Code Developments for Wind-resistant Design of Buildings

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History of Caribbean Wind-loading Standards

Pre-1950s

CP3 : Chapter V : Part 2 - 1952

South Florida Building Code

Ronan Point - 1968

CCEO-BAPE Standard – 1970

OAS-NCST-CCEO-BAPE Standard – 1981 (BNS CP28)

CUBiC : Part 2 : Section 2

A Brief Overview of Some Important Wind-loading Standards

- *ISO 4354 and **CUBiC:Part-2:Section-2***
- *ENV 1991-2-4*
- *ASCE 7-98 and DRBC-03*
- *AIJ Recommendations*
- *AS1170.2*
- *Barbados Standard **BNS CP28***

Different International Wind Standards

Standard	Identification
ISO	International Standard Organization
CUBiC	Caribbean Uniform Building Code
ENV	Eurocode
DRBC	Dominican Republic Building Code
AIJ	Japan Standard
AS	Australian Standard
BNSCP	Barbados Standard

Standard	Averaging Time	Return Period(s)
ISO 4354	10 minutes	50 years
CUBiC	10 minutes	50 years
ENV 1991-2-4	10 minutes	50 years
ASCE 7-98	3 seconds	50 years
AIJ	10 minutes	100 years
AS1170.2-1989	3 seconds	20 and 1000 years
BNS CP28	3 seconds	50 years

Note: Canadian and British standards now use 1-hour averaging time.

Comparative table with different ways of reporting wind velocity

Averaging time	Wind Velocity (mph)			
1 Hour	120	113	91	79
10 minutes	127	120	96	84
Fastest mile	158	149	120	105
3 second gust	181	171	137	120

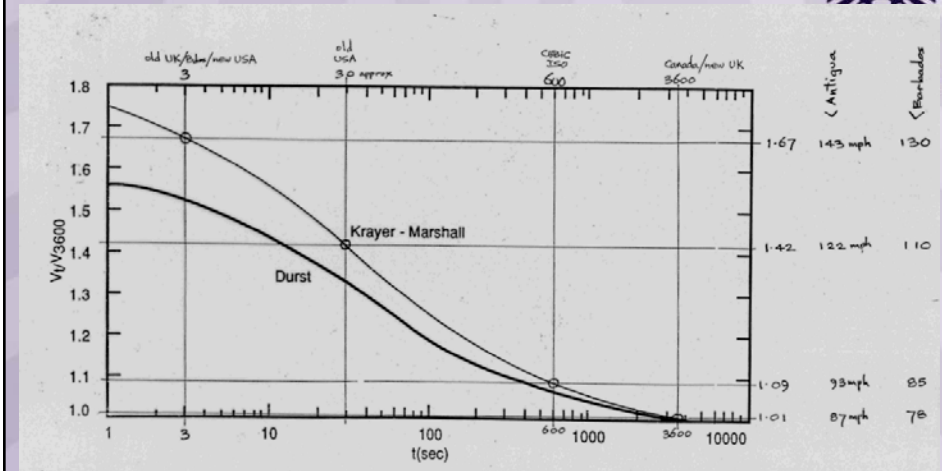

Fig. 2.1 Ratio of Probable Maximum Speed Averaged over *t* Seconds to Hourly Mean Speed

Differences and similarities for calculating design wind speeds and dynamic pressures

Standard	Speed	Pressure	Building Pressure/Force
ISO 4354	V	$q_{ref} = \frac{1}{2}\rho V^2$	$W = (q_{ref})(C_{exp})(C_{fig})(C_{dyn})$
CUBiC	V	$q_{ref} = \frac{1}{2}\rho V^2$	$W = q_{ref}(C_{exp})(C_{fig})C_{dyn}$
ENV 1991-2-4	$V_{ref} = C_{dir}C_{tem}C_{alt}C_{ref,0}$	$q_{ref} = \frac{1}{2}\rho(V_{ref})^2$	$W_e = q_{ref}C_{exp}(Z_e)C_{pe}$
DRBC-03	$V(3s-gust)$	$q_z = \frac{1}{2}\rho K_z K_{zt} K_d I V^2$	$p = q_z(GC_p) - q_h(GC_{pi})$
AIJ	$U_H = U_g E_f E_g R$	$q_h = \frac{1}{2}\rho U_H{}^2$	$W_f = q_h C_f G_f A$
AS1170.2-89	$V_z = V_{z,cat} M_s M_t M_i$	$q_h = \frac{1}{2}\rho V_z{}^2$	$P_e = C_{p,e}K_a K_l K_p q_z$
BNSCP28	V	$q = \frac{1}{2}\rho(VS_1S_2S_3)^2$	$P = qC_{pe}$

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Building Shape or Type	ISO 4354	CUBiC	ENV 1991	ASCE 7-98	AIJ	AS1170 .2	BNS CP28
stepped roofs	no	no	no	yes	no	no	yes
free-standing walls,	yes	yes	yes	yes	no	yes	no
free-standing roofs	no	no	yes	no	no	yes	yes
attached canopies	no	no	no	no	no	yes	yes
multispan roofs	no	no	yes	yes	yes	yes	yes
multispan canopies	no	no	yes	no	no	no	no
arched roofs	yes	yes	yes	yes	yes	yes	yes
domes	no	no	yes	no	yes	no	no
bins, silos, tanks	yes	yes	yes	no	no	yes	no
circular sections	yes	yes	yes	yes	yes	yes	yes
polygonal sections	no	no	yes	no	no	yes	yes
structural angle	yes	yes	yes	no	no	yes	yes
bridge decks	no	yes	yes	no	no	no	no
lattice sections	yes	yes	yes	yes	no	yes	yes
flags	no	no	yes	no	no	no	no
spheres	no	yes	yes	no	no	no	yes

The trend for Caribbean standards is to adopt and adapt the ASCE-7 approach
(Dominican Republic, new CUBiC, Cayman, Bahamas)

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ASCE 7 Methods

- Method 1: Simplified (tables & limited use)
- **Method 2: Analytical (almost all cases)**
- Method 3: Wind Tunnel (unusual cases)

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Method 1: Simplified

The building must be:

1. a simple diaphragm building;
2. a low-rise building;
3. **enclosed and conform to the wind-borne debris provisions;**
4. **a regular shaped building or structure;**
5. not classified as a flexible building;
6. **not assessed as having unfavourable aerodynamic characteristics and not having an unfavourable site location;**
7. of a structure with no expansion joints or separations;
8. **not subject to unfavourable topographic effects;**
9. **of an approximately symmetrical cross section.**

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Summary for Method 2

- MWFRS
  - $p = q\,GC_p - q_i\,(GC_{pi})$
- C&C for h$\leq$ 60 ft
  - $p = q_h\,[(GC_p) - (GC_{pi})]$
- where:
  - $q_z = 0.00256\,K_z\,K_{zt}\,K_d\,V^2\,I$
  - $q_h = 0.00256\,K_h\,K_{zt}\,K_d\,V^2\,I$

p = design pressure
q = effective velocity pressure
G = gust effect factor (gef)
C_p = external pressure coefficient
q_i = velocity pressure (internal)
GC_{pi} = gef + internal pressure coefficient
GC_p = gef + external pressure coefficient

K_z = exposure velocity pressure coefficient
K_{zt} = topographic factor
K_d = directionality factor
V = basic wind speed
I = importance factor

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The first step in Method 2 is to determine the appropreiate parameters for evaluating the velocity pressure, q

Parameter	Symbol	What does it mean?
Directionality	K_d	Takes into account the probability that the maximun wind has the same direction than that of the maximun pressure
Importance	I	Converts a 50-year return period into a 100-year return period recommended for hospitals
Exposure	K_z	Represents the wind velocity at height z above the ground in different terrains
Topography	K_{zt}	Takes into account the fact that the structure be located on top of a hill or on a escarpment increasing the wind velocity

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Meaning of factors in ASCE-7

Name	Symbol	What does it mean?
Gust Factor	G	Represents the turbulence-structure interaction and the corresponding dynamic amplification
External Pressure Coefficient	C_p	Represents the wind pressure on the building's external walls
Internal Pressure Coefficient	C_{pi}	Reflects the internal pressure due to quantity and sizes of wall openings
Design Pressure	p	Represents the design pressure
Design Force	F	Represents the net force on open structures

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Method 2: Analytical

1. basic wind speed V and wind directionality factor K_d
2. importance factor I
3. exposure category or exposure categories and velocity pressure exposure coefficient K_z or K_h
4. topographic factor K_{zt}
5. gust effect factor G or G_f
6. enclosure classification
7. internal pressure coefficient GC_{pi}
8. external pressure coefficients C_p or GC_{pf}, or force coefficient C_f
9. velocity pressure q_z or q_h
10. design wind load p or F

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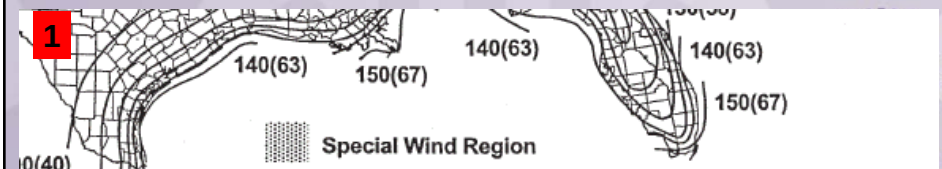


Location	V mph	(m/s)
Hawaii	105	(47)
Puerto Rico	145	(65)
Guam	170	(76)
Virgin Islands	145	(65)
American Samoa	125	(56)

Notes:
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.

FIGURE 1609—continued
BASIC WIND SPEED (3-SECOND GUST)

1

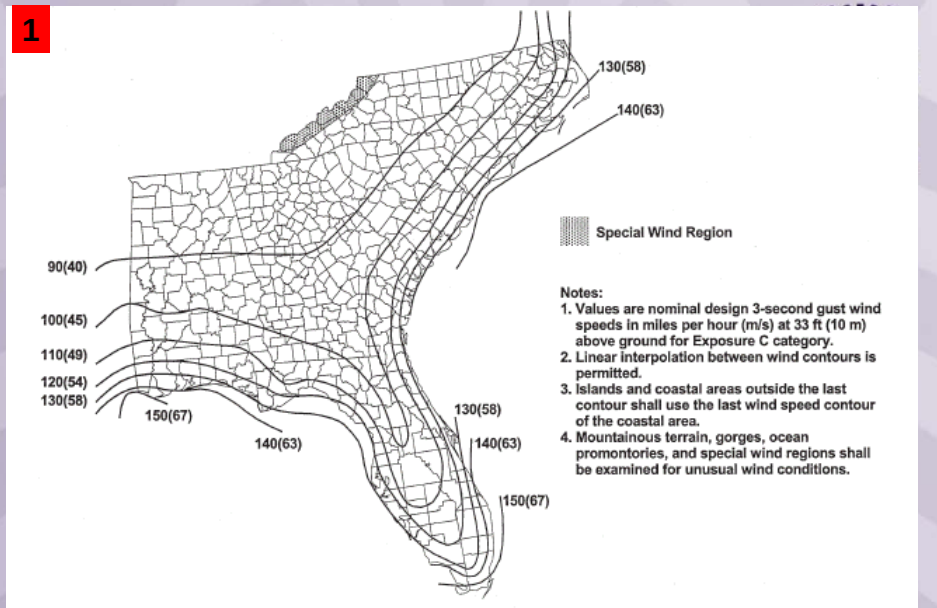


FIGURE 1609—continued
BASIC WIND SPEED (3-SECOND GUST)
EASTERN GULF OF MEXICO AND SOUTHEASTERN U.S. HURRICANE COASTLINE

1

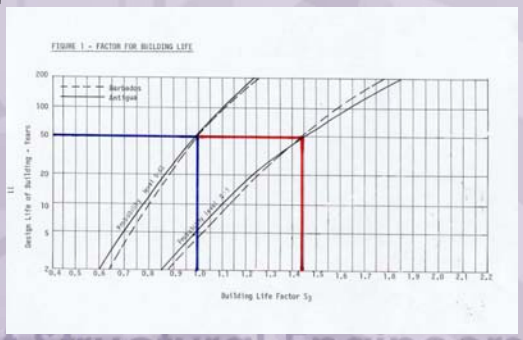
Directionality Factor K_d

Structure Type	K_d
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Round	0.95
Open Signs and Lattice Framework	0.85
Trussed Towers	
Triangular, square, rectangular	0.85
All other cross sections	0.95

2

Importance Factor *I*

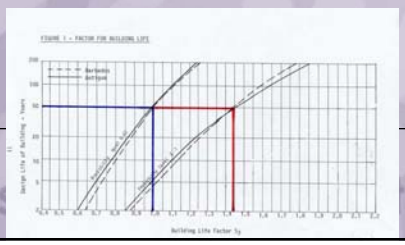
$$I = \left(\frac{V_{100}}{V_{50}}\right)^2 \text{ or } \left(\frac{V_{25}}{V_{50}}\right)^2$$



