SF**	**- 1.51**	**-1.83**
		≥ 100 SF	**- 1.43**	**- 1.74**

Components and Cladding – Wall (C & C)

Reference ASCE 7 Fig.6-11A **$h \leq 60$ feet**





a: 10% of least horizontal dimension
or 0.4 h
≥ 4 % of least horizontal Dimension
≥ 3 feet

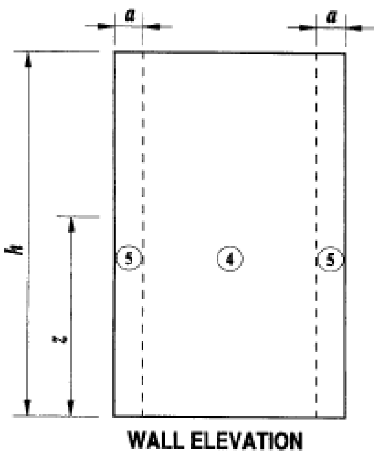
WALL

Zone	4	5	4, 5	4	5	4, 5
A, s.f.	20	20	20	500	500	500
GC_p	-0.9	-1.8	+0.9	-0.7	-1.0	+0.6
C_{net}	-0.92	-1.68	+0.92	+0.75	- 1.0	+0.66

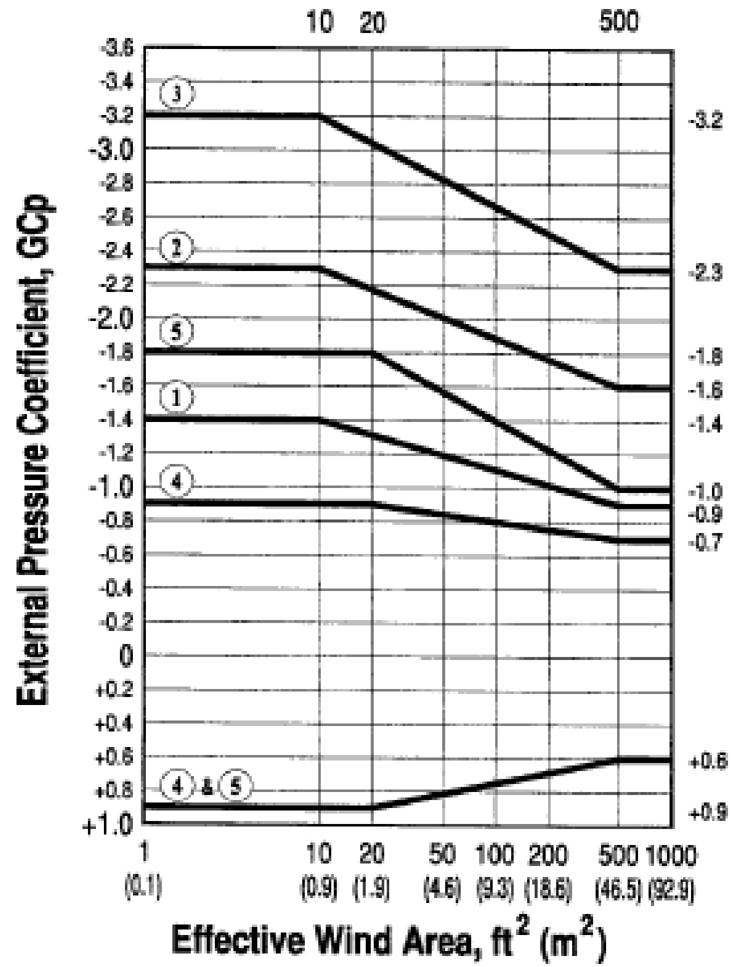
$C_{net} = 0.85\,(GC_p - (GC_{pi}))$ Eq. (A-5)

Components and Cladding – Wall (C & C)

Reference ASCE 7 Fig.6-17 **$h \geq 60$ feet**



a: 10% of least horiz. dimension
or 0.4 h
≥ 4 % of least horiz. Dimension, or
≥ 3 feet



