



Design for wind

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Wind load

Steady wind is static

Gusty wind is dynamic



Wind load

- Pressure on wind side
- Suction on lee side
- Uplift on roof leeward

1 Wind load on gabled building

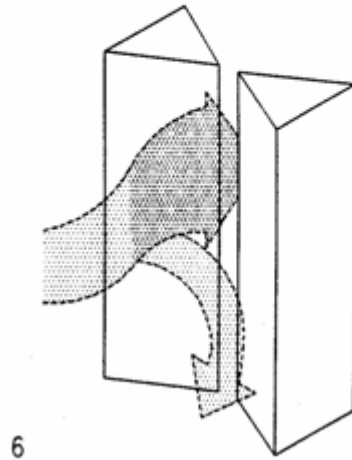
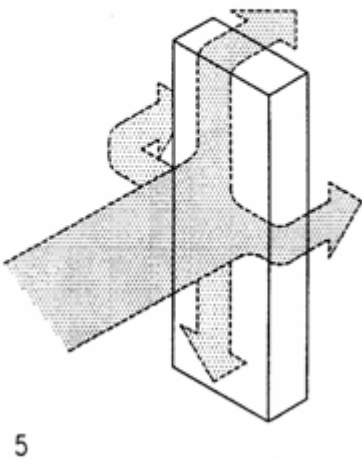
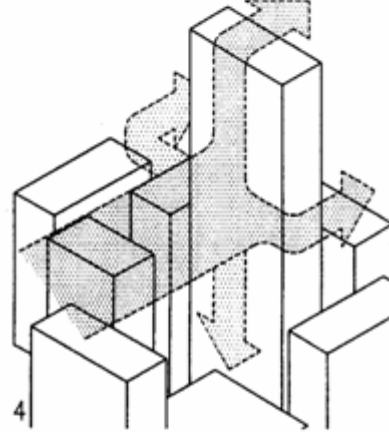
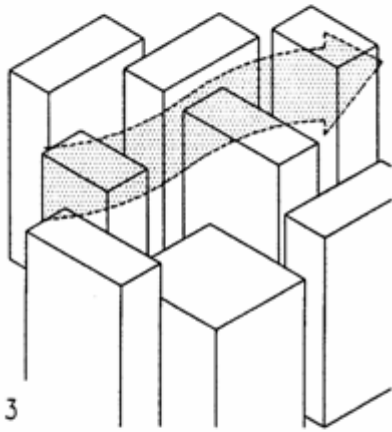
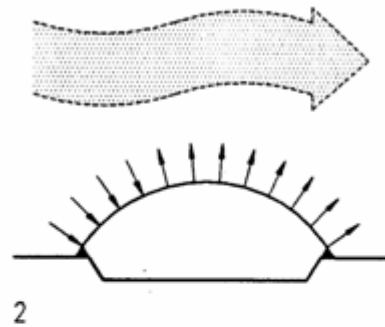
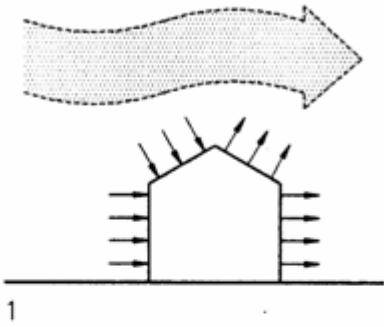
2 Wind load on dome or vault