2

Importance Factor *I*

Category	Non-Hurricane Prone Regions, Hurricane Prone Regions with V=85-100 mph, and Alaska	Hurricane Prone Regions with V>100 mph
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV		1.15



3

Velocity Pressure Exposure Coefficient K_z

$$V_z = V_{33}\left(\frac{z}{33}\right)^{1/\alpha}$$

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3

Exposure Constants

Exposure Category	Gradient Height	$1/\alpha$
A	1500 ft	1/5
B	1200 ft	1/7
C	900 ft	1/9.5
D	700 ft	1/11.5

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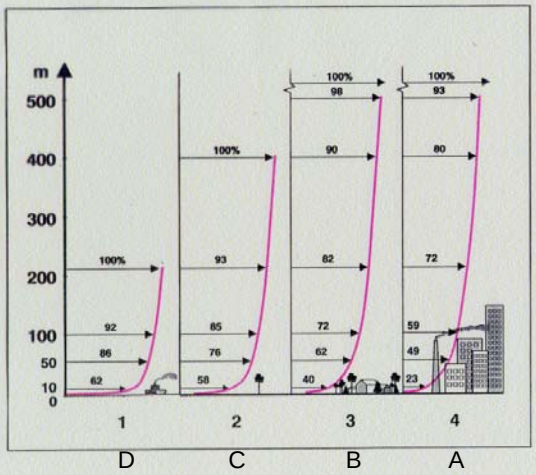

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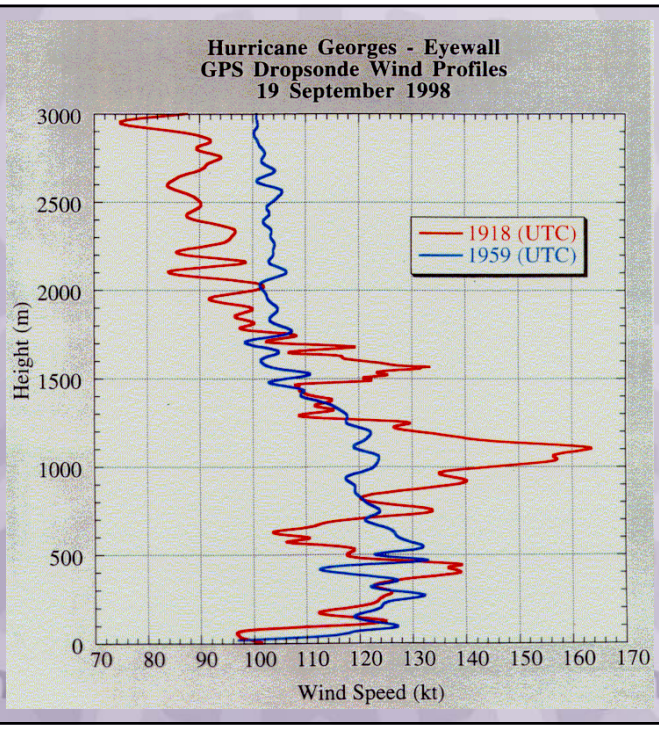

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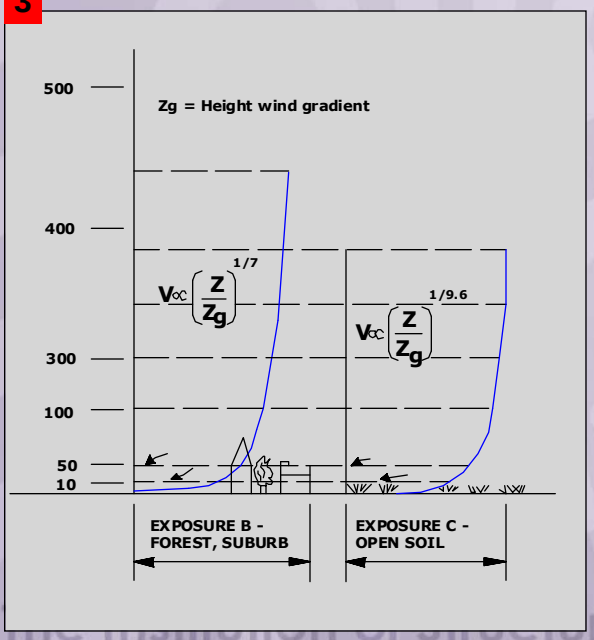


Effects of terrain roughness and height on wind speeds

3

K_z

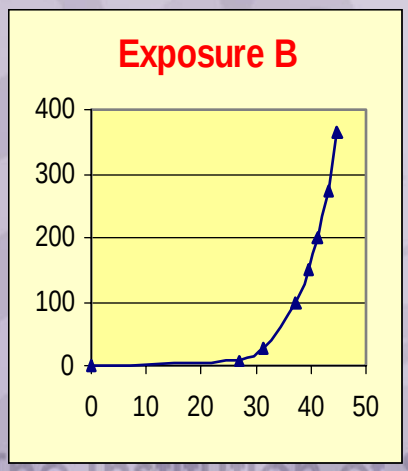
$$V_g = \left[V_{33} \left(\frac{900}{33} \right)^{\frac{1}{9.5}} \right]$$

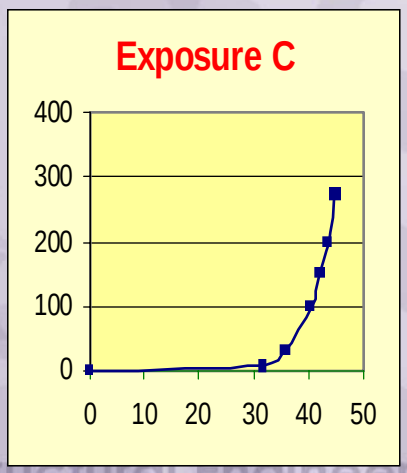
$$V_z = V_g \left(\frac{z}{z_g} \right)^{\frac{1}{\alpha}} = \left[1.42 V_{33} \right] \left(\frac{z}{z_g} \right)^{\frac{1}{\alpha}}$$

$$K_z = \left(\frac{V_z}{V_{33}} \right)^2 = 2.01 \left(\frac{z}{z_g} \right)^{\frac{2}{\alpha}}$$

3

Effects of exposure and altitude





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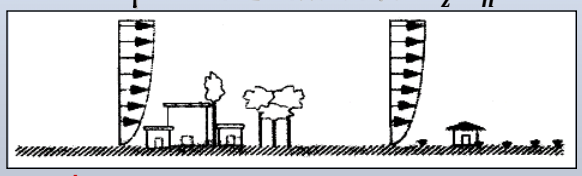
Exposure Coefficients K_z K_h



Exposure type B C

NOTE:

1. **Case 1** shall be used for all primary systems in buildings with height 'h' less than 18 m and for secondary systems of any type of structure
2. **Case 2** shall be used for all primary systems of any other structure not indicated in case 1
3. For values of **Z** not shown, linear interpolation shall be permitted

Exposure				Exposure			
Height Z (m)	B		C	Height Z (m)	B		C
	Case 1	Case 2	Case 1 y 2		Case 1	Case 2	Case 1 y 2
≤ 5	.70	.57	.85	32	1.03	1.03	1.30
6	.70	.62	.90	34	1.07	1.07	1.34
8	.70	.67	.96	36	1.10	1.10	1.37
10	.72	.72	1.00	38	1.14	1.14	1.4
12	.76	.76	1.04	40	1.17	1.17	1.43
14	.79	.79	1.07	42	1.20	1.20	1.46
16	.82	.82	1.11	44	1.23	1.23	1.48
18	.85	..85	1.13	46	1.25	1.25	1.51
20	.88	.88	1.16	48	1.28	1.28	1.53
22	.90	.90	1.18	50	1.30	1.30	1.55
24	.92	.92	1.20	52	1.32	1.32	1.57
26	.93	.93	1.21	54	1.35	1.35	1.59
28	.96	.96	1.24	56	1.37	1.37	1.61
30	.98	.98	1.26	58	1.39	1.39	1.63

3

K_z and K_h

Velocity Pressure Coefficients, K_h and K_z

Height above ground level, z ft (m)	A	B	C	D
0-15 (0-4.6)	0.32	0.57	0.85	1.03
20 (6.1)	0.36	0.62	0.90	1.08
25 (7.6)	0.39	0.66	0.94	1.12
30 (9.1)	0.42	**0.70**	0.98	1.16
40 (12.2)	0.47	0.76	1.04	1.22
50 (15.2)	0.52	0.81	1.09	1.27
60 (18)	0.55	0.85	1.13	1.31
70 (21.3)	0.59	0.89	1.17	1.34
80 (24.4)	0.62	0.93	1.21	1.38
90 (27.4)	0.65	0.96	1.24	1.40
100 (30.5)	**0.68**	0.99	1.26	1.43

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4

Topographic Factor K_{zt}

$$K_{zt} = \left[1 + K_1 K_2 K_3\right]^2$$

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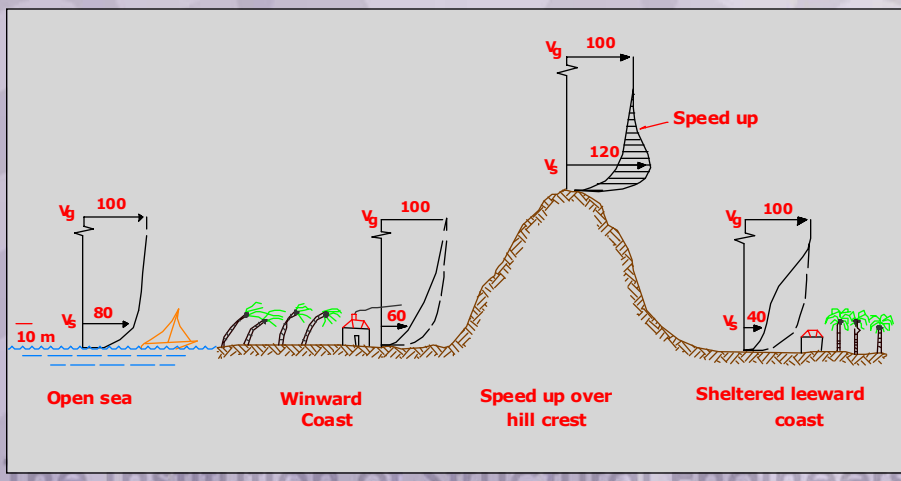
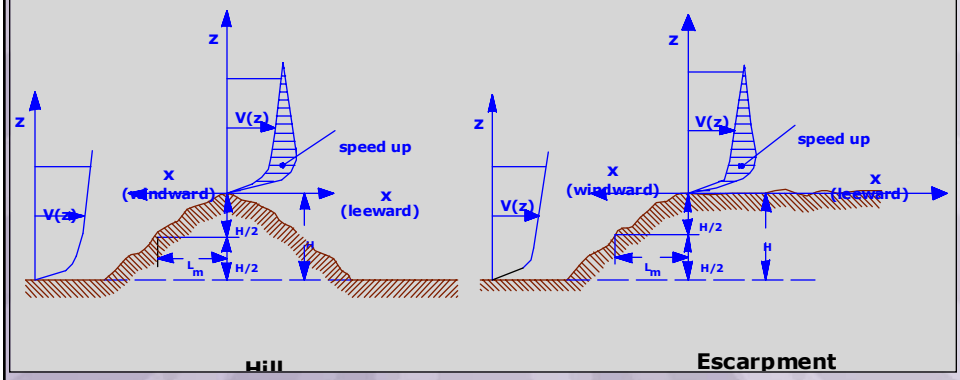
4

Sketch showing effects of topography on wind velocity on a hilly island



4

Topographic effect showing wind velocity increase



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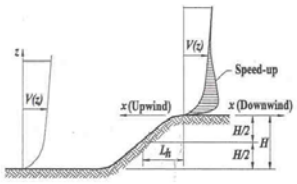
Topographic Factor, K_{zt} – Method 2

Figure 6-4



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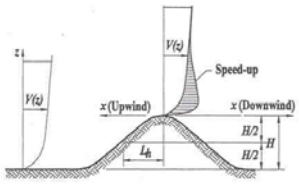

2-D RIDGE OR 3-D AXISYMMETRICAL HILL

Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier			x/L_h	K_2 Multiplier		z/L_h	K_3 Multiplier		
	2-D Ridge	2-D Escarp.	3-D Axisym. Hill		2-D Escarp.	All Other Cases		2-D Ridge	2-D Escarp.	3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

$$K_{zt} = \left[1 + K_1 K_2 K_3\right]^2$$

5

Gust Effect Factor G or G_f

- Gust intensity
- Gust frequency
- Gust size
  - Integral scale longitudinal and lateral
- Frequency of structure
- Structural damping
- Aerodynamic admittance
- Gust correlation

5

Gust Effect Factor *G*

Rigid Structures: Complete Analysis

$$G = 0.925\left[\frac{1+1.7 g_Q I_{\bar{z}} Q}{1+1.7 g_v I_{\bar{z}}}\right]$$

g_Q = peak factor for background response
I_Z = intensity of turbulence
Q = background response factor
g_v = peak factor for wind response

$$Q^2 = \frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}$$

L_Z = integral length scale of turbulence

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5

Gust Effect Factor G_f

MWFRS for flexible buildings and other structures

$$G_f = 0.925\left[\frac{1+1.7 I_{\bar{z}} \sqrt{g_Q^2 Q^2 g_R^2 R^2}}{1+1.7 g_v I_{\bar{z}}}\right]$$

g_Q = peak factor for background response
g_R = peak factor for resonant response
R = resonant response factor
I_Z = intensity of turbulence
Q = background response factor
g_v = peak factor for wind response

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6

Building, Enclosed

A building that does not comply with the requirements for open or partially enclosed buildings.