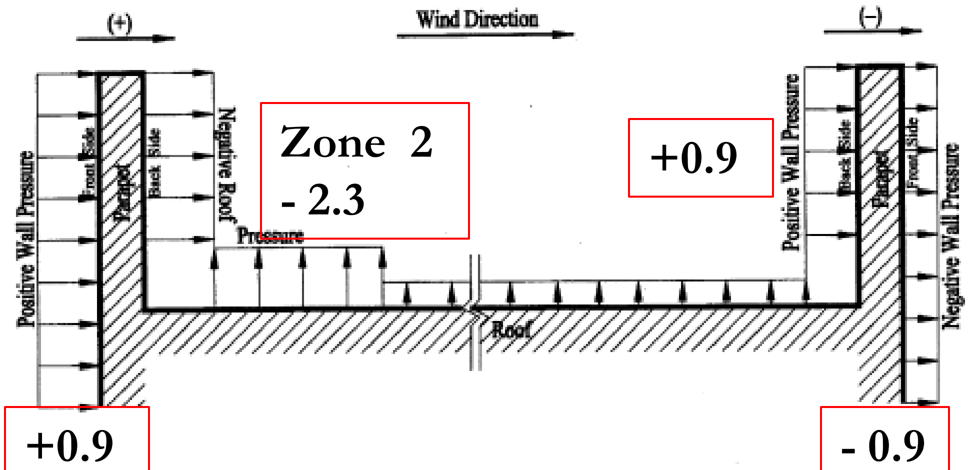
WALL

Zone	4	5	4	5	4, 5	4, 5
A, s.f.	20	20	500	500	20	500
GC_p	-0.9	-1.8	-0.7	-1.0	+0.9	+0.6
C_{net}	-0.92	-1.68	-0.75	-1.00	+0.92	+0.66

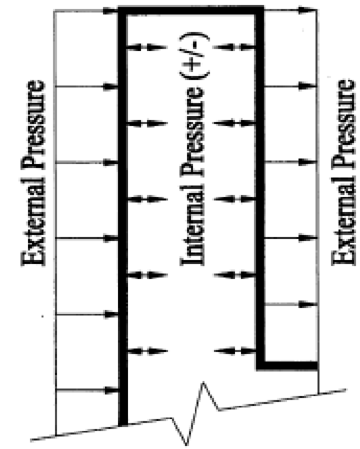
$$C_{net} = 0.85\,(GC_p - (GC_{pi}))$$ Eq. (A-5)

Derivation of C_{net} Coef. – Parapet (C & C)

Parapet (C & C) - Reference ASCE 7 Eq. (6-24), Fig. 6-17



Methodology used to Develop External Parapet Pressures
(Main Wind Force Resisting Systems and Components and Cladding)



External and Internal Parapet Pressures
(Components and Cladding Only)

For zone 4,

Case A	$C_{net} = 0.85[(+0.9-(-2.3) + 0.18]$	$= +2.87$
Case B	$C_{net} = 0.85[(-0.9- (+0.9) – 0.18]$	$= -1.68$

For zone 5

Case A	$C_{net} = 0.85[(0.9-(-3.2) + 0.18]$	$= +3.64$
Case B	$C_{net} = 0.85[(-1.8- (+0.9) – 0.18]$	$= -2.45$

Net Pressure Coefficient – Wall (C & C)

Reference IBC 2009 Table 1609.6.2 (2)

Structure or Part thereof	DESCRIPTION		C_{net} FACTOR	
4. C & C in areas of discontinuities – Walls & Parapets	**Wall Elem. h≤60 ft (Zone 4)**		**Enclosed**	**Partially Encl.**
	Positive	**≤ 10 SF**	**1.00**	**1.32**
		≥ 500 SF	**0.75**	**1.06**
	Negative	**≤ 10 SF**	**- 1.09**	**- 1.40**
		≥ 500 SF	**- 0.83**	**- 1.15**
	Wall Elem. H > 60 ft (Zone 4) – ASCE 7 Fig. 6-17 Zone 4			
	Positive	**≤ 20 SF**	**0.92**	**1.23**
		≥ 500 SF	**0.66**	**0.98**
	Negative	**≤ 20 SF**	**- 0.92**	**-1.23**
		≥ 500 SF	**- 0.75**	**- 1.06**
	Parapet Walls			
	Positive		**2.87**	**3.19**
	Negative		**-1.68**	**-2.00**

