FLORIDA BUILDING CODE

Wind Load Calculations

(7 hours)

Participant Guide

June 2005
Version 1.0

Florida Building Commission
2555 Shumard Oak Boulevard
Tallahassee, Florida 32399-2100
(850) 487-1824

Preface and Acknowledgments

This document is the **Participant Guide** that supports the **Florida Building Code, Wind Load Calculations** training program. It contains references to the 2004 *Florida Building Code* and ASCE 7-98 *Minimum Design Loads for Buildings and Other Structures* and the Federal Emergency Management Agency (FEMA). In addition, selected materials from the presentation *Microclimates and Buildings* have been included. Special thanks to Dr. Ir. Bert Blocken, Department of Building, Civil and Environmental Engineering, Concordia University for granting permission to include several graphics from that presentation. The carport wind load analysis was provided by Cool Shades, 3800 NW 32nd Ave, Miami FL, 33142, www.carportsbycoolshades.com. Also, a special thank-you is extended to H. Carrington McVeigh, P.E., for allowing the instructor to utilize *StruWare* Software for the purposes of demonstrating a software program that utilizes the Florida Building Code to conduct wind load analysis.

The module was developed under the direction of the Florida Energy Extension Service by Will Swanson, B.S.C.E, M.E.

Members of the Florida Building Commission, Building (Structural) Technical Advisory Committee and the Department of Community affairs staff were provided these materials for review prior to final printing.

Special thanks to Barbara Haldeman for technical support in the development, design, and layout of the educational materials contained in this module.

Products referenced in this course are for illustration only and are not an endorsement, warrant, or representation by the author or instructor that the product meets the requirements of the 2004 *Florida Building Code*. Use of all products requires the approval of the local jurisdictional authority.

For technical questions regarding the provision allowed by the Florida Building Code for determining wind loading requirements, or for more information regarding the Florida Building Code Training, contact:

Florida Building Commission, Department of Community Affairs
2555 Shumard Oak Boulevard
Tallahassee, FL 32399-2100
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To obtain a complete copy of the 2004 Florida Building Code contact:
The Florida Department of Community Affairs Building Code Information System web site
http://www.floridabuilding.org

The Florida Energy Extension Service worked with Building A Safer Florida, Inc. under contract to the Florida Building Commission through the Florida Department of Community Affairs to develop version 1.0 of this program. Mr. Craig Miller coordinated development of the training materials.

Version 1.0 Printed June 2005

Table of Contents

2004 FLORIDA BUILDING CODE

2004 Florida Building Code, Building

Chapter 16 Structural Design
Section 1609 Wind Loads

1

The following presentation is an educational course on **Florida Building Code Wind Loads**. Emphasis has been placed on working wind load solutions per the Florida Building Code stipulations.

Course Outline

- Wind characteristics
- Codes and Standards
- Review FBC/ASCE 7 wind load provisions
- Structure characteristics
- Wind/Structural
  - Carport analysis
  - Residential Method 2
- ASCE 7 method 1 and 2 wind analysis examples
- Group workshop—ASCE 7 method 1 and 2, and results comparison
- Latest findings
- Wind-driven rain / other discussion
- Commercial wind analysis software demo

2

Participants should have a basic understanding of engineering analysis.

As a result of this course, participants should be able to:

- Identify appropriate design tools given a set of site and design considerations.
- Understand how the basic design pressures are determined with an example using the analytical design procedures provided in Method 2 of ASCE 7-98
- Utilize some of the other performance/prescriptive methods in the FBC given a set of site and design conditions.
- Understand the variations in design (performance and prescriptive) pressures given the use of appropriate design tools.
- Understand the usage of engineering software for wind load analysis.

Course Objectives

- Understand some basic characteristics of wind
- Familiarity with the Florida Building Code and ASCE 7 wind load provisions
- Understand some basic characteristics of structures
- Be able to work wind load analysis problems
- Become familiar with a commercial wind load software
- Knowledge of some of the latest findings of structure performance during recent hurricanes
- Knowledge of some of the latest problems/solutions involving wind-driven rain

3

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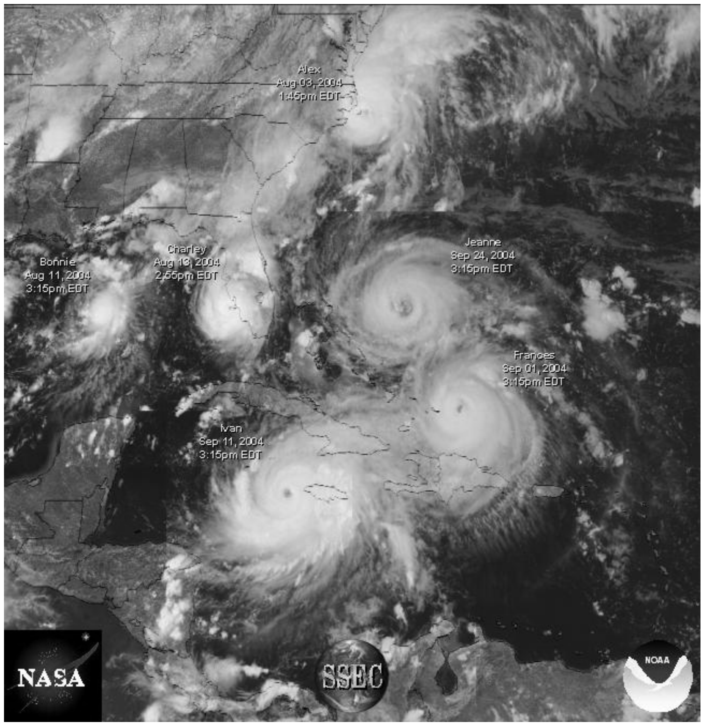
- Understand the usage of engineering software for wind load analysis.

"I’ll huff, and I’ll puff,
then I’ll blow your house down."

— The Big Bad Wolf

According to the learned opinion of one of the three little pigs, straw houses would not go over too well in Florida.



Alex
Aug 03, 2004
1:45pm EDT
Bonnie
Aug 11, 2004
3:15pm EDT
Charley
Aug 13, 2004
2:55pm EDT
Jeanne
Sep 24, 2004
3:15pm EDT
Frances
Sep 01, 2004
3:15pm EDT
Ivan
Sep 11, 2004
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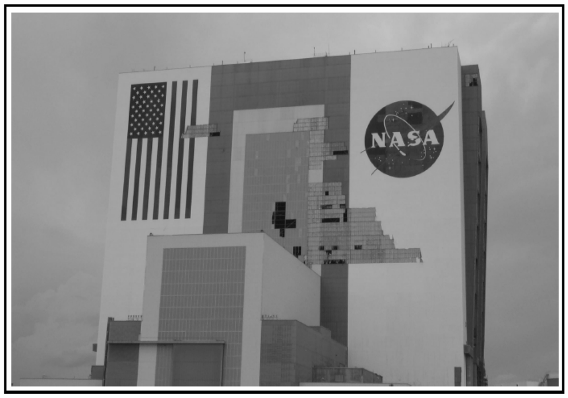
NASA
SSEC
NOAA

Wind characteristics



The Vehicle Assembly Building lost 820 panels, or the equivalent of 1.3 acres of area, due to the winds of Hurricane Frances.

6

1.3 acres!

Wind characteristics

The grandstand at the Launch Complex 39 Press Site lost portions of its roof during Hurricane Frances.

7

Wind characteristics

8

Church in Cocoa Beach - 2004 hurricane season.

15 year old building. Failure due to corrosion of flange/fasteners at visible interface.

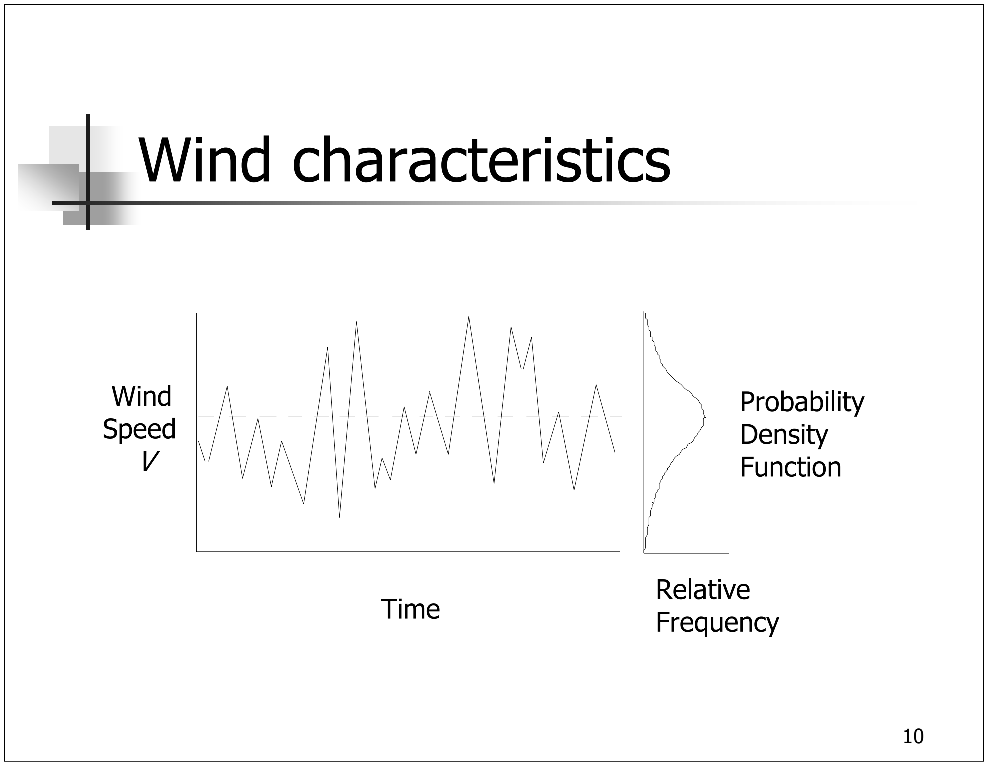
Wind characteristics

Natural wind is a highly turbulent flow of air over the surface of the earth.

Near the ground, its velocity is reduced by friction so that at a height of 50 feet it is about 90% as great as at 100 feet.

9

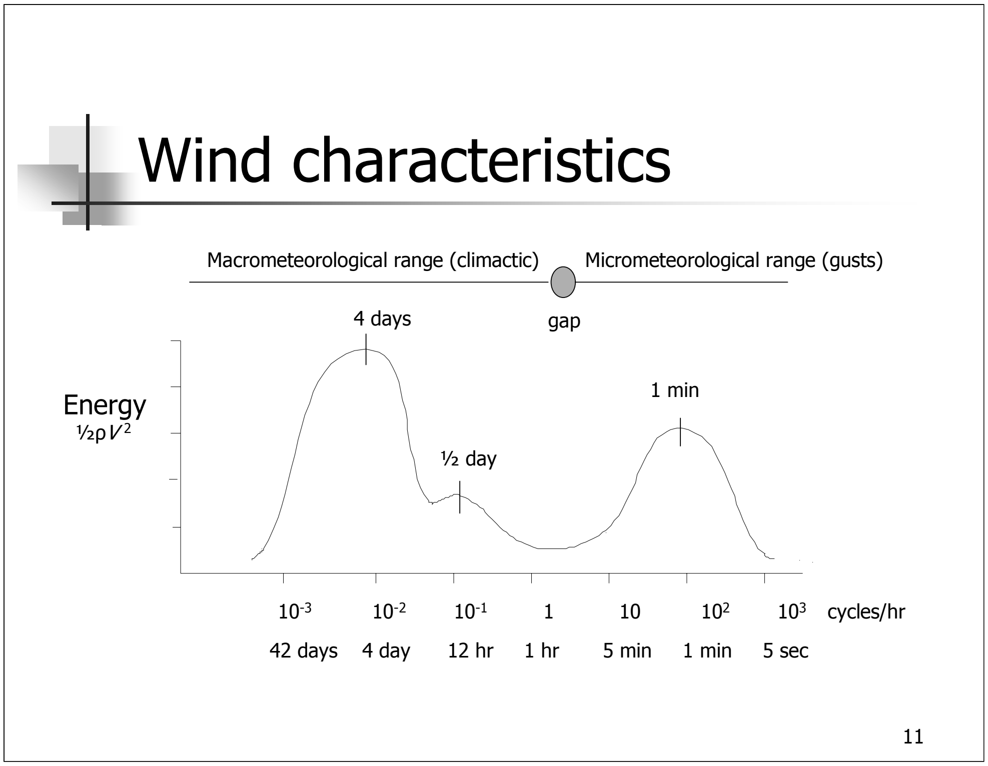
From *Marks' Mechanical Engineers' Handbook*



Wind speed measured over time

Statistical analysis provides probability density function – the relative occurrence of various wind speeds, i.e. gusts

Center of hump in probability density function curve is ‘mean wind speed’



Power spectrum

Two distinct types of air flow:

1. Macrometeorological (climactic fluctuations)
2. Micrometeorological fluctuations (gusts)

   Half-day cycle influenced by day/night fluctuations separated by stationary stable interval whose frequency is approximately centered at 1 cycle per ½ hour.

Wind characteristics

Critical maximum velocity with regards to structures is the maximum velocity of gusts comparable in size with the structure.

12

Wind can pulse building in resonance with natural frequency. Small amount of energy can induce almost unbounded deflections.

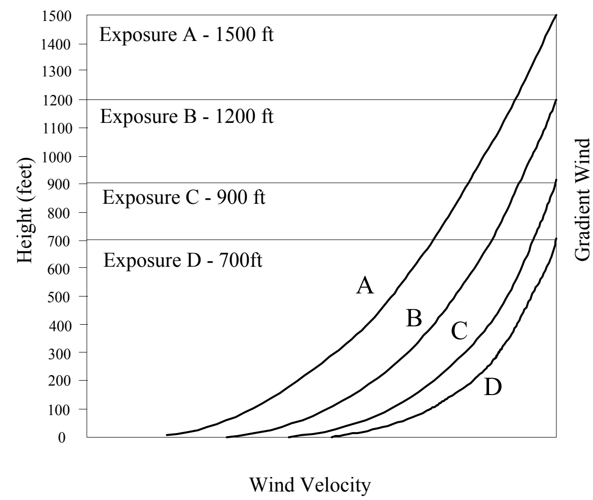
Same effect as pushing someone on a swing.

Wind characteristics

Mean wind speed of 38 mph, gusting to 85 mph over a duration of 0.8 sec gives gust length of approximately 40 feet.

13

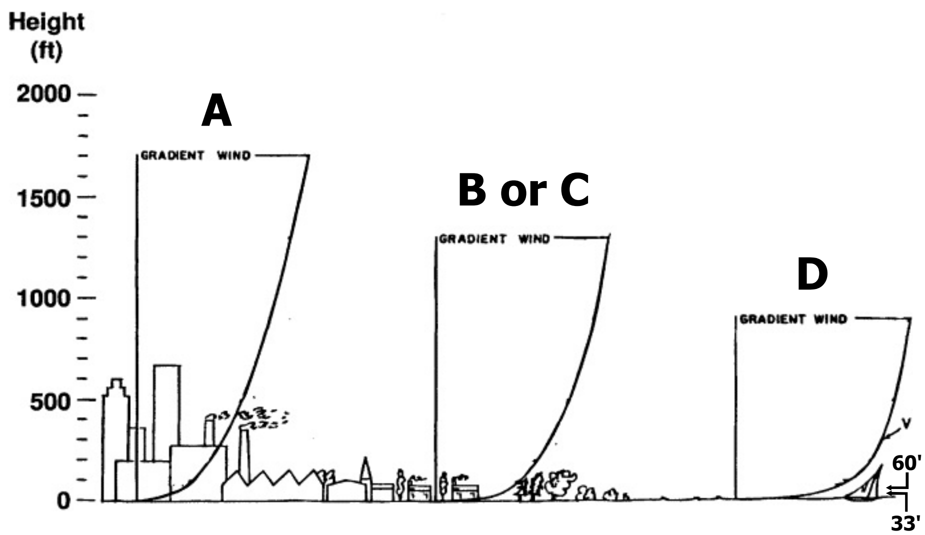
Wind characteristics



14

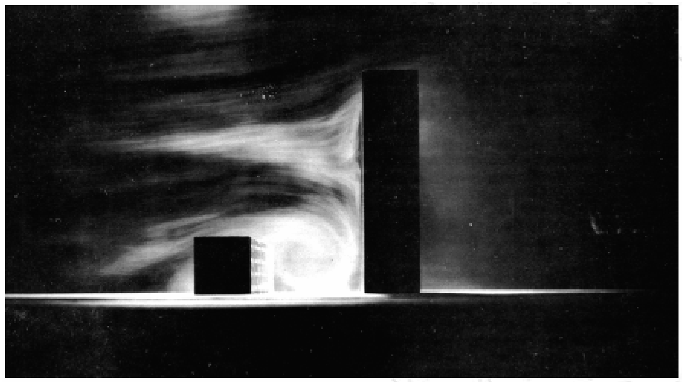
Wind Velocity Profiles and Boundary Layer Thickness

Wind characteristics:
Variation of Wind Speed with Exposure



This graph illustrates the variations of wind speeds by height and exposure categories (exposure categories will be reviewed later). The velocity pressures will vary for both the Main Wind Force Resisting Systems and Components and Cladding by Exposure categories.

Wind characteristics



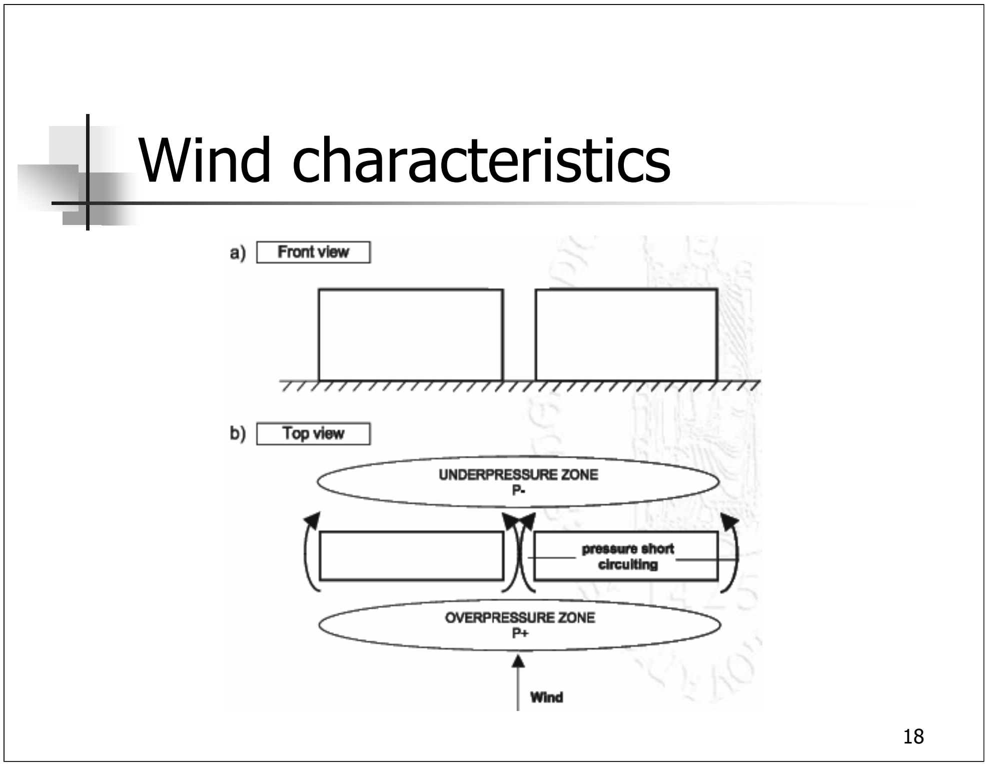
Wise et al. (1965)

16

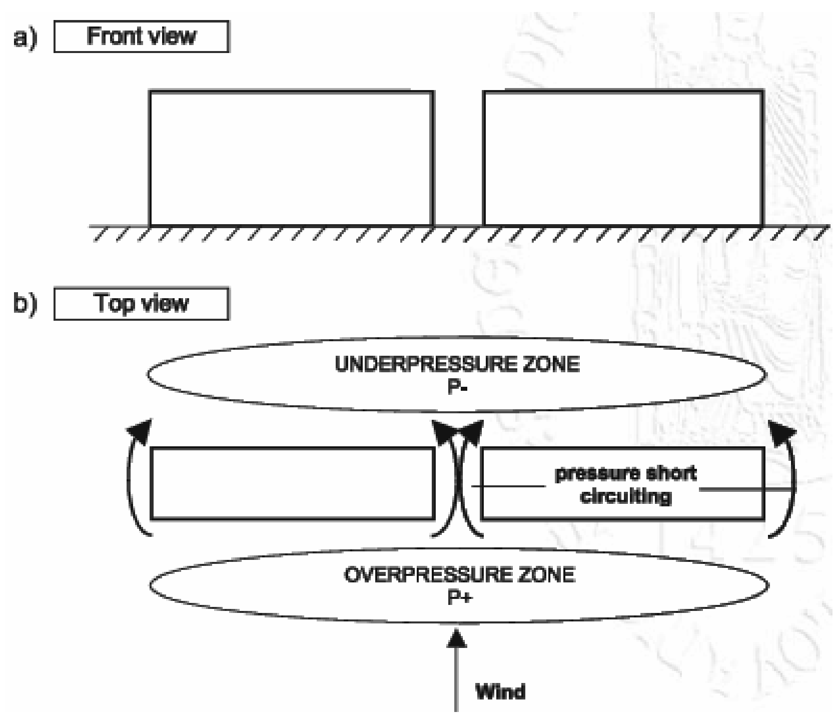
Note uplift induced on leeward side of windward building caused by vortex.

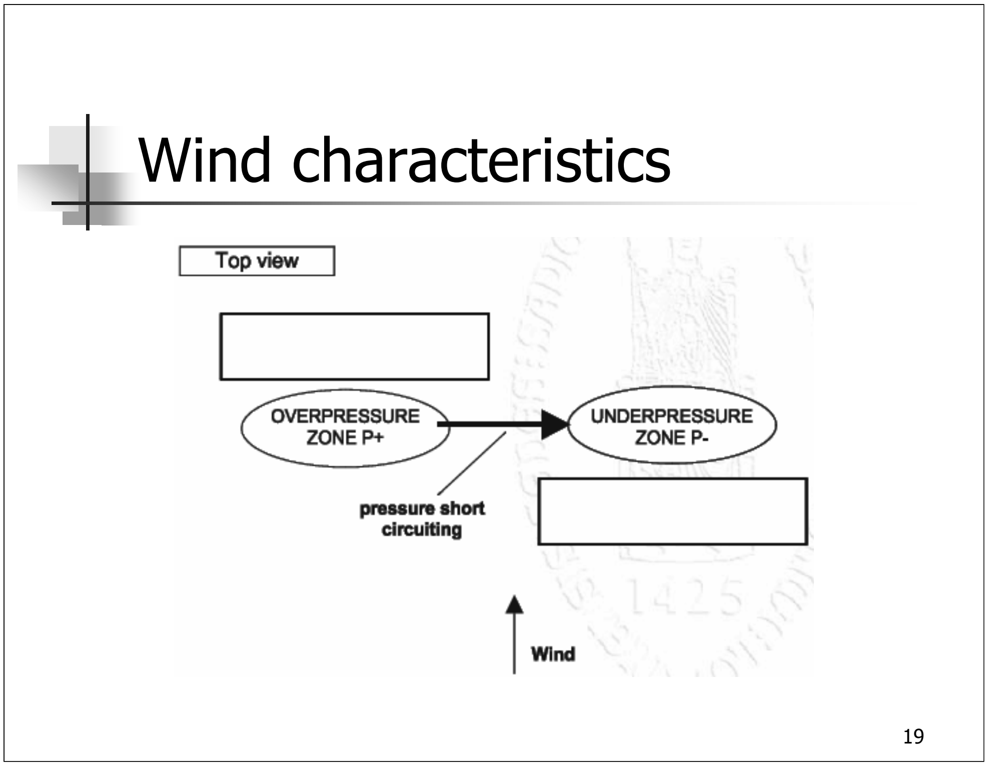
Wind characteristics

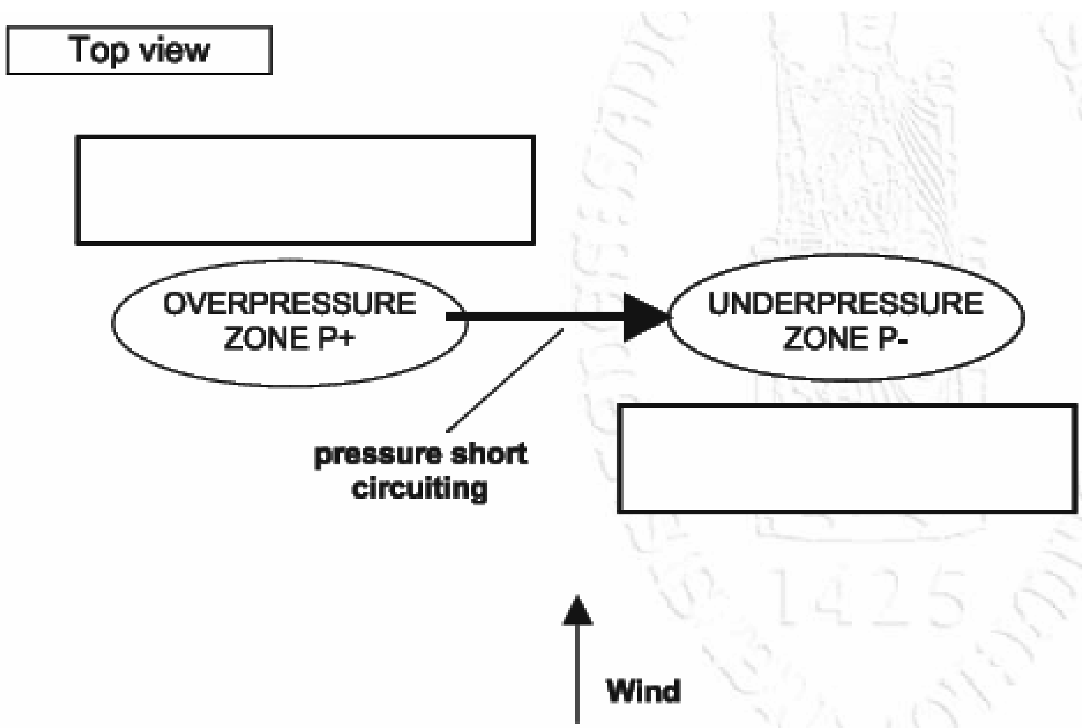
17



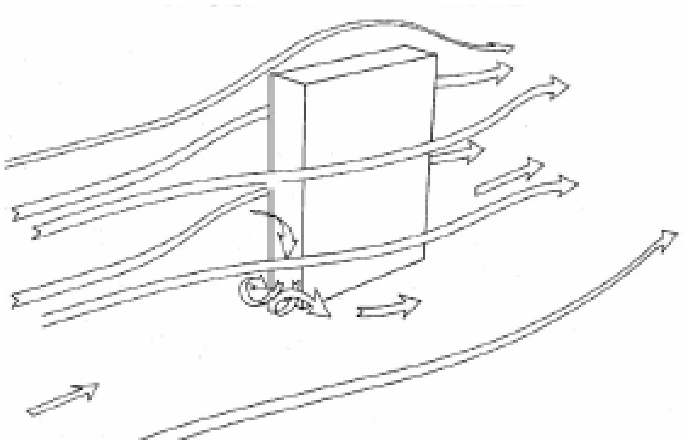
Wind accelerated between two buildings.




Wind characteristics
Top view
OVERPRESSURE
ZONE P+
UNDERPRESSURE
ZONE P-
pressure short
circuiting
Wind
19


Top view
OVERPRESSURE
ZONE P+
UNDERPRESSURE
ZONE P-
pressure short
circuiting
Wind

Wind characteristics



20

Wind flow around building. Arrows representing flow demonstrating turbulence at windward base of building and change in flow path as 'wind' encounters and goes around building.

Wind characteristics

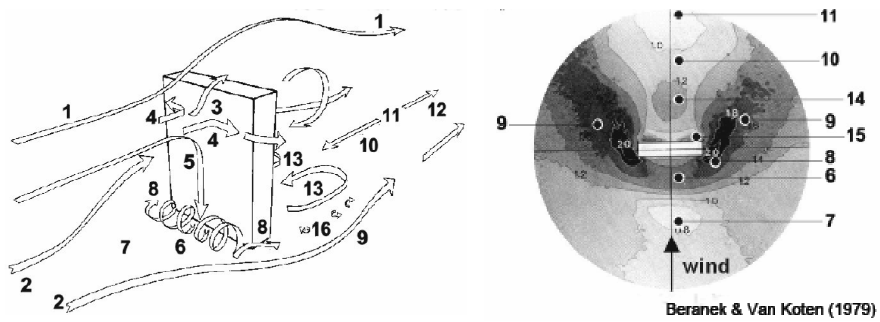
Anderson (1995):

"CFD is the art of replacing the integrals or the partial derivatives (as the case may be) in the Navier-Stokes equations by discretized algebraic forms, which in turn are solved to obtain numbers for the flow field values at discrete points in time and/or space."

21

The diagrams in the following slides show the results of computational fluid dynamic studies.

Wind characteristics



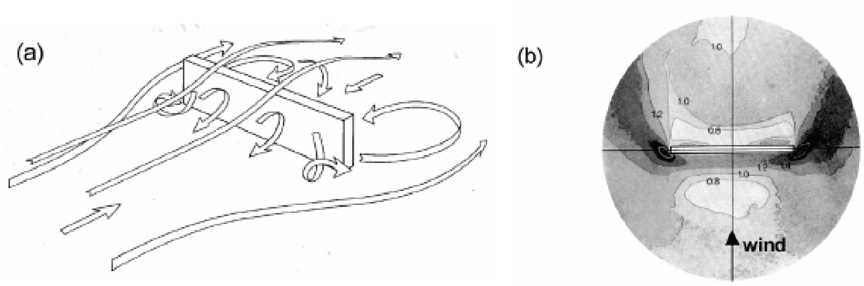
22

Results of research undertaken to investigate 'problem' wind caused by accelerations around buildings. Directed at finding ways to alleviate pedestrian annoyance, it also shows interaction of wind/buildings.

From workshop presentation *Microclimate Around Buildings* courtesy of:

Bert Blocken	Katholieke Universiteit Leuven, Belgium Concordia University, Montreal, Canada
Hugo Hens	Katholieke Universiteit Leuven, Belgium
Jan Carmeliet	Katholieke Universiteit Leuven, Belgium Eindhoven University of Technology, The Netherlands
K. U. Leuven	Laboratory of Building Physics

Wind characteristics



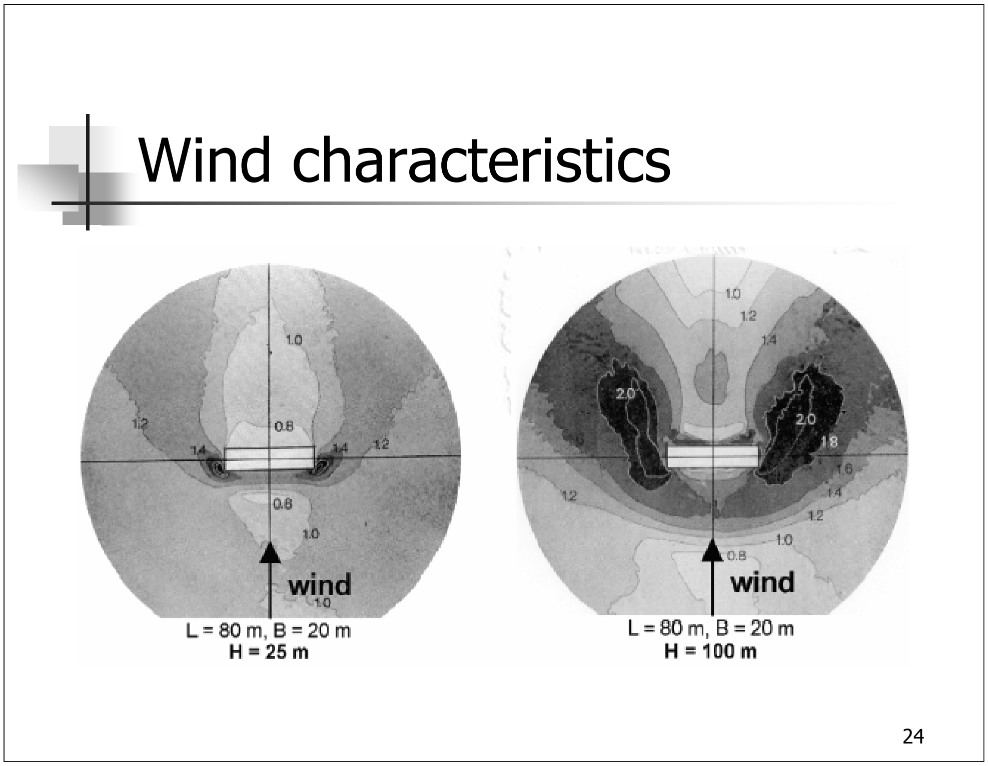
23

Values are multiples of ‘ambient’ wind speed.