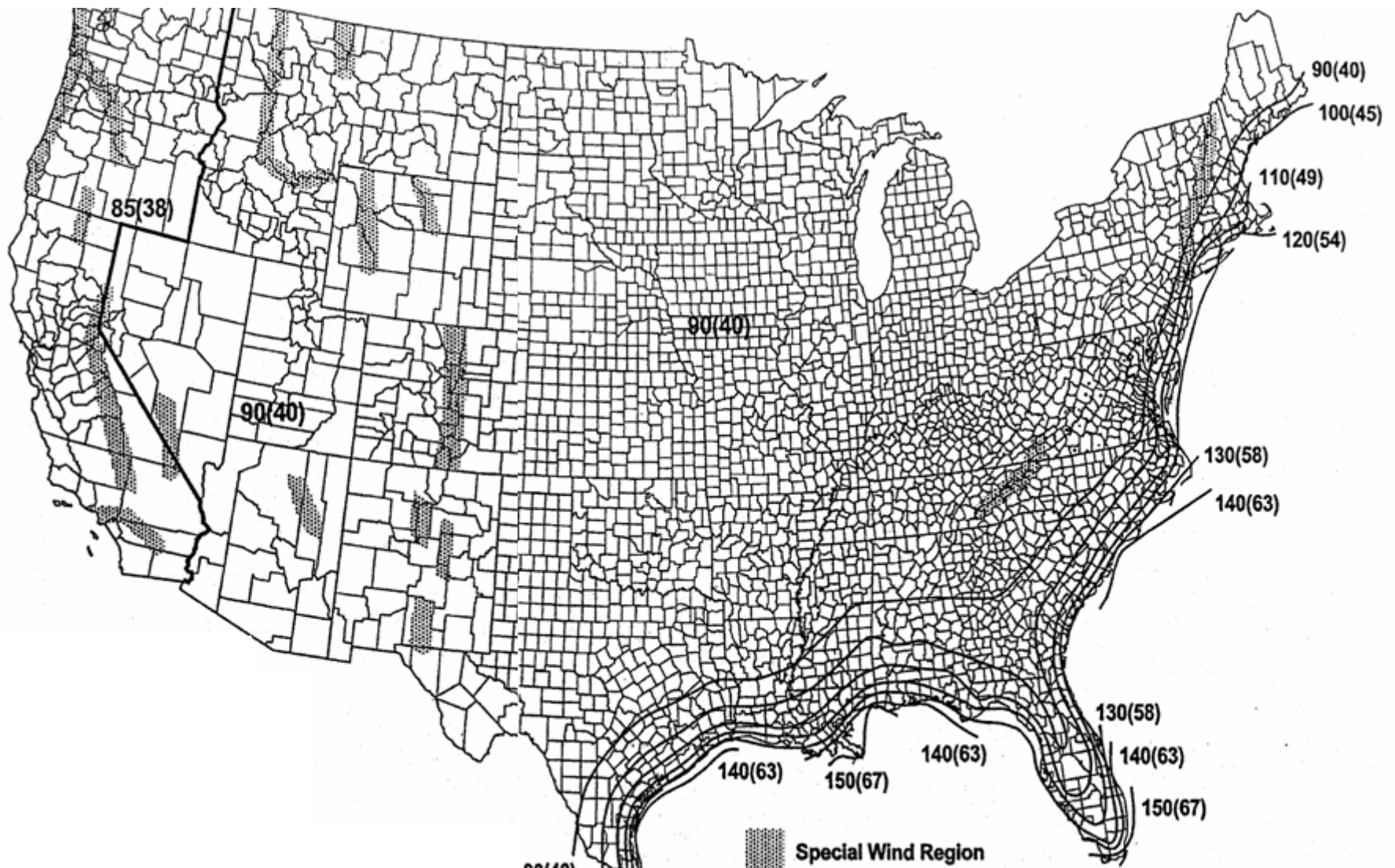
3 Protected city buildings

4 Exposed tall building

5 Exposed wide façade

6 Forms can increase wind speed





IBC Fig. 1609. Basic wind speed
 Values are nominal design 3-second gust wind speeds in mph (m/s), 33 ft (10 m) above ground for Exposure C. Special wind regions shall be examined for special wind conditions

Location	V mph	(m/s)
Hawaii	105	(47)
Puerto Rico	145	(65)
Guam	170	(76)
Virgin Islands	145	(65)
American Samoa	125	(56)

Hurricane





Photos courtesy Applied Research Associates, Raleigh. North Carolina

Wind effects

A building in the path of wind causes wind pressure that causes wind force, shear, and overturn per level.