Inspection Requirement

Reference: IBC 1706

- Special inspection for wind requirement;
  - Exp. Category B when $V_{3sec} \geq 120$ mph
  - Exp. Category C or D when $V_{3sec} \geq 110$ mph
- Structural Wood
  - Shear panels, diaphragms when nail spcg < 4″o.c. – nailing, bolting, hold-downs of MWFRS
- Steel light-framed
  - Gypsum board or fiberboard
  - Wood structural panel or steel sheets shear panel or diaphragms
- Roof cladding and wall cladding

SUMMARY

- Alternate Wind Design Approach satisfies ASCE 7 Method 2
- Some limitation on aspect ratio, flexibility, and site condition
- Consider torsion if not trivial
- Methodology applies to non-flexible building; simple diaphragms; flat, gable or hipped roofs
  - Simplification - combining K_d, G, C_p and GC_{pi} terms into a single parameter
- Derivation of design equation and C_{net} have been presented

Example No. 56B

Problem Description and Data

Given:

- **A three story office building as shown in Figure A1**
- **Structure is not susceptible to dynamic effects, and is considered to be enclosed**
- **\ Lateral force resisting system: special steel moment frame at three transverse grids and brace frames at longitudinal grids (1 & 3)**
- **Gable roof with a pitch of 4 ft. in 30 ft. (≈ 8°)**

Criteria:

- **Basic wind speed V= 85 mph**
- **Wind Exposure Category B**
- **K_d = 0.85, K_{zt} = 1.0 and I_w = 1.0**

Determine: **Based on 2009 IBC Alternate wind design approach**

- **Calculate base shear for wind and story forces along N-S direction at frame line A**
- **Determine Component Cladding Pressure for exterior wall elements at 2nd story mullion @ 5 ft. o. c.**

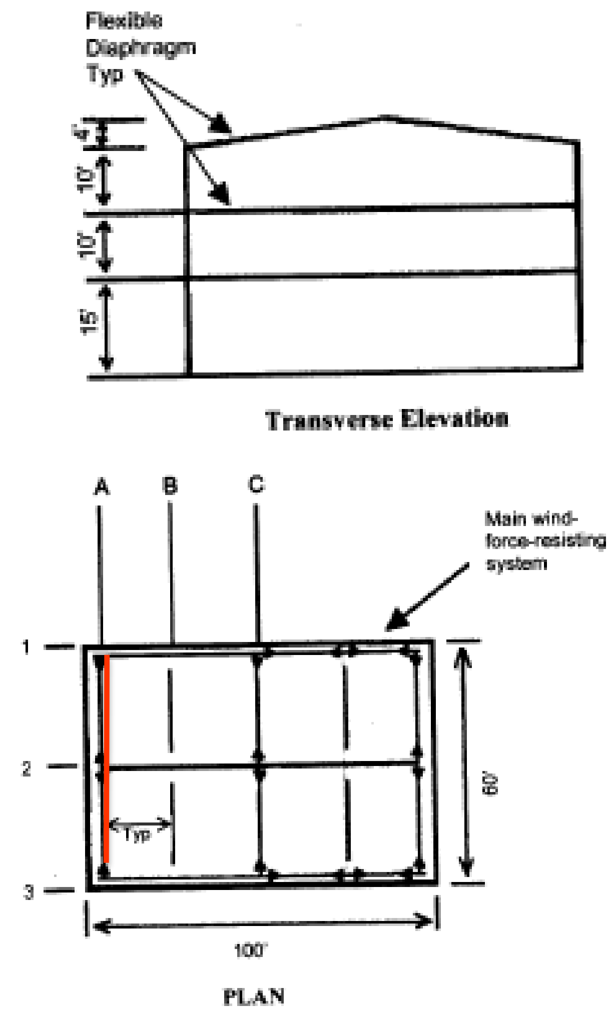


Fig. A-1 Typical Floor Plan and Elevation

Example No. 56B

Based on Alternate Design Procedure (IBC 2009)

Mean Roof Height $h = 15 + 2 \times 10 + 4/2 = 37$ ft.

Dim. Normal to wind direction $B = 100$ ft.

Dim. Parallel to wind direction $L = 60$ ft.