0.8 region at windward side of building is slower than ambient.

Amount of energy in air is constant.

When velocity drops, pressure rises, creating overpressure area. When air is moving faster than other air in same body, pressure drops, creating under pressure area.



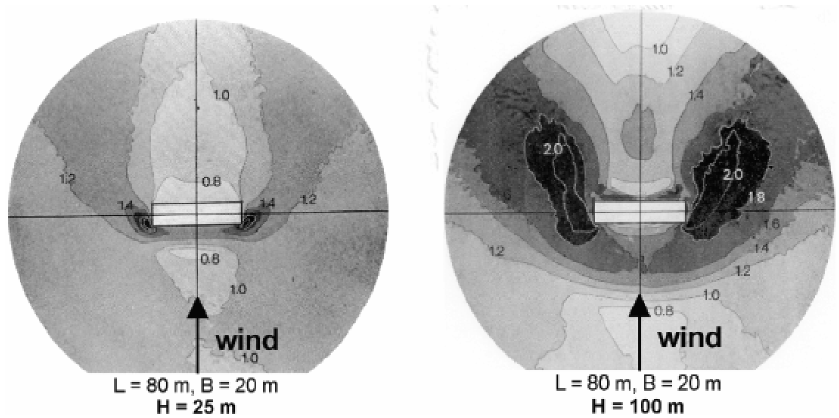
If building height is increased peak value of corners stay the same, size of corner stream increases.

H = height

L = length

B = width

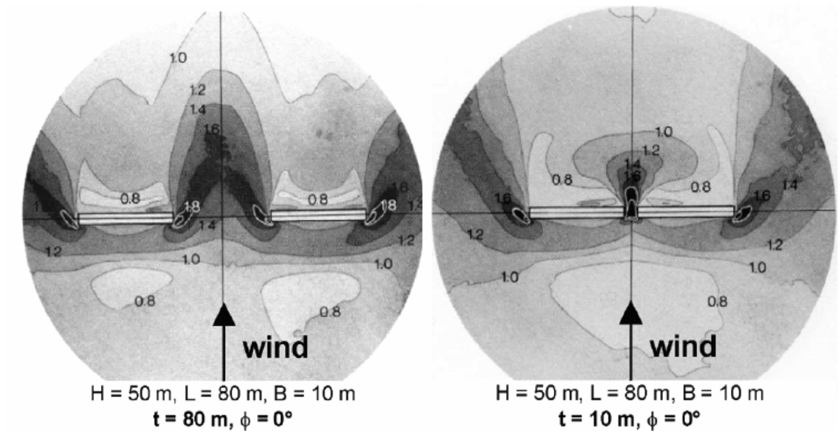
Wind characteristics



25

If building height is increased, the values in the standing vortex become larger. Stagnation region in front of building moves upstream.

Wind characteristics

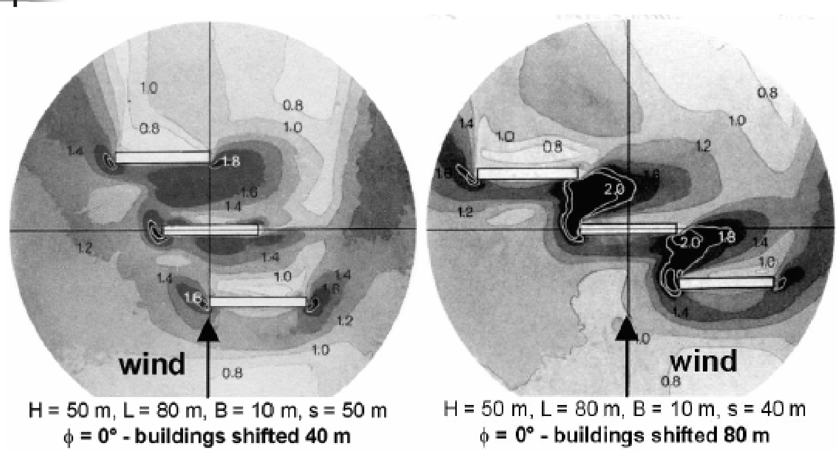


26

If passage between two buildings is decreased:

- Peak value remains the same
- Stagnation regions remain at same position but merge together
- Length of passage jet becomes smaller

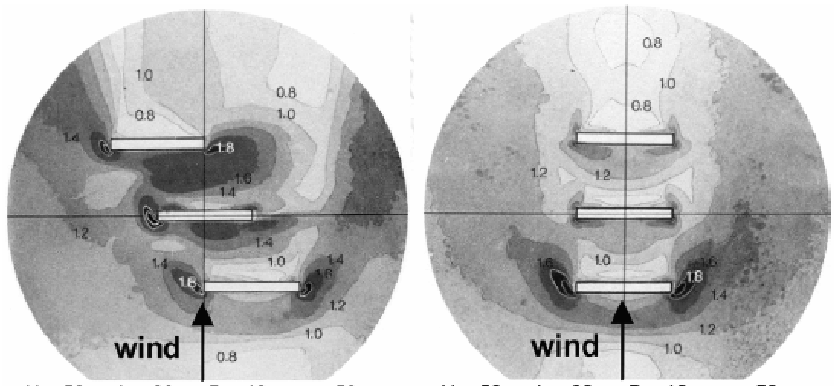
Wind characteristics



27

Highest wind speed through passages in right side configuration.

Wind characteristics



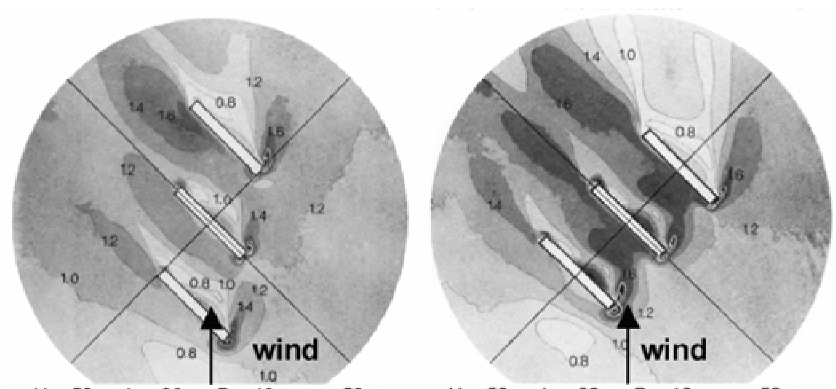
H = 50 m, L = 80 m, B = 10 m, s = 50 m
ϕ = 0° - buildings shifted 40 m

H = 50 m, L = 80 m, B = 10 m, s = 50 m
ϕ = 0° - buildings not shifted

28

Configuration on left gives highest wind speed in passages.

Wind characteristics



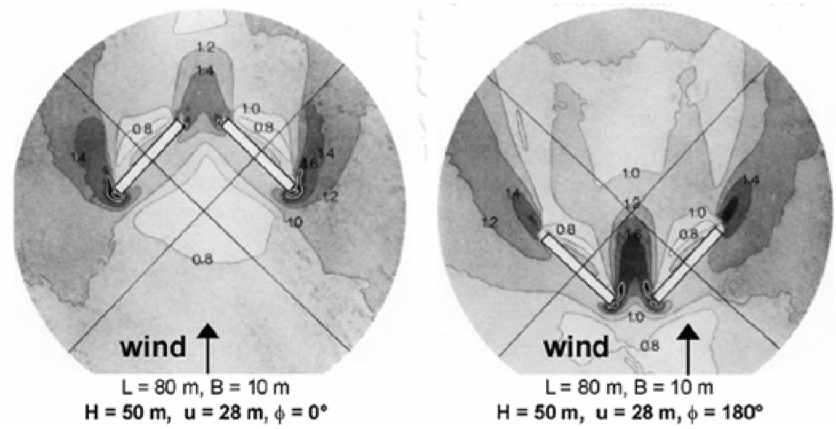
H = 50 m, L = 80 m, B = 10 m, s = 50 m
ϕ = 45° - buildings shifted 40 m

H = 50 m, L = 80 m, B = 10 m, s = 50 m
ϕ = 45° - buildings not shifted

29

Configuration on right gives highest wind speed in passages.

Wind characteristics



30

Configuration on right gives highest wind speed in passage *for given wind speed direction.*

—Somewhat counter-intuitive

Wind characteristics

Logarithmic law: $U_{(y)} = \frac{{}^{u}ABL}{\kappa}\ln\left(\frac{y}{y_0}\right)$ Power law: $\frac{U_{(y)}}{U_{ref}} = \left(\frac{y}{y_{ref}}\right)^{a}$

y_0 is the aerodynamic roughness length of the terrain
(e.g. y_0=0.03 m for a grass-covered plain.)

31

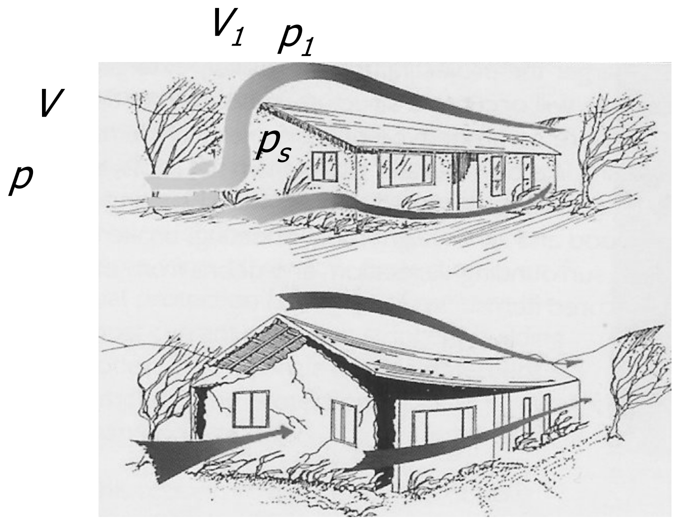
Wind velocity U, at height y, above ground.

Wind characteristics

Aerodynamic roughness length y_0 Wieringa (1992): roughness classification

Y_0(m)	Landscape description	
0.0002	Sea	Open sea or lake, snow-covered flat plain, desert, tarmac, concrete
0.03	Open	Level country with low vegetation (e.g. grass) and isolated obstacles with separations of at least 50 obstacle heights, e.g. grazing land without windbreaks, heather, moor and tundra, runway area of airports.
0.50	Very rough	"Old" cultivated landscape with many rather large obstacle groups (large farms, clumps of forest) separated by open spaces of about 10 obstacle heights. Also low large vegetation with small interspaces such as bush land, orchards, young densely-planted forest.
≥ 2.0	Chaotic	Centers of large towns with mixture of low-rise and high-rise buildings. Also irregular large forests with many clearings.

Wind Characteristics



33

Wind characteristics

$$p + \frac{1}{2} \rho V^2 = p_1 + \frac{1}{2} \rho V_1^2$$

34

Bernoulli's equation

Wind characteristics

If p_1 is taken at p_s, $V_1 = 0$

$$p_s - p = \frac{1}{2} \rho V^2$$

35

Wind characteristics

- Maximum pressure occurs at point where velocity is zero
  - Called stagnation point

36

Wind characteristics

p_s is called stagnation pressure or dynamic pressure, denoted q

Air at standard density moving at 100 mph q = 25.58 psf

37

From *Mark's Mechanical Engineers' Handbook*

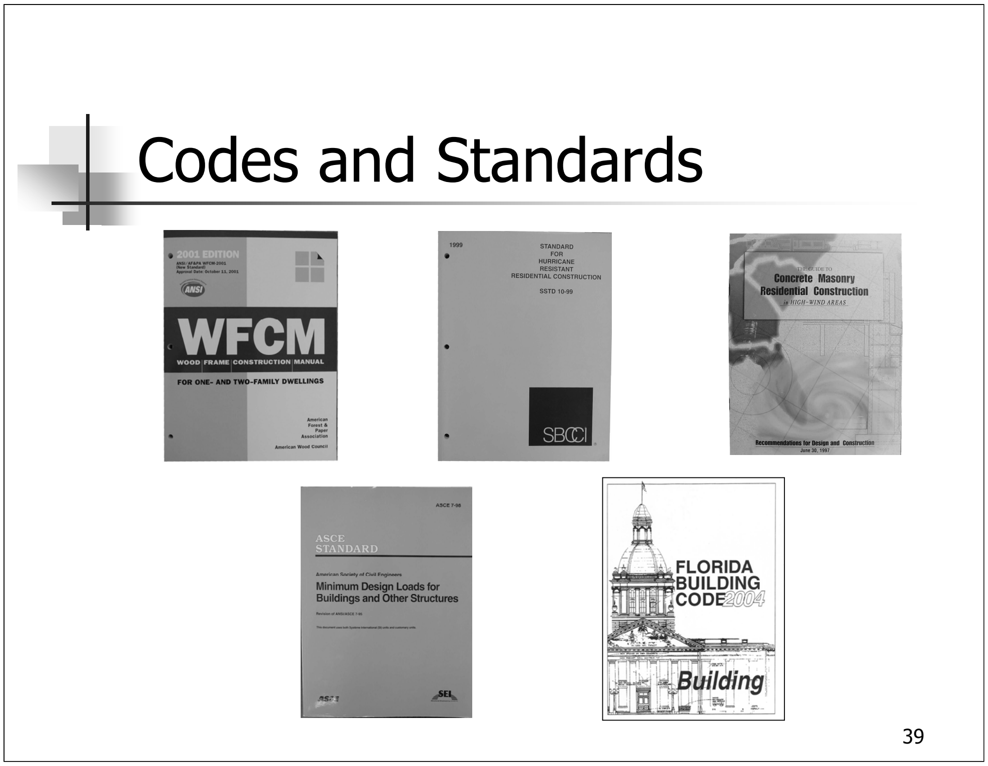
Codes and Standards

Wind Load Analysis Procedures

contained in the Florida Building Code

38

The following part of this presentation **“Codes and Standards”** reviews those design documents that are allowed by the Florida Building Code 2004, section **1609 Determination of wind forces**. The review provides an overview of the design tools and the design parameters of the referenced prescriptive documents.



FLORIDA BUILDING CODE

SECTION 1609 WIND LOADS

1609.1 Applications (FBC).

Buildings, structures and parts thereof shall be designed to withstand the minimum wind loads prescribed herein. Decreases in wind loads shall not be made for the effect of shielding by other structures.

1609.1.1 Determination of wind forces.

Wind forces on every building or structure shall be determined by the provisions Chapter 6 of ASCE 7. Wind pressures shall be assumed to come from any horizontal direction and to act normal to the surfaces considered.

Exceptions:

1. Provisions of 1609.6 shall be permitted for buildings 60 ft high or less.

Note:

The design Tables and Figures contained in Chapter 16 of the Florida Building Code are for use with the provisions and limitations of 1609.6 Simplified Provisions for Low Rise Buildings.

The version of ASCE 7 to be used in association with the FBC is stated explicitly in the Florida Statutes. It is understood to be acceptable to use the latest version of ASCE 7.

Codes and Standards

Wind Loads: Overview
Chapter 16—Section 1609

Determination of wind loads:

- Chapter 6 of ASCE 7
- Simplified provisions for Low Rise Buildings per 1609.6

or:

40

SECTION 1609 WIND LOADS

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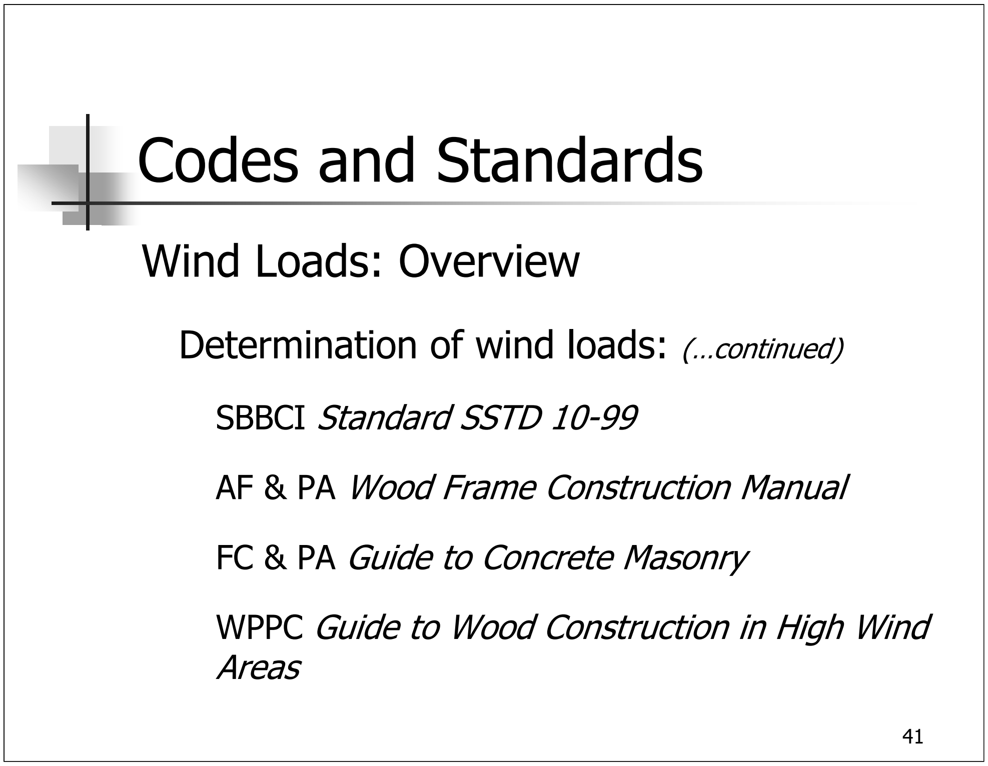


SECTION 1609 WIND LOADS

1609.1.1 Determination of Wind Force. Prescriptive documents

Alternatives:

Southern Building Code Congress International (SBCCI) SSTD 10.

American Forest & Paper Association (AF&PA) Wood Frame Construction Manual for One and Two-Family Dwellings – 2001.

Florida Concrete & Products Association (FC&PA) Guide to Concrete Masonry Residential Construction in High Wind Areas.

WPPC Guide to Wood Construction in High Wind Areas.

These prescriptive documents underwent extensive independent peer review prior to being approved for use. During the development of the FBC, the documents were reviewed for compliance with ASCE 7-98 and limits placed on their application.

Codes and Standards

ASCE 7 *Minimum Design Loads for Buildings and Other Structures* - Chapter 6.0 Wind Loads

Method 1 - Simplified Procedures

Method 2 - Analytical Procedures

Method 3 - Wind Tunnel Procedures

42

ASCE 7-98

6.0 WIND LOADS

6.1.2 Allowed Procedures

The design wind loads for buildings and other structures, including the main wind force resisting system and component and cladding elements thereof, shall be determined using one of the following procedures:

Method 1—Simplified Procedure as specified in Section 6.4 for buildings meeting the requirements specified therein;
Method 1 presents a procedure for determining velocity pressures for buildings defined as regular shaped that have a simple diaphragm, a mean roof height less than or equal to 30 feet, and a roof slope less than 10 degrees (a pitch of approximately 2:12).

Method 2—Analytical Procedure as specified in Section 6.5 for buildings meeting the requirements specified therein; and

Method 3—Wind Tunnel Procedure as specified in Section 6.6.

Codes and Standards

ASCE 7 Method 1

- Building, Simple Diaphragm
- Roof slopes less than 10 degrees
- Mean roof 30 feet ≤ (7-98), 60 feet (7-02)
- Building regular shaped
- Not a flexible building – Natural frequency ≤ 1
- No expansion joints or separations
- Not subject to topographic effects
- Enclosed – partially enclosed building

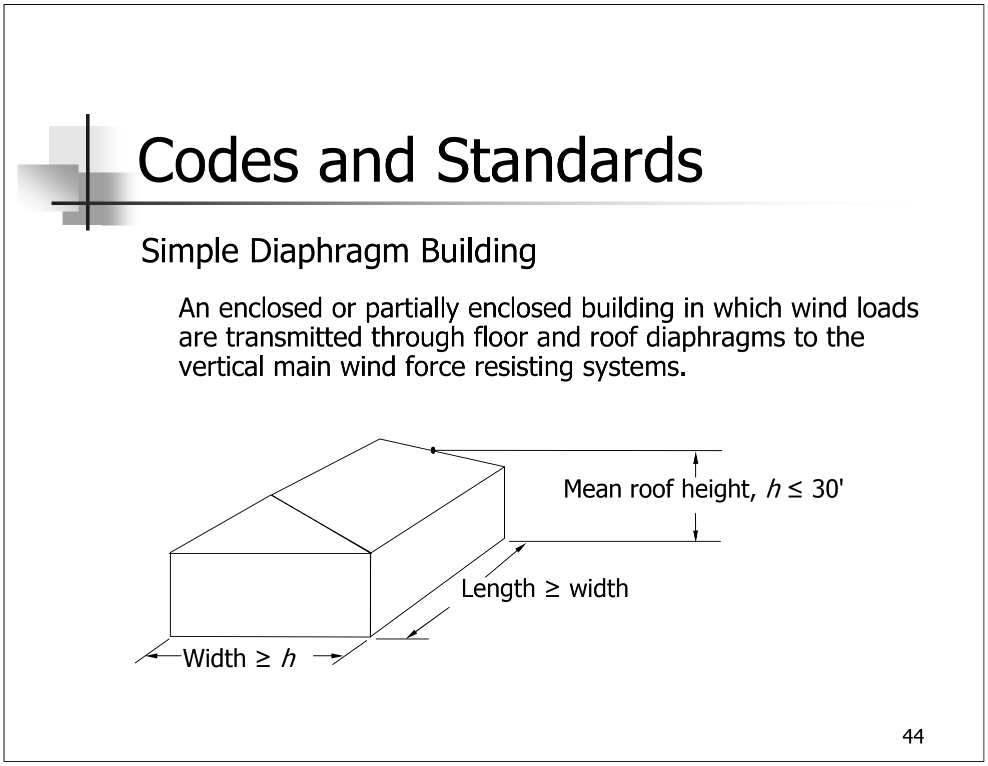
43

Can the ASCE-7 Simplified provisions be used?

Section 6.4.1 gives a list of seven conditions that must be satisfied in order to apply this method:

1. The building is a simple diaphragm building as defined in Section 6.2,
2. The building has roof slopes less than 10 degrees,
3. The mean roof height of the building is less than or equal to 30 ft (7-98), 60 ft (7-02)
4. The building is a regular shaped building or structure as defined in Section 6.2,
5. The building is not classified as a flexible building as defined in Section 6.2 (fundamental period greater than one second),
6. The building structure has no expansion joints or separations, and
7. The building is not subject to the topographic effects of Section 6.5.7 (i.e., K_{zt} = 1.0).

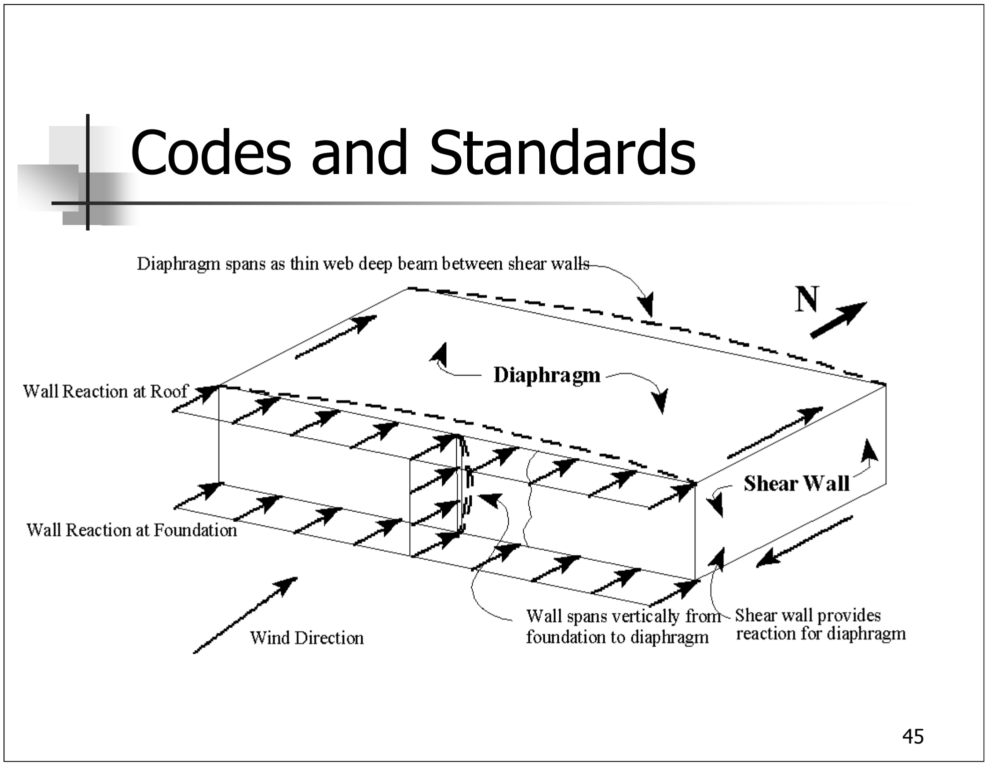
If all of the conditions are meet the designer may use ASCE 7 Method 1 – Simplified Procedure.



Definition for *Building, Simple Diaphragm* as found in ASCE 7-98: An enclosed or partially enclosed building in which wind loads are transmitted through floor and roof diaphragms to the vertical main wind force resisting systems.

Definition for *Building, Simple Diaphragm* as found in the Florida Building Code: A building which complies with all of the following conditions:

1. Enclosed building
2. Mean roof height, *h*, less than or equal to 60 ft.
3. Mean roof height, *h*, does not exceed least horizontal dimension
4. Building has an approximately symmetrical cross section
5. Building has no expansion joints or structural separations within the building
6. Wind loads are transmitted through floor and roof diaphragms to the vertical lateral force resisting systems
7. If the building has moment resisting frames, roof slopes do not exceed 30%



Building demonstrating 'diaphragm' action from wind loading

- Load on windward and leeward walls goes half into foundation, half into roof or floor diaphragm.
- Diaphragm distributes load into shear walls.
- When wind switches 90 degrees, walls exchange functions.

Codes and Standards:
Method 1 - Simplified Design Procedures

The basic wind speed *V* determined in accordance with Section 6.5.4.

An importance factor *I* determined in accordance with Section 6.5.5.

An exposure category or categories determined in accordance with Section 6.5.6.

An enclosure classification determined in accordance with Section 6.5.9.

46

For the designer to use Method 1, the building must conform the all seven requirements in Section 6.4.1.

Codes and Standards:
Method 1 - Simplified Design Procedures

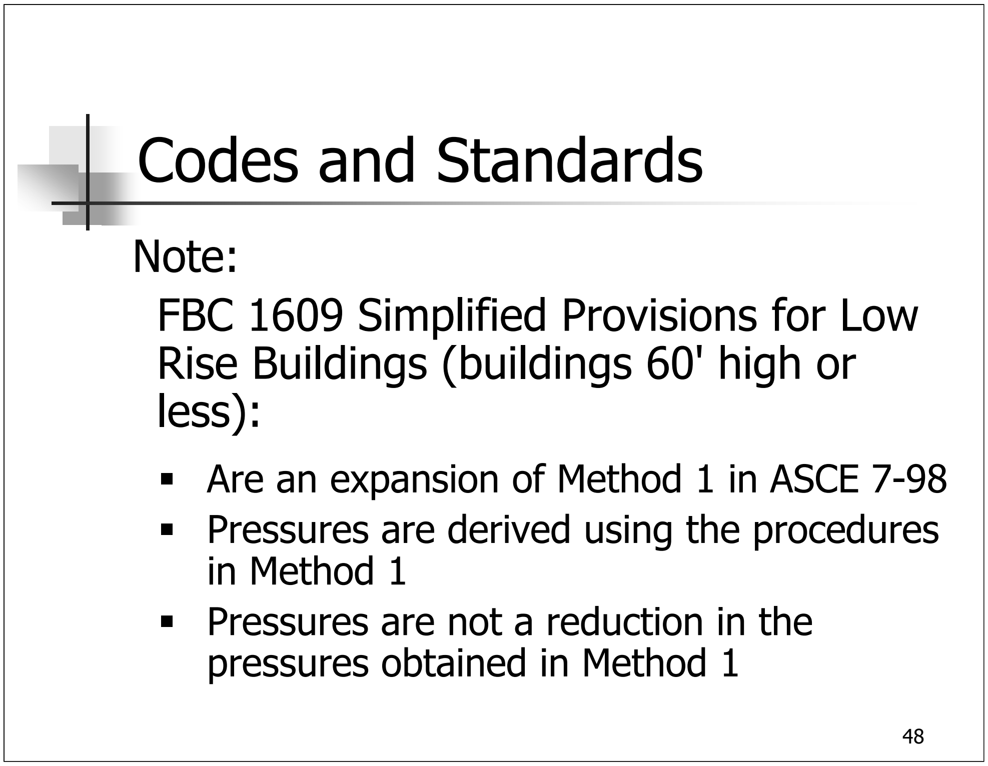
The design wind loads for the main wind force resisting system are determined from Table 6-2. The design wind loads are applied normal to the surface. The design wind loads are applied simultaneously, with the net combined wall pressure applied on all windward wall surfaces and the net roof pressure applied on all roof surfaces.

The design winds load for component and cladding elements are determined from Table 6-3. These net design pressures are applied to each exterior surface.

47

Method 1 has been added to the standard for a designer having the relatively common low-rise (h < 30 ft) regular shaped, simple diaphragm building case (see definitions for ‘‘simple diaphragm building’’ on the next slide) where pressures for the roof and walls can be selected directly from a table.

Two tables are provided: Table 6-2 for the Main Wind Force Resisting System and Table 6-3A and 6-3B for Components And Cladding. For components and cladding, values are provided for enclosed and partially enclosed buildings. Note that for the main wind force resisting system in a diaphragm building, the internal pressure cancels for loads on the walls, but must be considered for the roof.



Note:

A more detailed review of Section 1609.2 Simplified provisions for Low Rise Buildings is provided later. The Florida Building Code, Section 1609.2 Simplified provisions for Low Rise Buildings is derived from Method 1 of ASCE 7.

The provisions are an expansion of Method 1 in ASCE 7-98 and have pressures that are derived using the procedures in Method 1. The pressures are not a reduction in the pressures obtained in Method 1.

Codes and Standards

Can ACSE 7 Method 2 be used?

In order to qualify for use of Method 2, the structure must be regularly shaped and not have response characteristics making it susceptible to various dynamic wind effects.

49

6.5 Method 2 Analytical Procedures

6.5.1 Scope

A building or other structure whose design wind loads are determined in accordance with this section shall meet all of the following conditions:

1. The building or other structure is a regular shaped building or structure as defined in Section 6.2, and
2. The building or other structure does not have response characteristics making it subject to across wind loading, vortex shedding, instability due to galloping or flutter; or does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

"Regularly shaped" is defined as not having any geometrical irregularities in spatial form.

Codes and Standards

Building, regular shaped:

A building or other structure having no unusual geometrical irregularity in spatial form.

50

6.5 Method 2 Analytical Procedures

6.5.1 Scope

A building or other structure whose design wind loads are determined in accordance with this section shall meet all of the following conditions:

1. The building or other structure is a regular shaped building or structure as defined in Section 6.2, and
2. The building or other structure does not have response characteristics making it subject to across wind loading, vortex shedding, instability due to galloping or flutter; or does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

Codes and Standards:
Method 2 - Analytical Procedures

Basic Wind Speed *V* and wind directionality factor K_d, per 6.5.4

Importance Factor *I*, per 6.5.5

Exposure category (B or C for Florida) and velocity pressure exposure coefficient K_z or K_h, per 6.5.6

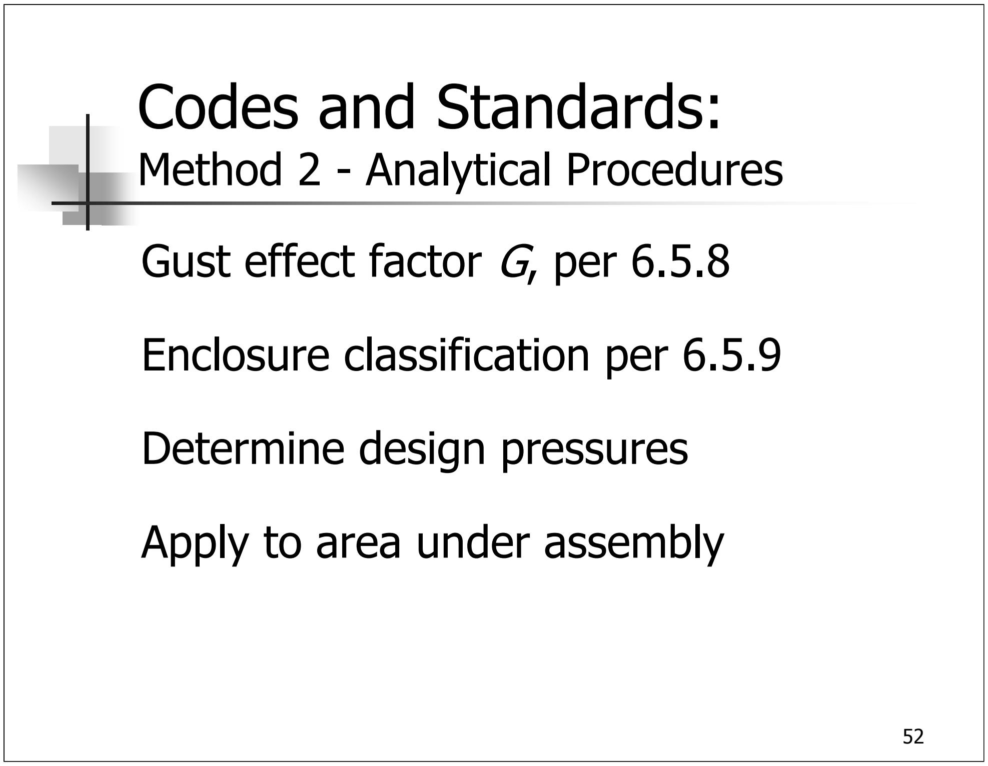
Topographic factor K_{zt}, per 6.5.7. If no topographic effects assume K_{zt}=1

51

6.5.3 Design Procedure

1. The *basic wind speed V* and *wind directionality factor* K_d shall be determined in accordance with Section 6.5.4.
2. An *importance factor I* shall be determined in accordance with Section 6.5.5.
3. An *exposure category* or *exposure categories* and *velocity pressure exposure coefficient* K_z or K_h, as applicable, shall be determined for each wind direction in accordance with Section 6.5.6.