Building, Open

A building having each wall at least 80%.

This condition is expressed for each wall by the equation:

$A_o \geq 0.8\, A_g$, where

A_o = total area of openings in a wall that receives positive external pressure, in ft^2

A_g = the gross area of that wall in which A_o is identified, in ft^2

6

Building, Partially Enclosed

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%, and
2. The total area of openings in a wall that receives positive external pressure exceeds 0.37 m^2 (4 ft^2) or 1% of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20%.

1. $A_o > 1.10\, A_{oi}$
2. $A_o > 4\ ft^2$ or $> 0.01\, A_g$, whichever is smaller, and $A_{oi}/A_{gi} \leq 0.20$

where

A_o, A_g are as defined for Open Building

A_{oi} = the sum of the areas of openings in the building envelope (walls and roof) not including A_o, in ft^2

7

GC_{pi} Gust Factor combined with Internal Pressure Coefficient

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

8

Analytical Method for MWFRS

$q_z = 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ I$

$p = qGC_p - q_i(GC_{pi})$

for all rigid buildings

$p = q_h[(GC_{pf}) - (GC_{pi})]$

alternate for low-rise rigid buildings

$p = qG_fC_p - q_i(GC_{pi})$

for flexible buildings

8

Design pressure on primary systems (structural)

Rigid Primary Systems

$$p = q\,GC_p - q_i\,(GC_{pi})$$

Flexible Primary Systems

$$p = qG_f\,C_p - q_i\,(GC_{pi})$$

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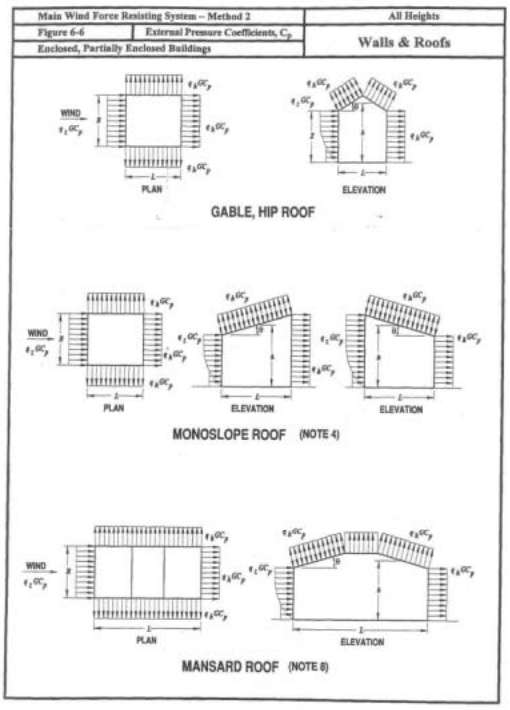
8



8

Main Wind Force Resisting System – Method 2	All Heights
Figure 6-6 (con't) External Pressure Coefficients, C_p	Walls & Roofs
Enclosed, Partially Enclosed Buildings	

Wall Pressure Coefficients, C_p

Surface	L/B	C_p	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

Roof Pressure Coefficients, C_p, for use with q_h

Wind Direction		Windward Angle, θ (degrees)						Leeward Angle, θ (degrees)					
	h/L	10	15	20	25	30	35	45	≥60#	10	15	≥20
Normal to ridge for θ ≥ 10°	≤0.25	-0.7 -0.18	-0.5 0.0*	-0.3 0.2	-0.2 0.3	-0.2 0.3	0.0* 0.4	0.4	0.01 θ	-0.3	-0.5	-0.6
	0.5	-0.9 -0.18	-0.7 -0.18	-0.4 0.0*	-0.3 0.2	-0.2 0.2	-0.2 0.3	0.0* 0.4	0.01 θ	-0.5	-0.5	-0.6
	≥1.0	-1.3** -0.18	-1.0 -0.18	-0.7 -0.18	-0.5 0.0*	-0.3 0.2	-0.2 0.2	0.0* 0.3	0.01 θ	-0.7	-0.6	-0.6

Normal to ridge for θ < 10 and Parallel to ridge for all θ		Horiz distance from windward edge	C_p
	≤ 0.5	0 to h/2	-0.9, -0.18
		h/2 to h	-0.9, -0.18
		h to 2 h	-0.5, -0.18
		> 2h	-0.3, -0.18
	≥ 1.0	0 to h/2	-1.3**, -0.18
		> h/2	-0.7, -0.18

*Value is provided for interpolation purposes.

**Value can be reduced linearly with area over which it is applicable as follows

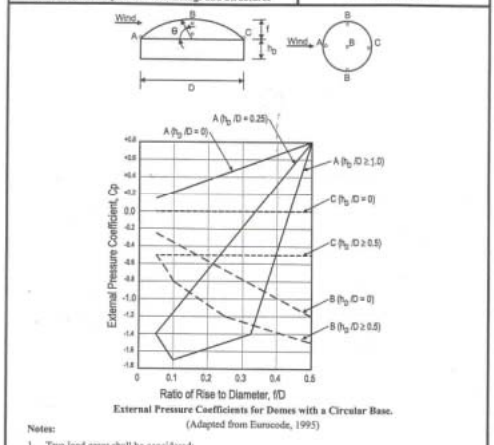
Area (sq ft)	Reduction Factor
≤ 100 (9.3 sq m)	1.0
200 (23.2 sq m)	0.9
≥ 1000 (92.9 sq m)	0.8

Notes:
1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. Linear interpolation is permitted for values of L/B, h/L and θ other than shown. Interpolation shall only be carried out between values of the same sign. Where no value of the same sign is given, assume 0.0 for interpolation purposes.
3. Where two values of C_p are listed, this indicates that the windward roof slope is subjected to either positive or negative pressures and the roof structure shall be designed for both conditions. Interpolation for intermediate ratios of h/L in this case shall only be carried out between C_p values of like sign.
4. For monoslope roofs, entire roof surface is either a windward or leeward surface.
5. For flexible buildings use appropriate C_f as determined by Section 6.5.8.
6. Refer to Figure 6-7 for domes and Figure 6-8 for arched roofs.
7. Notation:
   B: Horizontal dimension of building, in feet (meter), measured normal to wind direction.
   L: Horizontal dimension of building, in feet (meter), measured parallel to wind direction.
   h: Mean roof height in feet (meters), except that eave height shall be used for θ ≤ 10 degrees.
   z: Height above ground, in feet (meters).
   G: Gust effect factor.
   q_z, q_h: Velocity pressure, in pounds per square foot (N/m²), evaluated at respective height.
   θ: Angle of plane of roof from horizontal, in degrees.
8. For mansard roofs, the top horizontal surface and leeward inclined surface shall be treated as leeward surfaces from the table.
9. Except for MWFRS's at the roof consisting of moment resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.

#For roof slopes greater than 80°, use C_p = 0.8

8

Main Wind Force Resisting System – Method 2	All Heights
Figure 6-7 External Pressure Coefficients, C_p	Domed Roofs
Enclosed, Partially Enclosed Buildings and Structures	



External Pressure Coefficients for Domes with a Circular Base.
(Adapted from Eurocode, 1995)

Notes:
1. Two load cases shall be considered:
   Case A. C_p values between A and B and between B and C shall be determined by linear interpolation along arcs on the dome parallel to the wind direction;
   Case B. C_p shall be the constant value of A for θ ≤ 25 degrees, and shall be determined by linear interpolation from 25 degrees to B and from B to C.
2. Values denote C_p to be used with $q_{z=h}$ where h_D + f is the height at the top of the dome.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. C_p is constant on the dome surface for arcs of circles perpendicular to the wind direction; for example, the arc passing through B-B-B and all arcs parallel to B-B-B.
5. For values of h_D/D between those listed on the graph curves, linear interpolation shall be permitted.
6. θ = 0 degrees on dome springline, θ = 90 degrees at dome center top point. f is measured from springline to top.
7. The total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
8. For f/D values less than 0.05, use Figure 6-6.

8

Main Wind Force Res. Sys. / Comp and Clad. -- Method 2		All Heights
Figure 6-8	External Pressure Coefficients, C_p	Arched Roofs
Enclosed, Partially Enclosed Buildings and Structures		

Conditions	Rise-to-span ratio, r	C_p		
		Windward quarter	Center half	Leeward quarter
Roof on elevated structure	$0 < r < 0.2$	-0.9	-0.7 - r	-0.5
	$0.2 \le r < 0.3$*	1.5r - 0.3	-0.7 - r	-0.5
	$0.3 \le r \le 0.6$	2.75r - 0.7	-0.7 - r	-0.5
Roof springing from ground level	$0 < r \le 0.6$	1.4r	-0.7 - r	-0.5

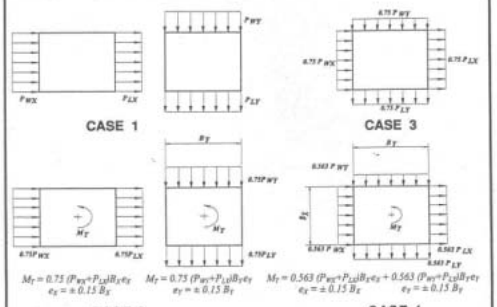
*When the rise-to-span ratio is $0.2 \le r \le 0.3$, alternate coefficients given by 6r - 2.1 shall also be used for the windward quarter.

Notes:

1. Values listed are for the determination of average loads on main wind force resisting systems.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. For wind directed parallel to the axis of the arch, use pressure coefficients from Fig. 6-6 with wind directed parallel to ridge.
4. For components and cladding: (1) At roof perimeter, use the external pressure coefficients in Fig. 6-11 with θ based on spring-line slope and (2) for remaining roof areas, use external pressure coefficients of this table multiplied by 0.87.

8

Main Wind Force Resisting System- Method 2		All Heights
Figure 6-9	Design Wind Load Cases	



Case 1. Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.

Case 2. Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.

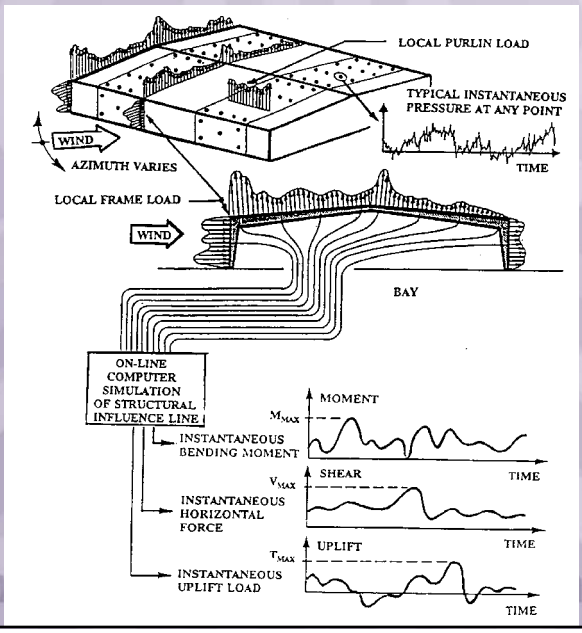
Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

Notes:

1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 6.5.12.2.1 and 6.5.12.2.3 as applicable for building of all heights.
2. Diagrams show plan views of building.
3. Notation:
   P_{WX}, P_{WY}: Windward face design pressure acting in the x, y principal axis, respectively.
   P_{LX}, P_{LY}: Leeward face design pressure acting in the x, y principal axis, respectively.
   e (e_X, e_Y): Eccentricity for the x, y principal axis of the structure, respectively.
   M_T: Torsional moment per unit height acting about a vertical axis of the building.