- Aspect ratios
  - Height to width ratio = 37/60 = 0.6 < 4
  - Height < 75 feet
  - Fundamental frequency $f > 1$ Hz
- Flexibility
  - Building not sensitive to dynamic effects
- Topography factor $K_{zt} = 1.0$ (Given)

Example No. 56B

Reference [T1609.6.2(1), T1609.6.2(2)]   For V= 85 mph q_s = 18.5 psf

Walls: C_{net} = 0.43 Windward and -0.51 Leeward

Roofs: C_{net} = -0.28 Windward and -0.66 Leeward

Floor	Ht.	Trib. Ht.	Trib. Width	Trib. Area	K_z	Windward				Leeward				Total
						K_zq_s	C_{net}	p_{net}	F_x	K_zq_s	C_{net}	p_{net}	F_x	
	Ft.	Ft.	Ft.	Ft^2		psf		psf	kip	psf		psf	kip	kip
R	37	4.0	100	400	0.74	13.7	-0.28	-3.8	-1.5	13.7	-0.66	-9.0	-3.6	2.1
Rf	35	5.0	100	500	0.73	13.5	0.43	5.8	2.9	13.5	-0.51	-6.9	-3.5	6.4
3	25	10.0	100	1000	0.70	13.0	0.43	5.6	5.6	13.5	-0.51	-6.9	-6.9	12.5
2	15	12.5	100	1250	0.70	13.0	0.43	5.6	7.0	13.5	-0.51	-6.9	-8.6	15.6
1							Σ =		14.0				-22.6	36.6

Consider flexible diaphragm and 25% tributary to frame lines,

Force to Frame A : Roof level (2.1+6.4) x 25% = 2.1 k

3rd Level 12.5 x 25% = 3.1 k

2nd Level 15.6 x 25% = 3.9 k

Example No. 56B

- Components and Cladding
  - Determine width 'a' of effective end zone

$a = 60.0 \times 10\% = 6.0$ feet SAY 6′0″ ends

OR $a = 37.0 \times 40\% = 14.8$ feet > $60.0 \times 4\%$ > 3.0 feet

$q_h = 18.5 \times 0.74 = 13.7$ psf

	Zone		a	q_h	A	C_{net}	p_{net}	A	C_{net}	p_{net}
			ft	psf	sf		psf	sf		psf
Wall	Field	4		13.7	10	-1.09	- 14.9	500	-0.83	- 11.4
Wall	Edge	5	6.0	13.7	10	-1.34	- 18.4	500	-0.83	- 11.4
Wall	ALL	4, 5	6.0	13.7	10	1.00	+13.7	500	0.75	+10.3

At 2nd story south elevation, mullions are 5 ft. o.c. away from end

Limiting width 1/3 x height =(10-1)/3 = 3.0 ft. for eff. pressure

Effective wind *A* = 3.0 x 9 = 27 ft^2 ; Trib. A = 5 x 9 = 45 ft^2

Design force: 13.7[1.09-(1.09-0.83)(log27 -log10)/(log500-log10)] x 5

= 14.1 x 5 = 70 lb/ft (75 lb/ft using linear interpretation)

Example No. 57B

Problem Description and Data

Given:

- **A nine story office building as shown in Figure A1**
- **Fundamental period = 0.9 seconds**
- **Structure is not susceptible to dynamic effects, and is considered to be enclosed**
- **Lateral force resisting system: special steel moment frame at building perimeter**
- **Parapet is 3'- 0" high all around perimeter of bldg**

Criteria:

- **Basic wind speed V= 85 mph**
- **Wind Exposure Category B**
- **K_d = 0.85, K_{zt} = 1.0 and I_w = 1.0**

Determine: Based on 2009 IBC Alternate wind design approach

- Calculate base shear for wind along N-S direction
- Determine Component Cladding Pressure for exterior wall elements