1 Wind force, shear, and overturn moment per level

F_x = wind force = wind pressure times tributary area

V_x = shear per level = sum of F_x above

M_x = overturn moment

M_x = sum of forces above times their distance

2 Overturn visualized

3 Wind pressure increase with height

4 Wind force per level F_x

$F_x = P A$

P = wind pressure and suction in psf (Pa)

A = tributary area exposed to wind

A = building width x halve story heights above & below

5 Wind shear

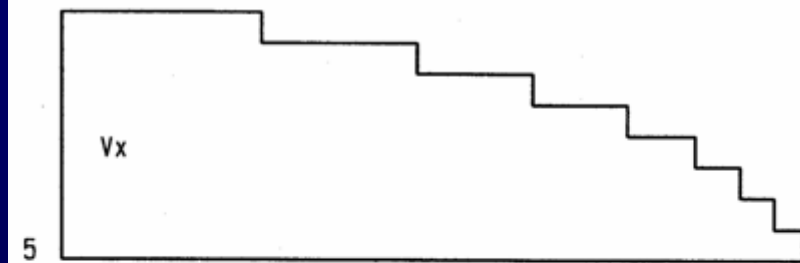
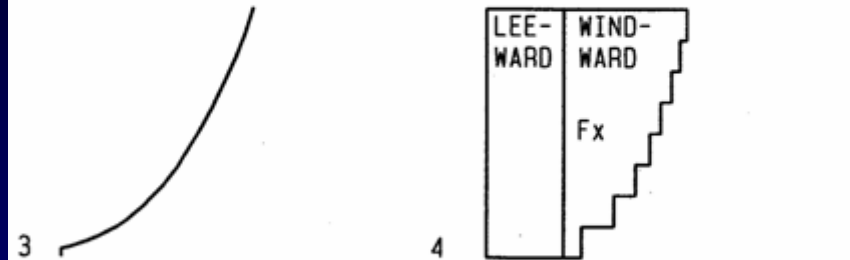
V = sum of all wind forces above