…continued after following slide



6.5.3 Design Procedure ...continued

4. A *topographic factor* K_{zt} shall be determined in accordance with Section 6.5.7.
5. A *gust effect factor* G or G_f, as applicable, shall be determined in accordance with Section 6.5.8.
6. An *enclosure classification* shall be determined in accordance with Section 6.5.9.
7. *Internal pressure coefficient* GC_{pi} shall be determined in accordance with Section 6.5.11.1.
8. *External pressure coefficients* C_p or GC_{pf}, or force coefficients C_f, as applicable, shall be determined in accordance with Section 6.5.11.2 or 6.5.11.3, respectively.
9. *Velocity pressure* q_z or q_h, as applicable, shall be determined in accordance with Section 6.5.10.
10. *Design wind load* P or F shall be determined in accordance with Sections 6.5.12 and 6.5.13, as applicable.

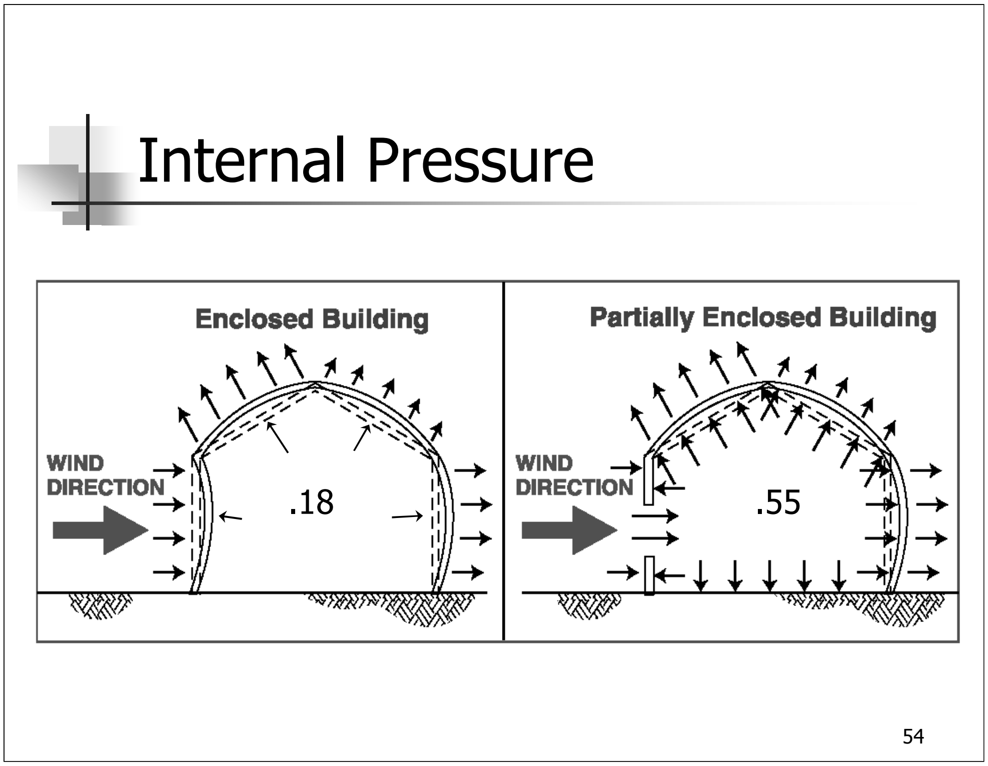
Importance Factor, I
Table 6-1 (ASCE)

Category	MRI	Non-Hurricane Prone Regions, Hurricane Prone Regions with V = 85–100 mph, and Alaska	Hurricane Prone Regions with V=>100 mph
I	25 yr	0.87	0.77
II	50 yr	1.00	1.00
III	100 yr	1.15	1.15
IV	100 yr	1.15	1.15

ASCE 7, Table 6-1

Importance Factor, I (Wind Loads)

The importance factor is used to adjust the level of structural reliability of a building or other structure to be consistent with the building classifications. The importance factors given in Table 6-1 adjust the velocity pressure to different annual probabilities of being exceeded. Importance factor values of 0.87 and 1.15 are, for the nonhurricane winds, associated, respectively, with annual probabilities of being exceeded of 0.04 and 0.01 (mean recurrence intervals of 25 and 100 years). In the case of hurricane winds, the annual exceedance probabilities implied by the use of the importance factors of 0.77 and 1.15 will vary along the coast.



Internal Pressure Coefficients (taken from ASCE Commentary)

The internal pressure coefficient values in ASCE 7-98 Table 6-7 are obtained from wind tunnel tests and full scale data. The values GC_{pi} = +0.18 and -0.18 are for enclosed buildings. It is assumed that the building has no dominant opening or openings and that the small leakage paths that do exist are essentially uniformly distributed over the building's envelope. The internal pressure coefficient values for partially enclosed buildings assume that the building has a dominant opening or openings. For such a building, the internal pressure is dictated by the exterior pressure at the opening and is typically increased substantially as a result. Net loads, i.e., the combination of the internal and exterior pressures, are therefore also significantly increased on the building surfaces that do not contain the opening. Therefore, higher GC_{pi} values of +0.55 and -0.55 are applicable to this case.

Codes and Standards:
Method 2 - Analytical Procedures

6.5.10 Velocity Pressure

Minimum Design Loads for Buildings and Other Structures

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

55

ASCE 7–98 Method 2 Analytical Procedures

6.5.10 Velocity Pressure

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$\mathbf{q_z = 0.00256 K_z \, K_{zt} \, K_d V^2 I}$ **(lb/ft^2)** (Eq. 6-13)

Where

K_d is the wind directionality factor defined in Section 6.5.4.4,

K_z is the velocity pressure exposure coefficient defined in Section 6.5.6.4,

K_{zt} is the topographic factor defined in Section 6.5.7.2, and

q_h is the velocity pressure calculated using Eq. 6-13 at mean roof height h.

The numerical coefficient 0.00256 shall be used except where sufficient climatic data are available to justify the selection of a different value of this factor for a design application.

Codes and Standards

Velocity Pressures Terminology/Definitions:

q_z or q_h	Velocity pressure
K_Z	Velocity pressure exposure coefficient
K_{zt}	Topographic factor
K_d	Wind directionality factor
V	Basic wind speed
I	Importance factor

56

Velocity Pressures: $q_z = 0.00256 K_z K_{zt} K_d V^2 I$

Velocity Pressure Exposure Coefficient. Based on the exposure category determined in Section 6.5.6.1, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 6-5.

Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}: $K_{zt} + (1 + K_1K_2K_3)^2$ where K_1, K_2, and K_3 are given in Fig. 6-2. For rigid structures as defined in Section 6.2, the gust effect factor shall be taken as 0.85 or calculated with formula found in 6.5.8.1.

Wind directionality factor. Determined from Table 6-6. This factor shall only be applicable when used in conjunction with load combinations specified in Sections 2.3 Combined Factored Loads Using Strength Design and 2.4 Combine Nominal Loads Using Allowable Stress Design.

V = Basic wind speed obtained from Fig. 6-1, in miles per hour. The basic wind speed corresponds to a 3-second gust speed at 33 feet above ground.

I = Importance factor. A factor that accounts for the degree of hazard to human life and damage to property.

Codes and Standards

Velocity Pressures terminology/definitions:

q directly proportional to K_Z, K_{zt}, K_d, I and to the square of the velocity V

K_Z values from 0.57 up to 15 feet of height in Exposure B, to 1.89 at 500 feet in Exposure D per Table 6-5 or calculate per equations:

$K_Z = 2.01(z/z_g)^{2/\alpha}$ for 15 ft < or = z < or = z_g

$K_Z = 2.01(15/z_g)^{2/\alpha}$ for z < 15 ft

57

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

Velocity Pressure Exposure Coefficient. Based on the exposure category determined in Section 6.5.6.1, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 6-5.

α and z_g from Table 6-4.

Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}: $K_{zt} + (1 + K_1K_2K_3)^2$ where K_1, K_2, and K_3 are given in Fig. 6-2. For rigid structures as defined in Section 6.2, the gust effect factor shall be taken as 0.85 or calculated with formula found in 6.5.8.1.

Wind directionality factor. Determined from Table 6-6. This factor shall only be applicable when used in conjunction with load combinations specified in Sections 2.3 Combined Factored Loads Using Strength Design and 2.4 Combine Nominal Loads Using Allowable Stress Design.

V = Basic wind speed obtained from Fig. 6-1, in miles per hour. The basic wind speed corresponds to a 3-second gust speed at 33 feet above ground.

I = Importance factor. A factor that accounts for the degree of hazard to human life and damage to property.

Codes and Standards

Velocity Pressures terminology/definitions:

K_{zt} Topography not typically a factor in Florida. No provisions in code to not use it. K_1 may not go to zero but K_{zt} typically used as 1.

K_d 0.85 for most buildings. Conveys reduced likelihood worst wind will hit building at most vulnerable angle. Would be 1.0 for round structure with equal strength in all directions.

58

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

Velocity Pressure Exposure Coefficient. Based on the exposure category determined in Section 6.5.6.1, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 6-5.

Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}: $K_{zt} + (1 + K_1K_2K_3)^2$ where K_1, K_2, and K_3 are given in Fig. 6-2. For rigid structures as defined in Section 6.2, the gust effect factor shall be taken as 0.85 or calculated with formula found in 6.5.8.1.

Wind directionality factor. Determined from Table 6-6. This factor shall only be applicable when used in conjunction with load combinations specified in Sections 2.3 Combined Factored Loads Using Strength Design and 2.4 Combine Nominal Loads Using Allowable Stress Design.

V = Basic wind speed obtained from Fig. 6-1, in miles per hour. The basic wind speed corresponds to a 3-second gust speed at 33 feet above ground.

I = Importance factor. A factor that accounts for the degree of hazard to human life and damage to property.

Codes and Standards

Velocity Pressures terminology/definitions:

V — 3 second gust speed from wind speed map. Is squared to convey typical flow behavior of a fluid—kinetic energy equals: $\frac{1}{2} \rho V^2$

I — Modifies velocity pressure according to mean recurrence interval of a wind event, MRI chosen according to necessity of building maintaining integrity during high wind event

59

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

Velocity Pressure Exposure Coefficient. Based on the exposure category determined in Section 6.5.6.1, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 6-5.

Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}: $K_{zt} + (1 + K_1 K_2 K_3)^2$ where K_1, K_2, and K_3 are given in Fig. 6-2. For rigid structures as defined in Section 6.2, the gust effect factor shall be taken as 0.85 or calculated with formula found in 6.5.8.1.

Wind directionality factor. Determined from Table 6-6. This factor shall only be applicable when used in conjunction with load combinations specified in Sections 2.3 Combined Factored Loads Using Strength Design and 2.4 Combine Nominal Loads Using Allowable Stress Design.

V = Basic wind speed obtained from Fig. 6-1, in miles per hour. The basic wind speed corresponds to a 3-second gust speed at 33 feet above ground.

I = Importance factor. A factor that accounts for the degree of hazard to human life and damage to property.

Codes and Standards

Velocity Pressures terminology/definitions:

0.00256 constant = ½[(0.0765 lb/ft^3)/(32.2 ft/sec^2)] × [(1mi/hr)(5280 ft/mi) × (1 hr/3600 sec)]^2 mass density of air for standard atmosphere (59º F sea level pressure, or 29.92 inches of mercury)

60

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

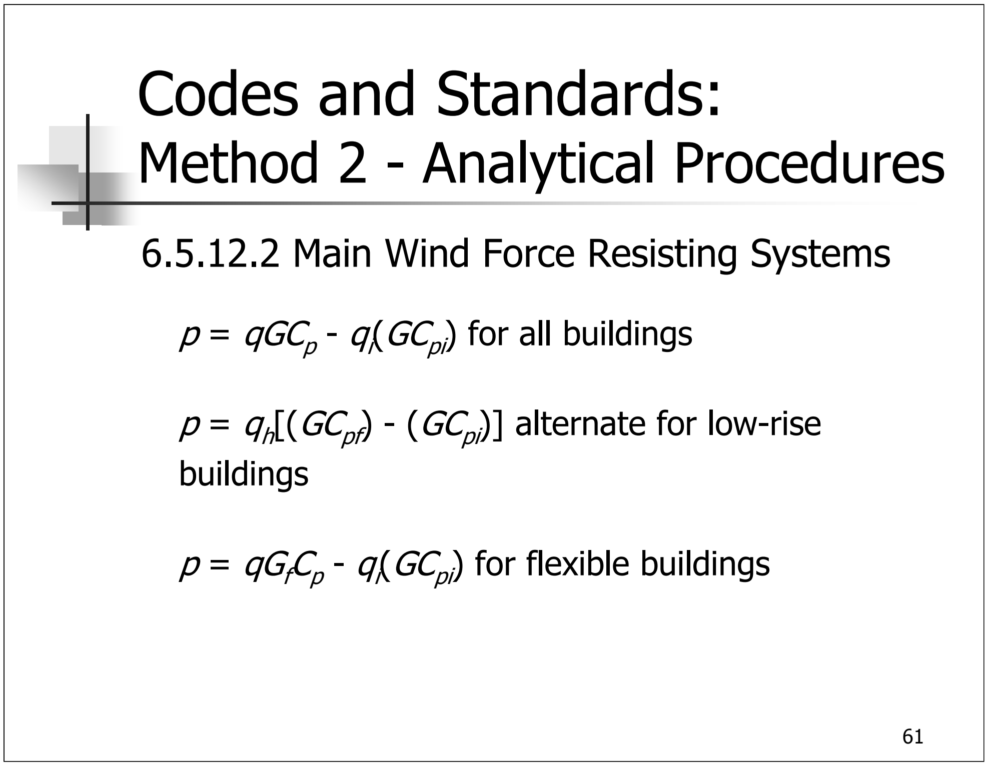
Velocity Pressure Exposure Coefficient. Based on the exposure category determined in Section 6.5.6.1, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 6-5.

Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}: $K_{zt} + (1 + K_1 K_2 K_3)^2$ where K_1, K_2, and K_3 are given in Fig. 6-2. For rigid structures as defined in Section 6.2, the gust effect factor shall be taken as 0.85 or calculated with formula found in 6.5.8.1.

Wind directionality factor. Determined from Table 6-6. This factor shall only be applicable when used in conjunction with load combinations specified in Sections 2.3 Combined Factored Loads Using Strength Design and 2.4 Combine Nominal Loads Using Allowable Stress Design.

V = Basic wind speed obtained from Fig. 6-1, in miles per hour. The basic wind speed corresponds to a 3-second gust speed at 33 feet above ground.

I = Importance factor. A factor that accounts for the degree of hazard to human life and damage to property.



Main Wind Force Resisting Systems

Design Wind Pressures for the Main Wind Force Resisting Systems shall be determined by the following equations to be explained in further detail:

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

$p = q_h[(GC_{pf}) - (GC_{pi})]$ alternate for low-rise buildings

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

Codes and Standards

MWFRS Terminology/Definitions:

q	velocity pressure
G	gust effect factor
G_f	gust effect factor - flexible buildings
C_p	external pressure coefficient all h
GC_{pf}	external pressure coefficient h < 60'
q_i	positive internal pressure
GC_{pi}	internal pressure coefficient

62

Main Force Resisting Systems (taken from ASCE 7-98)

p = qGC_p - $q_i(GC_{pi})$ for all buildings where:

q = q_z for windward walls evaluated at height z above the ground;

q = q_h for leeward walls, side walls, and roofs, evaluated at height h;

q_i = q_h for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings;

q_i = q_z for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind borne debris regions, glazing in the lower 60 ft that is not impact resistant or protected with an impact resistant covering, the glazing shall be treated as an opening in accordance with Section 6.5.9.3. For positive internal pressure evaluation, q_i may conservatively be evaluated at height h ($q_i = q_h$);

G = gust effect factor from 6.5.8;

C_p = external pressure coefficient from Fig. 6-3 or Table 6-8;

(GC_{pi}) = internal pressure coefficient from Table 6-7.

Codes and Standards

6.5.12.4 Components and Cladding

$p = q_h[(GC_p) - (GC_{pi})]$
for buildings with h ≤ 60 ft

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

63

Components and Cladding

Wind pressures on component and cladding elements of low-rise buildings and buildings with $h \leq$ 60 ft shall be determined from the following equation:

$p = q_h[(GC_p) - (GC_{pi})]$ for buildings with $h \leq$ 60 ft

Building with height greater than 60 ft shall determine wind pressures on components and cladding shall be determined using the following equation:

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

Codes and Standards

C & C Terminology/Definitions:

q	velocity pressure
q_h	velocity pressure evaluated at mean roof height *h*
q_i	positive internal pressure equals q_h or q_z
(GC_p)	external pressure coefficients
(GC_{pi})	internal pressure coefficient

64

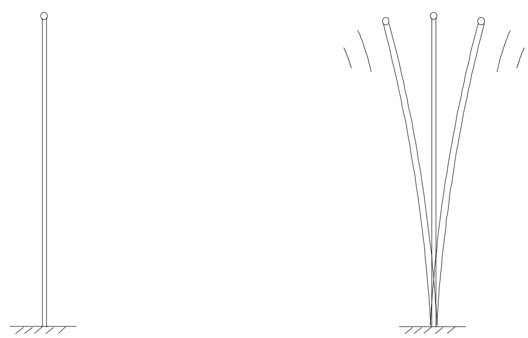
Components and Cladding

q_h = velocity pressure evaluated at mean roof height *h* using exposure defined in Section 6.5.6.3.1;

(GC_p) = external pressure coefficients given in Figs. 6-5 through 6-7; and

(GC_{pi}) = internal pressure coefficient given in Table 6-7.

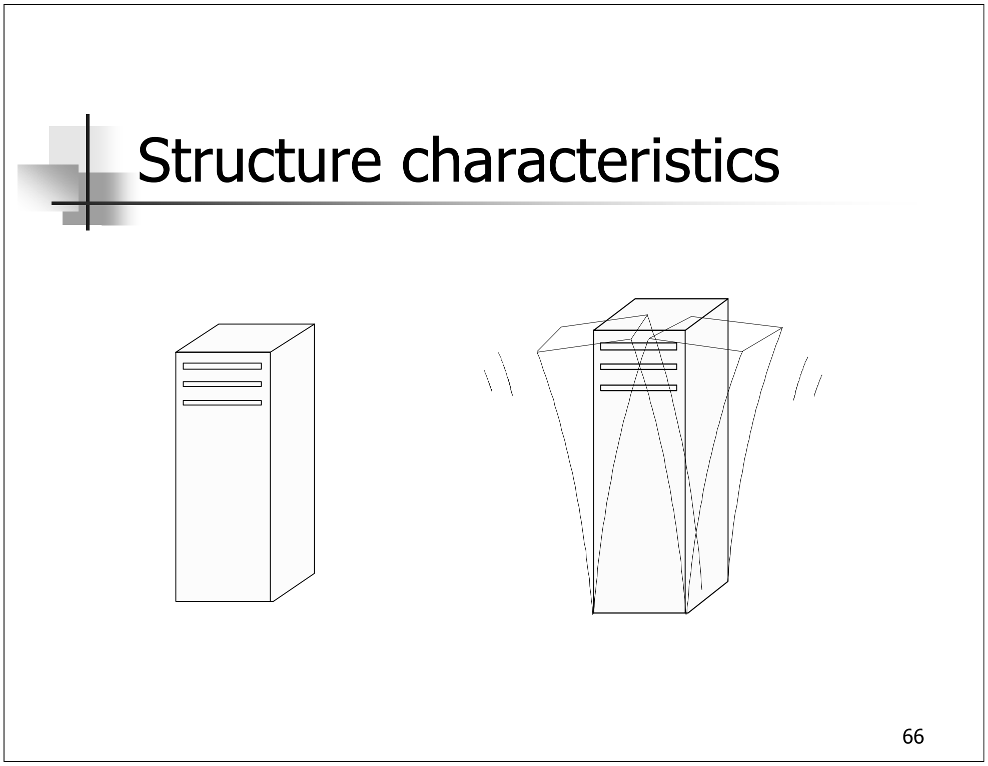
Structure characteristics



65

‘Pluck’ a flagpole and it vibrates at natural frequency.

First mode fundamental frequency shown.



Building behaves the same way

n story building calculated for *n* natural frequencies and *n* natural modes

First fundamental mode shown of concern for wind analysis.

All structures have infinite number of natural frequencies.

Structure characteristics

$$\omega = \sqrt{\frac{k}{m}}$$

Deceptively simple equation

67

ω = circular natural frequency

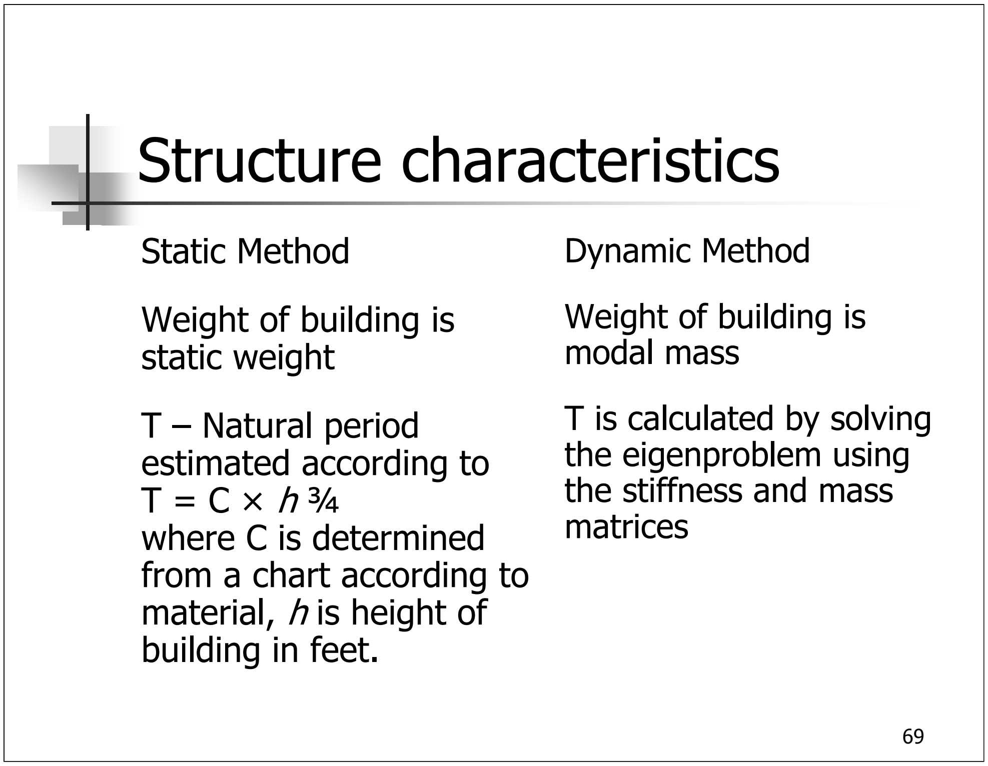
k = spring stiffness. For a building it is calculated from the combined stiffnesses of all columns per floor.

m = mass of system. Calculated from the mass at each floor of a building.

Structure characteristics

Complex problems have simple, easy to understand, wrong answers.

68



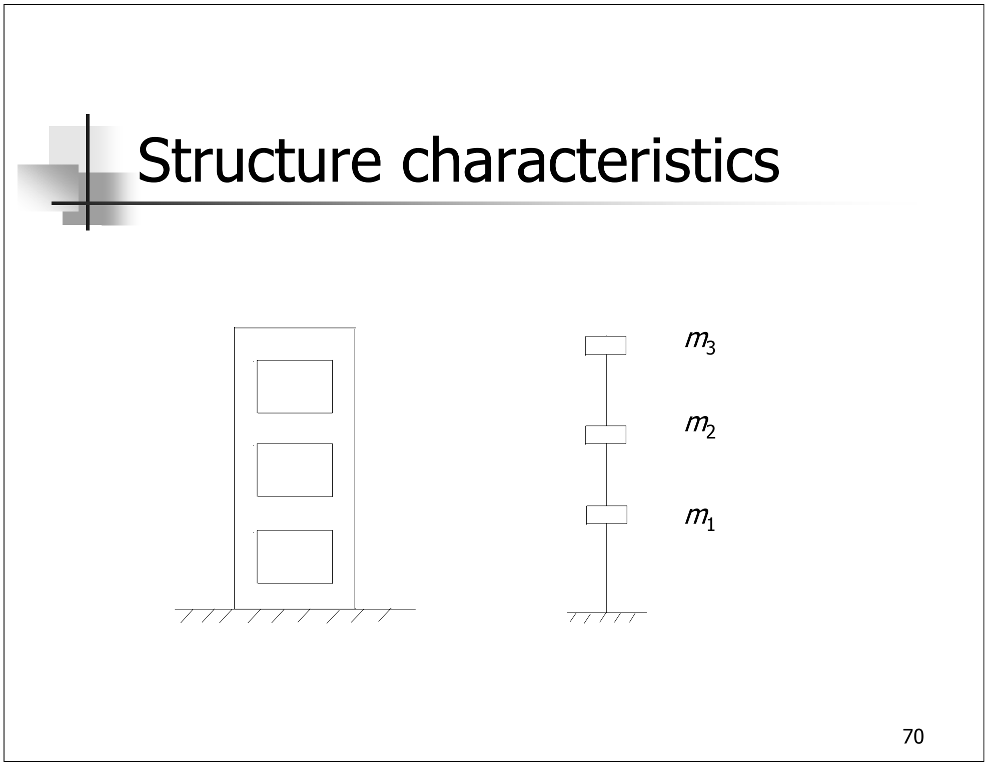
Calculating Natural Frequency

Static method is from Uniform Building Code - 1994. C = 0.035 for steel moment-resisting frames, 0.030 for reinforced concrete moment-resisting frames and eccentrically braced frames, 0.020 for all other buildings. Alternatively C may be calculated as 0.1 times the square root of (A_c).

$A_c = \Sigma A_e[0.2 + (d_e/h_N)^2]$

A_e is the minimum cross-sectional area in any horizontal plane in the first story of a structural wall (in square feet), d_e is the length, in feet, of a structural wall in the first story in the direction parallel to the applied forces, and h_N is the height of the building in feet.

Dynamic method requires computer solution using mass and stiffness matrices.



Three story building modeled as three degree of freedom structure for dynamic analysis. Mass of wall/columns divided and half added to floor above and half to floor below.

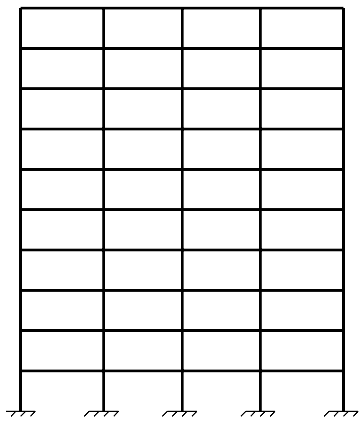
Structure characteristics

Gust effect factor for flexible $\omega \leq 1$, or dynamically sensitive buildings calculated using natural frequency

71

Per 6.5.8.2

Structure characteristics



Floors: 4-inch concrete slab….50 psf

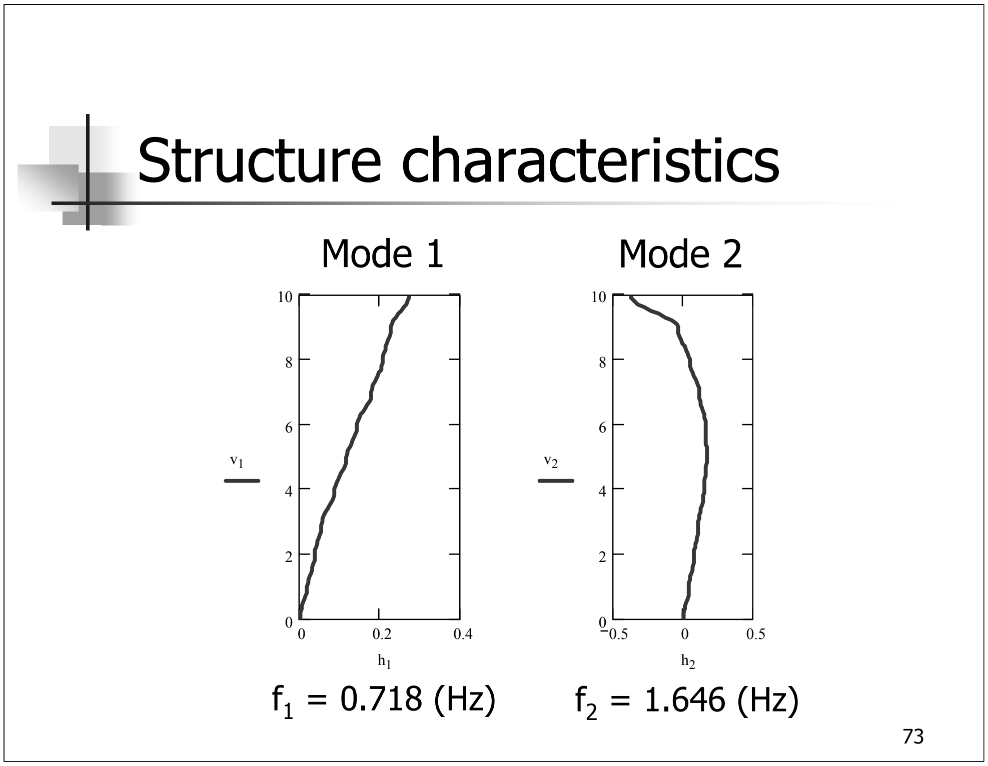
Framing: Roof………………………..85 psf
Levels 8, 9, and 10…..90 psf
Levels 5,6 and 7……..100 psf
Levels 2,3 and 4……..110 psf

Live loads at each level:
Roof………………………..20 psf
All floors…………………35 psf

72

10 story building modeled to calculate natural frequency and modes of building.

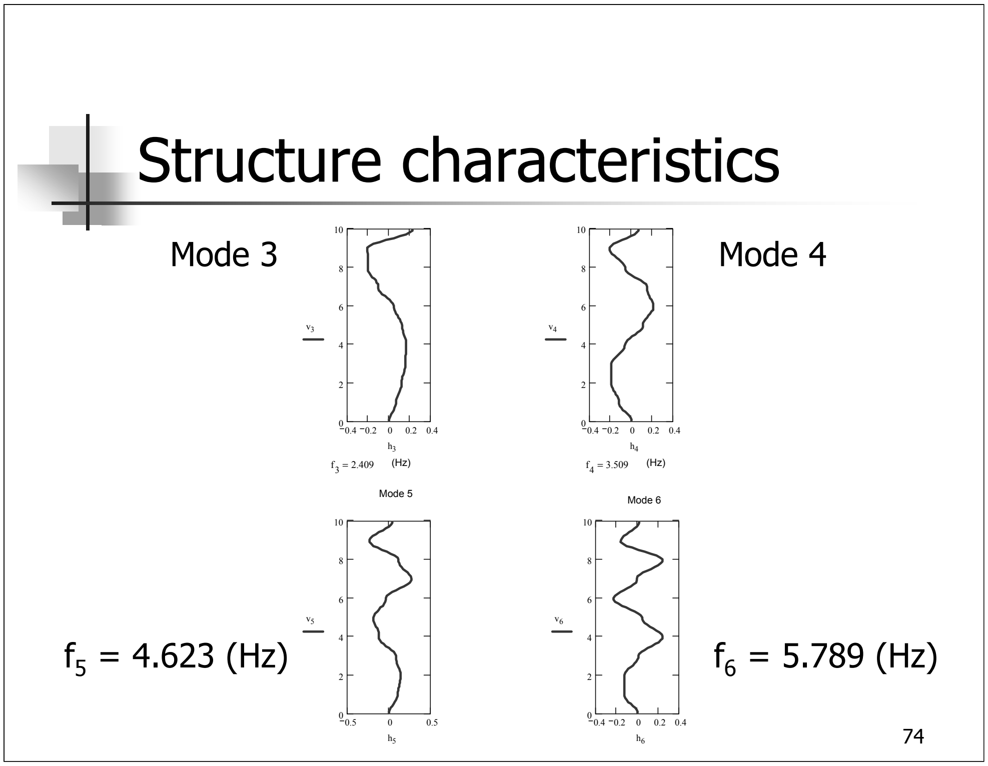
- Steel framed, moment resisting structure made with 50 ksi yield steel.
- 96 × 96 feet in plan and 120 feet tall.
- Total plan area is 9216 square feet per floor.
- Main structural framing consists of W shapes.
- 25 columns per level, 5 per row each direction spaced at 24 feet apart.
- Mass at each floor level is considered as a 4 inch concrete slab for the floor estimated at 50 pounds per square foot.
- Framing structure is estimated:
    - 85 psf for the roof structure
    - 90 psf for levels 8,9 and 10
    - 100 psf for levels 5,6 and 7
    - 110 psf for levels 2,3 and 4
- Dead weight is reduced from the ground up to account for diminishing weight of the columns as they are reduced in size.
- All other loads are equal for each floor.
- This structural weight includes the framing for each floor and the roof and half of each column above and below each floor.
- Live loads applied to each level are 20 psf for the roof and 35 psf for the remaining floors.