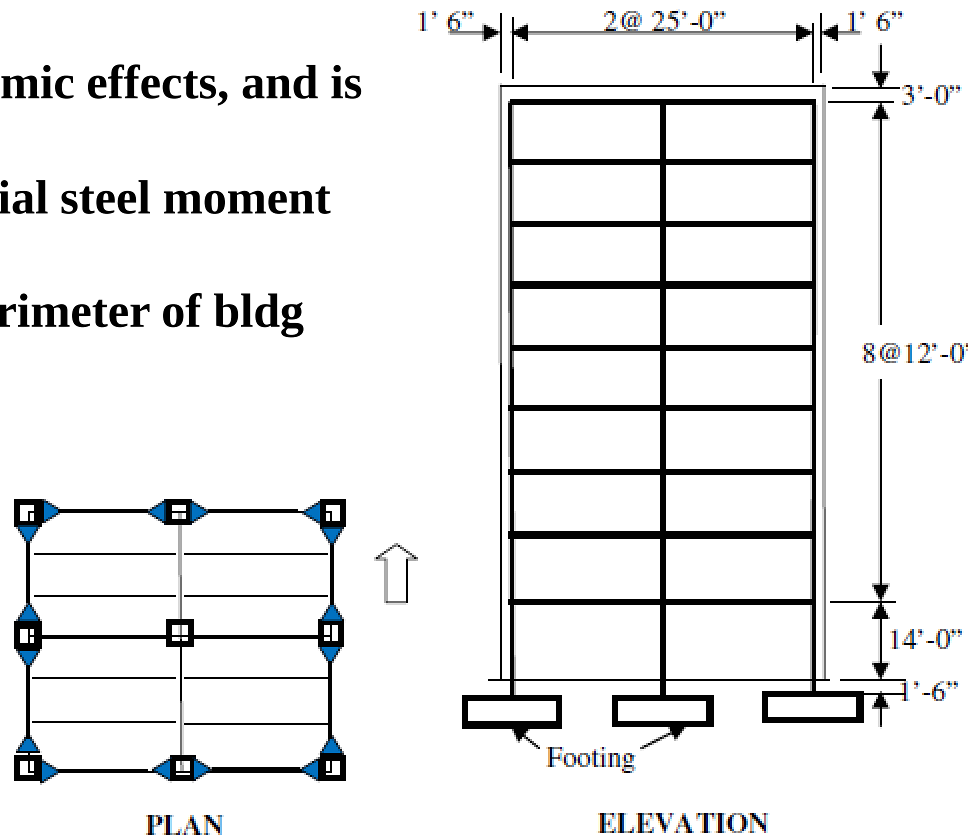


Fig. A-1 Typical Floor Plan and Elevation

Example No. 57B

Based on Alternate Design Procedure (IBC 2009)

Mean Roof Height h = 14 + 8 x 12 = 108 ft.

Dim. Normal to wind direction B = 53 ft.

Dim. Parallel to wind direction L = 53 ft.

- Aspect ratios
  - Height to width ratio = 108/53 = 2.0 < 4
  - Height > 75 feet, *BUT*
  - Fundamental frequency f = 1/0.9 = 1.1 > 1 Hz
- Wind stagnation pressure q_s=18.5 psf [T-1609.6.2(1)]
- Flexibility - Building not sensitive to dynamic effects
- Importance factor I_w = 1.0 (given)
- Exposure Category B (given)

Example No. 57B

- Main wind force resisting system (MWFRS)
  - Building is enclosed $V = 85$ mph $q_s = 18.5$ psf
  - Velocity exposure coefficient K_z - see ASCE 7 T 6-3)
  - Topography factor $K_{zt} = 1.0$ (given)
  - Determine net pressure coefficient, C_{net} [T1609.6.2(2)]

	+ve int. pressure	-ve int. pressure
Windward wall	$C_{net} = 0.43$	$C_{net} = 0.73$
Leeward wall	$C_{net} = -0.51$	$C_{net} = -0.21$
Side wall	$C_{net} = -0.35$	$C_{net} = -0.66$

  - Parapet wall

Windward	$C_{net} = 1.28$
Leeward	$C_{net} = -0.85$

Example No. 57B

C_{net} = 0.43 Windward and -0.51 Leeward [T1609.6.2(2)]