$$V_x = \sum_{i=x}^n F_i$$

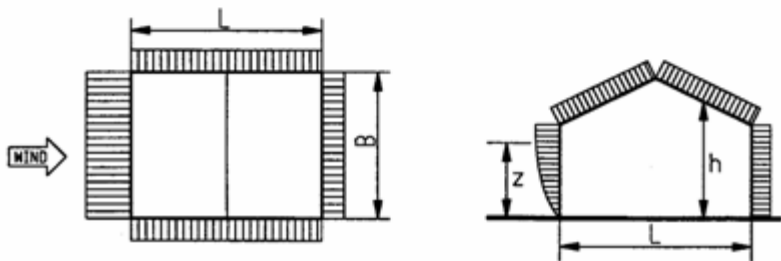
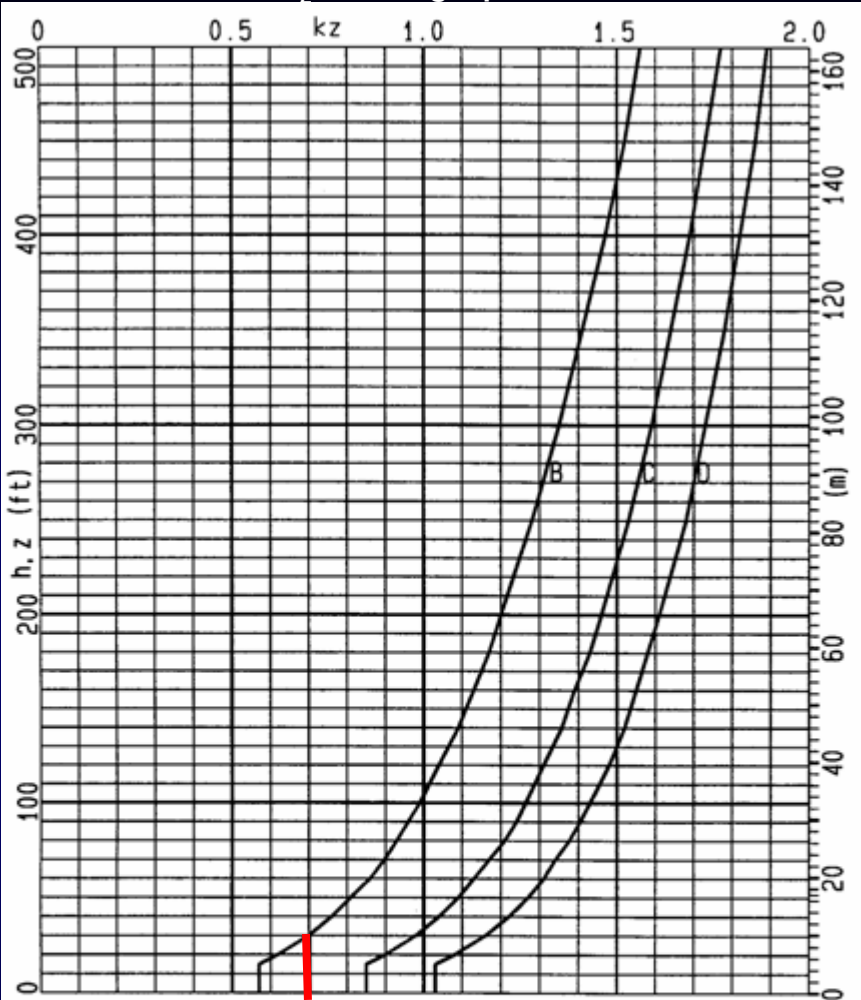
6 Overturn moment M

M = sum of forces above times their distance

$$M_x = \sum_{i=x}^n F_i (h_n - h_x)$$



K_z factor graph



Wind pressure (per IBC-03 / ASCE 7)

Method 2 – Analytical Procedure

- $p = qG C_p - q_i(GC_{pi})$ [minimum $p = 10$ psf (480 Pa)]
- q velocity pressure (defined below)
- q_z for windward wall (evaluated at height z above ground)
- q_h for leeward wall (constant, per mean roof height h)
- G gust factor ($G = 0.85$ for rigid structure ≥ 1 Hz)
- GC_{pi} Internal pressure (± 0.18 for enclosed structures)
- C_p pressure coefficient (from ASCE 7 figures and tables)
 - $C_p = 0.8$ (windward walls)
 - $C_p = -0.2$ to -0.5 (leeward walls)
 - $C_p = -1.3$ to $+0.5$ (for roofs)
- $q = 0.00256 IK_z K_{zt} K_d V^2$ (velocity pressure in psf)
- V = wind speed, mph (IBC Fig. 1609, or local speed)
- I = Importance factor (IBC table 1604.5)
 - $I = 1$ (all structures not listed below)
 - $I = 1.15$ (hospitals, police and fire stations, etc)
 - $I = 0.87$ (agricultural and temporary facilities)
- K_{zt} Topography factor ($K_{zt} = 1$ for regular sites)
- K_d Directionality factor ($K_d = 0.85$ for most structures)
- K_z Exposure factor (graph at left, **min. 0.7 for gladding**)
 - B = Exposure B (inner city, protected)
 - C = Exposure C (open area, unprotected)
 - D = Exposure D (near ocean or large lakes)

Example: 2-story wood building

Assume:

90 mph wind speed, Exposure C, I=1

Building size: 120'x66'x20' high

3 shear walls L=3x30' L= 90'