First and second modal shapes and natural frequencies of 10 story building.

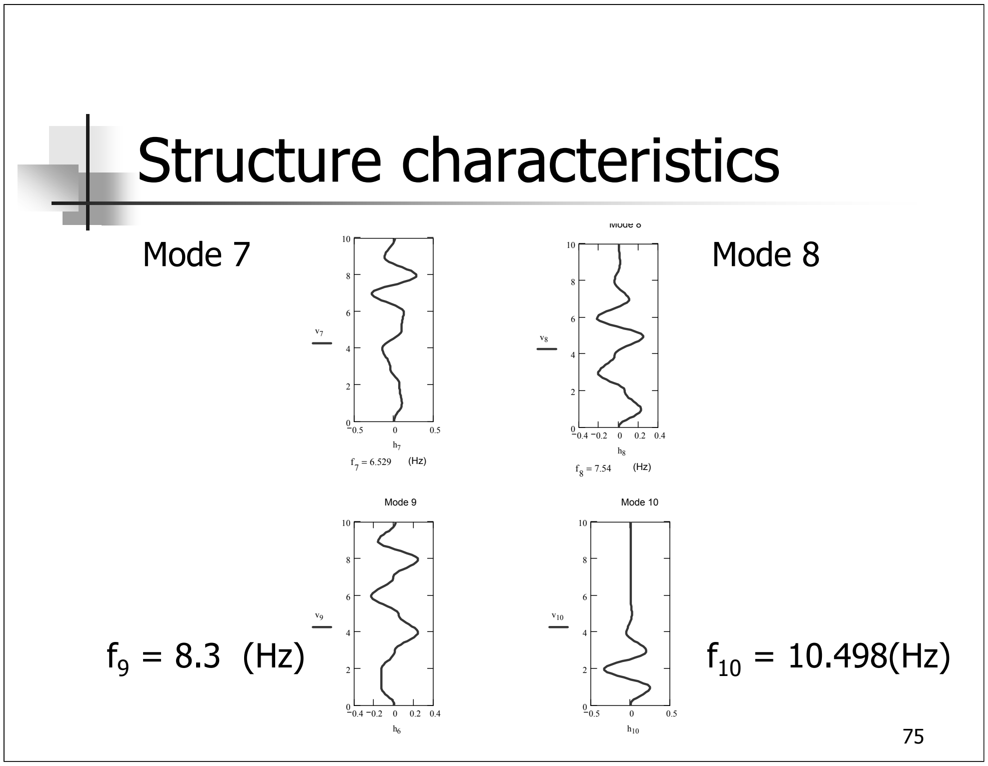
First mode models typical building behavior in wind.

Other modes used for earthquake analysis.



Third through sixth modal shapes and natural frequencies.

Actual shapes building oscillates at if excited at that natural frequency.



Seventh through tenth modal shapes and natural frequencies.

Structure characteristics

How could natural frequency be increased to make rigid structure if desired?

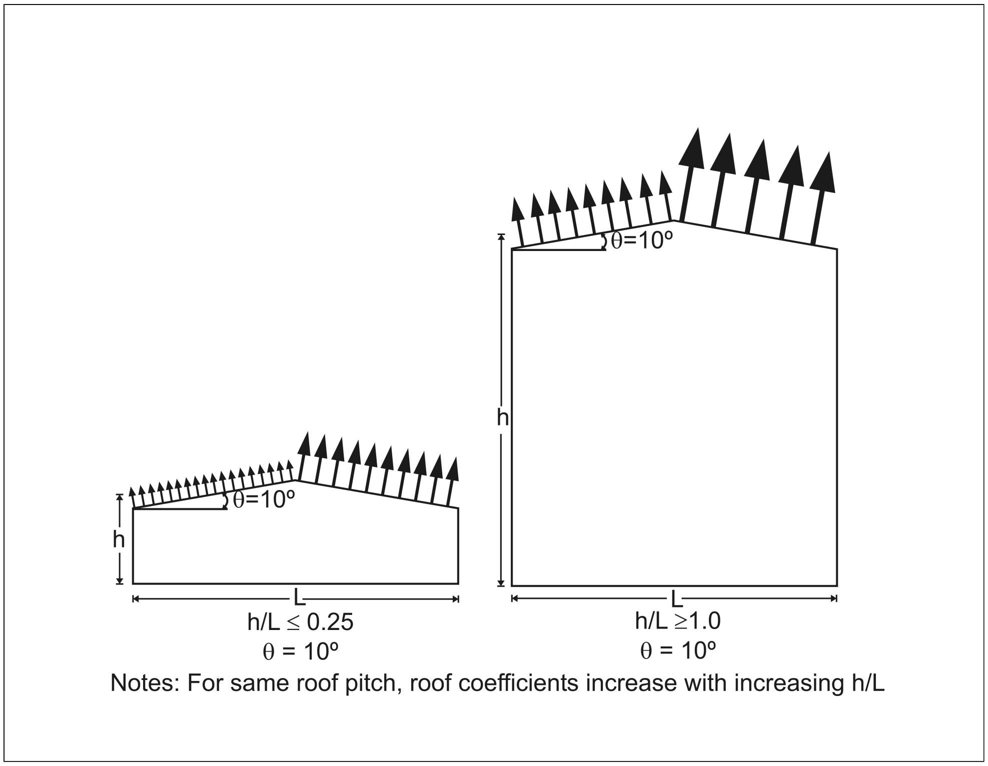
$$\omega = \sqrt{\frac{k}{m}}$$

First mode natural frequency is 0.718 Hz, therefore it is a flexible structure.

To increase natural frequency either increase column stiffness or reduce mass.

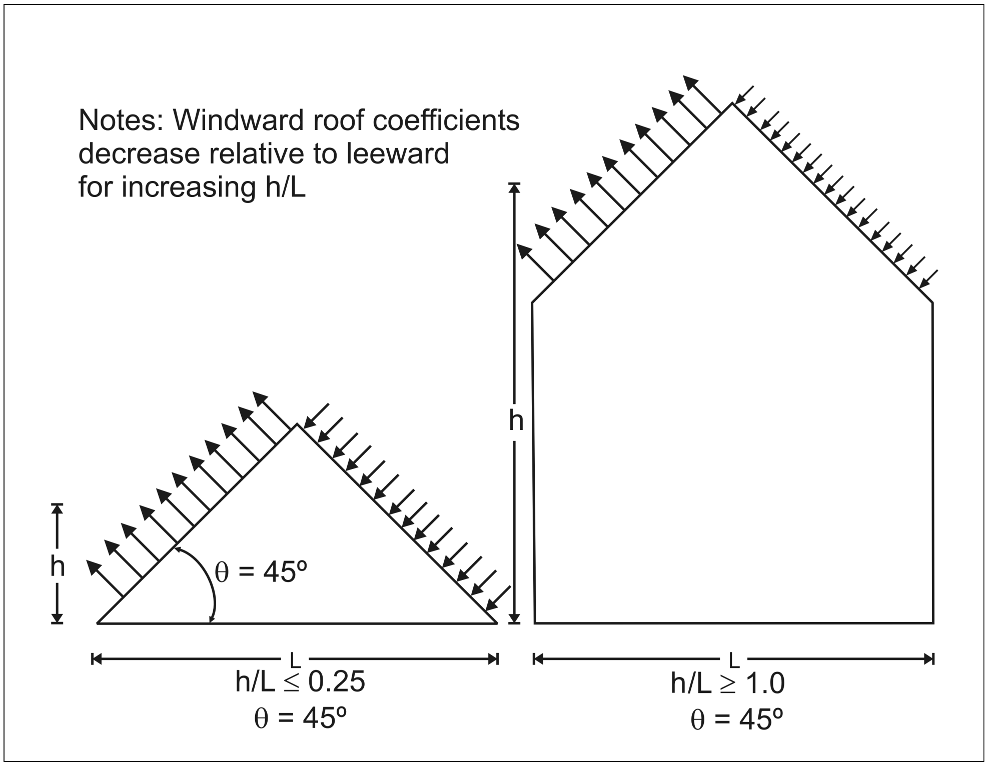
Wind/Structure interaction

The following five slides are graphical representations of the values in ASCE 7 Figures 6-3 and 6-4, Main Wind Force Resisting System coefficients showing the relative changes of C_p and GC_{pf} roof and wall coefficients with changes in building geometry.



Graphical representation of Figure 6-3 of ASCE 7-98.

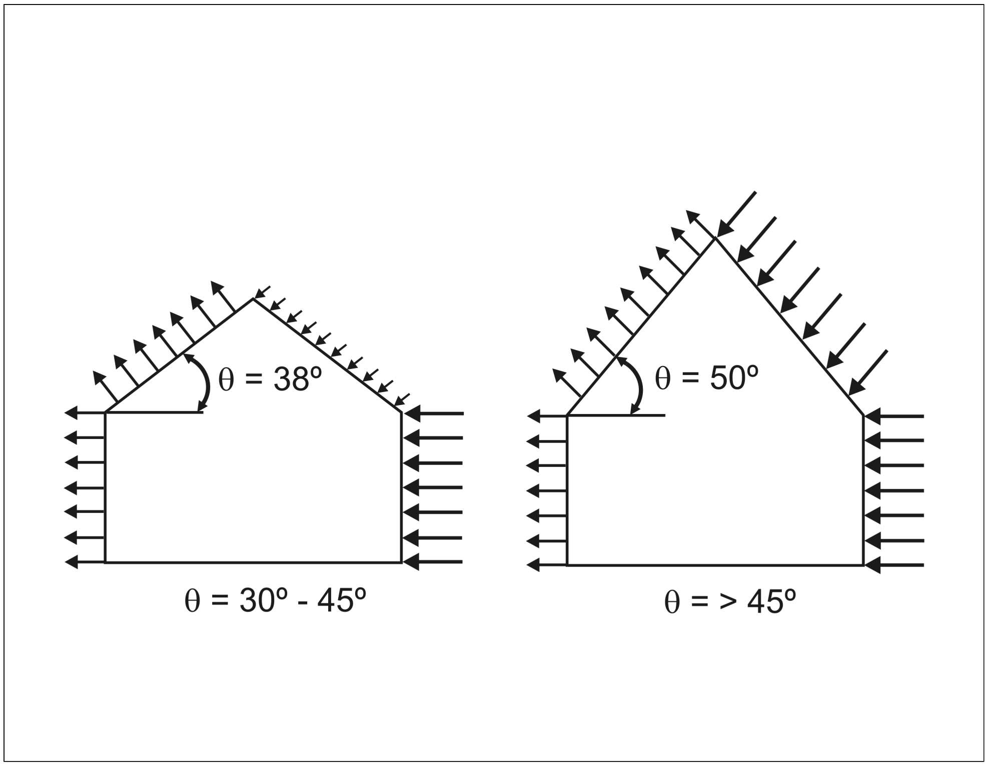
Roof pitch less than or equal to 30 degrees.



Graphical representation of Figure 6-3 of ASCE 7-98.

Roof pitch of 45 degrees.

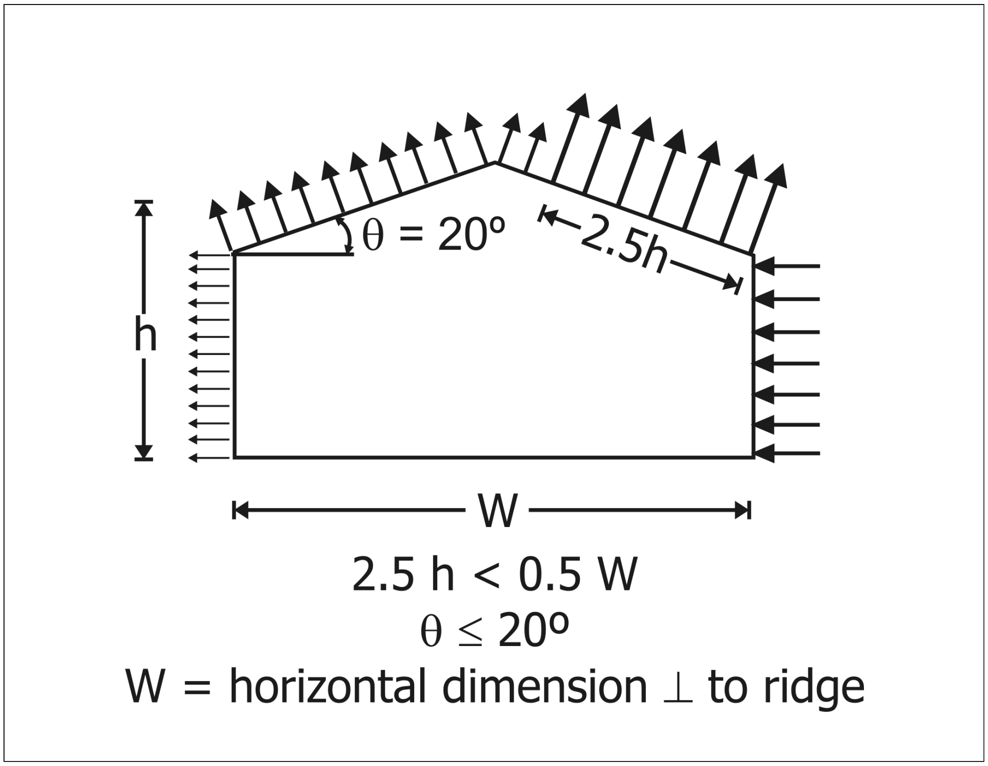
Changing *h*/L.



Graphical representation of Figure 6-3 of ASCE 7-98.

As roof pitch increases, windward roof coefficient C_p increases relative to leeward.

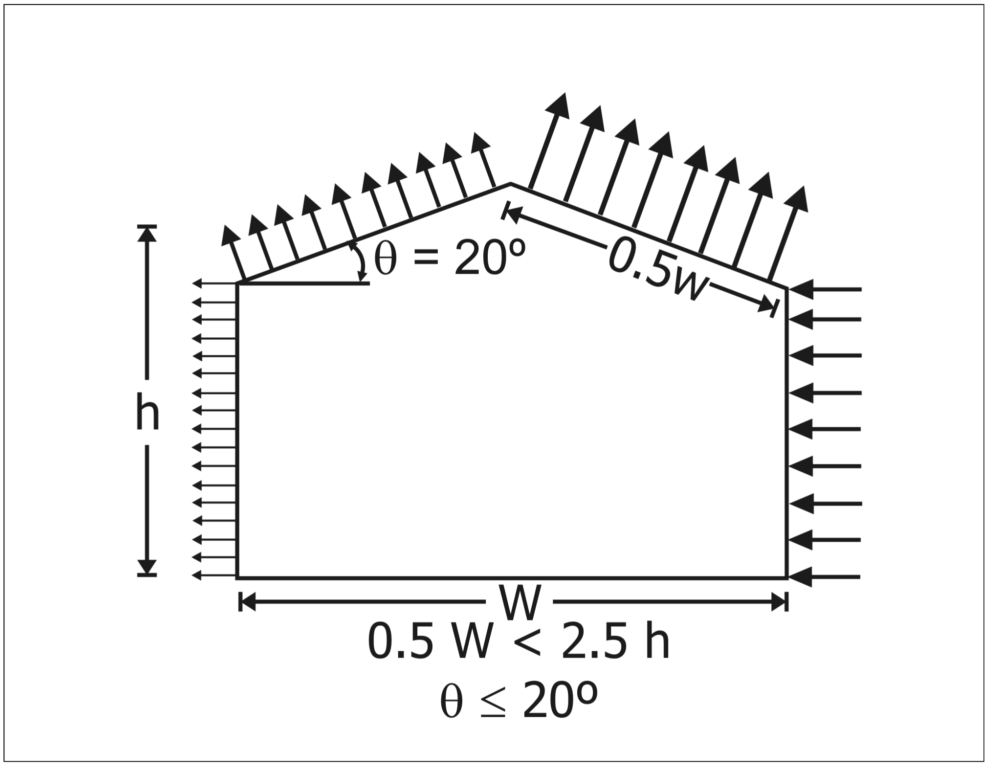
Windward wall coefficients relative to leeward.



Graphical representation of Figure 6-4 of ASCE 7-98.

Roof pressure coefficient GC_{pf}, when negative in zone 2, applies only for distance of 2.5 h from windward eave when 2.5 *h* is less than 0.5 W. Zone 3 coefficient applies for remainder of windward side of roof.

Relative windward/leeward wall coefficients.



Graphical representation of Figure 6-4 of ASCE 7-98.

Roof pressure coefficient GC_{pf}, when negative in zone 2, applies for distance of 0.5 W from windward eave when 0.5 W is less than 2.5 *h*. Zone 3 coefficient applies for remainder of windward side of roof.

Relative windward/leeward wall coefficients

Carport Analysis

83

Carport Analysis: CoolShades carport

Coolshades
3800 NW 32 Ave
Miami FL 33142

Survived 2004 hurricane season very well. Company received no reports of failures.

- All components designed to FBC 2001
- Frame designed to LRFD, Second Edition, 1998
- Materials used in canopy have yield strength of at least 43.5 ksi
- Arc-welded steel pipe frame: 8" diameter, 0.2" thick; 2.5" diameter, 0.2" thick; 2.3" diameter, 0.12" thick
- Frame designed to 146 mph wind with cover removed
- Awnings 'quick removal' for winds in excess of 110 mph
- Footing diameter: 36"; depth: 6' 6"
- ASTM 325 galvanized fasteners

Carport Analysis

84

Carport Analysis

Carport Analysis

85

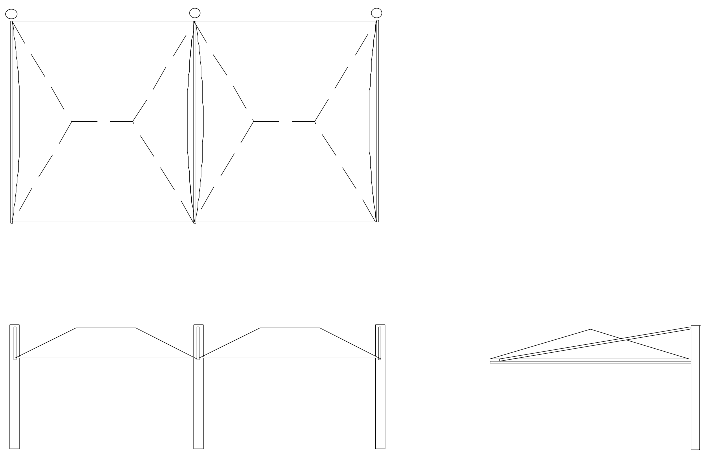
Carport Analysis

Carport Analysis

86

Carport Analysis

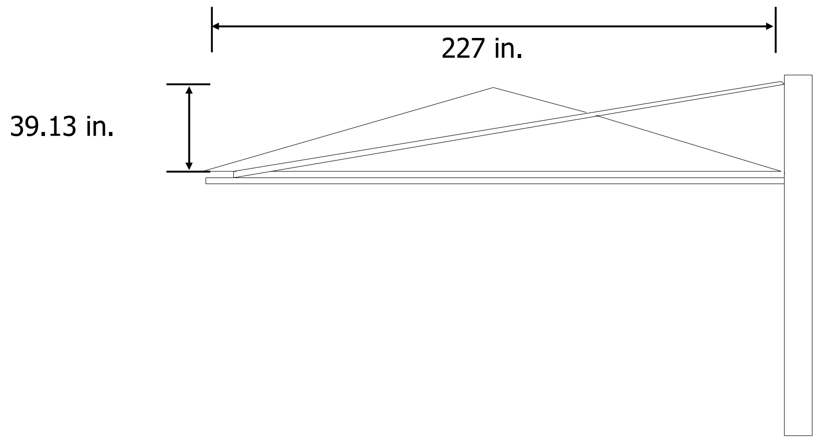
Carport Analysis



87

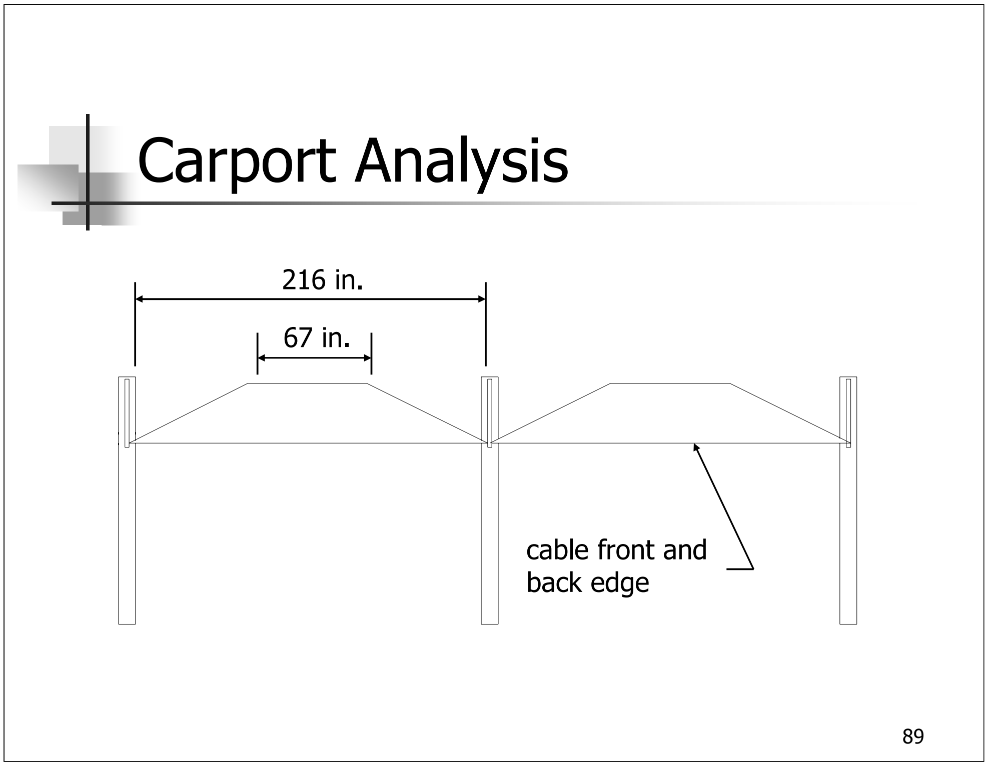
Carport Analysis

Carport Analysis

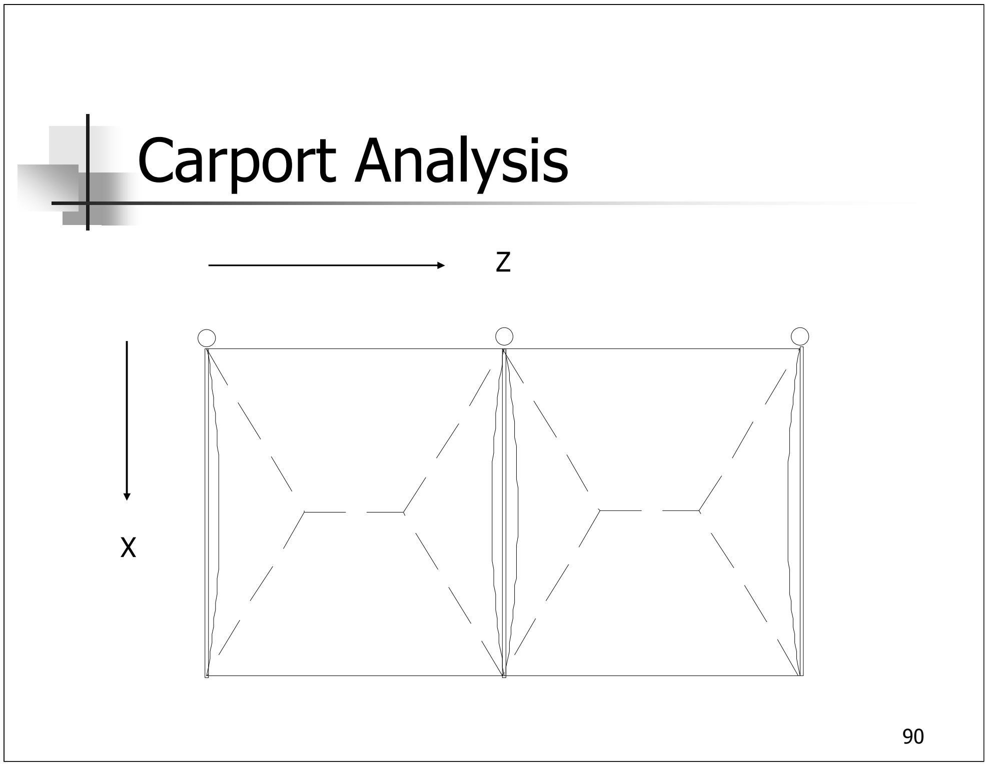


88

Carport Analysis



Carport Analysis



Carport Analysis

Carport Analysis

Carport designed for 110 mph winds with awning in place

G = 0.85 – Lowest natural frequency is 15 Hz

Analyze as solid sign:

M/N = (216/39.13) = 5.8 is less than 6 – X direction

M/N = (227/39.13) = 5.5 is less than 6 – Z direction

therefore C_f =1.2 Table 6 - 11

I = 0.77 Table 6 - 1

Category C

91

Analysis per ASCE 7

Awning is easily removable if winds expected to exceed 110 mph.

0.77 importance factor is used for category I buildings (storage sheds, agricultural buildings etc) which pose low risk to human life destroyed.

Carport Analysis

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

K_z = 0.85   Table 6.5

K_d = 0.85   Table 6.6

K_{zt} = 1   No topographic effects

92

Analysis per ASCE 7

Awning is easily removable if winds expected to exceed 110 mph.

Carport Analysis

q_z = 17.23 psf

93

Carport Analysis

Carport Analysis

$$F = q\ GC_f A_f$$

94

Carport Analysis

Equation 6-20

F = force on structure. q, in pounds per square foot × area in square feet yields F in pounds

q = velocity pressure evaluated at height z of centroid of area A_f

G = Gust effect factor

C_f = net force coefficient from Figures 6-8 through 6-22

A_f = projected area normal to the wind except where C_f is specified for the actual surface area. In square feet.

Carport Analysis

$$A_f = \frac{227}{2} \times 39.13$$

$= 4440\ in^2 = 30.83\ ft^2$ in Z direction

$$A_f = \frac{67 + 216}{2} \times 39.13$$

$= 5601\ in^2 = 38.9\ ft^2$ in X direction

95

Carport Analysis

Carport Analysis

F = 674 #   X direction

F = 542 #   Z direction

96

Carport Analysis

Equation 6-20

Force equals 674 pounds when 110 mph wind is blowing in the X or -X direction

Force equals 542 pounds when 110 mph wind is blowing in the Z or -Z direction

Carport Analysis

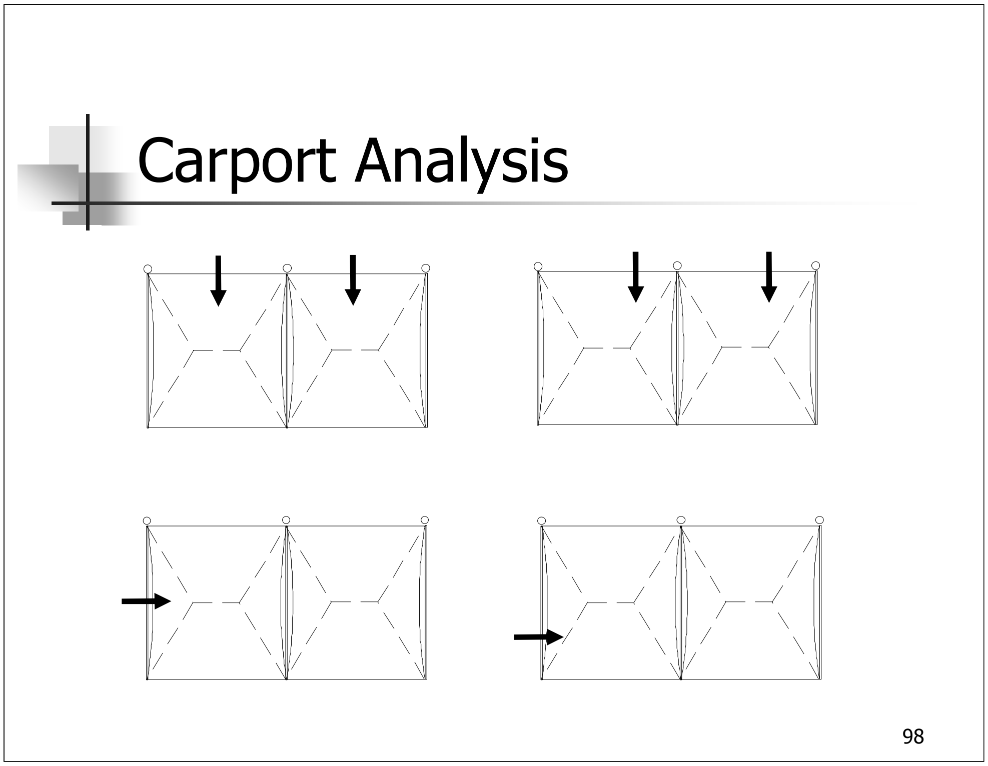
Force is applied at geometric center and at 20% offset from geometric center

For each wind direction:

- $0.20 \times 227'' = 45''$ offset from geometric center
- $0.20 \times 216'' = 43''$ offset from geometric center

97

Carport Analysis



Carport Analysis

Forces also applied in the opposite direction and on the opposite side of the geometric center.

