This is an unedited, uncorrected chapter.

The final chapter will be available in time for fall.

NOTE: Figures and tables appear at the end of the chapter.

WEB CHAPTER W4

Design Loads and Design Philosophy

W4.1 Some Load Tables and Figures from ASCE Standard 7-98

The loads for which a particular building must be designed are usually stipulated by an applicable building code. Where such a code is nonexistent, use of the ASCE Standard 7: Minimum design Loads for Buildings and Other Structures is recommended. For ease of reference, the following tables and figures from the ASCE 7-98 are reproduced in this section [ASCE, 2000].

ASCES Table 1-1:	Classification of Buildings and Other Structures for Flood, Wind, Snow and Earthquake Loads
ASCES Table C3-1:	Minimum Design Dead Loads
ASCES Table C3-2:	Minimum Densities for Design Loads for Materials
ASCES Table 4-1:	Minimum Uniformly Distributed Live Loads, L_o and Minimum Concentrated Live Loads
ASCES Table 4-2:	Live Load Element Factor, K_{LL}
ASCES Figure 6-1:	Basic wind speed.
ASCES Table 6-1:	Importance Factor, I (Wind Loads)

ASCES Table 6-5: Velocity pressure Exposure Coefficients, K_h and K_z

ASCES Table 6-6: Wind Directionality Factor, K_d

ASCES Figure 6-3: Main wind force resisting system.

ASCES Table 6-7: Internal Pressure Coefficients for Buildings, GC_{pi}

ASCES Figure 7-1: Ground snow loads, p_g for the United States.

ASCES Table 7-2: Exposure Factor, C_e

ASCES Table 7-3: Thermal Factor, C_t

ASCES Table 7-4: Importance Factor, I (Snow Loads)

ASCES Figure 7-2: Graphs for determining roof slope factor C_s for warm and cold roofs.

ASCES Figure 7-5: Balanced and unbalanced snow loads for hip and gable roofs.

W4.2 Velocity Pressure

W4.2.1 Stagnation Pressure

In accordance with Bernoulli's equation for streamline flow of fluids, when a column of air strikes normal to an immovable body, the increase in static pressure on the object, also known as the ***stagnation pressure***, equals the decrease in kinetic energy. Thus

$$q_o = \frac{1}{2}\frac{w}{g}v_o^2 \qquad \text{(W4.2.1)}$$

where q_o is the stagnation pressure, w is the weight in pounds per cubic foot of the fluid, g is the acceleration due to gravity (= 32.2 ft/sec^2) and v_o is the velocity of the fluid in ft/sec. For the so called standard atmosphere, with a temperature of 59° F, at a sea level pressure of 29.92 inches of mercury, the weight of air is 0.0765 pcf. Also, v_o = $(5280V_o)/3600$ where V_o is the wind velocity in miles per hour. If these substitutions are made in the above equation:

$$q_o = 0.00256\ V_o^2 \qquad \text{(W4.2.2)}$$

where V_o is wind speed in mph and q_o is the stagnation pressure in psf, acting on a flat surface that is perpendicular to the wind direction. Thus, it is seen that a wind speed of 88 mph converts to a wind pressure, q_o of 20 psf, and a wind speed of 100 mph corresponds to 25.6 psf.

W4.2.2 Velocity Pressure Exposure Coefficient, K_z

Wind velocity increases with height because the friction of the earth's surface reduces velocity near the ground. The effect of friction becomes progressively smaller with distance from the ground. At heights high enough for the wind to be virtually independent of surface friction, the wind moves freely under the influence of the pressure gradient and attains the so called ***gradient velocity, V_g***. The height at which this occurs is known as the ***gradient height, z_g***. The layer of air below the gradient height is known as the ***boundary layer.*** The characteristics of the wind in the boundary layer are those which are of concern to engineers in the calculation of wind loading on structures.