8

Wind Tunnel Results (GC_p)



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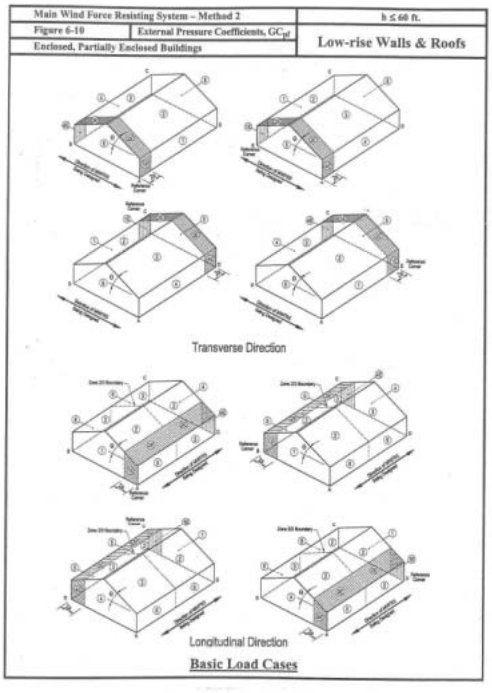
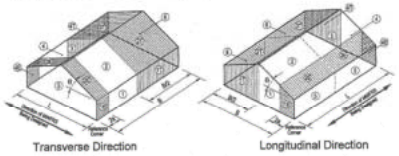


8

Main Wind Force Resisting System – Method 2		$h \le 60$ ft.
Figure 6-10 (cont'd)	External Pressure Coefficients, C_{gt}	Low-rise Walls & Roofs
Enclosed, Partially Enclosed Buildings		

Roof Angle θ (degrees)	Building Surface									
	1	2	3	4	5	6	1E	2E	3E	4E
0-5	0.40	-0.69	-0.37	-0.29	-0.45	-0.45	0.61	-1.07	-0.53	-0.43
20	0.53	-0.69	-0.48	-0.43	-0.45	-0.45	0.80	-1.07	-0.69	-0.64
30-45	0.56	0.21	-0.43	-0.37	-0.45	-0.45	0.69	0.27	-0.53	-0.48
90	0.56	0.56	-0.37	-0.37	-0.45	-0.45	0.69	0.69	-0.48	-0.48

Notes:
1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. For values of θ other than those shown, linear interpolation is permitted.
3. The building must be designed for all wind directions using the 8 loading patterns shown. The load patterns are applied to each building corner in turn as the Reference Corner.
4. Combinations of external and internal pressures (see Figure 6-5) shall be evaluated as required to obtain the most severe loadings.
5. For the torsional load cases shown below, the pressures in zones designated with a "T" (1T, 2T, 3T, 4T) shall be 25% of the full design wind pressures (zones 1, 2, 3, 4).
   Exception: One story buildings with h less than or equal to 30 ft (9.1m), buildings two stories or less framed with light frame construction, and buildings two stories or less designed with flexible diaphragms need not be designed for the torsional load cases.
   Torsional loading shall apply to all eight basic load patterns using the figures below applied at each reference corner.
6. Except for moment-resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
7. For the design of the MWFRS providing lateral resistance in a direction parallel to a ridge line or for flat roofs, use θ = 0° and locate the zone 2/3 boundary at the mid-length of the building.
8. The roof pressure coefficient GC_{pb}, when negative in Zone 2, shall be applied in Zone 2 for a distance from the edge of roof equal to 0.5 times the horizontal dimension of the building parallel to the direction of the MWFRS being designed or 2.5h, whichever is less; the remainder of Zone 2 extending shall use the pressure coefficient GC_p for Zone 3.
9. Notation:
   a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
   h: Mean roof height, in feet (meters), except that eave height shall be used for θ ≤ 10°.
   θ: Angle of plane of roof from horizontal, in degrees.



Transverse Direction Longitudinal Direction

Torsional Load Cases

8

Analytical Method for Components & Cladding

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I$$

$$p = q_h[(GC_p) - (GC_{pi})]$$

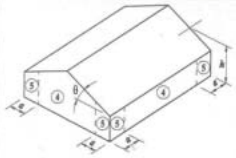
for buildings with $h \le 60$ ft

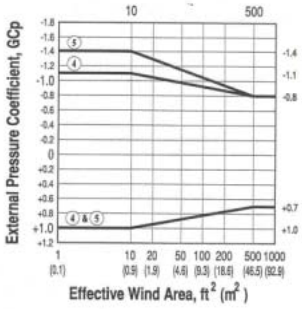
$$p = q(GC_p) - q_i(GC_{pi})$$

for buildings with $h > 60$ ft

8

Components and Cladding – Method 2		h ≤ 60 ft.
Figure 6-11A	External Pressure Coefficients, GC_{pf}	Walls
Enclosed, Partially Enclosed Buildings		



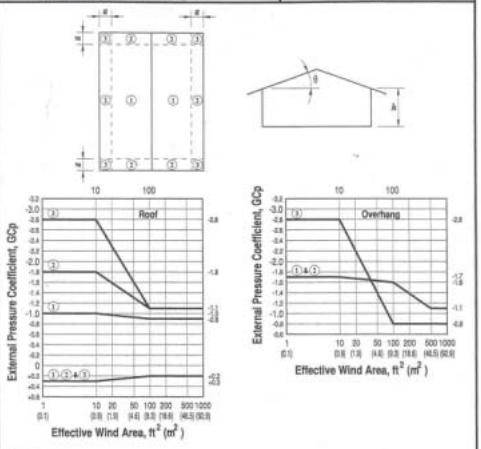


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GC_p for walls shall be reduced by 10% when $\theta \leq 10°$.
6. Notation:
   - a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
   - h: Mean roof height, in feet (meters), except that eave height shall be used for $\theta \leq 10°$.
   - θ: Angle of plane of roof from horizontal, in degrees.

8

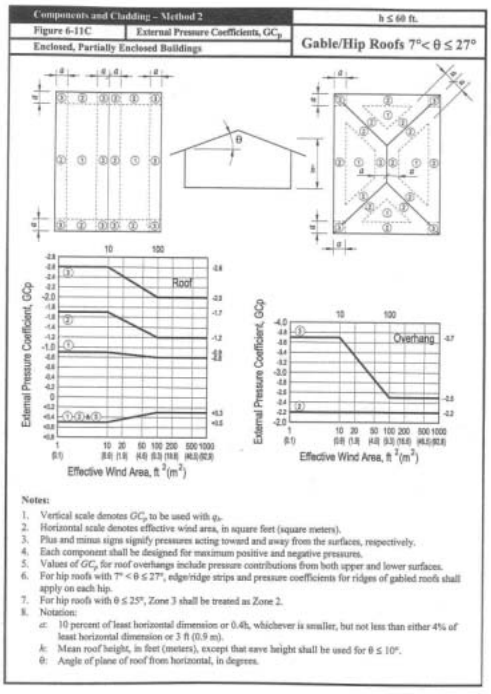
Components and Cladding – Method 2		h ≤ 60 ft.
Figure 6-11B	External Pressure Coefficients, GC_p	Gable Roofs θ ≤ 7°
Enclosed, Partially Enclosed Buildings		



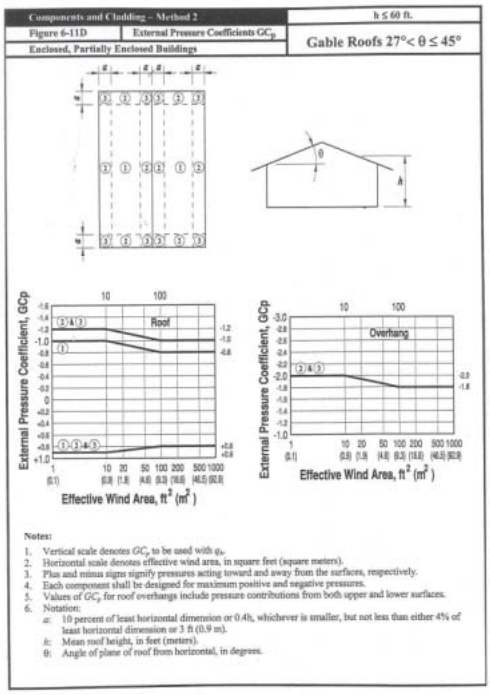
Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. If a parapet equal to or higher than 3 ft (0.9m) is provided around the perimeter of the roof with $\theta \leq 7°$, Zone 3 shall be treated as Zone 2.
6. Values of GC_p for roof overhangs include pressure contributions from both upper and lower surfaces.
7. Notation:
   - a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
   - h: Eave height shall be used for $\theta \leq 10°$.
   - θ: Angle of plane of roof from horizontal, in degrees.

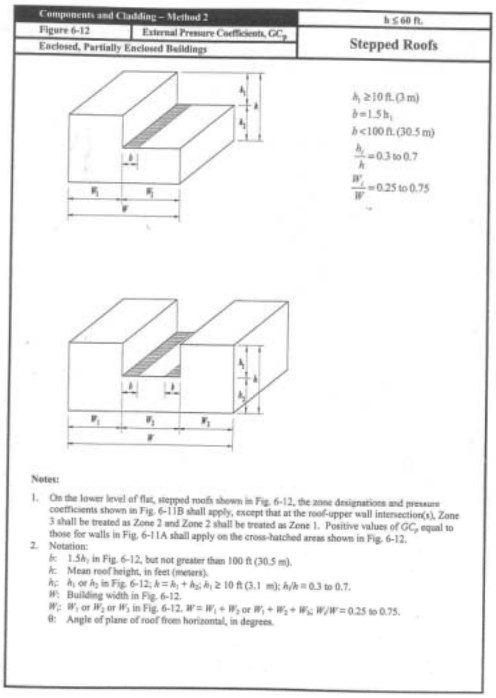
8


Components and Cladding – Method 2
h ≤ 60 ft.
Figure 6-11C
External Pressure Coefficients, GCp
Gable/Hip Roofs 7°< θ ≤ 27°
Enclosed, Partially Enclosed Buildings
Roof
Overhang
External Pressure Coefficient, GCp
Effective Wind Area, ft2 (m2)
Notes:
1. Vertical scale denotes GCp to be used with qh.
2. Horizontal scale denotes effective wind area, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GCp for roof overhangs include pressure contributions from both upper and lower surfaces.
6. For hip roofs with 7° < θ ≤ 27°, edge/ridge strips and pressure coefficients for ridges of gabled roofs shall apply on each hip.
7. For hip roofs with θ ≤ 25°, Zone 3 shall be treated as Zone 2.
8. Notation:
a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
h: Mean roof height, in feet (meters), except that eave height shall be used for θ ≤ 10°.
θ: Angle of plane of roof from horizontal, in degrees.

8


Components and Cladding – Method 2
h ≤ 60 ft.
Figure 6-11D
External Pressure Coefficients GCp
Gable Roofs 27°< θ ≤ 45°
Enclosed, Partially Enclosed Buildings
Roof
Overhang
External Pressure Coefficient, GCp
Effective Wind Area, ft2 (m2)
Notes:
1. Vertical scale denotes GCp to be used with qh.
2. Horizontal scale denotes effective wind area, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GCp for roof overhangs include pressure contributions from both upper and lower surfaces.
6. Notation:
a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).
h: Mean roof height, in feet (meters).
θ: Angle of plane of roof from horizontal, in degrees.

8



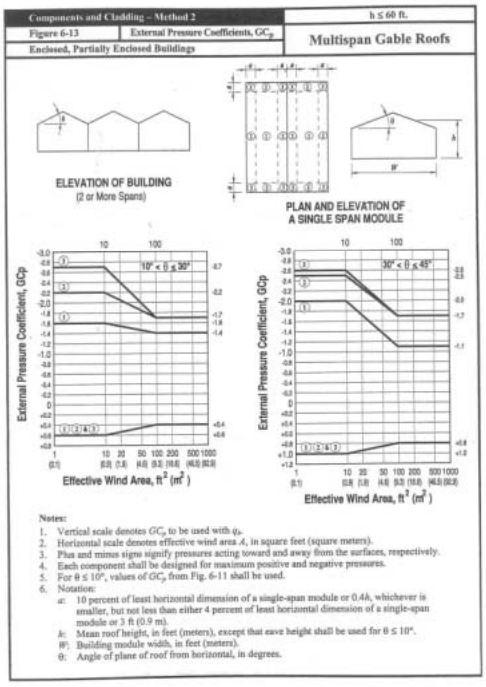
Components and Cladding – Method 2 | h ≤ 60 ft.
Figure 6-12 | External Pressure Coefficients, GC_p
Enclosed, Partially Enclosed Buildings
Stepped Roofs

$h_1 \geq 10$ ft. (3 m)
$b = 1.5\,h_1$
$b < 100$ ft. (30.5 m)
$\frac{h_2}{h_1} = 0.3$ to 0.7
$\frac{W_2}{W} = 0.25$ to 0.75

Notes:

1. On the lower level of flat, stepped roofs shown in Fig. 6-12, the zone designations and pressure coefficients shown in Fig. 6-11B shall apply, except that at the roof-upper wall intersection(s), Zone 3 shall be treated as Zone 2 and Zone 2 shall be treated as Zone 1. Positive values of GC_p equal to those for walls in Fig. 6-11A shall apply on the cross-hatched areas shown in Fig. 6-12.
2. Notation:
   b: $1.5h_1$ in Fig. 6-12, but not greater than 100 ft (30.5 m).
   h: Mean roof height, in feet (meters).
   h_2: h_1 or h_2 in Fig. 6-12; $h = h_1 + h_2$; $h_1 \geq 10$ ft (3.1 m); $h_2/h = 0.3$ to 0.7.
   W: Building width in Fig. 6-12.
   W_2: W_1 or W_2 or W_3 in Fig. 6-12. $W = W_1 + W_2$ or $W_1 + W_2 + W_3$; $W_2/W = 0.25$ to 0.75.
   θ: Angle of plane of roof from horizontal, in degrees.