Residential Home

Wind Load Analysis
of Residential Home

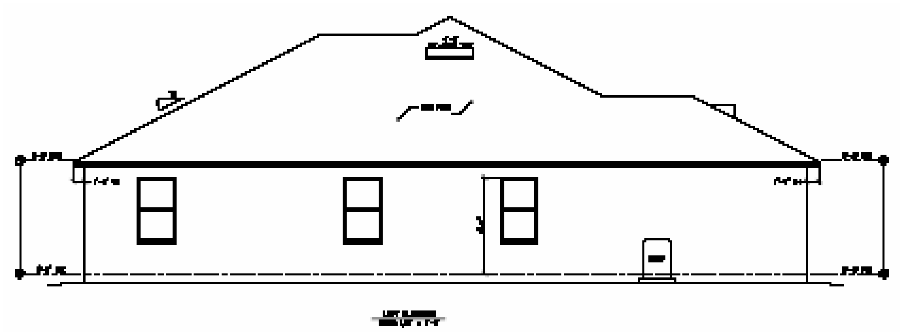
99

Residential Home

100

Front elevation

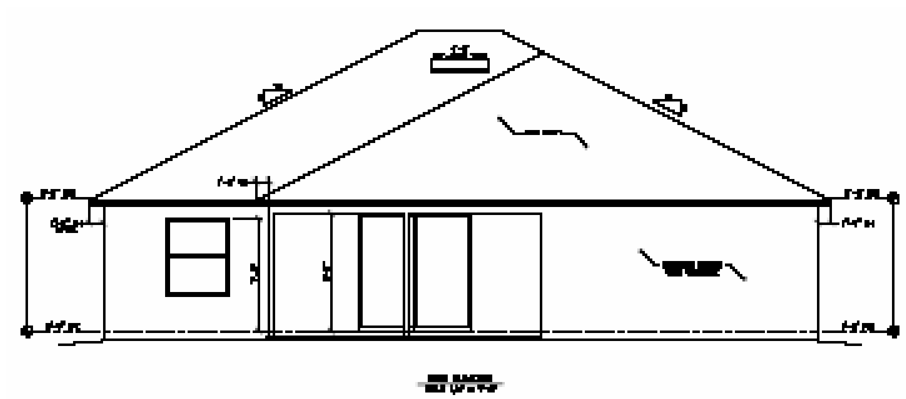
Residential Home



101

Left elevation

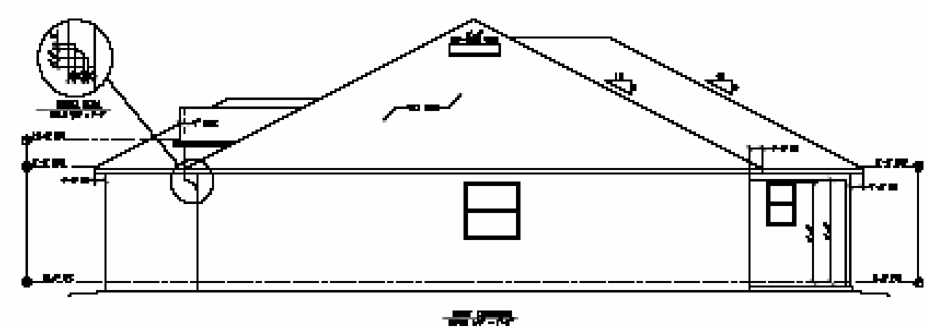
Residential Home



102

Rear elevation

Residential Home



103

Right elevation

Residential Home

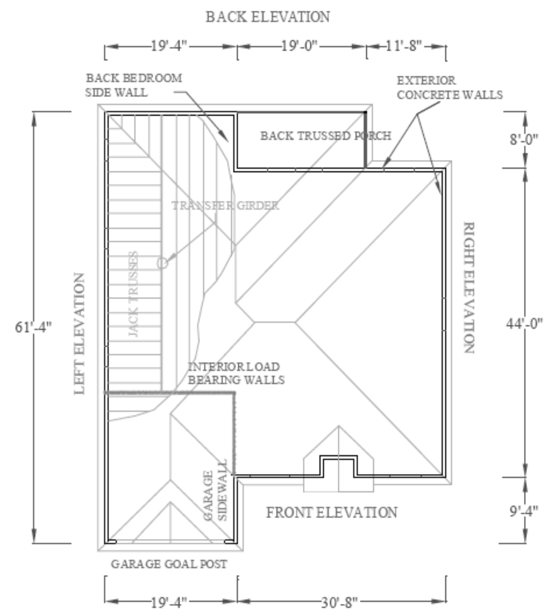
Building location:	Brevard County, FL
Building use:	Residential single-family
Building description:	3-bedroom

Structure shall be considered enclosed and located in Exposure C category

Improved hurricane-resistant design using continuous-poured concrete wall

104

Residential Home



Plan view

Residential Home

Velocity Pressure Exposure Coefficient

Section 6.5.6.4, Table 6-5

$K_z := 0.85$

Topographic Factor

Section 6.5.7.2, Figure 6-2

No escarpment

$K_1 := 0$, $K_2 = 0$, $K_3=0$

$K_{zt} := (1 + K_1 K_2 K_3)^2$

$K_{zt} = 1$

106

Please note that this example problem uses MathCad programming notation.

Residential Home

Wind Directionality Factor

Section 6.5.4.4, Table 6-6

$K_d := 0.83$

Importance Factor

Section 6.5.5, Table 6-1

Category II

$I := 1.0$

Basic Wind Speed: Fig 6-1b

$V := 125$ mph

107

Residential Home

Define units

$$psf := 1\frac{lbf}{ft^2}$$

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

$$q_z = 28.9\ psf$$

Section 6.5.6.3 states that for buildings with $h \leq 60$ feet, components and cladding shall be designed using a velocity pressure q_h.

$$q_h := q_z$$

108

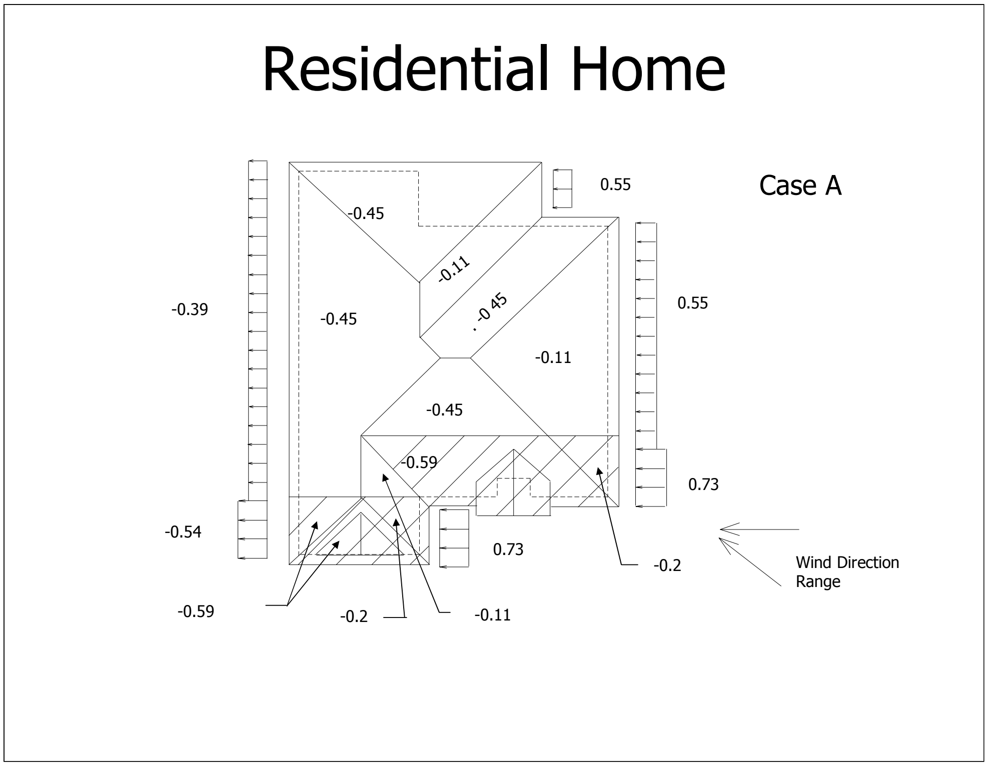
Residential Home

Main Wind Force Resisting System

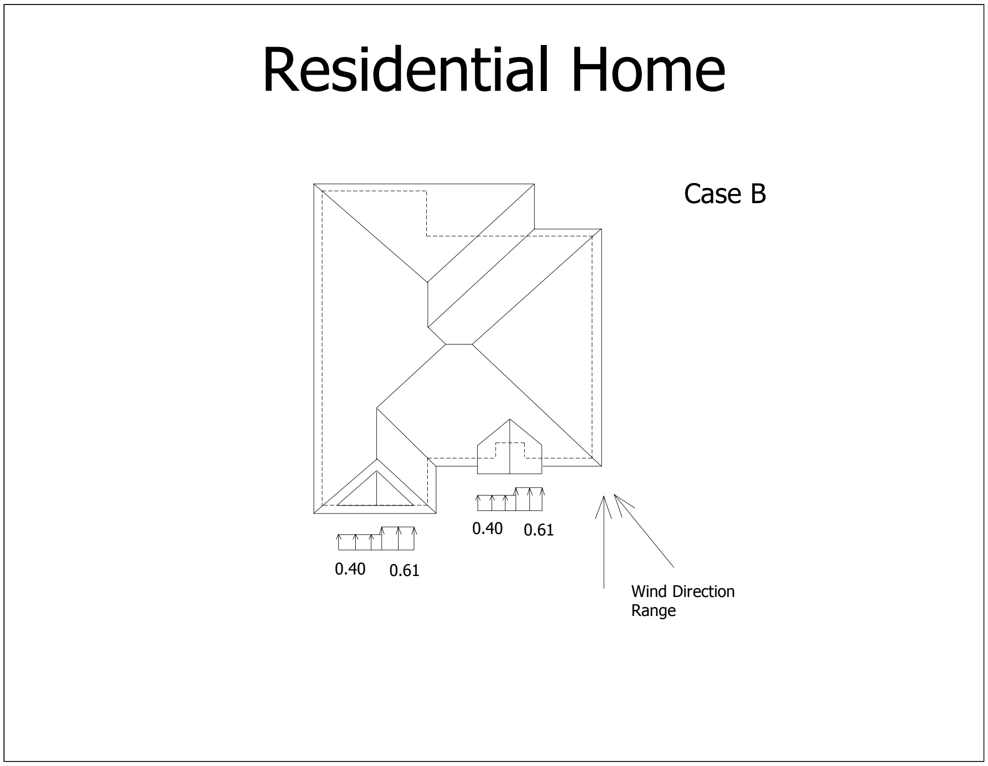
- GC_{pf} external pressure from Figure 6-4
- Roof angle = 26.5º
- Interpolation used for obtaining GC_{pf}
- Case A valid for all side elevations (hip roof)
- Case B valid for garage and front entrance

109

Case A valid for all side elevation because building has hip roof.



External pressure coefficients interpolated from Figure 6-4 for MWFRS Case A.



External pressure coefficients interpolated from Figure 6-4 for MWFRS Case B.

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Determine value for "a" using Note 7 of Figure 6-4

To simplify the procedure and to be conservative, the "a" value that will be used for the common living area (interior square) shall be the same as that used on the trussed porch and garage.

$h_d := 44$

$height := 14.5$

$a_p := \min(0.1\, h_d, 0.4\ \text{height})$

$a := \max(a_p, 0.04\, h_d, 3)$

a = 4.4 ft

112

Residential Home

Diaphragm and Shear Walls

The external wind pressure coefficients are used to determine the wind pressures that are applied to the shear walls and diaphragm. Internal pressures cancel.

$GC_{pf} := 0.61$

$p := q_h \, GCp_f$

$p = 17.629$ psf

113

Typical calculation for determining design pressures.

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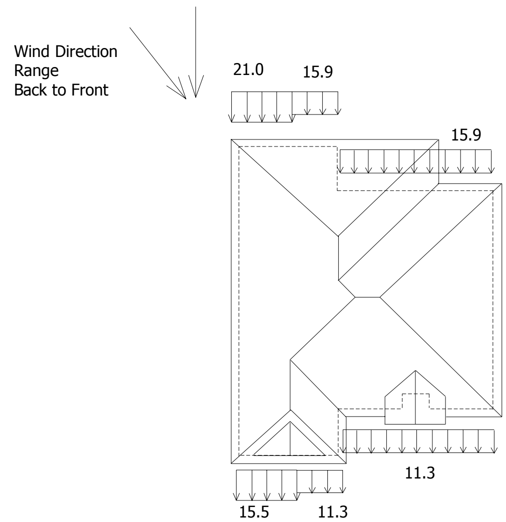
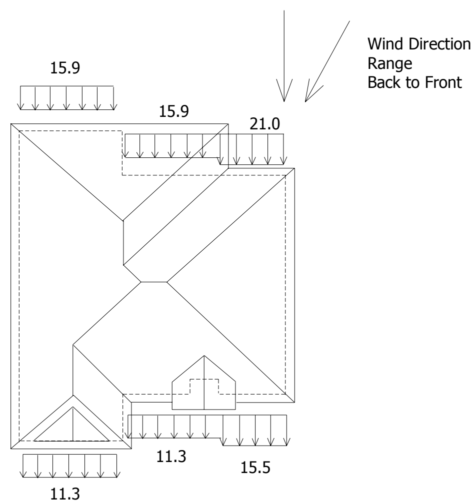


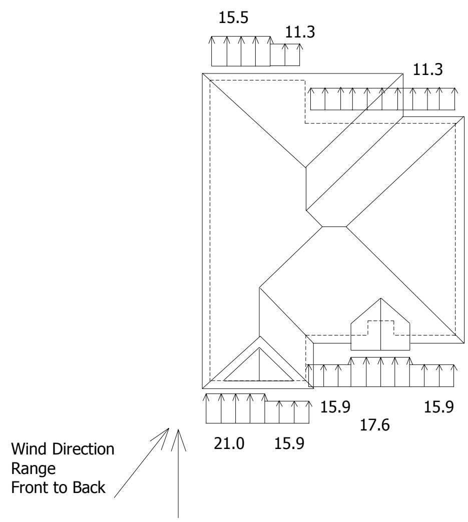
Design pressures applied to exterior walls

Residential Home



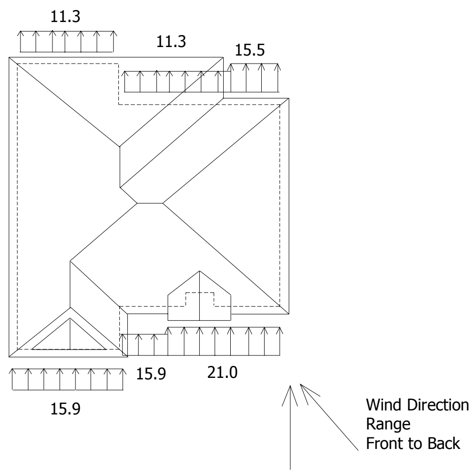
Design pressures applied to exterior walls

Residential Home



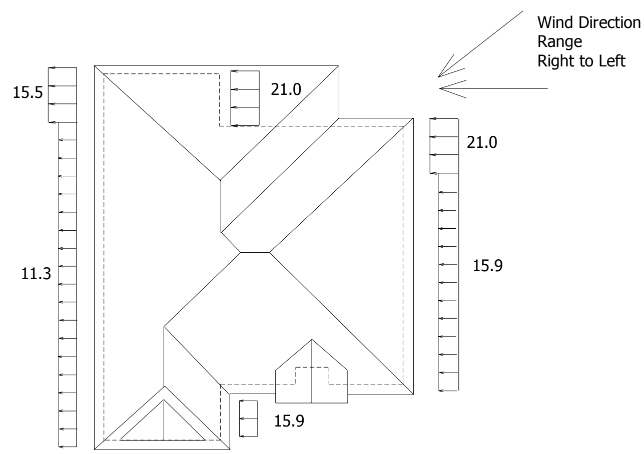
Design pressures applied to exterior walls

Residential Home



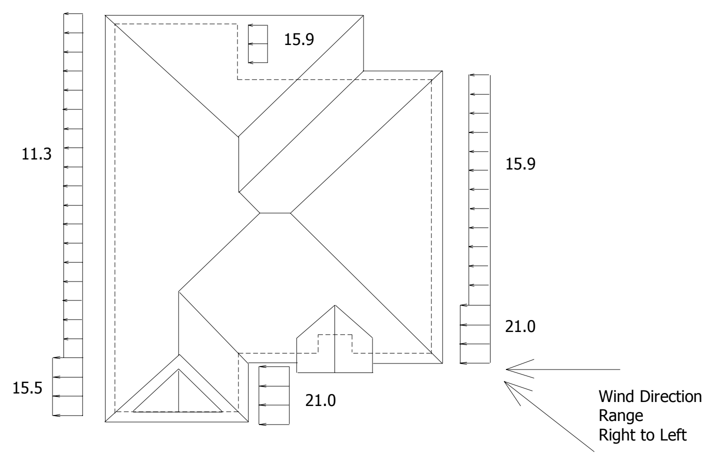
Design pressures applied to exterior walls

Residential Home



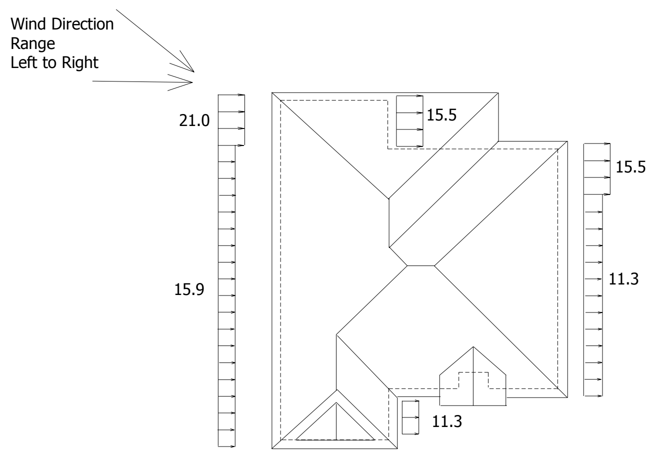
Design pressures applied to exterior walls

Residential Home



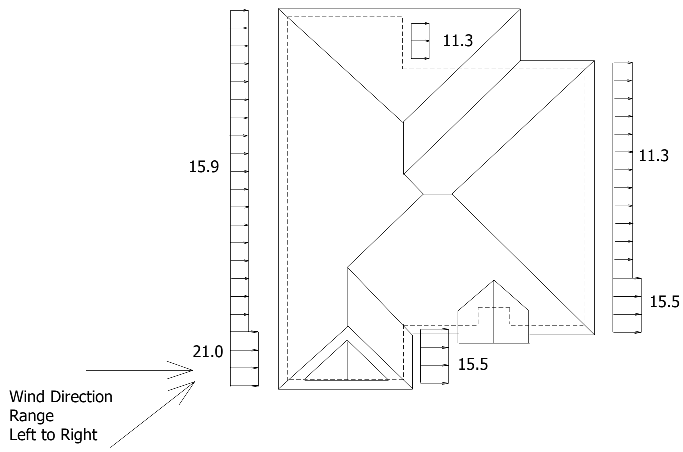
Design pressures applied to exterior walls

Residential Home



Design pressures applied to exterior walls

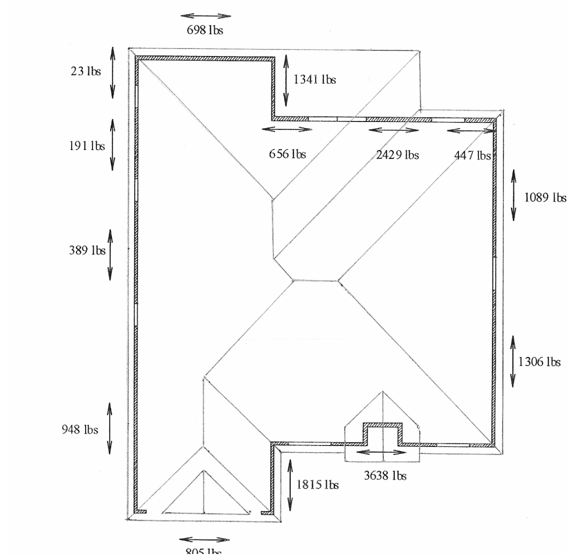
Residential Home



Design pressures applied to exterior walls

Residential Home

Figure 6 Shear forces applied to the walls of the project structure



Shear forces applied to exterior walls

Residential Home

Bearing walls as part of MWFRS

Bearing wall analysis requires use of internal pressure coefficient

GC_{pi} := -0.18 (from Table 6-7)
GC_{pipos} := 0.18 (from Table 6-7)

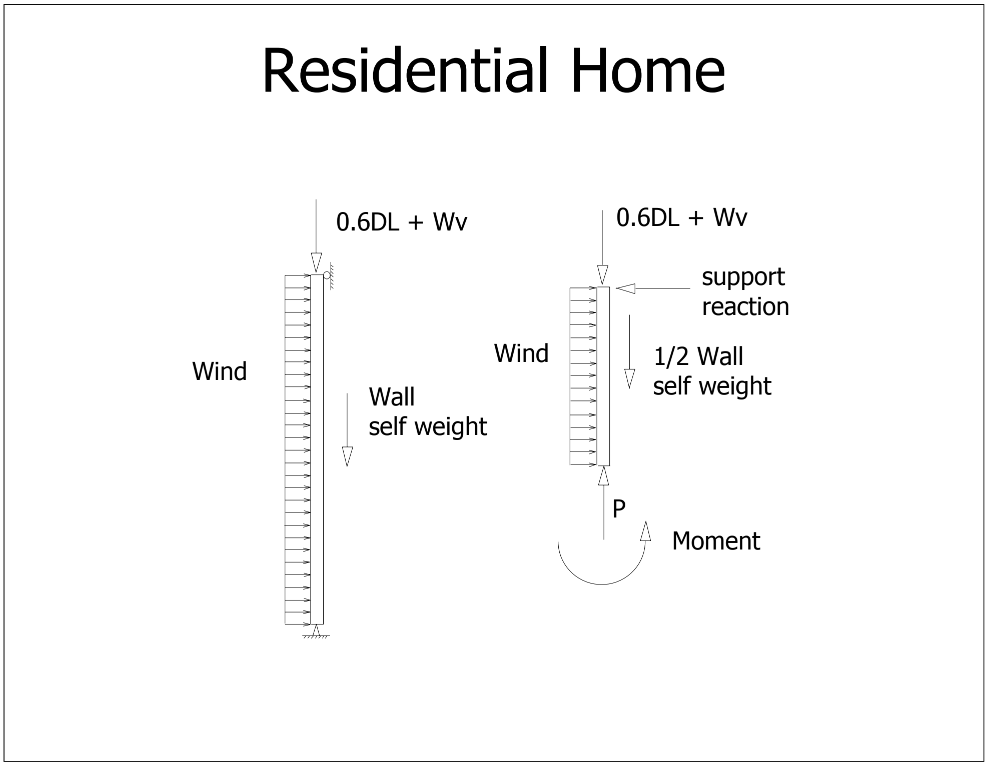
Maximum tension: $(-0.586 + GC_{pi})q_h$ = -22.137 psf

Moment associated with maximum tension: $(-0.536 + GC_{pi})q_h$ = -20.692 psf

Maximum moment: $(-0.728 + GC_{pi})q_h$ = -26.241 psf

Tension associated with maximum moment: $(0.20 - GC_{pipos})q_h$ = 0.578 psf

123



Application of wind load to wall/roof for bearing wall analysis

W_v = Vertical wind load on roof

P = Vertical reaction

DL = Dead load of structure

Residential Home

Components and Cladding

GC_p external pressure coefficients: Figures 6-5 through 6-7

Roof sheathing: Figure 6-5B (Hip roof at 26.5 deg.)

Effective Wind Area (EWA) taken as nailing pattern of sheathing

$EWA_r := 6\ in \times 12\ in$

$EWA_r = 0.5\ ft^2$

125

Residential Home

- GC_p = -2.1, +0.5 for corners
- GC_p = -0.9, +0.5 for interior of sloped face
- GC_p = -2.1, +0.5 for edges of sloped face
- Roof overhang of structure = 1 foot
- GC_p = -2.2 along edges
- GC_p = -3.7 at corners

126

Residential Home

Roof corners	$p_{rc} := (-2.1 + GC_{pi})q_h$	p_{rc} = - 65.892	Upward on 4.4' × 4.4' corners of roof (including peaks of gables)
Roof interior	$p_{ri} := (-0.9 + GC_{pi})q_h$	p_r = -31.212	Upward on interior of sloped faces
Roof end zones	$p_{re} := (-2.1 + GC_{pi})q_h$	p_{re} = -65.892	Upward on 4.4' end zones of sloped face
Entire roof	$p_r := (0.5 + GC_{pipos})q_h$	p_r = 19.652	Downward on entire roof
Overhang end zones	$p_{oe} := (-2.2 + GC_{pi})q_h$	p_{oe} = -68.782	Upward on end zones of 1' overhang
Overhang corners	$p_{oc} := (-3.7 + GC_{pi})q_h$	p_{oc} = -112.132	Upward on 1' × 1' corner of overhang

Residential Home

Reinforced Concrete Walls

Figure 6-5A

$EWA_w := 9\ ft \times \frac{9\ ft}{3}$

$EWA_w = 27\ ft^2$

GC_p = -1.2, +0.95 for corners

GC_p = -1.0, +0.95 for interior

$P_{wc} := (-1.2 + GC_{pi})q_h$

P_{wc} = -39.882 psf wind pressure on walls near corners

$P_{wc} := (-1.0 + GC_{pi})q_h$

P_{wc} = -34.102 psf wind pressure on interior walls

128

Effective Wind Area shall be taken as the span length multiplied by an effective width that need not be less than one-third the span length.

Residential Home

Roof trusses as Components and Cladding

Interior trusses:	$645\ ft^2 > 100\ ft^2$
Trusses along right and left sides:	$21\ ft^2$
Trusses above garage and porch:	$125\ ft^2 > 100\ ft^2$

129

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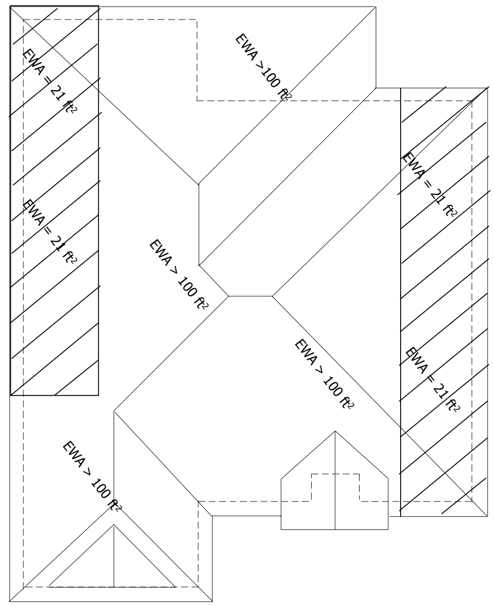


Effective Wind Area of pre-engineered roof trusses.

Residential Home

EWA = 21 ft²

$p_{2li} := (-0.85 + GC_{pi})\ q_h$	$p_{2li} = -29.767$	Upward on interior tributary area affecting trusses
$p_{2le} := (-1.9 + GC_{pi})\ q_h$	$p_{2le} = -60.112$	Upward on end zones and peaks
$p_{2lc} := (-3.3 + GC_{pi})\ q_h$	$p_{2lc} = -100.572$	Upward on corners (part of overhang)
$p_{21a} := (0.43 + GC_{pipos})\ q_h$	$p_{21a} = 17.629$	Downward on all parts of EWA = 21 ft²

Residential Home

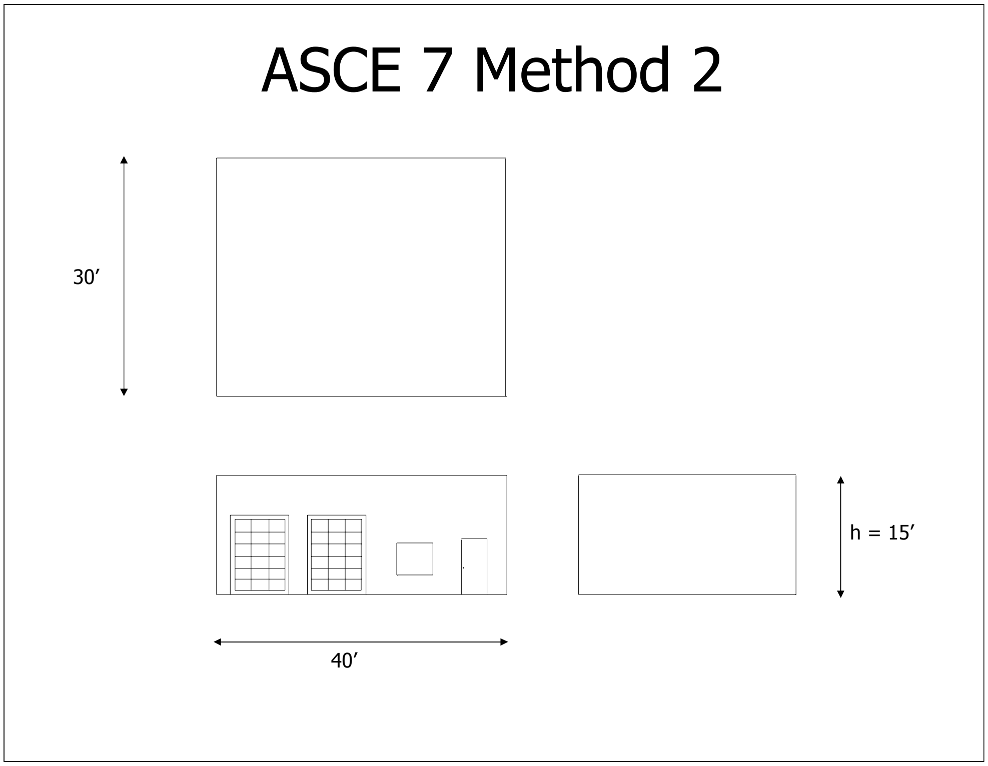
EWA > 100 ft^2

$p_{100i} := (-0.8 + GC_{pi})\ q_h$	$p_{100i} = -28.322$	Upward on interior entry roof area affecting trusses
$p_{100e} := (-1.4 + GC_{pi})\ q_h$	$p_{100e} = -45.662$	Upward on end zones and peaks of roof areas
$p_{100c} := (-1.4 + GC_{pi})\ q_h$	$p_{100c} = -45.662$	Upward on corners
$p_{100a} := (0.3 + GC_{pipos})\ q_h$	$p_{100a} = 13.872$	Downward on all parts of EWA > 100 ft^2

ASCE 7 Method 2

Example wind load analysis of a low rise structure:

A fire station located in Melbourne Beach, Florida



Roof joists spanning 30 feet, spaced 5 feet on center

Metal roof panels, 20 feet long

Glazing is impact resistant

CMU walls

ASCE 7 Method 2

Example of ASCE Method 2

Basic wind speed *V* __________

Exposure category __________

Building classification
– I Importance Factor __________

Enclosure classification __________

135

Basic wind speed from Figure 6-1 (page 227 in Appendix) per Section 6.5.4

Exposure category per Section 6.5.6

Building classification importance factor I from Table 6-1 based on Table 1-1, per Section 6.5.5

q = q_z for windward walls evaluated at height z above the ground

q = q_h for leeward walls, side walls, and roofs evaluated at height h

q_i = q_h for windward walls, side walls, leeward walls, and roofs of enclosed buildings

ASCE 7 Method 2

Velocity Pressure

$q =$ ________

q_z, q_h, and $q_i = q$, for h = 15 feet

137

$q = q_z$ for windward walls evaluated at height z above the ground

$q = q_h$ for leeward walls, side walls, and roofs evaluated at height h

$q_i = q_h$ for windward walls, side walls, leeward walls, and roofs of enclosed buildings

q_z, q_h, and $q_i = q$ for h = 0 to 15 feet and for enclosed building

ASCE 7 Method 2

Gust effect factor – *G*

$$G = 0.925\left(\frac{(1 + 1.7 g_q I_{\bar{z}} Q)}{1 + 1.7 g_v I_{\bar{z}}}\right)$$

$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6}$$

138

$I_{\bar{z}}$ is intensity of turbulence at height $\bar{z}$.

$\bar{z}$ is the equivalent height of the structure defined as 0.6 h but not less than z_{min} for all building heights h

z_{min} and c listed in Table 6-4 (page 241 in Appendix)

g_Q and g_v taken as 3.4

ASCE 7 Method 2

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

$$L_{\bar{z}} = l\left(\frac{\bar{z}}{33}\right)^{\bar{\varepsilon}}$$

139

B and *h* are defined in Section 6.3

$L_{\bar{z}}$ is the integral length scale of turbulence at the equivalent height

l, $\bar{\epsilon}$, and $\bar{z}$ from Table 6-4 (page 241 in Appendix)

ASCE 7 Method 2

G = _________

Internal pressure coefficient

GC_{pi} = _________

140

GC_{pi} determined per Table 6-7 (page 244 in Appendix)

ASCE 7 Method 2

Wind pressures – MWFRS

Buildings of all heights

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

141

Wind pressure determined per equation 6-15 for buildings of all heights.