Level 2

Interior pressure 2.9 psf

Windward pressure 10.8 psf + 2.9 psf $p = 13.7$ psf

Leeward pressure 6.7 psf + 2.9 psf $p = 9.6$ psf

Total pressure 13.7 psf + 9.6 psf $p = 23.3$ psf

Force $F = 23.3$ psf x 120' x 10'/2 $F = 13,980$ #

Shear $V = F$ $V = 13,980$ #

Level 1

Interior pressure 2.7 psf

Windward pressure 10.2 psf + 2.7 psf $p = 12.9$ psf

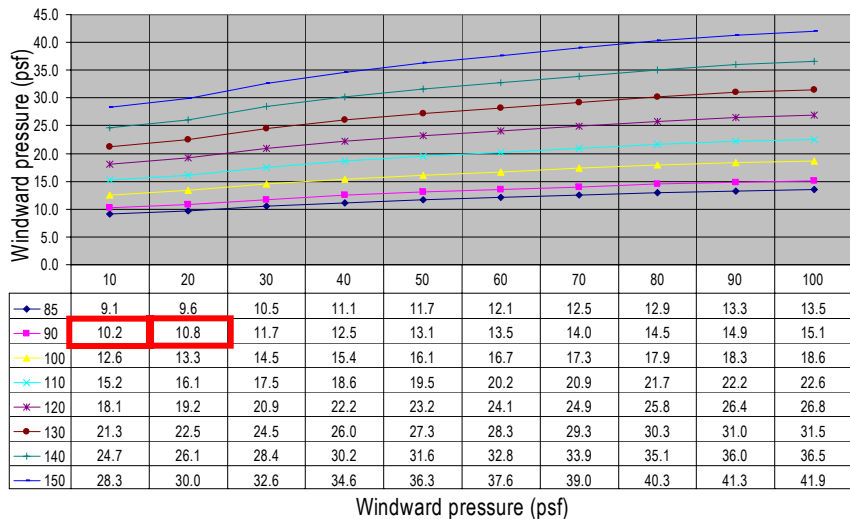
Leeward pressure 6.4 psf + 2.7 psf $p = 9.7$ psf

Total pressure 12.9 psf + 9.7 psf $p = 22.6$ psf

Force $F = 22.6$ psf x 120' x 10' $F = 27,120$ #

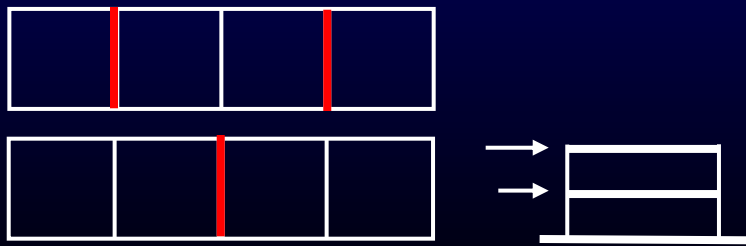
Shear $V = 13,980$ # + 27,120 # $V = 41,100$ #

Exposure C wind pressure for 10' to 100' height and 85 to 150 mph wind speed



	10	20	30	40	50	60	70	80	90	100
85	5.7	6.0	6.5	6.9	7.3	7.6	7.8	8.1	8.3	8.4
90	6.4	6.7	7.3	7.8	8.2	8.5	8.8	9.1	9.3	9.4
100	7.9	8.3	9.1	9.6	10.1	10.5	10.8	11.2	11.5	11.7
110	9.5	10.1	11.0	11.6	12.2	12.6	13.1	13.5	13.9	14.1
120	11.3	12.0	13.1	13.8	14.5	15.0	15.6	16.1	16.5	16.8
130	13.3	14.1	15.3	16.3	17.0	17.7	18.3	18.9	19.4	19.7
140	15.4	16.3	17.8	18.9	19.8	20.5	21.2	21.9	22.5	22.8
150	17.7	18.7	20.4	21.6	22.7	23.5	24.3	25.2	25.8	26.2