Floor	Ht.	Trib. Ht.	Trib. Width	Trib. Area	K_z	Windward				Leeward				Total
						K_zq_s	C_{net}	p_{net}	F_x	K_zq_s	C_{net}	p_{net}	F_x	
	Ft.	Ft.	Ft.	Ft^2		psf		psf	kip	psf		psf	kip	kip
Pp	113	3	53.0	159	1.02	18.9	1.28	24.1	3.8	18.9	-0.85	-16.1	-2.6	6.4
Rf	110	6	53.0	318	1.02	18.8	0.43	8.1	2.6	18.8	-0.51	-9.6	-3.0	5.6
9	98	12	53.0	636	0.98	18.2	0.43	7.8	5.0	18.8	-0.51	-9.6	-6.1	11.1
8	86	12	53.0	636	0.95	17.5	0.43	7.5	4.8	18.8	-0.51	-9.6	-6.1	10.9
7	74	12	53.0	636	0.91	16.8	0.43	7.2	4.6	18.8	-0.51	-9.6	-6.1	10.7
6	62	12	53.0	636	0.86	15.9	0.43	6.9	4.4	18.8	-0.51	-9.6	-6.1	10.5
5	50	12	53.0	636	0.81	15.0	0.43	6.4	4.1	18.8	-0.51	-9.6	-6.1	10.2
4	38	12	53.0	636	0.75	13.9	0.43	6.0	3.8	18.8	-0.51	-9.6	-6.1	9.9
3	26	12	53.0	636	0.67	12.4	0.43	5.3	3.4	18.8	-0.51	-9.6	-6.1	9.5
2	14	13	53.0	689	0.56	10.4	0.43	4.5	3.1	18.8	-0.51	-9.6	-6.6	9.7
1							Σ =		39.6				-54.9	94.5

Example No. 57B

- Components and Cladding
  - Determine width 'a' of effective end zone

a = 53.0 x 1 0% = 5.3 feet SAY 5′6″

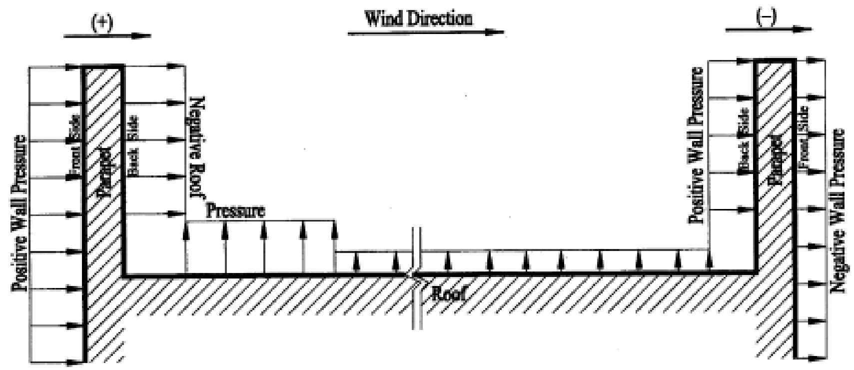
OR a = 108.0 x 40% = 43.2 feet > 53.0 x 4% > 3.0 feet

q_h = 18.5 x 1.02 = 18.8 psf

	Zone		a	2a	q_h	A	C_{net}	p_{net}	A	C_{net}	p_{net}
			ft	ft	psf	sf		psf	sf		psf
Roof	Field	1			18.8	10	- 1.34	- 25.2	500	- 0.92	- 17.2
Roof	Edge	2	6.0	12.0	18.8	10	- 2.11	- 39.6	500	- 1.51	- 28.4
Roof	Corner	3	6.0	12.0	18.8	10	- 2.87	- 54.0	500	- 2.11	- 39.6
Wall	Field	4	--	--	18.8	20	- 0.92	- 17.2	500	- 0.75	- 14.0
Wall	Edge	5	6.0	12.0	18.8	20	- 1.68	- 31.6	500	- 1.00	- 18.8
Wall	ALL	4, 5	6.0	12.0	18.8	20	+ 0.92	+17.2	500	+ 0.66	+12.5

Example No. 57B

Parapet (C & C) - Reference ASCE 7 Eq. (6-24), Fig. 6-17



Methodology used to Develop External Parapet Pressures
(Main Wind Force Resisting Systems and Components and Cladding)

For zone 4,

Case A	$C_{net} = +2.87$	$p_{net} = 18.8 \times 2.87 = 54.0$ psf
Case B	$C_{net} = -1.68$	$p_{net} = 18.8 \times (-1.68) = -31.6$ psf

For zone 5

Case A	$C_{net} = +3.64$	$p_{net} = 18.8 \times 3.64 = 68.4$ psf
Case B	$C_{net} = -2.45$	$p_{net} = 18.8 \times (-2.45) = -46.0$ psf