ASCE 7 Method 2

External pressure coefficients — MWFRS

Windward Wall C_p ________

Side Wall C_p ________

142

C_p external pressure coefficients per Table 6-3 (pages 239–40 in Appendix)

ASCE 7 Method 2

External pressure coefficients — MWFRS

Leeward Wall

L/B = 0.75 Wind parallel to 30' C_p ________

L/B = 1.33 Wind parallel to 40' C_p ________

143

C_p external pressure coefficients per Table 6-3 (pages 239–40 in Appendix)

ASCE 7 Method 2

Roof pressure coefficients — MWFRS

h/L = _____ h/L = _____

C_p

0 to h _____ h to 2h _____ >2h _____

144

ASCE 7 Method 2

MWFRS Pressures

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

145

ASCE 7 Method 2

Windward wall p = _____±____ psf

Side wall p = _____±____ psf

Leeward wall p = _____±____ psf
wind normal to 40 ft

Leeward wall p = _____±____ psf
wind normal to 30 ft

ASCE 7 Method 2

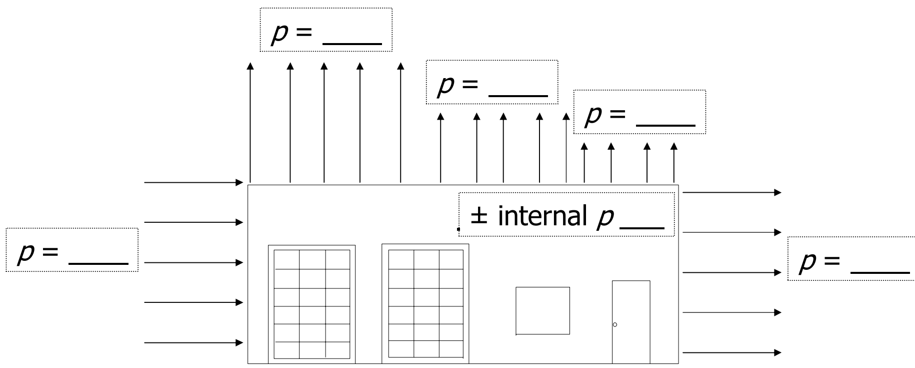
Roof 0 to 15 ft *p* = _____±____ psf

Roof 15 to 30 ft *p* = _____±____ psf

Roof >30 ft *p* = _____±____ psf

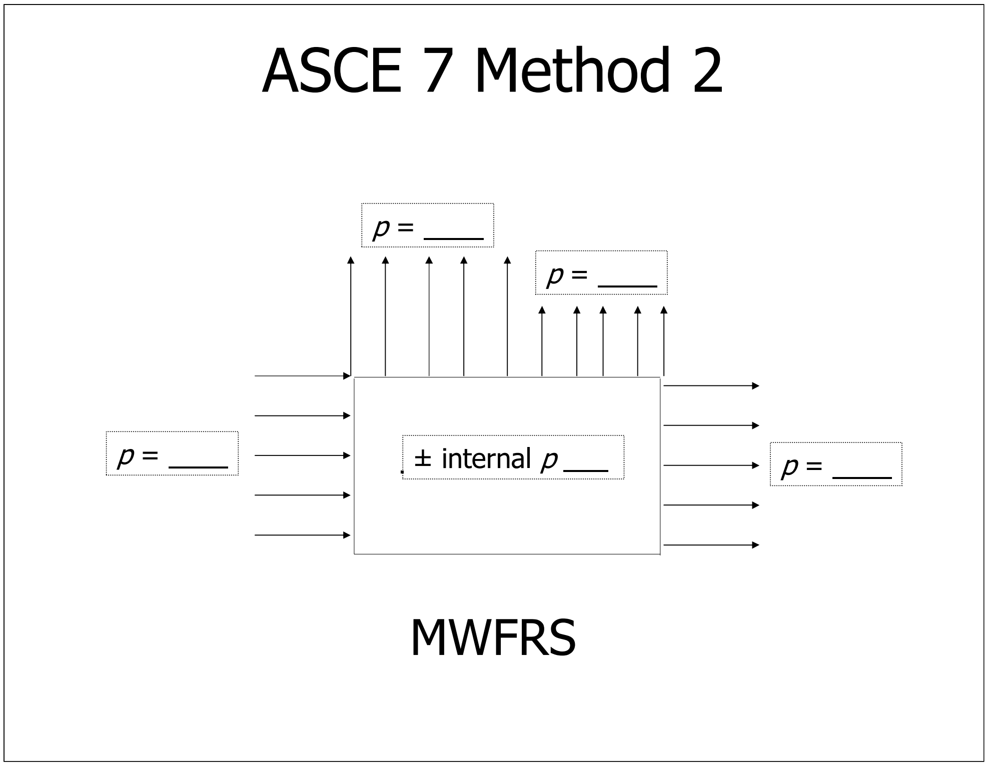
147

ASCE 7 Method 2

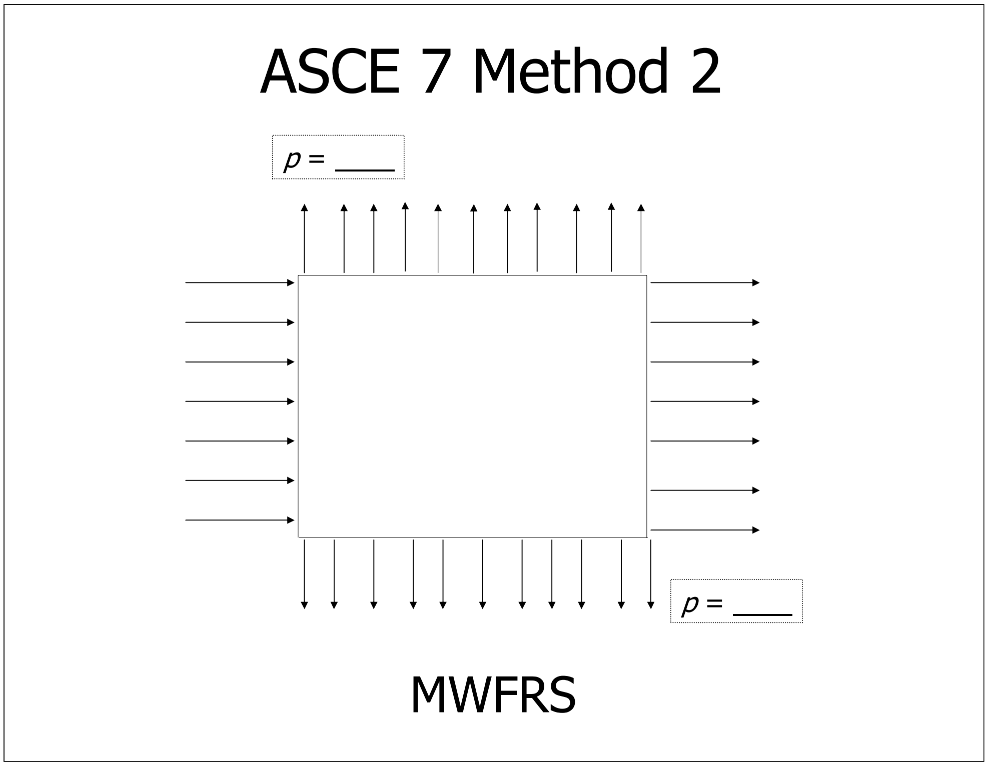


MWFRS

Pressures on windward and leeward walls and along roof for 40 foot length.



Pressures on windward and leeward walls and along roof for 30 foot length.



Pressures on sidewalls along 40 foot length

ASCE 7 Method 2

Components and Cladding (C & C) Pressures

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

for buildings with $h \leq 60$ ft

151

ASCE 7 Method 2

Components and Cladding

External pressure coefficients are a function of Effective Wind Area (EWA) and zone where component is located on building

ASCE 7 Method 2

Components and Cladding

EWA for C & C is calculated as the larger of the tributary area, or the span of the component times an effective width that need not be less than 1/3 of the span

For CMU Walls, span is the height of the wall (wall supported at roof diaphragm and foundation)

EWA = $h \times h/3$ = _____

153

ASCE 7 Method 2

Components and Cladding

EWA for roof joists = larger of:

$30 \times 5 =$ _____

$30 \times 30/3 =$ _____

154

ASCE 7 Method 2

Components and Cladding

Roof panel span is 5 feet between joists

EWA for roof panels = larger of:

5 × 2 = _____

5 × 5/3 = _____

155

ASCE 7 Method 2

Components and Cladding

Coefficients can be taken from Tables 6-5 thru 6-8 or calculated by formula (on next slide):

ASCE 7 Method 2
Components and Cladding

Wall coefficients for EWA $10 < A \leq 500$

Positive Zones 4 and 5

(GC_p) = 1.1766 – 0.1766 log A = _____

Negative Zone 4

(GC_p) = -1.2766 + 0.1766 log A = _____

Negative Zone 5

(GC_p) = -1.7532 + 0.3532 log A = _____

157

Note 5 in Figure 6-5a (page 231 in Appendix) states that pressure coefficients for walls can be reduced by 10% for buildings with roof slopes of 10 deg. or less.

Adjust coefficients in pressure equation.

ASCE 7 Method 2

Components and Cladding

Roof joist coefficients for EWA A > 100

Positive – Zones 1, 2, and 3 _____

Negative – Zone 1 _____

Negative – Zone 2 and 3 _____

158

Coefficients from Figure 6-5b (page 232 in Appendix).

ASCE 7 Method 2

Components and Cladding

Roof panel coefficients for EWA A = 10

Positive zones 1, 2, and 3 ______

Negative zone 1 ______

Negative zone 2 ______

Negative zone 3 ______

159

ASCE 7 Method 2

Components and Cladding

Width of "a" for zones 2, 3, and 5

Smaller of:

0.10 × (least horizontal dimension) = _____

<u>or</u> 0.4 *h* = _____

but not less than:

0.04 × (least horizontal dimension) = _____

<u>or</u> 3 ft = _____

160

ASCE 7 Method 2
Components and Cladding

Wall component design pressures

Zone 4

$$-p = \_\_\_\_[(\_\_\_\_)(0.9) - (\_\_\_\_)] = - \_\_\_\_\_ \text{ psf}$$

$$+p = \_\_\_\_[(\_\_\_\_)(0.9) - (\_\_\_\_)] = + \_\_\_\_\_ \text{ psf}$$

Zone 5

$$-p = \_\_\_\_[(\_\_\_\_)(0.9) - (\_\_\_\_)] = - \_\_\_\_\_ \text{ psf}$$

$$+p = \_\_\_\_[(\_\_\_\_)(0.9) - (\_\_\_\_)] = + \_\_\_\_\_ \text{ psf}$$

161

0.9 factor provides 10% reduction in external wall pressure coefficients, allowed because building roof pitch is less than 10 degrees.

ASCE 7 Method 2

Components and Cladding

Roof components design pressures - joists

Zone 1

− p = ____[(____) − (____)] = − _____ psf

+ p = ____[(____) − (____)] = + _____ psf

Zone 2 and 3

− p = ____[(____) − (____)] = − _____ psf

+ p = ____[(____) − (____)] = + _____ psf

162

ASCE 7 Method 2

Components and Cladding

Roof components design pressures – roof panels

Zone 1

− p = ____[(____) − (____)] = − _____ psf

+ p = ____[(____) − (____)] = + _____ psf

Zone 2

− p = ____[(____) − (____)] = − _____ psf

+ p = ____[(____) − (____)] = + _____ psf

163

ASCE 7 Method 2

Components and Cladding

Roof components design pressures – roof panels

Zone 3

− *p* = ____[(____) − (____)] = − _____ psf

+ *p* = ____[(____) − (____)] = + _____ psf

ASCE 7 Method 2

Components and Cladding

Roof components design pressures – roof panel fasteners

Design pressures are the same as for panel because coefficients are constant for EWA’s less than 10 ft^2

165

ASCE 7 Simplified Method

Wind load analysis of Melbourne fire station using simplified methods from ASCE 7

ASCE 7 Simplified Method

Main Wind Force Resisting System

Roof pressure from table (rpt) _____

Wall pressure from table (wpt) _____

Multiply pressure values from table times exposure factor (ef) and importance factor (I)

Roof tributary area calculated and roof pressures adjusted with reduction factor (rrf) if appropriate

167

Pressures, exposure factor, roof reduction factor from Table 6-2 (page 238 in Appendix)

Pressure values according to basic wind speed, enclosure classification.

Pressures in pounds per square foot

ASCE 7 Simplified Method

Main Wind Force Resisting System

Design roof pressure:

rpt ____ × ef ____ × I ____ × rrf ____

p = ____ psf

Design wall pressure:

wpt ____ × ef ____ × I ____

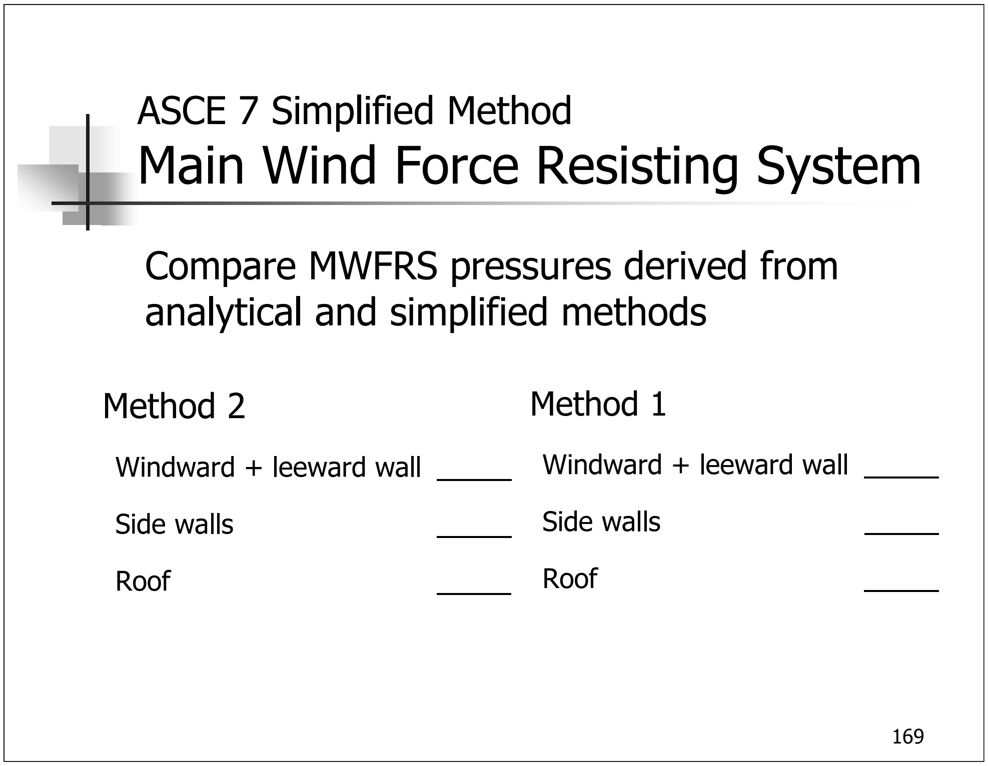
p =____ psf

168

Design roof pressure acts uniformly over entire roof, includes internal pressure.

Design wall pressure is combined windward and leeward wall pressures and is applied to the windward wall.

Internal pressures cancel for MWFRS wall pressures.



Add internal pressures to roof pressures from analytical procedure for comparison to simplified numbers.

Combine leeward and windward wall pressures from Method 2 for comparison.

ASCE 7 Simplified Method
Components and Cladding

Wall and roof pressures in table based on Effective Wind Area (EWA)

Wall EWA = _____

Roof Joist EWA = _____

Roof Panel EWA = _____

170

ASCE 7 Simplified Method

Components and Cladding

Wall Pressures

Zone 4 design pressure:

+ wpt ____ × ef ____ × I ____

+ *p* = ____ psf

– wpt ____ × ef ____ × I ____

– *p* = ____ psf

171

Pressures from Table 6-3 (pages 239–40 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Wall Pressures

Zone 5 design pressure:

+ wpt ____ × ef ____ × I ____

+ *p* = ____ psf

– wpt ____ × ef ____ × I ____

– *p* = ____ psf

172

Pressures from Table 6-3A (page 239 in Appendix).

Pressures interpolated from given values between table EWA's and calculated EWA.

Pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Roof Joist Pressures

Zone 1 design pressure:

+ rpt ____ × ef ____ × I ____

+ p = ____

– rpt ____ × ef ____ × I ____

– p = ____

173

Pressures from Table 6-3A (page 239 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Design pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Roof Joist Pressures

Zone 2 and 3 design pressures:

+ rpt ____ × ef ____ × I ____

+ *p* = ____

– rpt ____ × ef ____ × I ____

– *p* = ____

174

Pressures from Table 6-3A (page 239 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Design pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Roof Panel Pressures

Zone 1 design pressures:

+ rpt ____ × ef ____ × I ____

+ *p* = ____

– rpt ____ × ef ____ × I ____

– *p* = ____

175

Pressures from Table 6-3A (page 239 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Design pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Roof Panel Pressures

Zone 2 design pressures:

+ rpt ____ × ef ____ × I ____

+ p = ____

– rpt ____ × ef ____ × I ____

– p = ____

176

Pressures from Table 6-3A (page 239 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Design pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method

Components and Cladding

Roof Panel Pressures

Zone 3 design pressures:

+ rpt ____ × ef ____ × I ____

+ p = ____

– rpt ____ × ef ____ × I ____

– p = ____

177

Pressures from Table 6-3A (page 239 in Appendix).

Pressures from table interpolated from given values between table EWA's and calculated EWA.

Design pressures adjusted per notes for exposure category and importance factor.

ASCE 7 Simplified Method
Components and Cladding

a for zones 1–5 dimension calculated as per analytical method example.

178

ASCE 7 Simplified Method

Components and Cladding

Discuss Component and Cladding pressures derived from analytical and simplified methods.

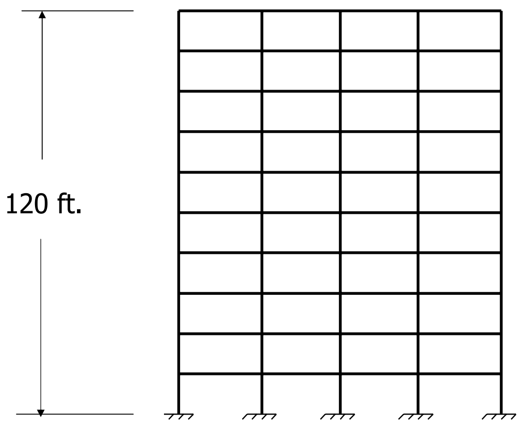
179

High-rise building

Analytical method applied
to a multi-story building

180

High-rise building



10 story building modeled to calculate natural frequency and modes of building.

- Steel framed, moment resisting structure made with 50 ksi yield steel.
- 96 × 96 feet in plan and 120 feet tall.
- Total plan area is 9216 square feet per floor.
- Main structural framing consists of W shapes.
- 25 columns per level, 5 per row each direction spaced at 24 feet apart.
- Mass at each floor level is considered as a 4 inch concrete slab for the floor estimated at 50 pounds per square foot.
- Framing structure is estimated:
  - 85 psf for the roof structure.
  - 90 psf for levels 8,9 and 10.
  - 100 psf for levels 5,6 and 7.
  - 110 psf for levels 2,3 and 4.
- Dead weight is reduced from the ground up to account for diminishing weight of the columns as they are reduced in size.
- All other loads are equal for each floor.
- This structural weight includes the framing for each floor and the roof and half of each column above and below each floor.
- Live loads applied to each level are 20 psf for the roof and 35 psf for the remaining floors.

High-rise building

Basic parameters are determined

- Dimensions
- Framing characteristics
- Cladding characteristics
- Exposure
- Building classification
- Basic wind speed

182

High-rise building

Velocity pressure equation parameters are determined

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

183

Velocity pressure equation from ASCE 7-98

High-rise building

All variables have one value except K_z, which varies from a minimum at ground level to a maximum at h.

$$q_z = (XYZ)\ K_z \text{ psf}$$

184

High-rise building

Height, ft	MWFRS		Components & Cladding	
	k_z	q_z psf	k_z	q_z psf
1-15	0.57	(XYZ) 0.57	0.70	(XYZ) 0.70
30	0.70	(XYZ) 0.70	0.70	(XYZ) 0.70
40	0.76	(XYZ) 0.76	0.76	(XYZ) 0.76
50				
—				
—				
—				
120	1.04	(XYZ) 1.04	1.04	(XYZ) 1.04

K_z values from Table 6-5 (page 242 in Appendix) for case 1 and 2 in Exposure B.

K_z increases with increasing height above ground. All other variables are constant for a given building situation.

Calculate velocity pressures for each increase in K_z

High-rise building

Determine design pressures – *p* – for MWFRS

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

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

for a flexible building)

186

Design pressures are determined for each value of velocity pressure.

High-rise building

q – q_z per velocity pressure table

q_z – q_h for leeward wall, side walls, and roof

C_p – per Fig. 6-3, Windward, side walls one value each.

Leeward wall coefficient is a function of building proportions L/B.

Roof coefficients a function of building proportions *h*/L, several zones, reduction factor may be applicable

187

High-rise building

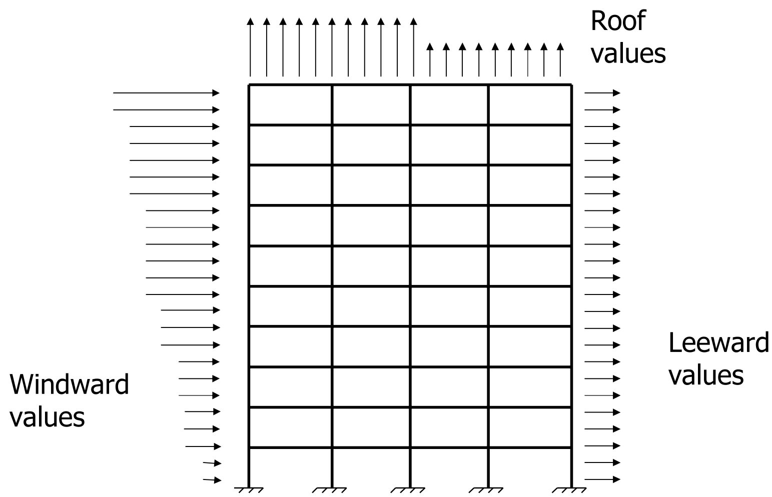
G – per rigid structure formula or 0.85 or per flexible structure formula (for G_f)

High-rise building

Design pressures calculated for each value of K_z on windward wall, at q_h for leeward wall and side walls, and at zones on roof

189

High-rise building



Design Pressures

High-rise building

For buildings over 60 feet in height, ASCE-7 requires the structure to be subjected to four load cases shown in Figure 6-9.

Case 1 is the loading shown in this example.

A combination of various percentages of the windward and leeward pressures is applied to the structure for the other three cases in order to assess torsional response.

191

High-rise building

Repeat process for Components and Cladding.

High-rise building

Use velocity pressure – *q* – at each level *z* for windward wall, *h* for leeward and side walls and roof.

Calculate effective wind areas so that pressure coefficients can be determined.

High-rise building

Determine width of "a" zones.

Calculate design pressures at each height level and zone for Components and Cladding and at roof.

194

Wind-driven rain

Influencing parameters of wind-drive rain:

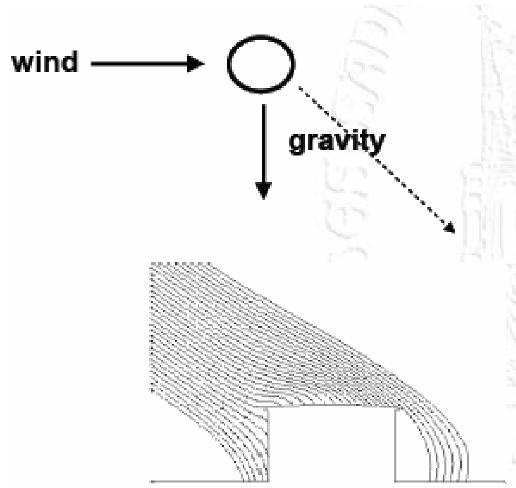
- Building geometry (and environment topology
- Position on the building façade
- Wind speed
- Wind direction
- Rainfall intensity
- Raindrop-size distribution

195

From workshop presentation *Microclimate Around Buildings* courtesy of:

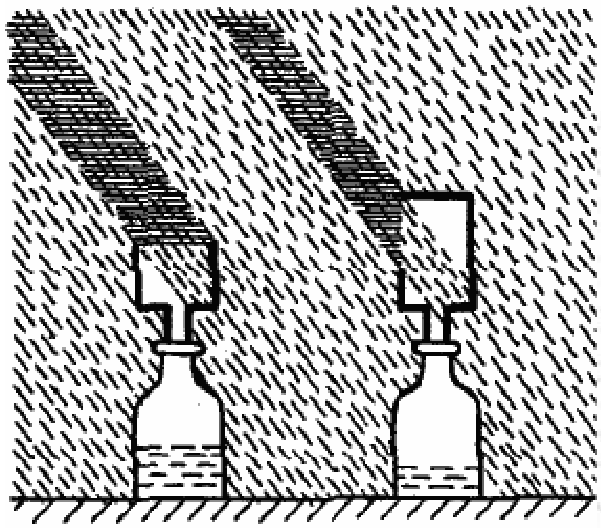
Bert Blocken	Katholieke Universiteit Leuven, Belgium Concordia University, Montreal, Canada
Hugo Hens	Katholieke Universiteit Leuven, Belgium
Jan Carmeliet	Katholieke Universiteit Leuven, Belgium Eindhoven University of Technology, The Netherlands
K. U. Leuven	Laboratory of Building Physics

Wind-driven rain



Two factors affecting the direction rain will travel

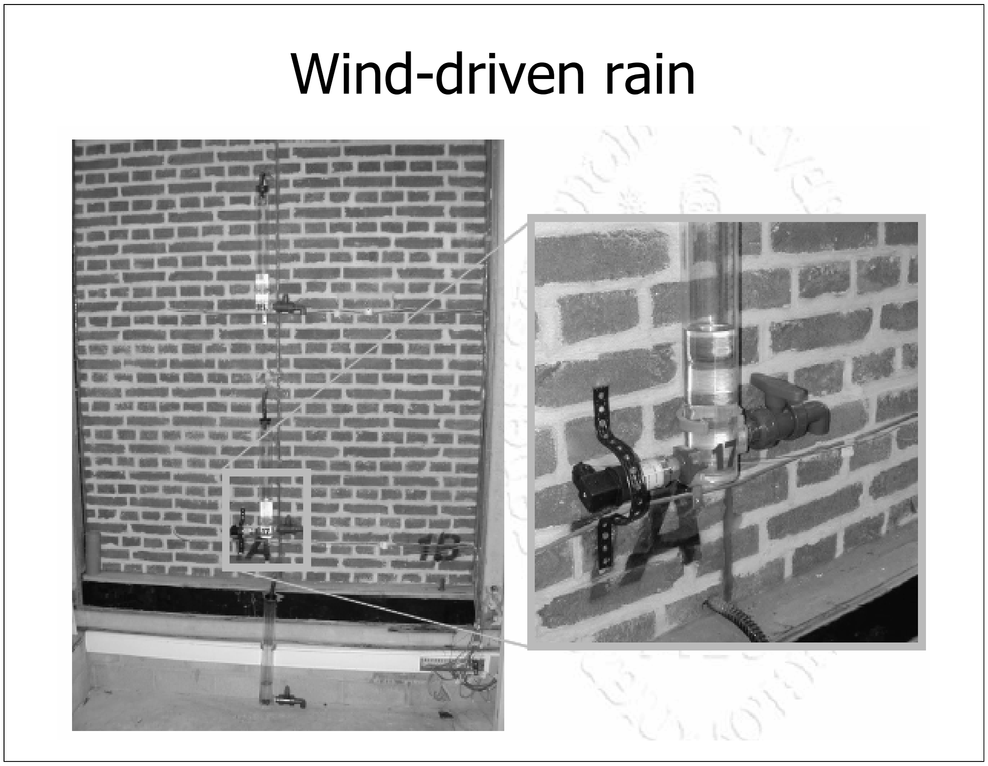
Wind-driven rain



Test systems that measure the amount of rain entering an area from a vertical direction and a horizontal direction

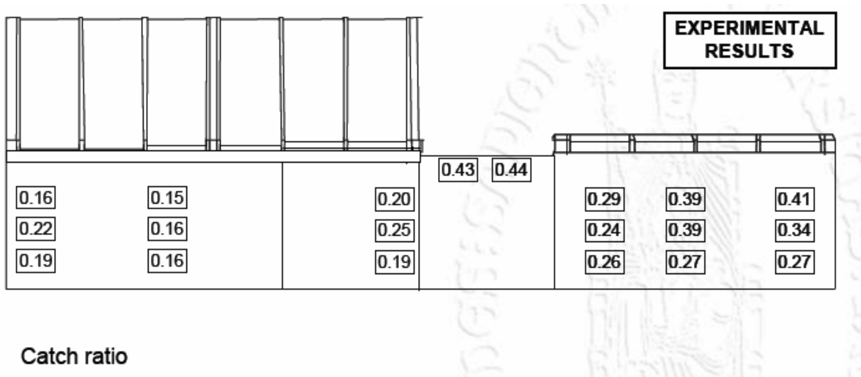
Wind-driven rain

Rain measurement instruments mounted to the side of the test facility

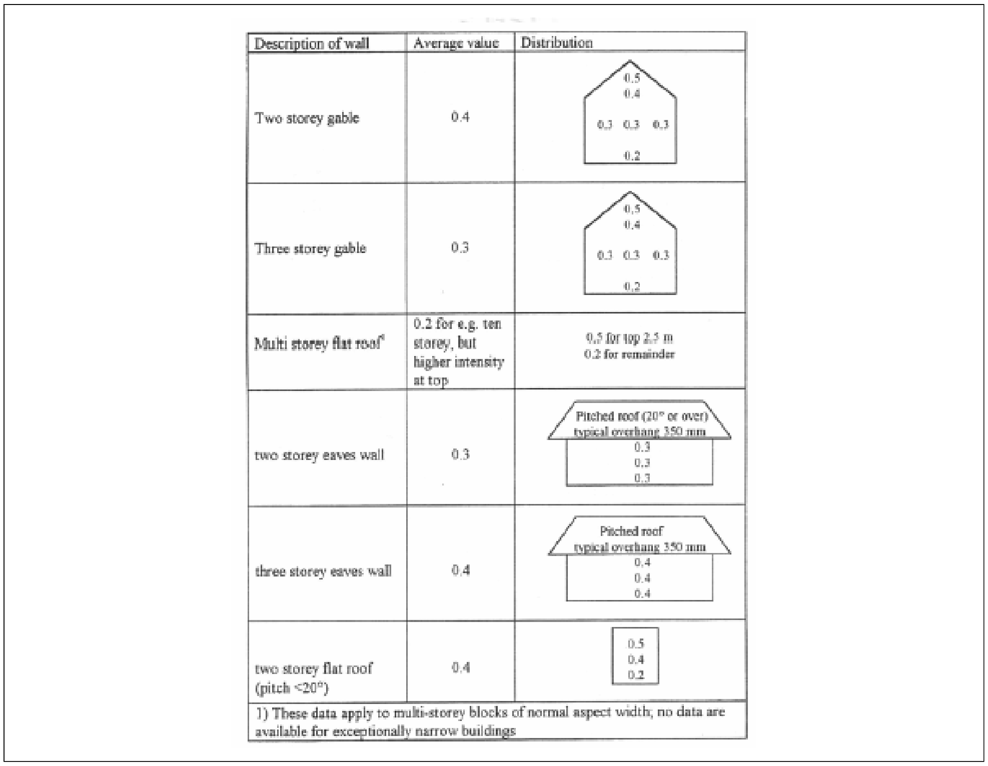


Rain measurement system

Wind-driven rain



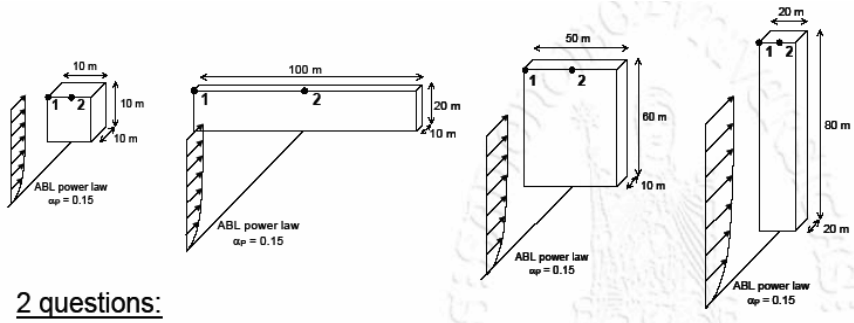
Results of measurements on test building. Ratios of rain collected at various positions on the building.



Description of wall	Average value	Distribution
Two storey gable	0.4	0.5 0.4 0.3 0.3 0.3 0.2
Three storey gable	0.3	0.5 0.4 0.3 0.3 0.3 0.2
Multi storey flat roof[1]	0.2 for e.g. ten storey, but higher intensity at top	0.5 for top 2.5 m 0.2 for remainder
two storey eaves wall	0.3	Pitched roof (20° or over) typical overhang 350 mm 0.3 0.3 0.3
three storey eaves wall	0.4	Pitched roof typical overhang 350 mm 0.4 0.4 0.4
two storey flat roof (pitch <20°)	0.4	0.5 0.4 0.2

1) These data apply to multi-storey blocks of normal aspect width; no data are available for exceptionally narrow buildings

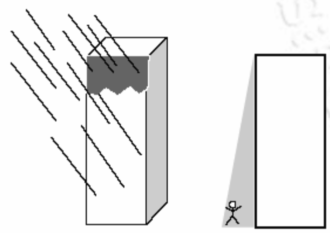
Results of a semi-empirical study of rainfall catch ratios. Methods beyond the scope of this course.



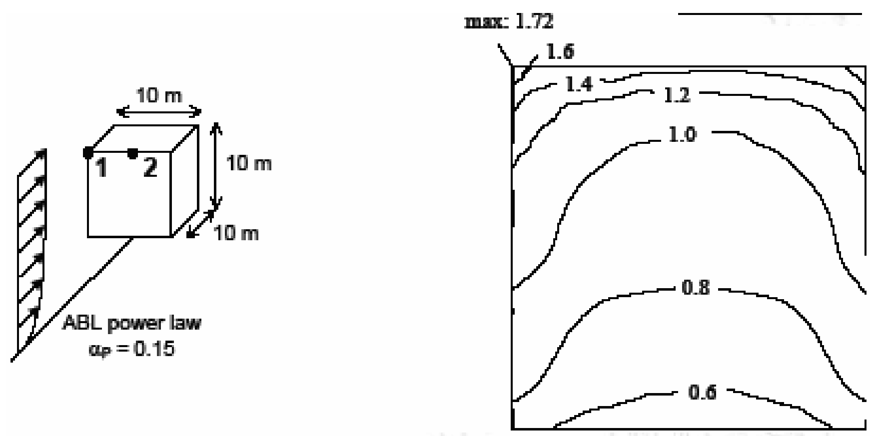
2 questions:

1) Which building has the maximum catch ratio (wind-driven rain)?

2) Can we take a shower at the bottom part of a high-rise curtain wall building facade?