The variation of wind velocity with height can be expressed, for a given exposure *e*, by a simple power law formula of the form [Davenport, 1968]:

$$\frac{V_z}{V_g} = \left(\frac{z}{z_{ge}}\right)^{\frac{1}{\alpha_e}} \qquad \text{for} \quad z \leq z_{ge} \tag{W4.2.3}$$

$$= 1 \qquad \text{for} \quad z \geq z_{ge}$$

where z = height above ground

V_z = wind speed at height z in exposure e

z_{ge} = gradient height for exposure e

V_g = gradient wind speed (i.e., wind speed at height z_{ge})

α_e = coefficient depending on ground roughness of exposure e

TABLE W4.2.1: Wind Exposure Constants (Adapted from Table 6.4 of the ASCES)

The values of gradient height z_{ge} and the exponential coefficient α_e depend on the ground surface roughness. The roughness is a function of the spacing, size, and height of structures, trees, vegetation, etc. on the ground. It is a minimum over large bodies of water and a maximum over centers of large cities. The ASCE Standard divides the ground roughness into four categories, namely, Exposures A, B, C and D. Values of parameters z_{ge} and α_e are given in Table W4.2.1, and velocity profiles for Exposures A, B, C and D are schematically shown in Fig. W4.2.1. They are based on the classical work of Davenport [1968]. Guidelines for selecting the appropriate exposure categories are given below:

Exposure A

Large city centers with at least 50% of the buildings having a height in excess of 70 ft. Because wind speeds are lowest in downtown areas, the standard imposes certain restrictions on the use of these lower velocity pressures. Thus, use of this exposure category is limited to those areas for which terrain representative of exposure A prevails in the upwind direction for a distance of at least one-half mile or 10 times the height of building whichever is greater.

Exposure B

Urban and suburban areas, wooded areas, and other terrain with numerous closely spaced obstructions having the size of single family dwellings or larger. Use of this exposure category is limited to those areas for which terrain representative of Exposure B prevails in the upwind direction for a distance of at least 1500 ft or 10 times the height of the building or structure, whichever is greater.

Exposure C

Open terrain with scattered obstructions having heights generally less than 30 ft. This category includes flat open country, grass lands, and shorelines in hurricane prone regions. This exposure category should be used whenever terrain does not fit the description of other exposure categories. Also, use of this exposure category is mandatory for determining wind pressures on components and cladding of buildings with a mean roof height of less than 60 ft.

Exposure D

Flat, unobstructed areas exposed to wind flowing over open water (excluding shorelines in hurricane prone regions) for a distance of at least 1 mile. Shorelines in Exposure D include inland waterways, the Great Lakes, and coastal areas of California, Oregon, Washington and Alaska. This exposure shall be used only for those buildings and other structures exposed to wind coming from over the water. Exposure D extends inland from the shoreline a distance of 1500 ft or 10 times the height of the building or structure, whichever is greater.

Figure W4.2.1: Variation of wind speed with height and terrain.

As the surface friction (roughness) increases, the gradient height also increases. Thus, in a particular weather situation, the gradient level will be at progressively higher elevations going from open country and suburban locations to a nearby downtown location (W4.2.1). Buildings and structures are required to be designed to resist wind from any direction, and the exposure category applicable to each wind direction should be used.

The basic wind speed values, V, provided in the standard (Fig. 6.1 of the ASCES) are for flat, open country terrain typical of Exposure C terrain at $z =$ 33 ft. As the gradient wind speed, V_g, is the same at all four gradient levels considered in the standard, the power law affords a method of adjusting design wind speeds from the open country conditions (Exposure C) to the other exposure conditions. We have from Eq. W4.2.3:

$$V_g = V\left(\frac{z_{gC}}{33}\right)^{\frac{1}{\alpha_C}} \qquad \text{(W4.2.4)}$$

and

$$V_z = V_g\left(\frac{z}{z_{ge}}\right)^{\frac{1}{\alpha_e}} = V\left(\frac{z_{gC}}{33}\right)^{\frac{1}{\alpha_C}}\left(\frac{z}{z_{ge}}\right)^{\frac{1}{\alpha_e}} \qquad \text{(W4.2.5)}$$

where V = basic wind speed from contour map (wind speed at $z = 33$ ft above ground level in Exposure C)

V_g = gradient wind speed

V_z = design wind speed at height z and given exposure e (= A, B, C, or D)

z = height above ground

z_{gC} = gradient height for Exposure C

z_{ge} = gradient height for exposure e

α_e = power law coefficient for exposure e

α_C = power law coefficient for Exposure C

Using Eqs. W4.2.2 and W4.2.5, and noting that the gradient height for Exposure C (from Table W4.2.1) is 900 ft, , the velocity pressure for any height (z) and exposure (e) may be expressed as:

$$q_z = 0.00256\ V_z^2 = 0.00256 \left[\left(\frac{900}{33} \right)^{\frac{2}{9.5}} \left(\frac{z}{z_{ge}} \right)^{\frac{2}{\alpha_e}} \right] V^2$$

Or,

$$q_z = 0.00256\, K_z\, V^2 \qquad \text{(W4.2.6)}$$

where K_z is known as the ***velocity pressure exposure coefficient*** and is given by:

$$K_z = \left(\frac{900}{33} \right)^{\frac{2}{9.5}} \left(\frac{z}{z_{ge}} \right)^{\frac{2}{\alpha_e}} = 2.01 \left(\frac{z}{z_{ge}} \right)^{\frac{2}{\alpha_e}} \qquad \text{(W4.2.7)}$$

Values of K_z are tabulated in the ASCE Standard to 500 ft above ground, for Exposure categories A, B, C, and D.