	10	20	30	40	50	60	70	80	90	100
85	2.4	2.5	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6
90	2.7	2.9	3.1	3.3	3.5	3.6	3.7	3.8	3.9	4.0
100	3.3	3.5	3.8	4.1	4.3	4.4	4.6	4.7	4.9	4.9
110	4.0	4.3	4.6	4.9	5.2	5.4	5.5	5.7	5.9	6.0
120	4.8	5.1	5.5	5.9	6.1	6.4	6.6	6.8	7.0	7.1
130	5.6	6.0	6.5	6.9	7.2	7.5	7.7	8.0	8.2	8.3
140	6.5	6.9	7.5	8.0	8.4	8.7	9.0	9.3	9.5	9.7
150	7.5	7.9	8.6	9.2	9.6	10.0	10.3	10.7	10.9	11.1

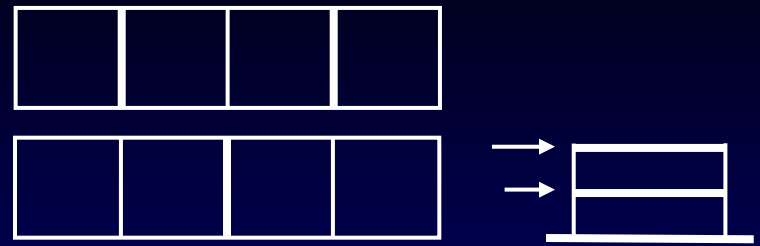


IBC table 2306.4.1 excerpts

Allowable shear for wood panels with Douglas-Fir-Large or Southern Pine

Panel grade	Panel thickness	Nail penetration	Nail size	Nail spacing at panel edge (inches)			
				6	4	3	2
Structural I sheathing	5/16 in	1 1/4 in	6d	200	300	390	510
	3/8 in	1 3/8 in	8d	230	360	460	610
	7/16 in	1 3/8 in	8d	255	395	505	670
	15/32 in	1 3/8 in	8d	280	430	550	730
		1 1/2 in	10d	340	510	665	870

* Requires 3 x framing and staggered nailing



Example: 2-story wood building

90 mph wind, exposure C, I=1

Level 2

Shear

$$\text{Req. wall} = 13,980 \# / 90' = 155 \text{ plf}$$

× Use 5/16", 6d @ 6"

$$V = 13,980 \#$$

$$200 > 155$$

Level 1

Shear

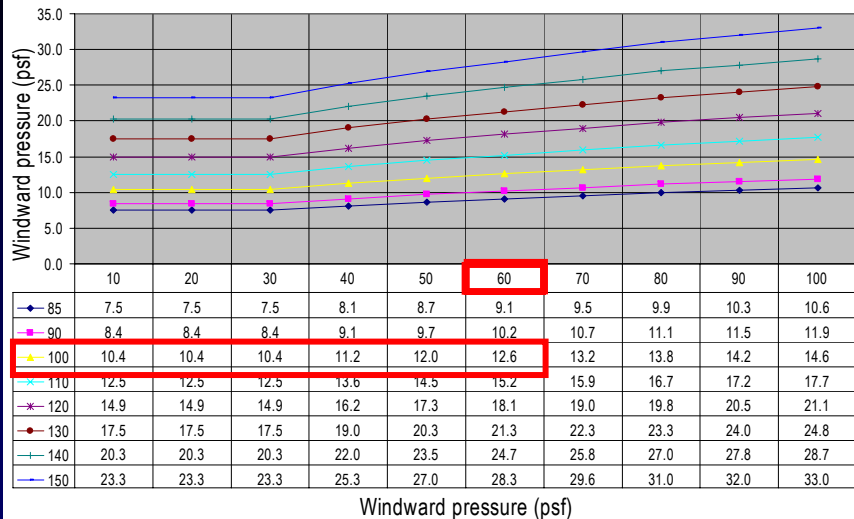
$$\text{Req. wall} = 41,100 \# / 90' = 457 \text{ plf}$$