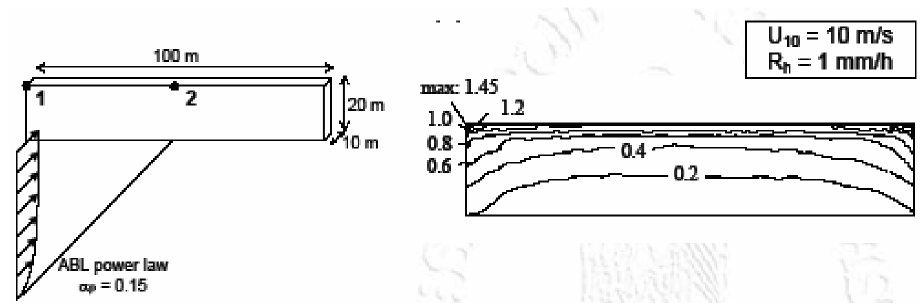


Wind-driven rain

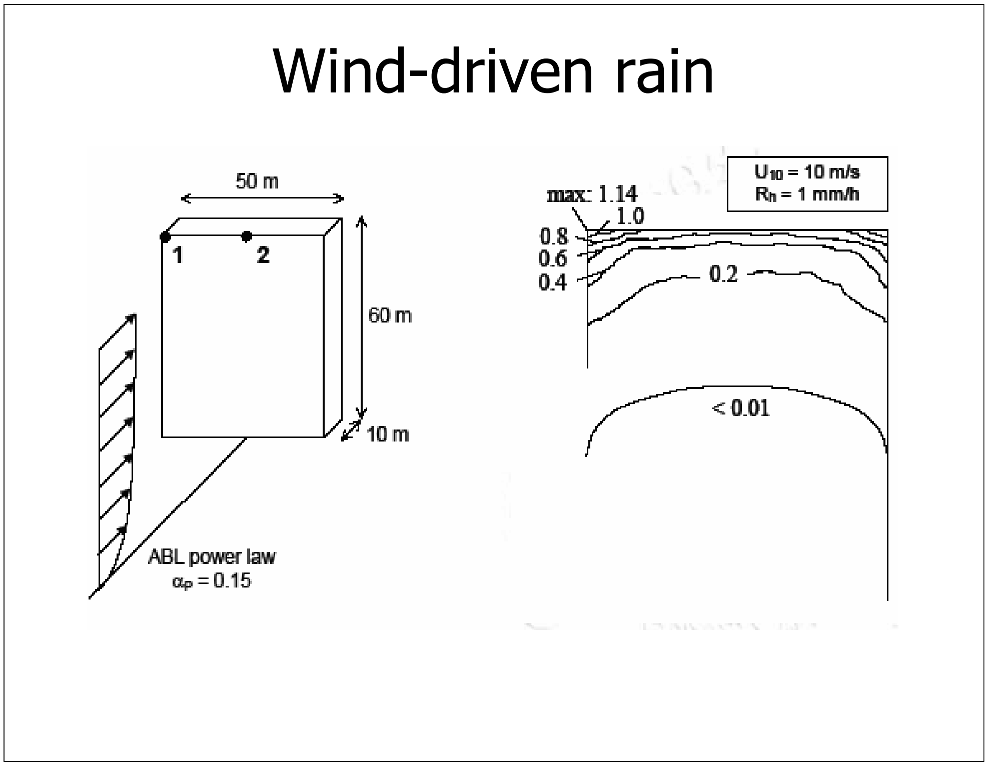


Rainfall catch distribution on face of cubic building.

Wind-driven rain

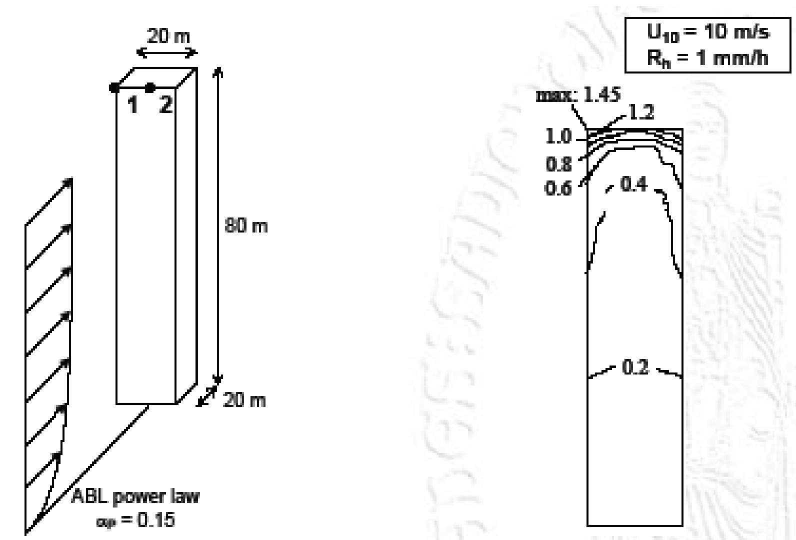


Rainfall catch distribution on face of rectangular building.



Rainfall catch distribution on face of medium rise building.

Wind-driven rain



Rainfall catch distribution on face of high aspect ratio building.

Wind-driven rain

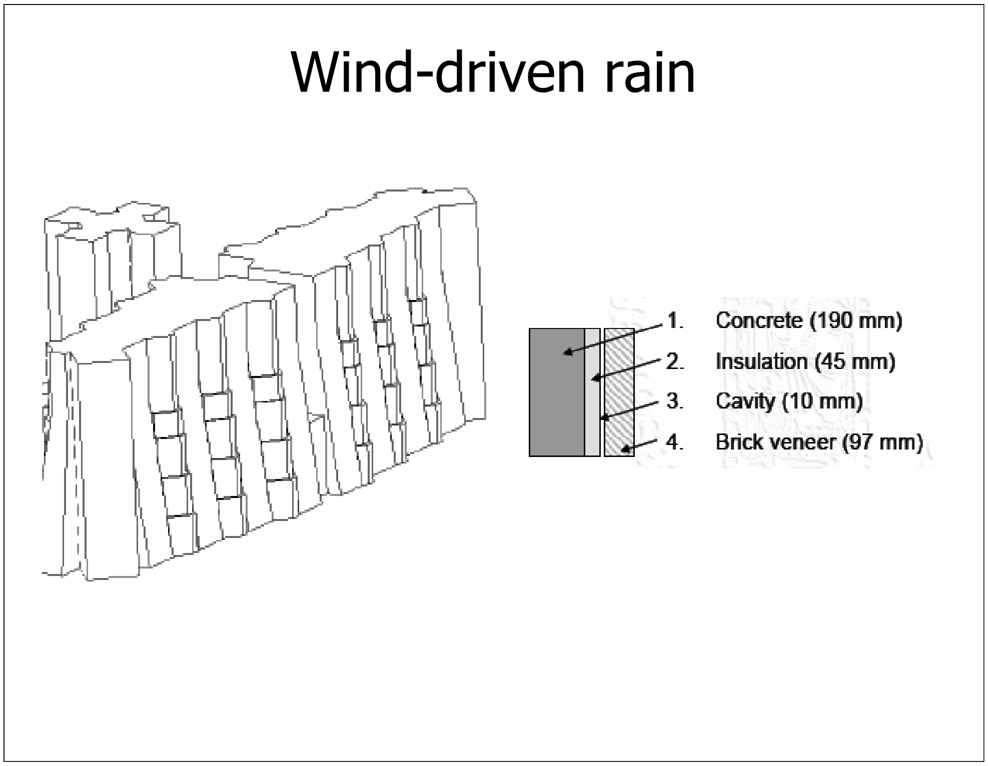
Low-rise cubic building	1.72
Wide medium-rise slab	1.45
High-rise slab	1.14
Tower building	1.45

Wind speed increases with height.

The higher the building, the higher the wind speed at the top of the building.

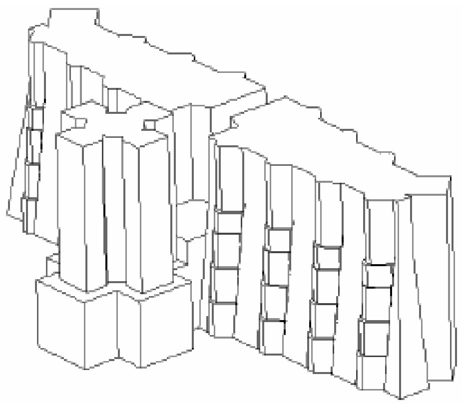
The higher the wind speed, the more wind-driven rain.

207



Construction of building shown in following slides.

Wind-driven rain



Building is located at the University of Brussels.

Wind-driven rain

Wind-driven rain

Stability problems

- Bending, buckling of brick veneer wall...

Rain-related problems

- Rain penetration, façade soiling...

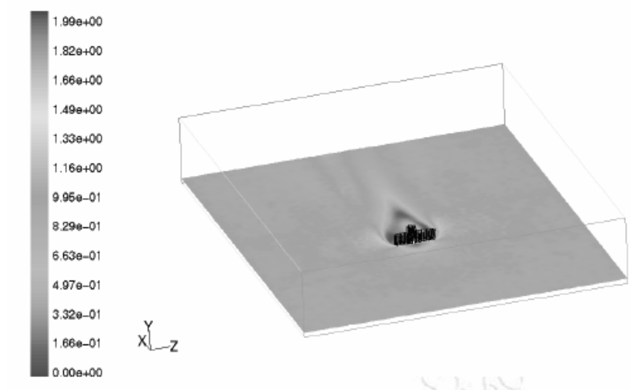
211

Wind-driven rain

Wind-driven rain

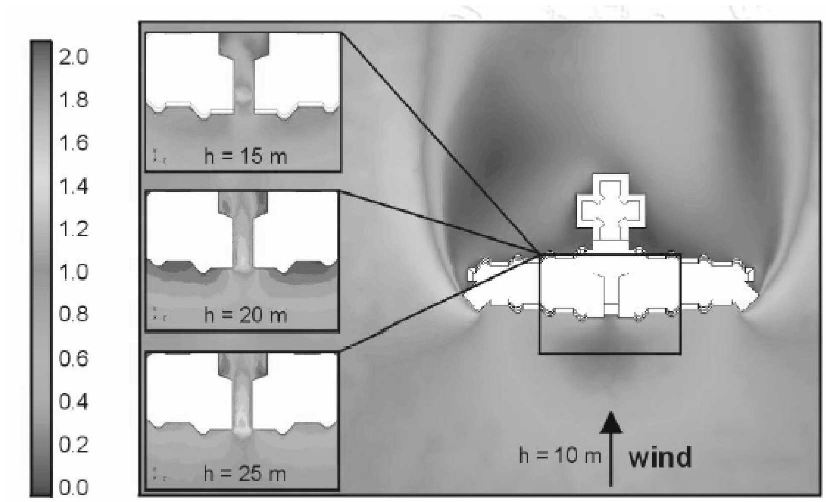
Numerical study with CFD

Wind flow field



213

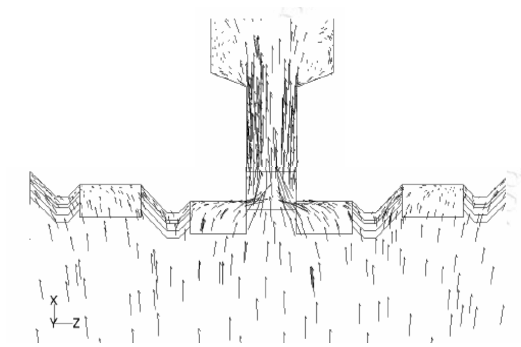
Wind-driven rain



Wind-driven rain

Numerical study with CFD

Wind flow field: south wind



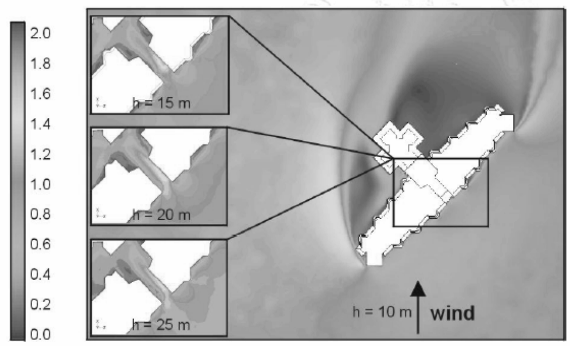
215

Intensity of water travel proportional to arrow distribution.

Wind-driven rain

Numerical study with CFD

Wind flow field: south-west wind

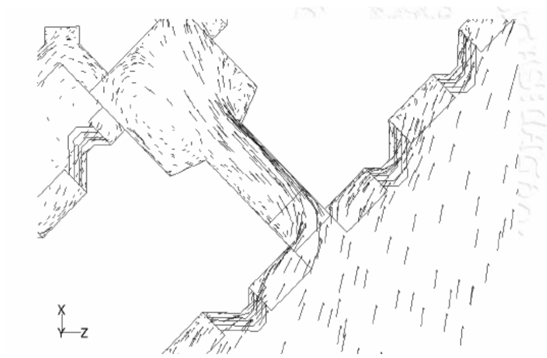


216

Wind-driven rain

Numerical study with CFD

Wind flow field: south-west wind



217

Intensity of water travel proportional to arrow distribution.

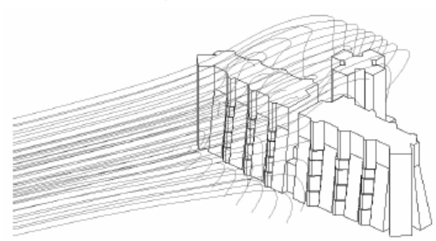
Wind-driven rain

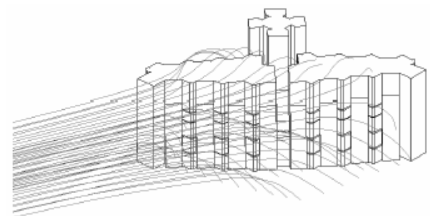
Numerical study with CFD

- Catch ratio
  - South wind direction
  - U_{10} = 10 m/s
  - d = 1 mm

Numerical study with CFD

- Catch ratio
  - South-west wind direction
  - U_{10} = 10 m/s
  - d = 1 mm



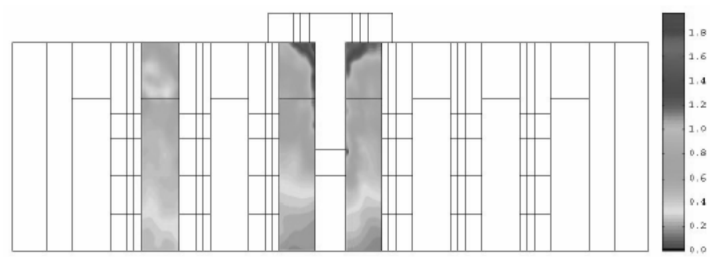


218

Wind-driven rain

Numerical study with CFD

- Catch ratio
  - South wind direction
  - U_{10} = 10 m/s
  - d = 1 mm



219

Wind-driven rain

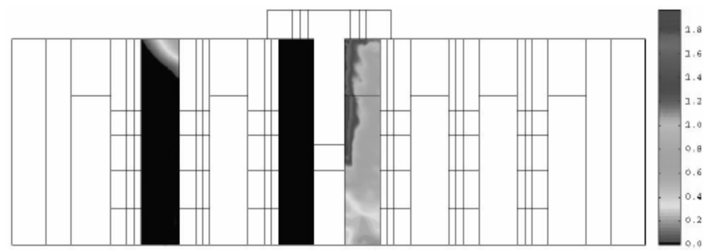
Numerical study with CFD

Catch ratio

South-west wind direction

U_{10} = 10 m/s

d = 1 mm



220

Wind-driven rain

Water intrusion mitigation:
- Overhangs
- Proper flashing—little or no maintenance
- Sealants age and require upkeep
- Flow path directing water that penetrates envelope to proper areas (to lower mass or exterior from second story; from window intrusion back to exterior of building)
- A properly drained seat in foundation for masonry block wall to sit on

221

Wind-driven rain

- Proper sill design for windows:
  - A seat that directs water to exterior of building, rather than directing it inside or trapping it
- A bond break between vapor/water barrier and stucco finish provides an area for moisture to "fall out" before soaking to interior.
- Good paint:
  - Paint will not necessarily fill micro-cracks in stucco, but after several repaintings leakage seems to diminish.
  - Thick coatings have tended to bubble.

Latest Findings

Some results of recent hurricane aftermath investigations:

- Most structures built to recent building code standards fared well compared to older structures.
- Roof tile loss, especially barrel tiles, is a widespread problem.
- Secondary structures did poorly (screen porches, carports, etc.).
- Rain penetration is a major problem.

223

Latest Findings

Soffits blew out—lots of soffits.

Ridge tiles on roof tend to come loose and become debris, causing further damage.

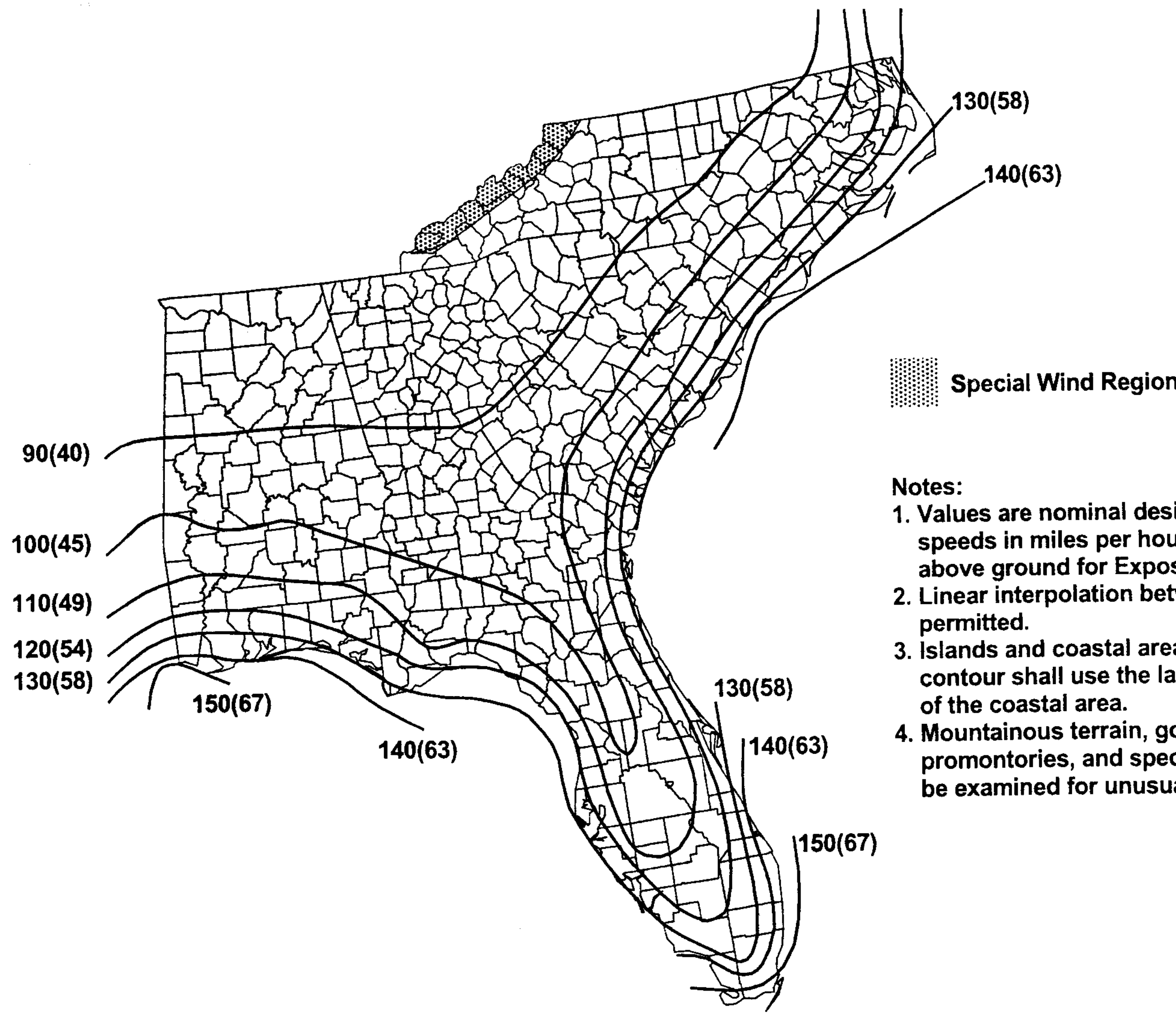
- The missing tiles expose remaining tiles to greater effects of wind.

Owner of failed secondary structure may have a solid house but neighborhood can suffer damage from flying debris.

224

Appendix:

Tables and Graphs

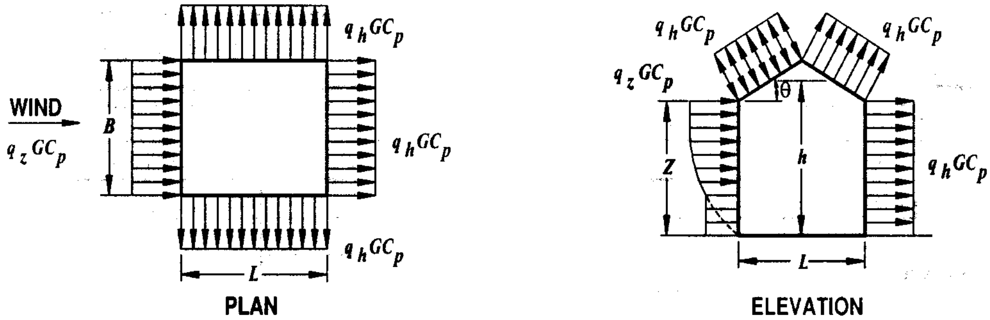


Notes:

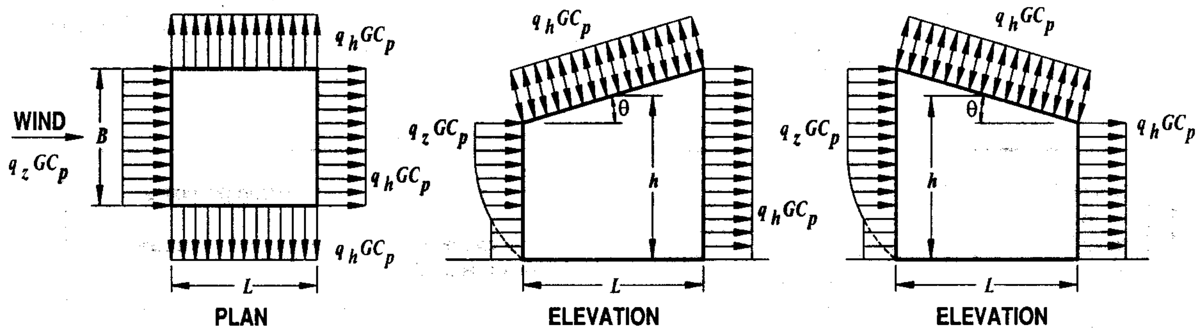
1. Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10 m) above ground for Exposure C category.
2. Linear interpolation between wind contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.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

FIGURE 6-1b. Basic Wind Speed—Eastern Gulf of Mexico and Southeastern U.S. Hurricane Coastline

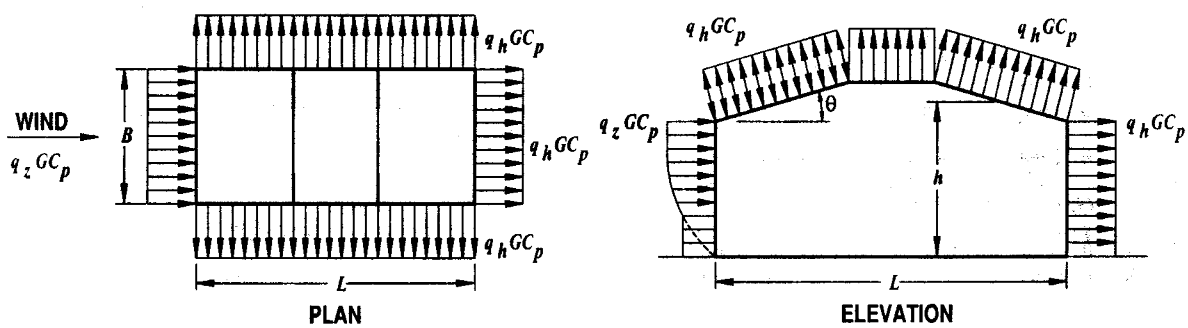
Main Wind Force Resisting System		All h
Figure 6-3	External Pressure Coefficients, C_p	**Walls & Roofs**
Enclosed, Partially Enclosed Buildings		



GABLE, HIP ROOF



MONOSLOPE ROOF (NOTE 4)



MANSARD ROOF (NOTE 8)

Main Wind Force Resisting System		All h
Figure 6-3 (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									Leeward		
	Angle, θ (degrees)									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	-0.5 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	-0.7	-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**	-1.0	-0.7	-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

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

*Value is provided for interpolation purposes.

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

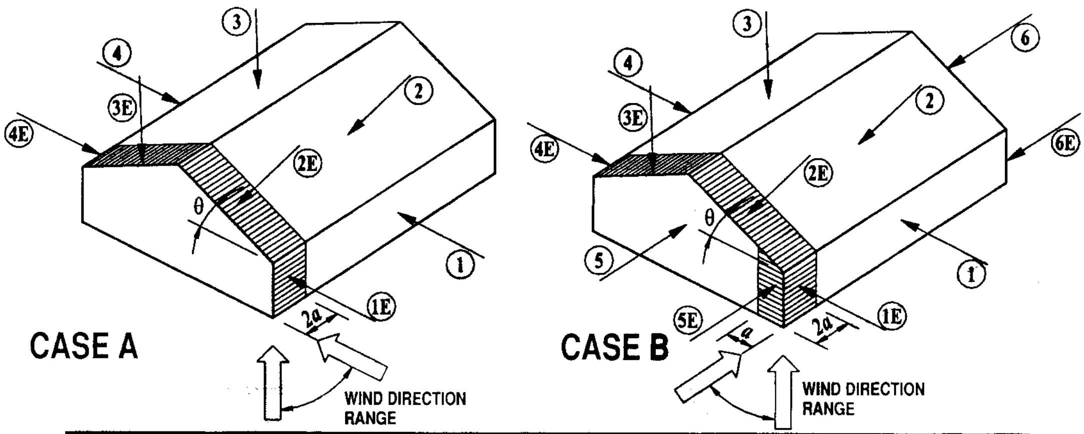
Area (sq ft)	Reduction Factor
≤ 100 (9.29 sq m)	1.0
200 (23.23 sq m)	0.9
≥ 1000 (92.9 sq m)	0.8

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 G_f as determined by rational analysis.
6. Refer to Table 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/m^2), 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.

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

Main Wind Force Resisting System		h ≤ 60 ft.
Figure 6-4	External Pressure Coefficients, GC_{pf}	Walls & Gable Roof
Enclosed, Partially Enclosed Buildings		



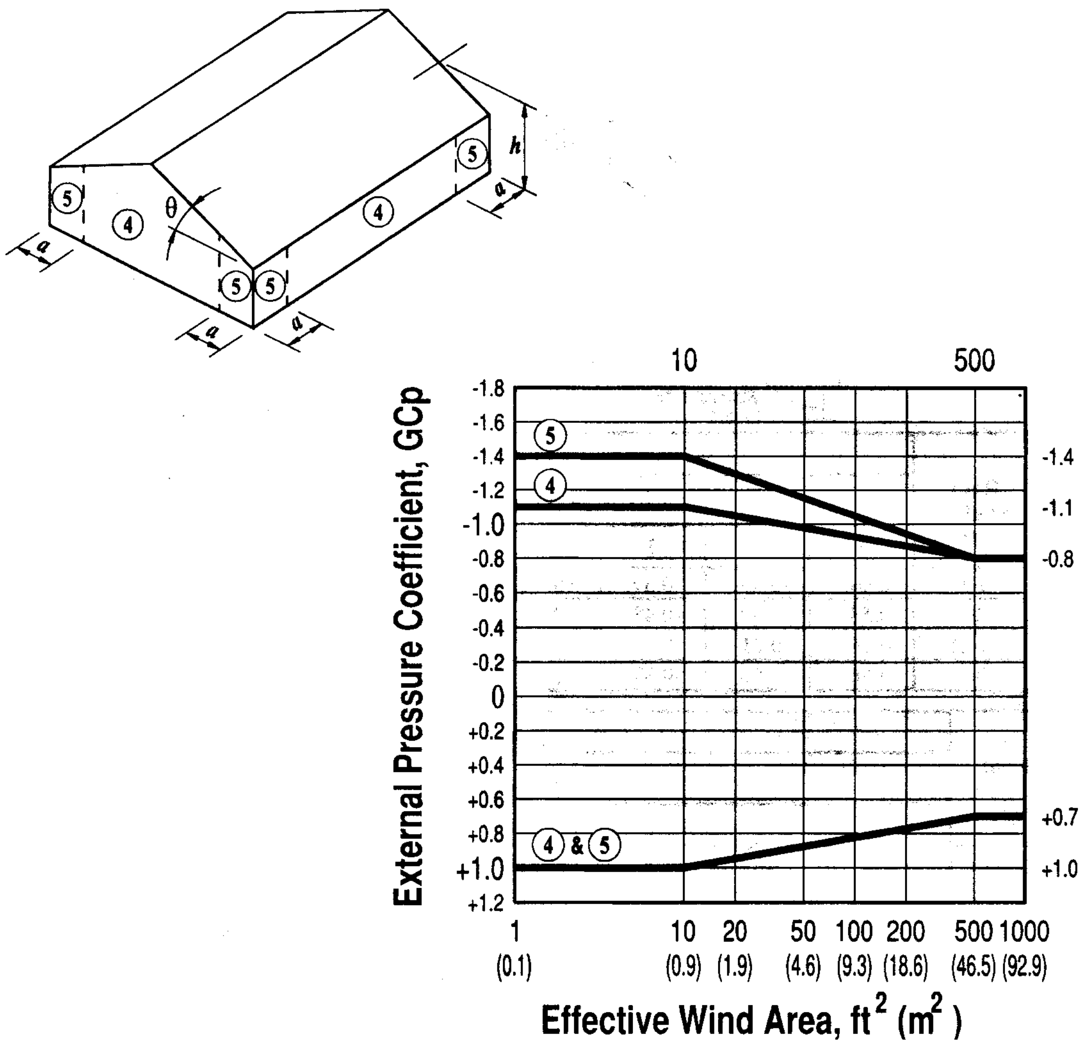
Roof Angle θ (degrees)	CASE A							
	Building Surface							
	1	2	3	4	1E	2E	3E	4E
0-5	0.40	-0.69	-0.37	-0.29	0.61	-1.07	-0.53	-0.43
20	0.53	-0.69	-0.48	-0.43	0.80	-1.07	-0.69	-0.64
30-45	0.56	0.21	-0.43	-0.37	0.69	0.27	-0.53	-0.48
90	0.56	0.56	-0.37	-0.37	0.69	0.69	-0.48	-0.48

Roof Angle θ (degrees)	CASE B											
	Building Surface											
	1	2	3	4	5	6	1E	2E	3E	4E	5E	6E
0-90	-0.45	-0.69	-0.37	-0.45	0.40	-0.29	-0.48	-1.07	-0.53	-0.48	0.61	-0.43

Notes:

1. Case A and Case B are required as two separate loading conditions to generate the wind actions, including torsion, to be resisted by the main wind-force resisting system.
2. To obtain the critical wind actions, the building shall be rotated in 90° degree increments so that each corner in turn becomes the windward corner while the loading patterns in the sketches remain fixed. For the design of structural systems providing lateral resistance in the direction parallel to the ridge line, Case A shall be based on θ = 0°.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. For Case A loading the following restrictions apply:
   a. The roof pressure coefficient GC_{pf}, 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 dimensions of the building measured perpendicular to the eave line or 2.5*h*, whichever is less; the remainder of Zone 2 extending to the ridge line shall use the pressure coefficient GC_{pf} for Zone 3.
   b. Except for moment-resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
5. Combinations of external and internal pressures (see Table 6-7) shall be evaluated as required to obtain the most severe loadings.
6. For values of θ other than those shown, linear interpolation is permitted.
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 (1 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.