8



Components and Cladding – Method 2 | h ≤ 60 ft.
Figure 6-13 | External Pressure Coefficients, GC_p
Enclosed, Partially Enclosed Buildings
Multispan Gable Roofs

ELEVATION OF BUILDING
(2 or More Spans)

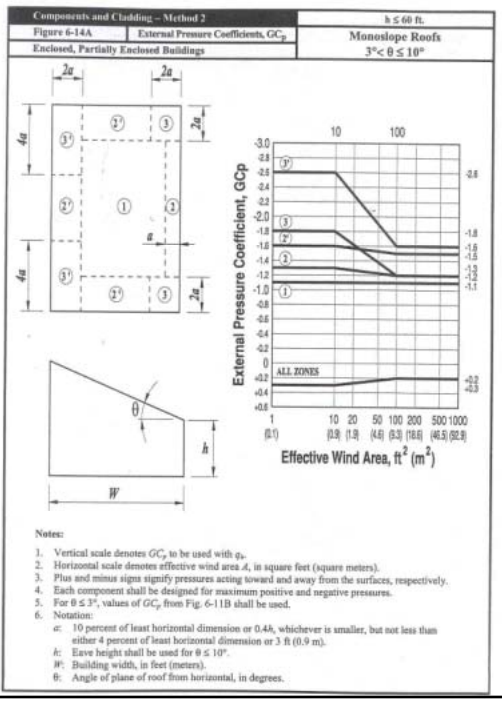
PLAN AND ELEVATION OF
A SINGLE SPAN MODULE

External Pressure Coefficient, GCp
Effective Wind Area, ft² (m²)
10° < θ ≤ 90°
30° < θ ≤ 45°

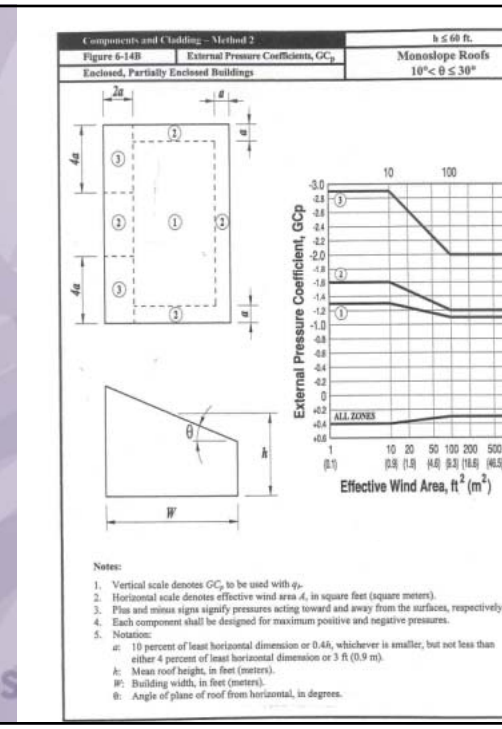
Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For $\theta \leq 10°$, values of GC_p from Fig. 6-11 shall be used.
6. Notation:
   a: 10 percent of least horizontal dimension of a single-span module or $0.4h$, whichever is smaller, but not less than either 4 percent of least horizontal dimension of a single-span module or 3 ft (0.9 m).
   h: Mean roof height, in feet (meters), except that eave height shall be used for $\theta \leq 10°$.
   W: Building module width, in feet (meters).
   θ: Angle of plane of roof from horizontal, in degrees.

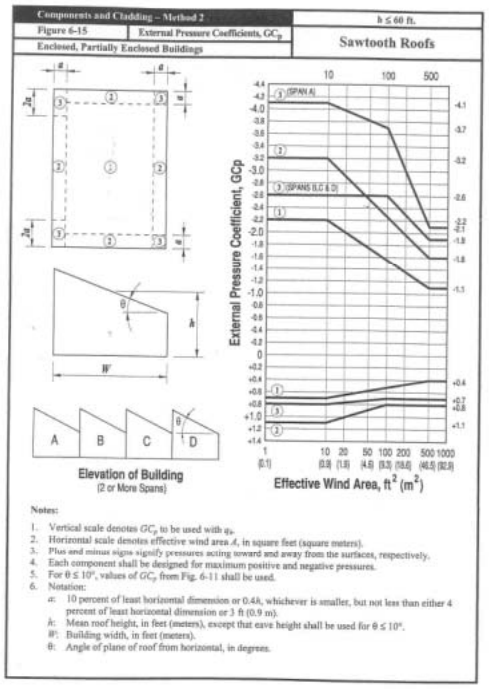
8


Components and Cladding – Method 2
Figure 6-14A
External Pressure Coefficients, GCp
Enclosed, Partially Enclosed Buildings
h ≤ 60 ft.
Monoslope Roofs
3°< θ ≤ 10°
External Pressure Coefficient, GCp
ALL ZONES
Effective Wind Area, ft² (m²)
Notes:
1. Vertical scale denotes GCp to be used with qh.
2. Horizontal scale denotes effective wind area A, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For θ ≤ 3°, values of GCp from Fig. 6-11B shall be used.
6. Notation:
a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4 percent of least horizontal dimension or 3 ft (0.9 m).
h: Eave height shall be used for θ ≤ 10°.
W: Building width, in feet (meters).
θ: Angle of plane of roof from horizontal, in degrees.

8


Components and Cladding – Method 2
Figure 6-14B
External Pressure Coefficients, GCp
Enclosed, Partially Enclosed Buildings
h ≤ 60 ft.
Monoslope Roofs
10°< θ ≤ 30°
External Pressure Coefficient, GCp
ALL ZONES
Effective Wind Area, ft² (m²)
Notes:
1. Vertical scale denotes GCp to be used with qh.
2. Horizontal scale denotes effective wind area A, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Notation:
a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4 percent of least horizontal dimension or 3 ft (0.9 m).
h: Mean roof height, in feet (meters).
W: Building width, in feet (meters).
θ: Angle of plane of roof from horizontal, in degrees.

8



Components and Cladding – Method 2 | h ≤ 60 ft.
Figure 6-15 | External Pressure Coefficients, GC_p
Enclosed, Partially Enclosed Buildings | Sawtooth Roofs

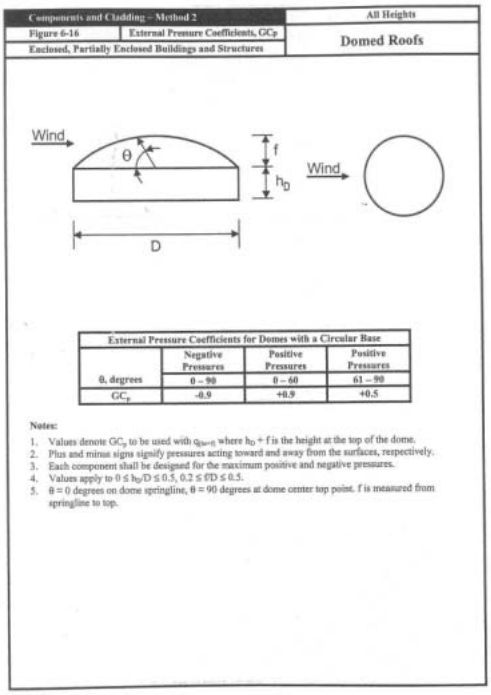
External Pressure Coefficient, GCp

Effective Wind Area, ft² (m²)

Elevation of Building
(2 or More Spans)

Notes:
1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For $\theta \leq 10°$, values of GC_p from Fig. 6-11 shall be used.
6. Notation:
   a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4 percent of least horizontal dimension or 3 ft (0.9 m).
   h: Mean roof height, in feet (meters), except that eave height shall be used for $\theta \leq 10°$.
   W: Building width, in feet (meters).
   θ: Angle of plane of roof from horizontal, in degrees.

8



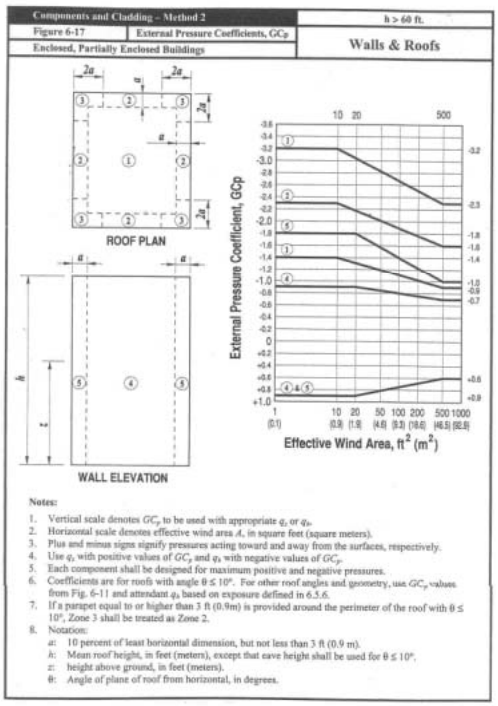
Components and Cladding – Method 2 | All Heights
Figure 6-16 | External Pressure Coefficients, GCp
Enclosed, Partially Enclosed Buildings and Structures | Domed Roofs

Wind
θ
f
h_D
D
Wind

External Pressure Coefficients for Domes with a Circular Base			
	Negative Pressures	Positive Pressures	Positive Pressures
θ, degrees	0 – 90	0 – 60	61 – 90
GC_p	-0.9	+0.9	+0.5

Notes:
1. Values denote GC_p to be used with $q_{h=D}$ where $h_D + f$ is the height at the top of the dome.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. Each component shall be designed for the maximum positive and negative pressures.
4. Values apply to $0 \leq h_D/D \leq 0.5$, $0.2 \leq f/D \leq 0.5$.
5. $\theta = 0$ degrees on dome springline, $\theta = 90$ degrees at dome center top point. f is measured from springline to top.

8



9

Wind basic pressure

Dynamic part of Bernoulli's basic equation

$$q = \frac{1}{2}\rho V^2$$

9

Constant 0.00256

$$P = \frac{1}{2}\rho V^2$$

$$P = \frac{1}{2}\left(\frac{0.0765}{32.2}\right)\left(\frac{5280}{3600}\right)^2 V^2$$

$$P = 0.00256V^2$$

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9

Modified basic pressure in ASCE-7 to accomodate local parameters

modified basic pressure:
ASCE-7

$$q = \frac{1}{2}\rho K_z K_{zt} K_d I V^2$$

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9

Velocity Pressure

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I$$

$$q_h = 0.00256\, K_h\, K_{zt}\, K_d\, V^2\, I$$

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9 & 10

Analytical Method for Open Buildings and Other Structures

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2\, I$$

$$F = q_z\, G\, C_f\, A_f$$

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10

Design pressure for components and cladding and design force for special and open structures

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Design pressure

$$p = q_h [(GC_p) - (GC_{pi})]$$

Design force

$$F = q_z G C_f A_f$$

towers, signs, tanks, silos

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8

Main Wind Force Resisting System – Method 2		All Heights
Figure 6-18	Force Coefficients, C_f	Monoslope Roofs
Open Buildings		

Roof angle θ degrees	L/B						
	5	3	2	1	1/2	1/3	1/5
10	0.2	0.25	0.3	0.45	0.55	0.7	0.75
15	0.35	0.45	0.5	0.7	0.85	0.9	0.85
20	0.5	0.6	0.75	0.9	1.0	0.95	0.9
25	0.7	0.8	0.95	1.15	1.1	1.05	0.95
30	0.9	1.0	1.2	1.3	1.2	1.1	1.0

Roof angle θ degrees	Center of Pressure X/L		
	L/B		
	2 to 5	1	1/5 to 1/2
10 to 20	0.35	0.3	0.3
25	0.35	0.35	0.4
30	0.35	0.4	0.45

Notes:

1. Wind forces act normal to the surface. Two cases shall be considered: (1) wind forces directed inward; and (2) wind forces directed outward.
2. The roof angle shall be assumed to vary ± 10° from the actual angle and the angle resulting in the greatest force coefficient shall be used.
3. Notation:
   - B: dimension of roof measured normal to wind direction, in feet (meters);
   - L: Dimension of roof measured parallel to wind direction, in feet (meters);
   - X: Distance to center of pressure from windward edge of roof, in feet (meters); and
   - θ: Angle of plane of roof from horizontal, in degrees.