Use 3/8", 8d @ 3"

$$V = 41,100 \#$$

$$460 > 457$$

Exposure B wind pressure for 10' to 100' height and 85 to 150 mph wind speed



Windward pressure (psf)	10	20	30	40	50	60	70	80	90	100
85	4.7	4.7	4.7	5.1	5.4	5.7	5.9	6.2	6.4	6.6
90	5.2	5.2	5.2	5.7	6.1	6.4	6.7	7.0	7.2	7.4
100	6.5	6.5	6.5	7.0	7.5	7.9	8.2	8.6	8.9	9.2
110	7.8	7.8	7.8	8.5	9.1	9.5	10.0	10.4	10.7	11.1
120	9.3	9.3	9.3	10.1	10.8	11.3	11.9	12.4	12.8	13.2
130	10.9	10.9	10.9	11.9	12.7	13.3	13.9	14.5	15.0	15.5
140	12.7	12.7	12.7	13.8	14.7	15.4	16.1	16.9	17.4	17.9
150	14.6	14.6	14.6	15.8	16.9	17.7	18.5	19.4	20.0	20.6

Windward pressure (psf)	10	20	30	40	50	60	70	80	90	100
85	2.0	2.0	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.8
90	2.2	2.2	2.2	2.4	2.6	2.7	2.8	3.0	3.0	3.1
100	2.7	2.7	2.7	3.0	3.2	3.3	3.5	3.6	3.8	3.9
110	3.3	3.3	3.3	3.6	3.8	4.0	4.2	4.4	4.5	4.7
120	3.9	3.9	3.9	4.3	4.6	4.8	5.0	5.2	5.4	5.6
130	4.6	4.6	4.6	5.0	5.4	5.6	5.9	6.2	6.4	6.6
140	5.4	5.4	5.4	5.8	6.2	6.5	6.8	7.1	7.4	7.6
150	6.2	6.2	6.2	6.7	7.1	7.5	7.8	8.2	8.5	8.7

Example: Six-story building

Assume:

Regular flat site, exposure B, V=100 mph, I = 1
6-story, 90'x90'x60', 30'x30'core, 8" CMU walls

Note: 8" nominal wall width t = 7 5/8" = 7.625"

Shear wall length (assume 2 6' doors)

$L = 2 \times (30' - 6')$

$L = 48'$

Find base shear and shear wall stress

Interior pressure = 3.3 psf

Leeward pressure = 7.9 psf + 3.3 $p = 11.3$ psf

Average windward pressure

$p = (3 \times 10.4 + 11.2 + 12.0 + 12.6) / 6 = 11.2$ psf

$p = 11.2 + 3.3$ $p = 14.5$ psf

Average combined wind pressure

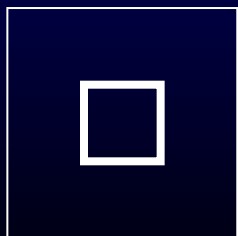
$p = 11.3 + 14.5$ $p = 25.8$ psf

Base shear (ignore lower half of first floor)

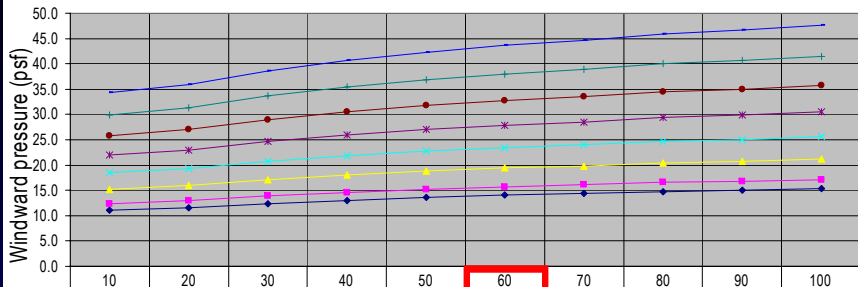
$V = 25.8 \text{ psf} \times 90 \times (60' - 5')$ $V = 127,710 \text{ \#}$