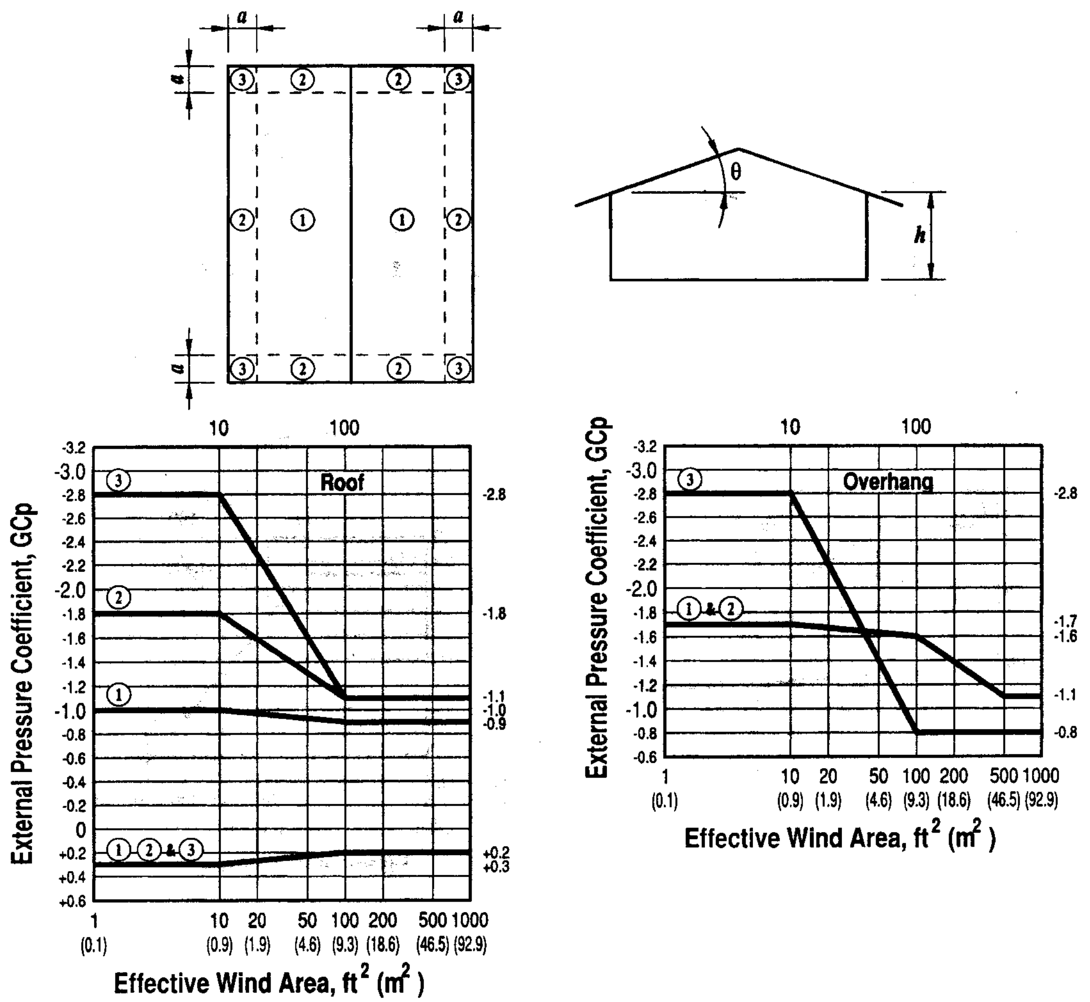
Components and Cladding		$h \leq 60$ ft.
Figure 6-5A	External Pressure Coefficients, GC_p	**Walls**
Enclosed, Partially Enclosed Buildings		



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 (1 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.

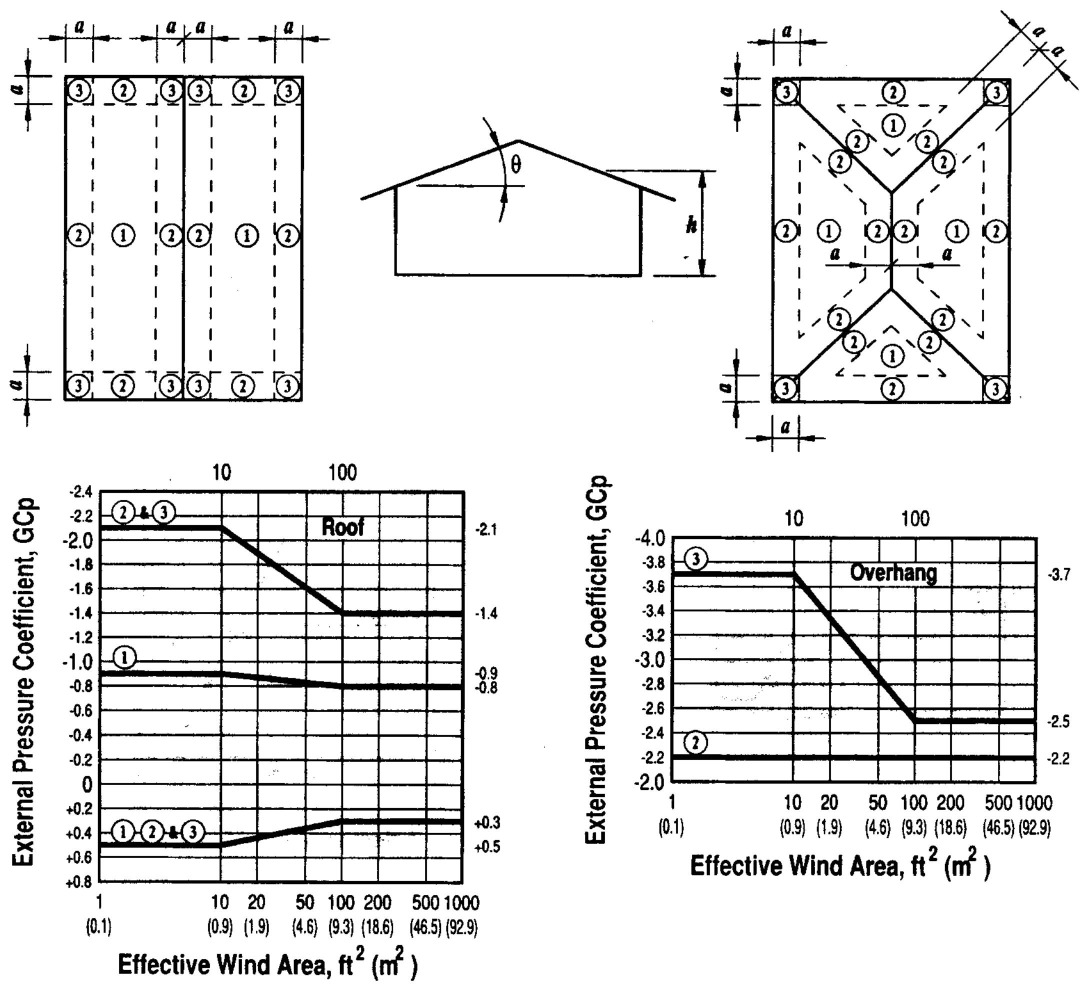
Components and Cladding		h ≤ 60 ft.
Figure 6-5B	External Pressure Coefficients, GC_p	**Gable Roofs θ ≤ 10°**
Enclosed, Partially Enclosed Buildings		



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 (1m) is provided around the perimeter of the roof with θ ≤ 10°, 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 (1 m).
   h: Eave height shall be used for θ ≤ 10°.
   θ: Angle of plane of roof from horizontal, in degrees.

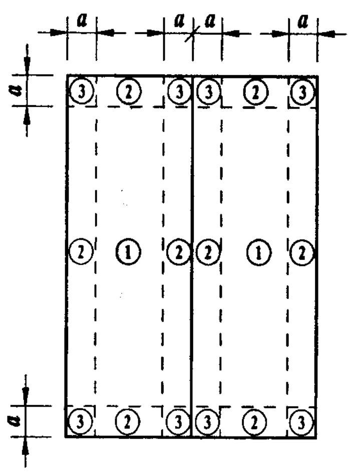
Components and Cladding		h ≤ 60 ft.
Figure 6-5B (con't)	External Pressure Coefficients GC_p	Gable/Hip Roofs 10°< θ ≤ 30°
Enclosed, Partially Enclosed Buildings		

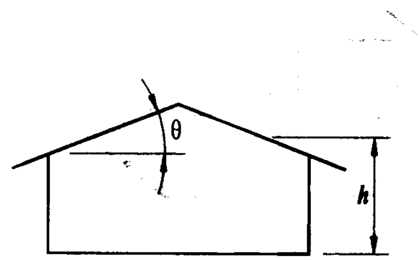


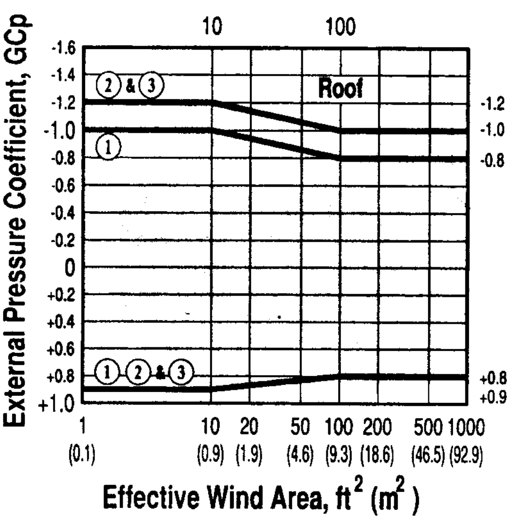
Notes:

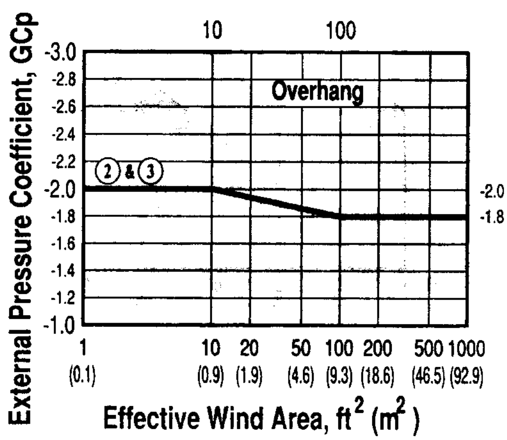
1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, in square feet (square meters).
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GC_p for roof overhangs include pressure contributions from both upper and lower surfaces.
6. For hipped roofs with 10° < θ ≤ 30°, edge/ridge strips and pressure coefficients for ridges of gabled roofs shall apply on each hip.
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 (1 m).
   - *h*: Mean roof height, in feet (meters).
   - θ: Angle of plane of roof from horizontal, in degrees.

Components and Cladding		h ≤ 60 ft.
Figure 6-5B (con't)	External Pressure Coefficients, GC_p	**Gable Roofs 30°< θ ≤ 45°**
Enclosed, Partially Enclosed Buildings		





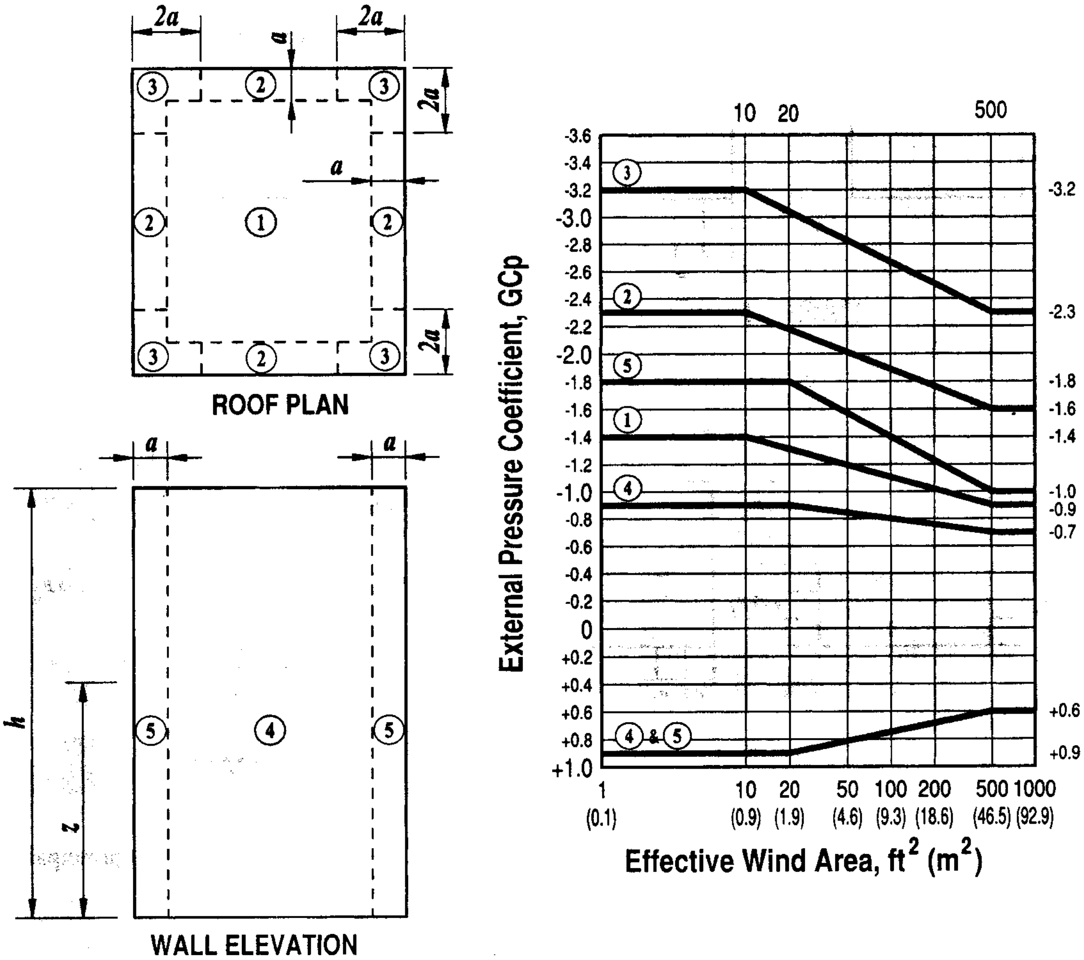




Notes:

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 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 (1 m).
   - h: Mean roof height, in feet (meters).
   - θ: Angle of plane of roof from horizontal, in degrees.

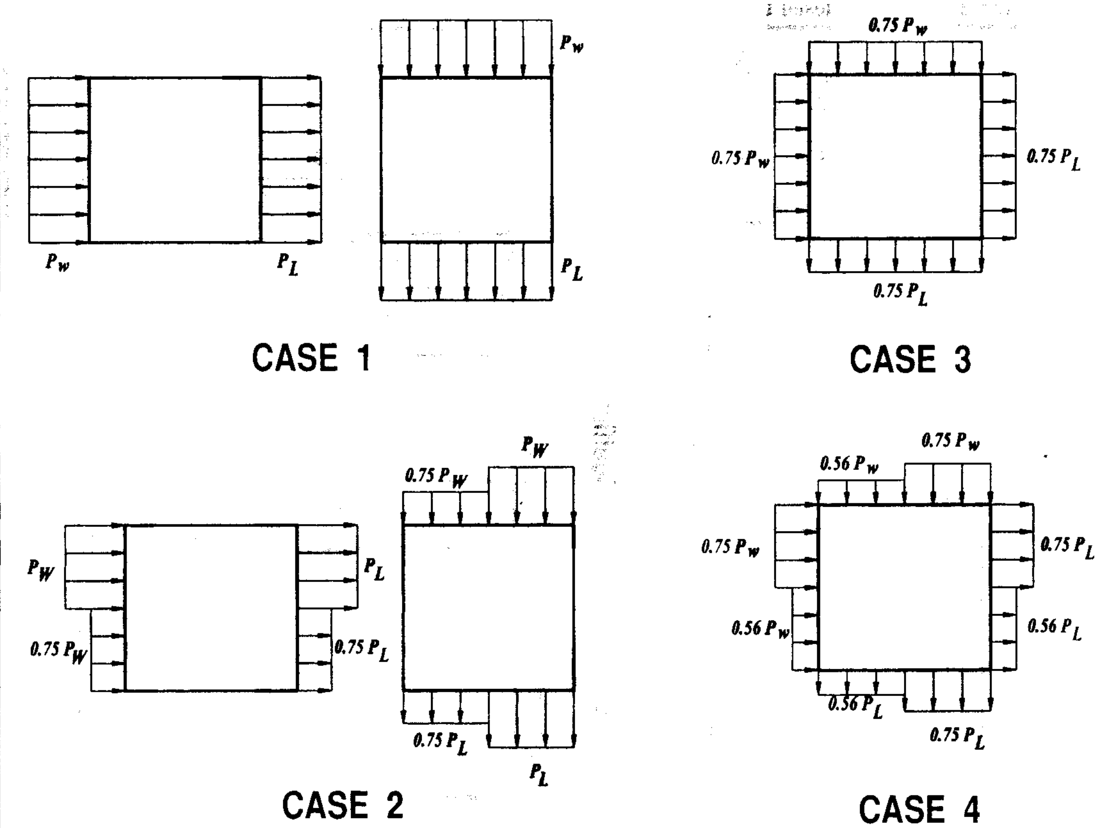
Components and Cladding		h >60 ft.
Figure 6-8	External Pressure Coefficients, GC_p	Walls & Roofs
Enclosed, Partially Enclosed Buildings		



Notes:

1. Vertical scale denotes GC_p to be used with appropriate q_z or 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. Use q_z with positive values of GC_p and q_h with negative values of GC_p.
5. Each component shall be designed for maximum positive and negative pressures.
6. Coefficients are for roofs with angle $\theta \leq 10°$. For other roof angles and geometry, use GC_p values from Fig. 6-5B and attendant q_h based on exposure defined in 6.5.6.
7. If a parapet equal to or higher than 3 ft (1m) is provided around the perimeter of the roof with $\theta \leq 10°$, Zone 3 shall be treated as Zone 2.
8. Notation:
   - a: 10 percent of least horizontal dimension, but not less than 3 ft (1 m).
   - h: Mean roof height, in feet (meters), except that eave height shall be used for $\theta \leq 10°$.
   - z: height above ground, in feet (meters).
   - θ: Angle of plane of roof from horizontal, in degrees.

Main Wind Force Resisting System		h >60 ft.
Figure 6-9	Full & Partial Loadings	



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

Case 2. Wind pressure as defined in Case 1, but with a 25% reduction in pressure acting on 50% of the projected area bounded by the extreme projected edge of the building.

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

Case 4. Wind pressure as defined in Case 3, but with a 25% reduction of these pressures acting on 50% of the projected area bounded by the extreme projected edge of the building.

Notes:

1. Design wind pressures for windward and leeward faces obtained in accordance with the provisions of 6.5.12 for main wind-force resisting systems for buildings with mean roof height *h* greater than 60 ft (18 m).
2. Diagrams show plan view of building.
3. Notation:
   P_W: Windward face design pressure.
   P_L: Leeward face design pressure.

Importance Factor, I (Wind Loads)

Table 6-1

Category	Non-Hurricane Prone Regions and 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	1.15

Note:

1. The building and structure classification categories are listed in Table 1-1.

Main Wind Force Resisting System		h ≤ 30 ft.
Table 6-2	Design Wind Pressure	Simplified Procedure Walls & Roofs
Enclosed, Partially Enclosed Buildings		

DESIGN WIND PRESSURE (PSF)

Location	Building Classification	Basic Wind Speed V (MPH)									
		85	90	100	110	120	130	140	150	160	170
Roof	Enclosed	-14	-16	-20	-24	-29	-33	-39	-45	-51	-57
	Partially Enclosed	-19	-21	-26	-31	-37	-44	-51	-58	-66	-74
Wall	Enclosed or Partially Enclosed	12	14	17	20	24	29	33	38	43	49

Notes:

1. Design wind pressures above represent the following:
   Roof – Net pressure (sum of external and internal pressures) applied normal to all roof surfaces.
   Wall – Combined net pressure (sum of windward and leeward, external and internal pressures) applied normal to all windward wall surfaces.
2. Values shown are for exposure B. For other exposures, multiply values shown by the factor below:

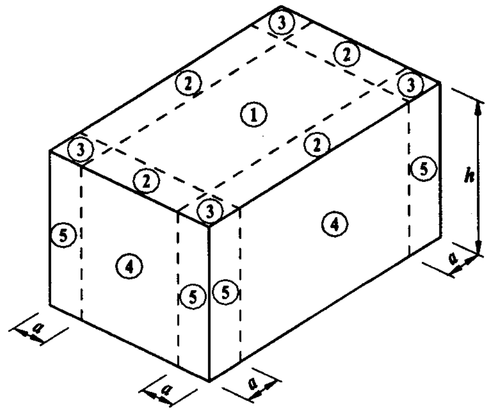
Exposure	Factor
C	1.40
D	1.66

3. Values shown for roof are based on a tributary area less than or equal to 100 sf. For larger tributary areas, multiply values shown by reduction factor below:

Area (SF)	Reduction Factor (Linear Interpolation Permitted)
≤ 100	1.0
250	0.9
≥ 1000	0.8

4. Values shown are for importance factor I = 1.0. For other values of I, multiply values shown by I.
5. Plus and minus signs indicate pressures acting toward and away from exterior surface, respectively.

Components and Cladding		h ≤ 30 ft.
Table 6-3A	Design Wind Pressures	Simplified Procedure Walls & Roofs
Enclosed Buildings		



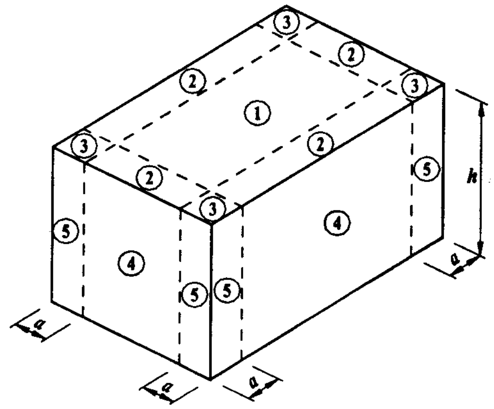
DESIGN WIND PRESSURE (PSF)												
Location	Zone	Effective Wind Area (SF)	Basic Wind Speed V (MPH)									
			85	90	100	110	120	130	140	150	160	170
Roof	1	10	+10 -13	+10 -15	+10 -18	+10 -22	+11 -26	+12 -30	+14 -35	+16 -40	+19 -46	+21 -52
		20	+10 -13	+10 -14	+10 -18	+10 -21	+10 -25	+12 -30	+13 -34	+15 -39	+18 -45	+20 -51
		100	+10 -12	+10 -13	+10 -16	+10 -20	+10 -24	+10 -28	+11 -32	+13 -37	+15 -42	+17 -48
	2	10	+10 -22	+10 -24	+10 -30	+10 -36	+11 -43	+12 -51	+14 -59	+16 -68	+19 -77	+21 -87
		20	+10 -19	+10 -22	+10 -27	+10 -33	+10 -39	+12 -46	+13 -53	+15 -61	+18 -69	+20 -78
		100	+10 -14	+10 -16	+10 -19	+10 -24	+10 -28	+10 -33	+11 -38	+13 -44	+15 -50	+17 -56
	3	10	+10 -33	+10 -37	+10 -45	+10 -55	+11 -65	+12 -77	+14 -89	+16 -102	+19 -116	+21 -131
		20	+10 -27	+10 -30	+10 -37	+10 -45	+10 -54	+12 -63	+13 -73	+15 -84	+18 -96	+20 -108
		100	+10 -14	+10 -16	+10 -19	+10 -24	+10 -28	+10 -33	+11 -38	+13 -44	+15 -50	+17 -56
Walls	4	10	+13 -14	+15 -16	+18 -19	+22 -24	+26 -28	+30 -33	+35 -38	+40 -44	+46 -50	+52 -56
		50	+12 -13	+13 -14	+16 -18	+19 -22	+23 -26	+27 -30	+31 -35	+36 -40	+41 -46	+46 -51
		500	+10 -11	+11 -12	+13 -15	+16 -18	+19 -21	+23 -25	+26 -29	+30 -34	+34 -38	+39 -43
	5	10	+13 -17	+15 -19	+18 -24	+22 -29	+26 -35	+30 -41	+35 -47	+40 -54	+46 -62	+52 -70
		50	+12 -15	+13 -16	+16 -20	+19 -25	+23 -29	+27 -34	+31 -40	+36 -46	+41 -52	+46 -59
		500	+10 -11	+11 -12	+13 -15	+16 -18	+19 -21	+23 -25	+26 -29	+30 -34	+34 -38	+39 -43

Metric Conversion: 1 PSF = 47.9 pascals   1 SF = 0.0929 SM   1 MPH = 0.447 M/S

Notes:

1. Design wind pressures above represent the net pressure (sum of external and internal pressures) applied normal to all surfaces.
2. Values shown are for exposure B. For other exposures, multiply values shown by the following factor: exposure C: 1.40 and exposure D: 1.66.
3. Linear interpolation between values of tributary area is permissible.
4. Values shown are for an importance factor I = 1.0. For other values of I, multiply values shown by I.
5. Plus and minus signs signify pressure acting toward and away from the exterior surface, respectively.
6. All component and cladding elements shall be designed for both positive and negative pressures shown in the table.
7. Notation:
   a: 10 percent of least horizontal dimension or 0.4 *h*, whichever is smaller, but not less than 4% of least horizontal dimension or 3 ft.
   h: Mean roof height in feet (meters).

Components and Cladding		h ≤ 30 ft.
Table 6-3B	Net Pressure Coefficients	Simplified Procedure Walls & Roofs
Partially Enclosed Buildings		



DESIGN WIND PRESSURE (PSF)

Location	Zone	Effective Wind Area (SF)	Basic Wind Speed V (MPH) 85	90	100	110	120	130	140	150	160	170
Roof	1	10	+10 -17	+10 -19	+13 -24	+16 -29	+19 -34	+22 -40	+25 -46	+29 -53	+33 -60	+37 -68
		20	+10 -17	+10 -19	+12 -23	+15 -28	+18 -33	+21 -39	+24 -45	+28 -52	+32 -59	+36 -67
		100	+10 -16	+9 -18	+11 -22	+14 -27	+16 -32	+19 -37	+22 -43	+26 -50	+29 -57	+33 -64
	2	10	+10 -26	+10 -29	+13 -36	+16 -43	+19 -52	+22 -60	+25 -70	+29 -81	+33 -92	+37 -103
		20	+10 -24	+10 -26	+12 -33	+15 -39	+18 -47	+21 -55	+24 -64	+28 -73	+32 -83	+36 -94
		100	+10 -18	+10 -20	+11 -25	+14 -30	+16 -36	+19 -42	+22 -49	+26 -57	+29 -64	+33 -73
	3	10	+10 -37	+10 -41	+13 -51	+16 -62	+19 -73	+22 -86	+25 -100	+29 -115	+33 -131	+37 -147
		20	+10 -31	+10 -35	+12 -43	+15 -52	+18 -62	+21 -73	+24 -84	+28 -97	+32 -110	+36 -125
		100	+10 -18	+10 -20	+11 -25	+14 -30	+16 -36	+19 -42	+22 -49	+26 -57	+29 -64	+33 -73
Walls	4	10	+17 -18	+19 -20	+24 -25	+29 -30	+34 -36	+40 -42	+46 -49	+53 -57	+60 -64	+68 -73
		50	+16 -17	+18 -19	+22 -23	+26 -28	+31 -34	+37 -40	+42 -46	+49 -53	+55 -60	+63 -68
		500	+14 -15	+15 -17	+19 -21	+23 -25	+27 -30	+32 -35	+37 -40	+43 -46	+49 -53	+55 -59
	5	10	+17 -21	+19 -24	+24 -30	+29 -36	+34 -43	+40 -50	+46 -58	+53 -67	+60 -76	+68 -86
		50	+16 -19	+18 -21	+22 -26	+26 -31	+31 -37	+37 -44	+42 -51	+49 -58	+55 -66	+63 -75
		500	+14 -15	+15 -17	+19 -21	+23 -25	+27 -30	+32 -35	+37 -40	+43 -46	+49 -53	+55 -59

Metric Conversion: 1 PSF = 47.9 pascals   1 SF = 0.0929 SM   1 MPH = 0.447 M/S

Notes:

1. Design wind pressures above represent the net pressure (sum of external and internal pressures) applied normal to all surfaces.
2. Values shown are for exposure B. For other exposures, multiply values shown by the following factor: exposure C: 1.40 and exposure D: 1.66.
3. Linear interpolation between values of tributary area is permissible.
4. Values shown are for an importance factor I = 1.0. For other values of I, multiply values shown by I.
5. Plus and minus signs signify pressure acting toward and away from the exterior surface, respectively.
6. All component and cladding elements shall be designed for both positive and negative pressures shown in the table.
7. Notation:
   a: 10 percent of least horizontal dimension or 0.4 *h*, whichever is smaller, but not less than 4% of least horizontal dimension or 3 ft.
   h: Mean roof height in feet (meters).

Terrain Exposure Constants

Table 6-4

Exposure	α	z_g (ft)	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	ℓ (ft)	$\bar{\in}$	z_{min} (ft)*
A	5.0	1500	1/5	0.64	1/3.0	0.30	0.45	180	1/2.0	60
B	7.0	1200	1/7	0.84	1/4.0	0.45	0.30	320	1/3.0	30
C	9.5	900	1/9.5	1.00	1/6.5	0.65	0.20	500	1/5.0	15
D	11.5	700	1/11.5	1.07	1/9.0	0.80	0.15	650	1/8.0	7

*z_{min} = minimum height used to ensure that the equivalent height $\bar{z}$ is greater of $0.6h$ or z_{min}. For buildings with $h \leq z_{min}$, $\bar{z}$ shall be taken as z_{min}.

Velocity Pressure Exposure Coefficients, K_h and K_z

Table 6-5

Height above ground level, z		Exposure (Note 1)					
		A		B		C	D
ft	(m)	Case 1	Case 2	Case 1	Case 2	Cases 1 & 2	Cases 1 & 2
0-15	(0-4.6)	0.68	0.32	0.70	0.57	0.85	1.03
20	(6.1)	0.68	0.36	0.70	0.62	0.90	1.08
25	(7.6)	0.68	0.39	0.70	0.66	0.94	1.12
30	(9.1)	0.68	0.42	0.70	0.70	0.98	1.16
40	(12.2)	0.68	0.47	0.76	0.76	1.04	1.22
50	(15.2)	0.68	0.52	0.81	0.81	1.09	1.27
60	(18)	0.68	0.55	0.85	0.85	1.13	1.31
70	(21.3)	0.68	0.59	0.89	0.89	1.17	1.34
80	(24.4)	0.68	0.62	0.93	0.93	1.21	1.38
90	(27.4)	0.68	0.65	0.96	0.96	1.24	1.40
100	(30.5)	0.68	0.68	0.99	0.99	1.26	1.43
120	(36.6)	0.73	0.73	1.04	1.04	1.31	1.48
140	(42.7)	0.78	0.78	1.09	1.09	1.36	1.52
160	(48.8)	0.82	0.82	1.13	1.13	1.39	1.55
180	(54.9)	0.86	0.86	1.17	1.17	1.43	1.58
200	(61.0)	0.90	0.90	1.20	1.20	1.46	1.61
250	(76.2)	0.98	0.98	1.28	1.28	1.53	1.68
300	(91.4)	1.05	1.05	1.35	1.35	1.59	1.73
350	(106.7)	1.12	1.12	1.41	1.41	1.64	1.78
400	(121.9)	1.18	1.18	1.47	1.47	1.69	1.82
450	(137.2)	1.24	1.24	1.52	1.52	1.73	1.86
500	(152.4)	1.29	1.29	1.56	1.56	1.77	1.89

Notes:

1. **Case 1:** a. All components and cladding.
   b. Main wind force resisting system in low-rise buildings designed using Figure 6-4.

   Case 2: a. All main wind force resisting systems in buildings except those in low-rise buildings designed using Figure 6-4.
   b. All main wind force resisting systems in other structures.
2. The velocity pressure exposure coefficient K_z may be determined from the following formula:

   For 15 ft. $\leq z \leq z_g$ — $K_z = 2.01\,(z/z_g)^{2/\alpha}$

   For $z <$ 15 ft. — $K_z = 2.01\,(15/z_g)^{2/\alpha}$

   Note: z shall not be taken less than 100 feet for Case 1 in exposure A or less than 30 feet for Case 1 in exposure B.
3. α and z_g are tabulated in Table 6-4.
4. Linear interpolation for intermediate values of height z is acceptable.
5. Exposure categories are defined in 6.5.6.

Wind Directionality Factor, K_d

Table 6-6

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

*Directionality Factor K_d has been calibrated with combinations of loads specified in Section 2. This factor shall only be applied when used in conjunction with load combinations specified in 2.3 and 2.4.

Internal Pressure Coefficients for Buildings, GC_{pi}

Table 6-7

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

Notes:

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces.
2. Values of GC_{pi} shall be used with q_z or q_h as specified in 6.5.12.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:

   (i) a positive value of GC_{pi} applied to all internal surfaces
   (ii) a negative value of GC_{pi} applied to all internal surfaces

Other Structures		All h
Table 6-11	Force Coefficients, C_f	Solid Freestanding Walls & Solid Signs

At Ground Level		Above Ground Level	
ν	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:

   ν: ratio of height to width;

   M: larger dimension of sign, in feet (meters); and

   N: smaller dimension of sign, in feet (meters).

Course Evaluation

Course Title: **FBC Wind Load Calculations**

Course #: ____________ **License type:** ____________________
(Architect, contractor, etc)

Date: ____________ **Location:** ______________________

Please circle your response:	**Strongly Disagree**	⟷			**Strongly Agree**
Question 1: The course objectives were accomplished.	1	2	3	4	5
Question 2: The course started and finished on time.	1	2	3	4	5
Question 3: The instructor(s) was well-versed in their topic and well-prepared.	1	2	3	4	5
Question 4: The materials presented were effective.	1	2	3	4	5

What did you like most about the course?

What did you like least about the course?

Please list other comments about this course, including ways to improve the course or suggestions for other courses.