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8

Other Structures – Method 2		All Heights
Figure 6-19	Force Coefficients, C_f	Chimneys, Tanks, Rooftop Equipment, & Similar Structures

Cross-Section	Type of Surface	h/D		
		1	7	25
Square (wind normal to face)	All	1.3	1.4	2.0
Square (wind along diagonal)	All	1.0	1.1	1.5
Hexagonal or octagonal	All	1.0	1.2	1.4
Round ($D\sqrt{q_z} > 2.5$) ($D\sqrt{q_z} > 5.3$, D in m, q_z in N/m^2)	Moderately smooth	0.5	0.6	0.7
	Rough (D'/D = 0.02)	0.7	0.8	0.9
	Very rough (D'/D = 0.08)	0.8	1.0	1.2
Round ($D\sqrt{q_z} \le 2.5$) ($D\sqrt{q_z} \le 5.3$, D in m, q_z in N/m^2)	All	0.7	0.8	1.2

Notes:

1. The design wind force shall be calculated based on the area of the structure projected on a plane normal to the wind direction. The force shall be assumed to act parallel to the wind direction.
2. Linear interpolation is permitted for h/D values other than shown.
3. Notation:
   - D: diameter of circular cross-section and least horizontal dimension of square, hexagonal or octagonal cross-sections at elevation under consideration, in feet (meters);
   - D': depth of protruding elements such as ribs and spoilers, in feet (meters); and
   - h: height of structure, in feet (meters); and
   - q_z: velocity pressure evaluated at height z above ground, in pounds per square foot (N/m^2).

8

Other Structures – Method 2		All Heights
Figure 6-20	Force Coefficients, C_f	Solid Freestanding Walls & Solid Signs

At Ground Level		Above Ground Level	
s	C_f	M/N	C_f
≤3	1.2	≤6	1.2
5	1.3	10	1.3
8	1.4	16	1.4
10	1.5	20	1.5
20	1.75	40	1.75
30	1.85	60	1.85
≥40	2.0	≥80	2.0

Notes:

1. The term "signs" in notes below applies also to "freestanding walls".
2. Signs with openings comprising less than 30% of the gross area shall be considered as solid signs.
3. Signs for which the distance from the ground to the bottom edge is less than 0.25 times the vertical dimension shall be considered to be at ground level.
4. To allow for both normal and oblique wind directions, two cases shall be considered:
   a. resultant force acts normal to the face of the sign on a vertical line passing through the geometric center, and
   b. resultant force acts normal to the face of the sign at a distance from a vertical line passing through the geometric center equal to 0.2 times the average width of the sign.
5. Notation:
   - s: ratio of height to width;
   - M: larger dimension of sign, in feet (meters); and
   - N: smaller dimension of sign, in feet (meters).

8

Other Structures – Method 2		All Heights
Figure 6-21	Force Coefficients, C_f	Open Signs & Lattice Frameworks

ε	Flat-Sided Members	Rounded Members	
		$D\sqrt{q_z} \le 2.5$ ($D\sqrt{q_z} \le 5.3$)	$D\sqrt{q_z} > 2.5$ ($D\sqrt{q_z} > 5.3$)
< 0.1	2.0	1.2	0.8
0.1 to 0.29	1.8	1.3	0.9
0.3 to 0.7	1.6	1.5	1.1

Notes:

1. Signs with openings comprising 30% or more of the gross area are classified as open signs.
2. The calculation of the design wind forces shall be based on the area of all exposed members and elements projected on a plane normal to the wind direction. Forces shall be assumed to act parallel to the wind direction.
3. The area A_f consistent with these force coefficients is the solid area projected normal to the wind direction.
4. Notation:
   - ε: ratio of solid area to gross area;
   - D: diameter of a typical round member, in feet (meters);
   - q_z: velocity pressure evaluated at height z above ground in pounds per square foot (N/m^2).

8

Other Structures – Method 2		All Heights
Figure 6-22	Force Coefficients, C_f	Trussed Towers
Open Structures		

Tower Cross Section	C_f
Square	$4.0\,\varepsilon^2 - 5.9\,\varepsilon + 4.0$
Triangle	$3.4\,\varepsilon^2 - 4.7\,\varepsilon + 3.4$

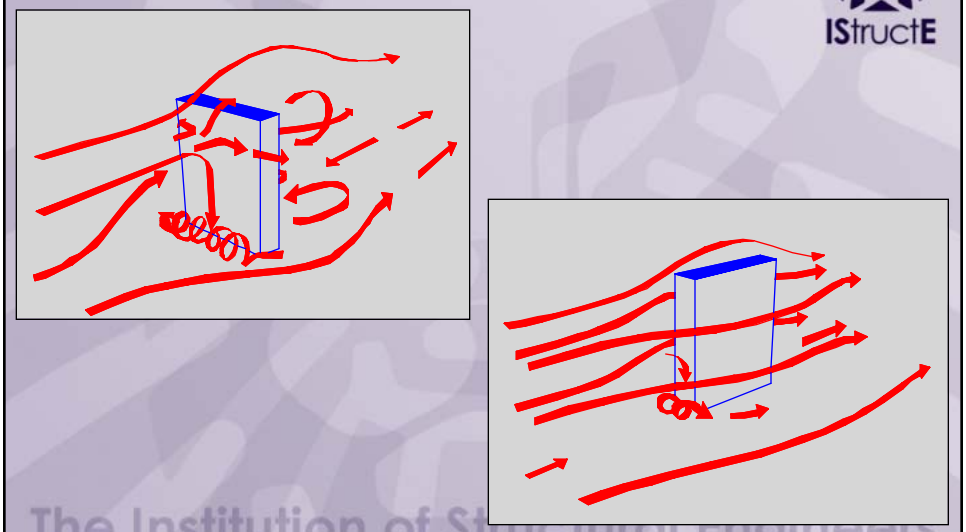
Notes:

1. For all wind directions considered, the area A_f consistent with the specified force coefficients shall be the solid area of a tower face projected on the plane of that face for the tower segment under consideration.
2. The specified force coefficients are for towers with structural angles or similar flat-sided members.
3. For towers containing rounded members, it is acceptable to multiply the specified force coefficients by the following factor when determining wind forces on such members:

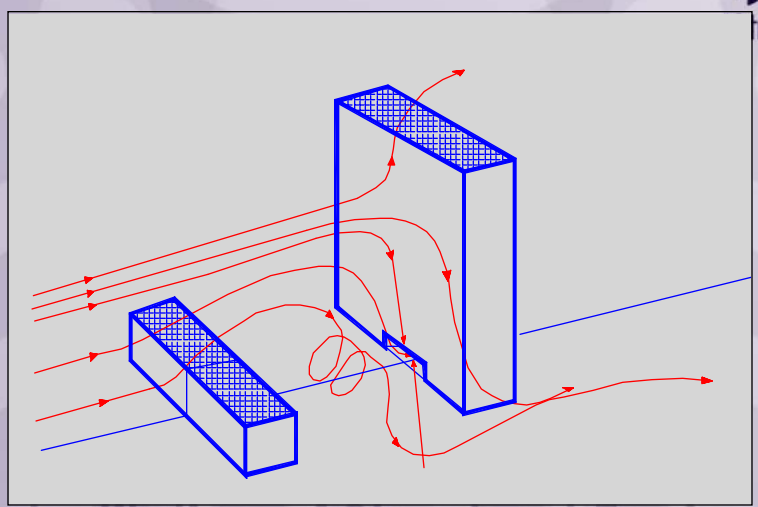
   $0.51\,\varepsilon^2 + 0.57$, but not > 1.0
4. Wind forces shall be applied in the directions resulting in maximum member forces and reactions. For towers with square cross-sections, wind forces shall be multiplied by the following factor when the wind is directed along a tower diagonal:

   $1 + 0.75\,\varepsilon$, but not > 1.2
5. Wind forces on tower appurtenances such as ladders, conduits, lights, elevators, etc., shall be calculated using appropriate force coefficients for these elements.
6. Loads due to ice accretion as described in Section 11 shall be accounted for.
7. Notation:
   - ε: ratio of solid area to gross area of one tower face for the segment under consideration.

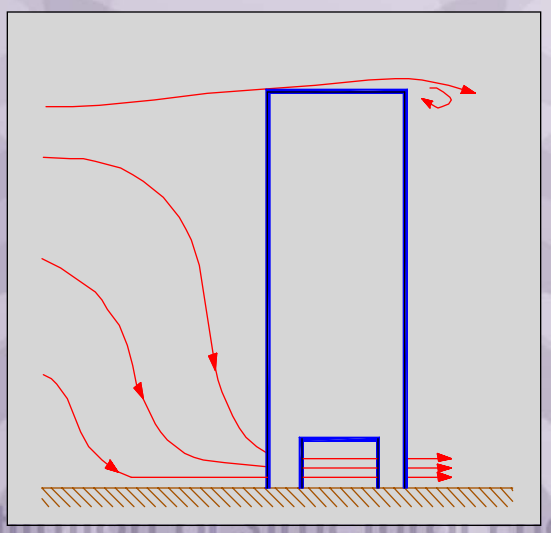
Turbulent flow of wind on longitudinal and transverse sides of high rise buildings



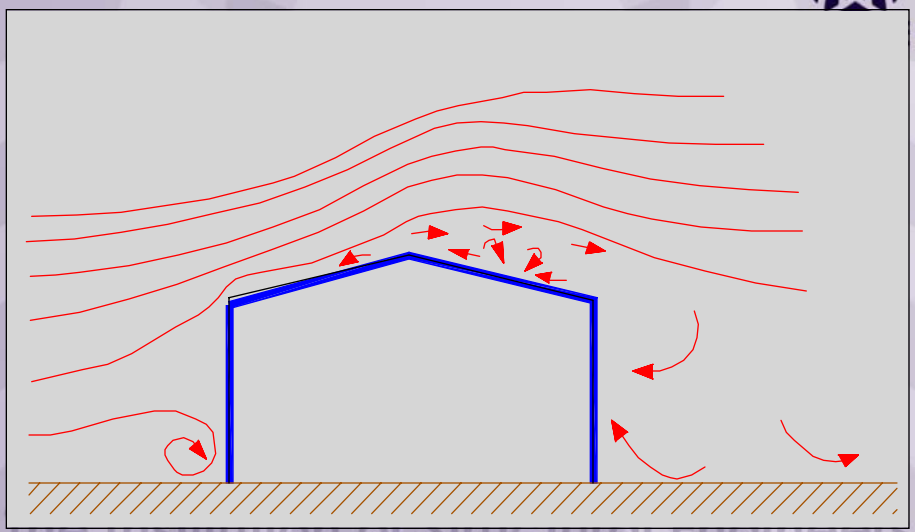
Turbulent flow on high rise buildings due to upwind obstructions



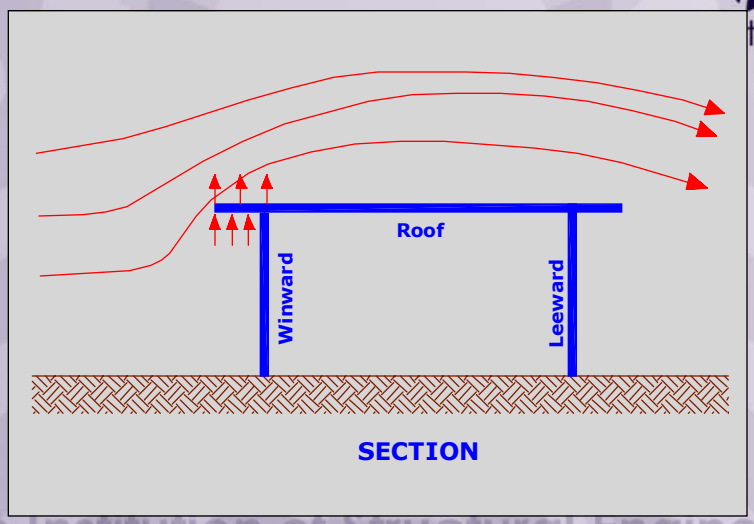
Wind velocity increase due to large openings at lower floors