Core shear stress

$v = V / A = 127,710 \text{ \#} / (48' \times 12" \times 7.625")$ $v = 29$ psi



Exposure D wind pressure for 10' to 100' height and 85 to 150 mph wind speed



	10	20	30	40	50	60	70	80	90	100
85	11.0	11.5	12.4	13.0	13.6	14.0	14.3	14.8	15.0	15.3
90	12.3	12.9	13.9	14.6	15.2	15.7	16.1	16.5	16.8	17.1
100	15.2	16.0	17.2	18.1	18.8	19.4	19.8	20.4	20.7	21.2
110	18.4	19.3	20.8	21.8	22.7	23.5	24.0	24.7	25.1	25.6
120	21.9	23.0	24.7	26.0	27.1	27.9	28.6	29.4	29.8	30.5
130	25.8	27.0	29.0	30.5	31.8	32.8	33.5	34.5	35.0	35.8
140	29.9	31.3	33.6	35.4	36.8	38.0	38.9	40.0	40.6	41.5
150	34.3	36.0	38.6	40.6	42.3	43.6	44.6	45.9	46.6	47.6

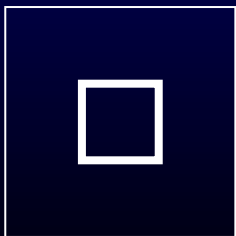
Windward pressure (psf)

85	6.9	7.2	7.8	8.2	8.5	8.8	9.0	9.2	9.4	9.6
90	7.7	8.1	8.7	9.1	9.5	9.8	10.0	10.3	10.5	10.7
100	9.5	10.0	10.7	11.3	11.7	12.1	12.4	12.8	12.9	13.2
110	11.5	12.1	13.0	13.7	14.2	14.7	15.0	15.4	15.7	16.0
120	13.7	14.4	15.4	16.2	16.9	17.4	17.8	18.4	18.6	19.0
130	16.1	16.9	18.1	19.1	19.8	20.5	20.9	21.6	21.9	22.3
140	18.7	19.6	21.0	22.1	23.0	23.7	24.3	25.0	25.4	25.9
150	21.4	22.5	24.1	25.4	26.4	27.3	27.9	28.7	29.1	29.8

Leeward pressure (psf)

85	2.9	3.1	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.0
90	3.3	3.4	3.7	3.9	4.0	4.2	4.3	4.4	4.4	4.5
100	4.0	4.2	4.5	4.8	5.0	5.1	5.2	5.4	5.5	5.6
110	4.9	5.1	5.5	5.8	6.0	6.2	6.4	6.5	6.6	6.8
120	5.8	6.1	6.5	6.9	7.2	7.4	7.6	7.8	7.9	8.1
130	6.8	7.1	7.7	8.1	8.4	8.7	8.9	9.1	9.3	9.5
140	7.9	8.3	8.9	9.4	9.7	10.1	10.3	10.6	10.7	11.0
150	9.1	9.5	10.2	10.8	11.2	11.5	11.8	12.2	12.3	12.6

Interior pressure (psf)



Example: Six-story building

Assume:

The same building at exposure D

Find total wind load at base and stress in shear walls

Interior pressure

$$p = 5.1 \text{ psf}$$

Leeward pressure = 12.1 psf + 5.1

$$p = 17.2 \text{ psf}$$

Average windward pressure

$$p = (15.2 + 16.0 + 17.2 + 18.1 + 18.8 + 19.4) / 6 \quad p = 17.5 \text{ psf}$$

Average combined wind pressure

$$p = 17.2 + 17.5 \quad p = 34.7 \text{ psf}$$

Base shear (ignore lower half of first floor)

$$V = 34.7 \text{ psf} \times 90 \times (60' - 5') \quad V = 171,765 \text{ \#}$$

Core shear stress

$$v = V/A = 171,765 \text{ \#} / (48' \times 12" \times 7.625") \quad v = 39 \text{ psi}$$

Note:

Compared to exposure C, stress increased 35 %



Design for real wind