Wind flow over gabled roof buildings showing turbulence on leeward roof and walls

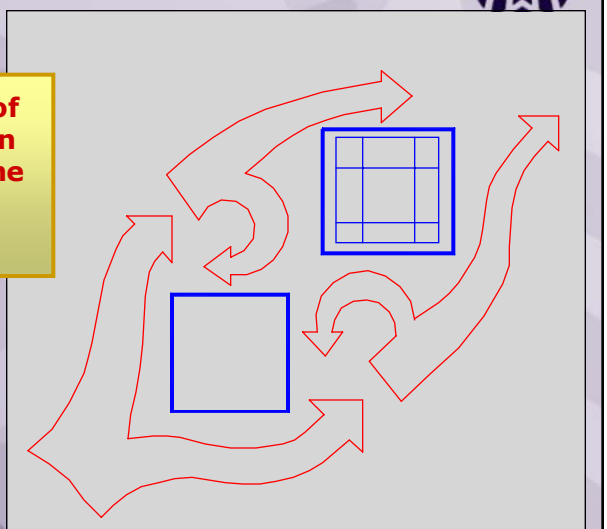


Pressure increase due to wind on overhanging roofs



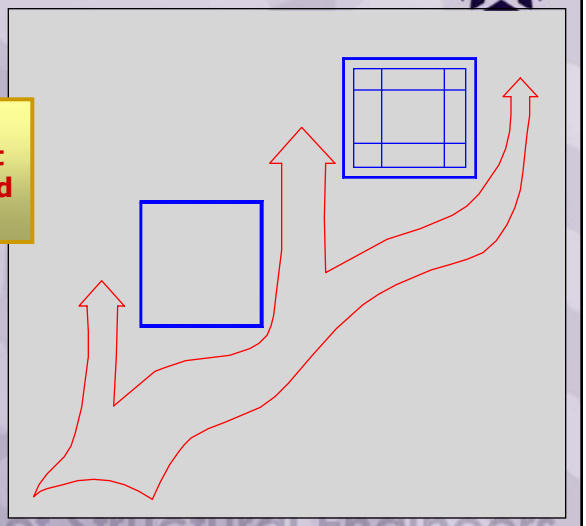
Protection effect of upstream building

A favorable location of adjacent buildings can decrease the hurricane effects reducing the wind loads

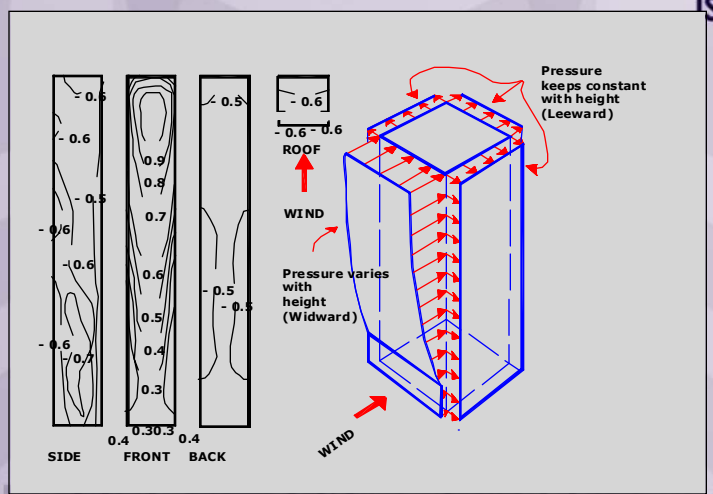


Unfavorable location of an adjacent building

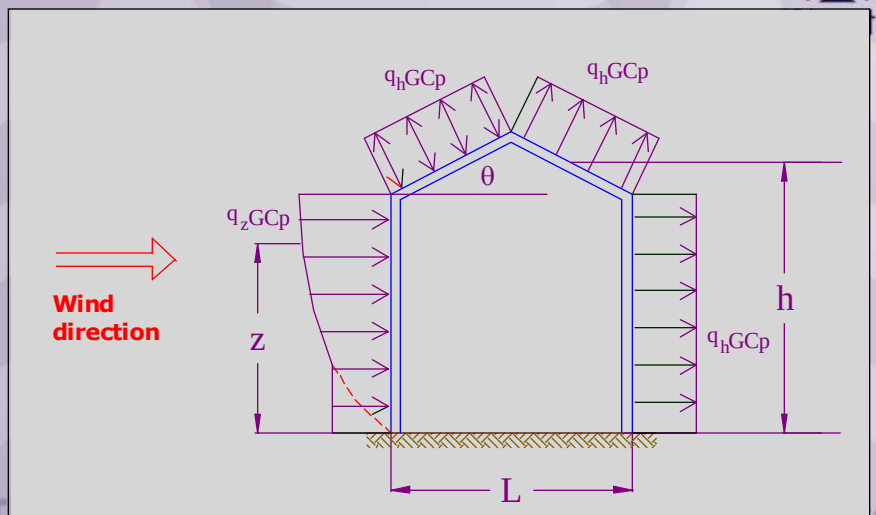
A bad location of nearby buildings might induce increase of wind loads



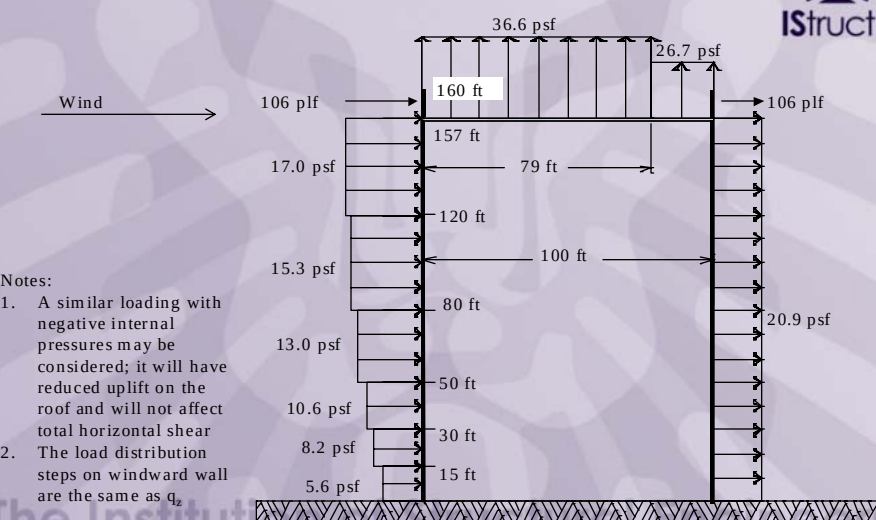
Pressure coefficients on high rise buildings



Design pressure diagram on gabled roof building

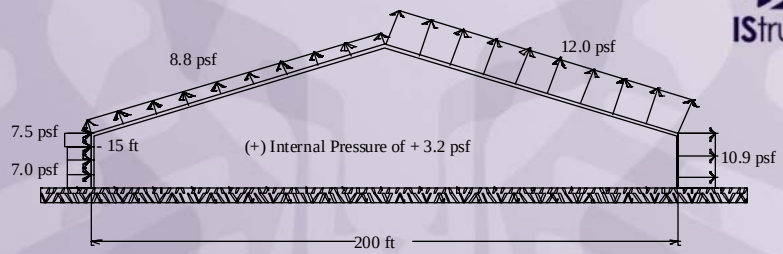


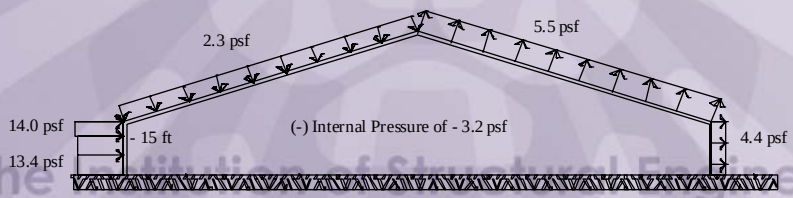
Design pressure diagram on flat roof building



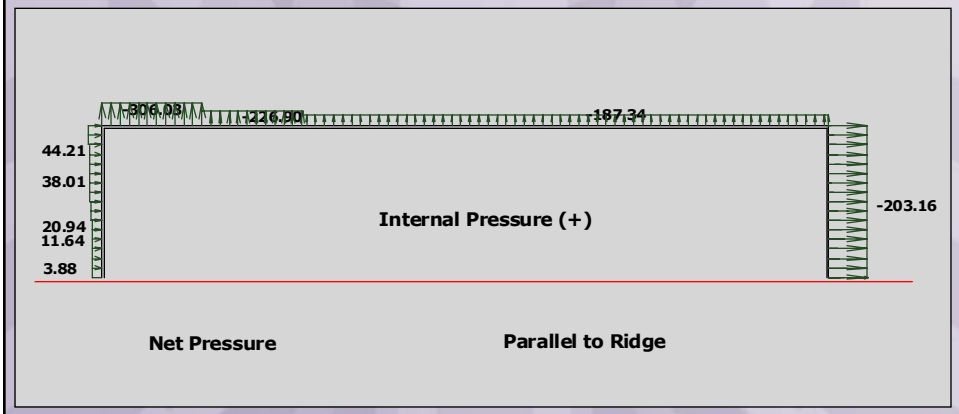
Notes:
1. A similar loading with negative internal pressures may be considered; it will have reduced uplift on the roof and will not affect total horizontal shear
2. The load distribution steps on windward wall are the same as q_z

Pressure sketch for wind perpendicular to the ridge on a pitched-roof industrial building

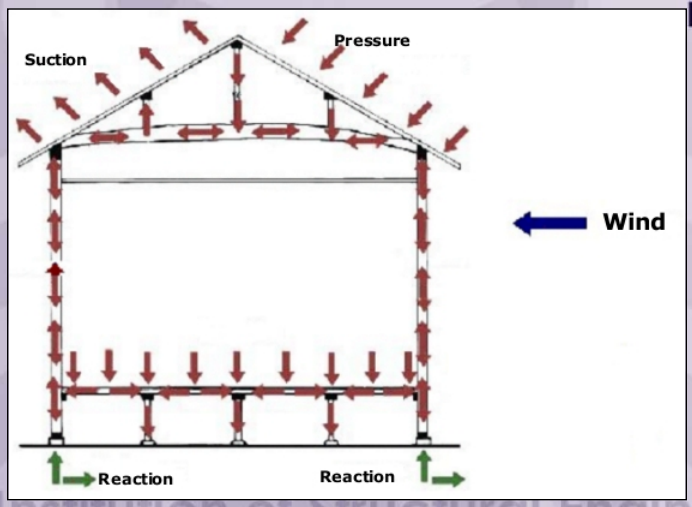




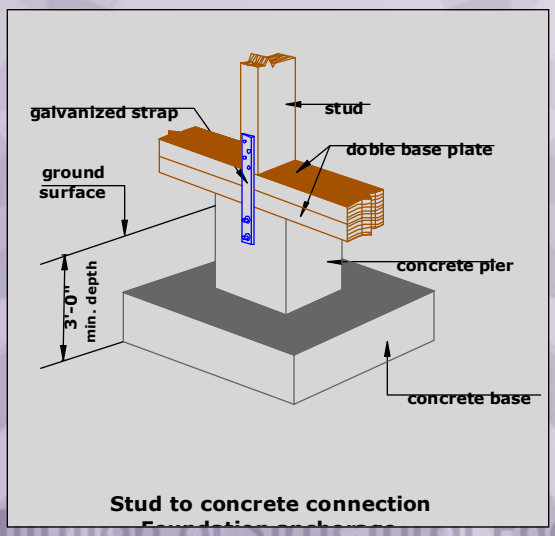
Pressure sketch for wind parallel to the ridge on a pitched-roof industrial building



Wind load path on pitched roof buildings

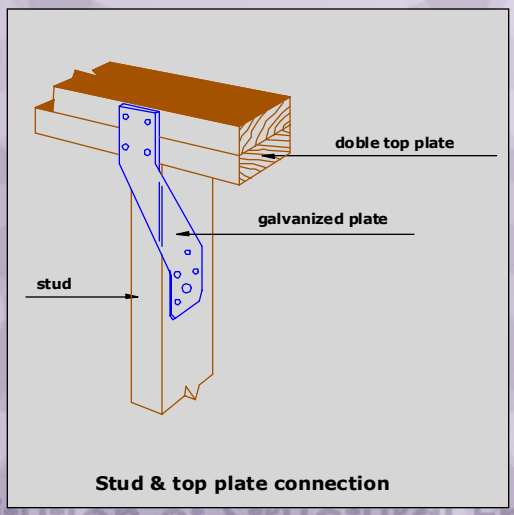


Detail of stud to concrete footing connection



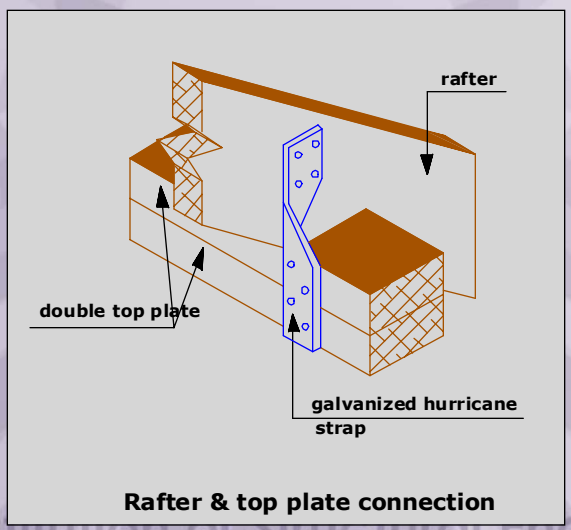
Stud to concrete connection

Stud and top plate connection



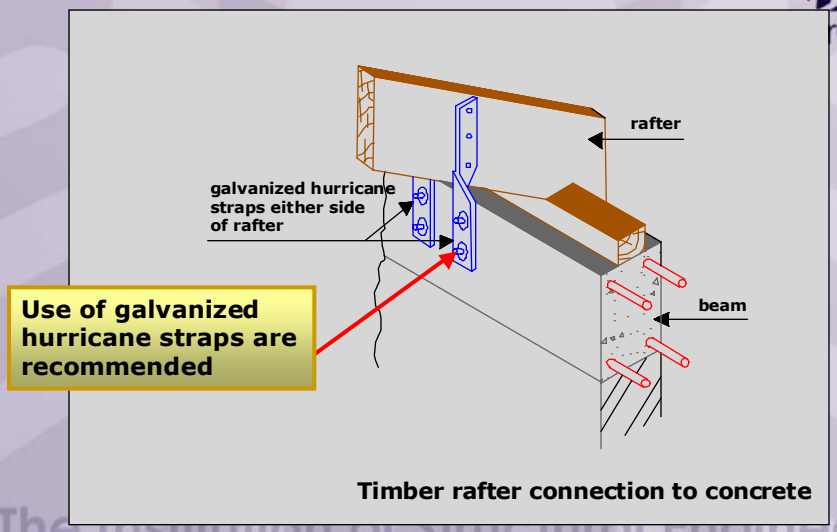
Stud & top plate connection

Rafters and top plates should be anchored by galvanized straps

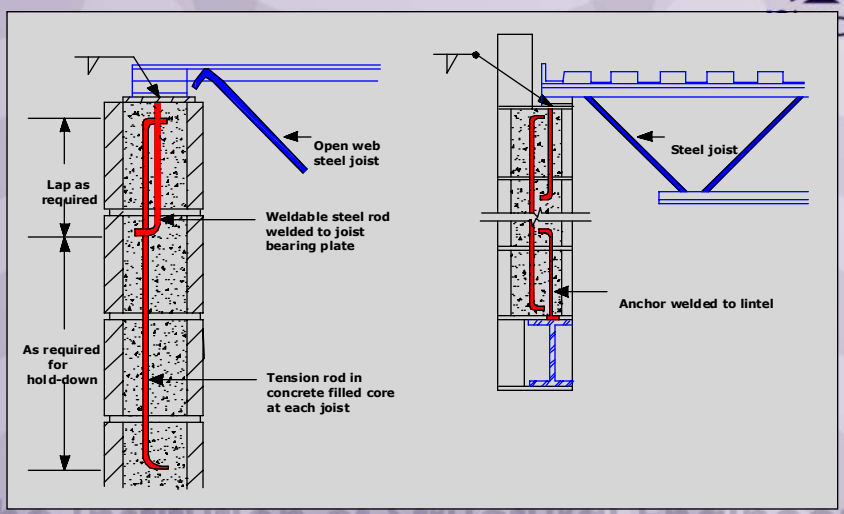


Rafter & top plate connection

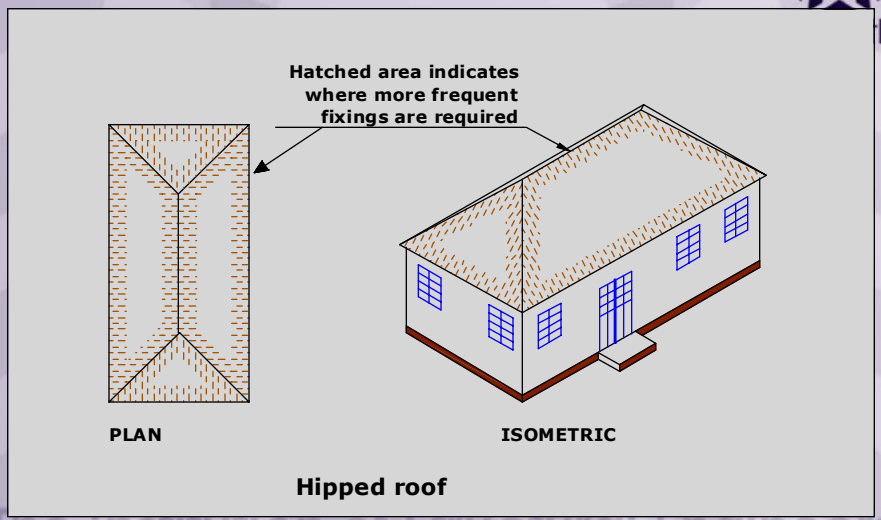
Anchorage of timber beams to concrete beams



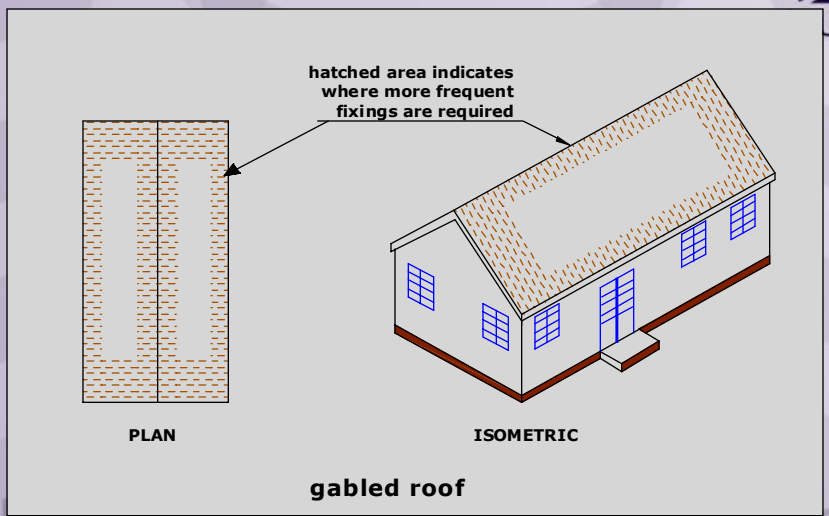
Anchorage details between steel joist and masonry walls



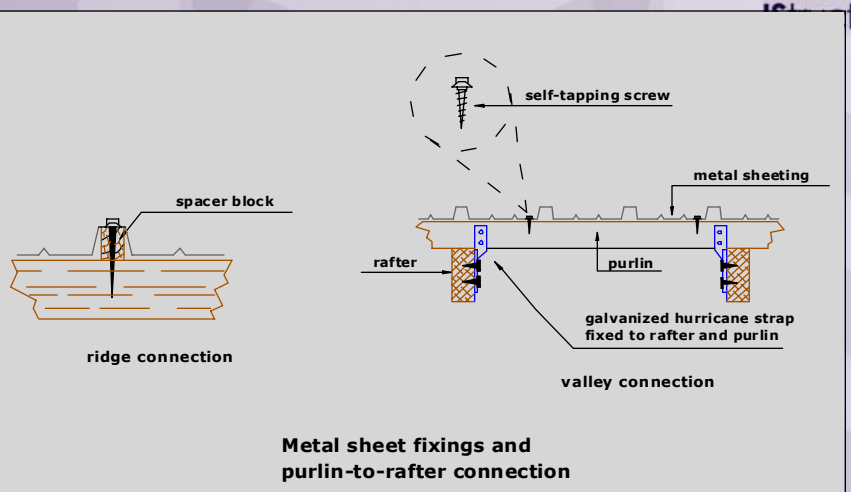
Hipped roof recommended over flat roof



Gabled roof with slopes of 20 to 30 degrees are preferred against hurricanes

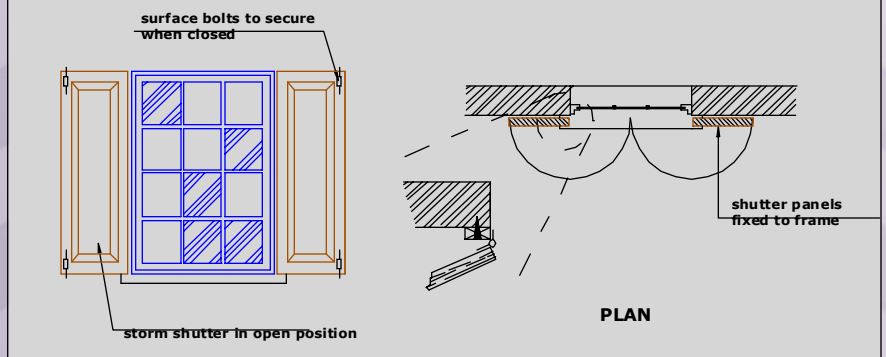


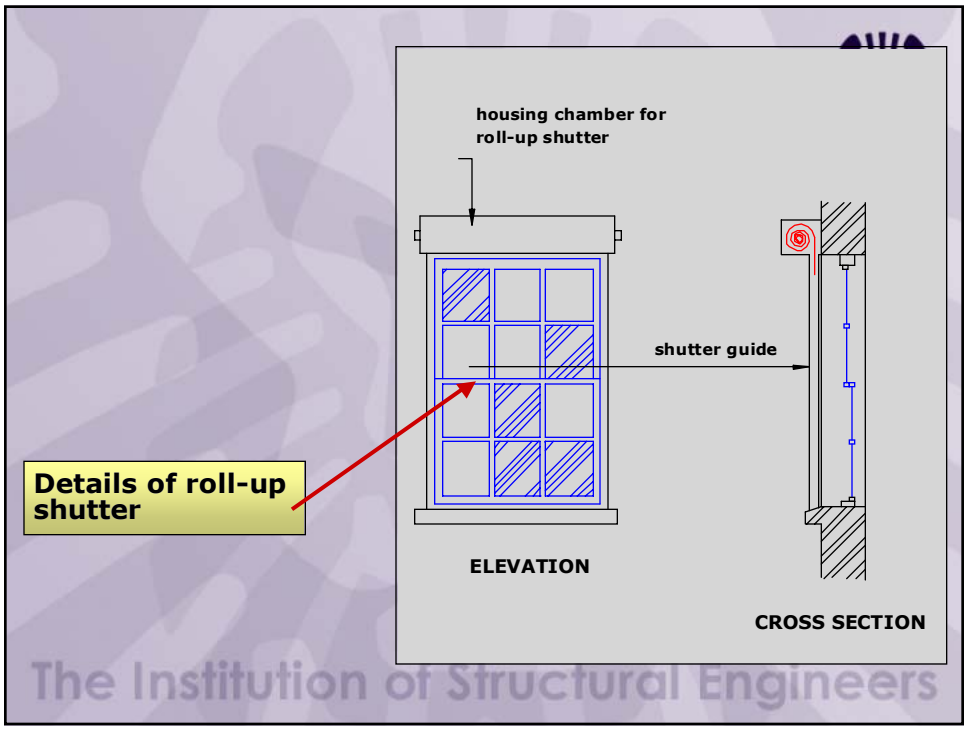
Connection details between metal sheet roof and purlins



Metal sheet fixings and purlin-to-rafter connection

Permanent window shutter details





Summary for Method 2

- MWFRS
  - $p = q\,GC_p - q_i\,(GC_{pi})$
- C&C for h$\underline{\leq}$ 60 ft
  - $p = q_h\,[(GC_p) - (GC_{pi})]$
- where:
  - $q_z = 0.00256\,K_z\,K_{zt}\,K_d\,V^2\,I$
  - $q_h = 0.00256\,K_h\,K_{zt}\,K_d\,V^2\,I$

p = design pressure
q = effective velocity pressure
G = gust effect factor (gef)
C_p = external pressure coefficient
q_i = velocity pressure (internal)
GC_{pi} = gef + internal pressure coefficient
GC_p = gef + external pressure coefficient

K_z = exposure velocity pressure coefficient
K_{zt} = topographic factor
K_d = directionality factor
V = basic wind speed
I = importance factor

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