TABLE W4.2.1: Wind Exposure Constants

Exposure	α_e	z_{ge} (ft)
A	5.0	1500
B	7.0	1200
C	9.5	900
D	11.5	700

W4.3 Earthquake Loads, E

Material will be added later.

W4.4 Probabilistic Basis for LRFD

Load and resistance factor design (LRFD) is that design philosophy in which the structure is proportioned such that the probability of exceeding a limit state is held to an acceptably small value. It recognizes that neither the external loads acting on a structure nor the resistance are deterministic but are random in character. The probabilistic design format used by Galambos and Ravindra [1976] to develop the LRFD criteria for steel structures is due to Cornell [1969] and Lind [1971]. The format is explained briefly in the following.

Structural safety is a function of the resistance, R, of the structure and of the load effect, Q, acting on it. R and Q are statistically random variables. The frequency distributions for Q and R are shown in Fig. W4.4.1a as separate curves on a common plot for a hypothetical structure. As long as the resistance R is greater than (to the right of) the effects of the loads Q, a margin of safety for the particular limit state exists. However, because Q and R are random variables, there is some small probability that the resistance R may be less than the load effect Q (i.e., $R < Q$). This limit state probability is related to the degree of overlap of the frequency distributions (shaded area in Fig. W4.4.1a). This area depends on the relative positioning of (R_m vs Q_m) and their dispersions. Here, R_m and Q_m are the mean values of the variables R and Q, respectively.

Figure W4.4.1: Definitions of structural safety in LRFD.

An equivalent representation of structural safety is shown in Fig. W4.4.1*b*. If the expression $R < Q$ is divided by Q and the result expressed logarithmically, the result will be a single distribution curve combining the uncertainties of both R and Q. The probability of attaining a limit state ($R < Q$) is equal to the probability that $\ln(R/Q) < \ln(1) = 0$ and is represented by the shaded area in the diagram. The smaller this area is, the more reliable is the structure. In this case the probability of failure (a given limit state being reached) is

$$P_f = P\left[\ln\left(\frac{R}{Q}\right) < 0\right] \qquad \text{(W4.4.1)}$$

If we introduce the standard variate, U, defined by

$$U = \frac{\ln(R/Q) - \left[\ln(R/Q)\right]_m}{\sigma_{\ln(R/Q)}} \qquad \text{(W4.4.2)}$$

in which $\left[\ln(R/Q)\right]_m$ and $\sigma_{\ln(R/Q)}$ are the mean and standard deviation of the distribution of the natural logarithm of the ratio (R/Q). The variable $\ln(R/Q)$ is a normally distributed variable. For this reason U is a normally distributed variable as well, having a mean value of 0 and a standard deviation of 1 (i.e., $U_m = 0$ and $\sigma_U = 1$). The expression for the probability of failure from Eq. W4.4.1, becomes:

$$P_f = P\left[\ln(R/Q) < 0\right] = P\left[U < -\frac{\left[\ln(R/Q)\right]_m}{\sigma_{\ln(R/Q)}}\right]$$

$$= F_U\left[-\frac{[\ln(R/Q)]_m}{\sigma_{\ln(R/Q)}}\right] = F_U[-\beta] \qquad \text{(W4.4.3)}$$

Here F_U is the ***cumulative distribution function*** of the normalized variable U. The quantity

$$[\ln(R/Q)]_m / \sigma_{\ln(R/Q)} = \beta \qquad \text{(W4.4.4)}$$

defines the reliability of the structure under consideration. The coefficient β represents the number of standard deviations that the mean value of ln (R /Q) is located from the origin. Now, the farther away the mean of ln (R /Q) is from the origin (i.e., the larger the value of β), the smaller will be the probability of failure. Hence, theoretically one can make P_f as small as is desired, by making β larger, although it can never be equal to zero. This indicates that there is always some probability that the structure will fail. Hence, β is called the ***safety index*** or ***reliability index.*** For any given distribution ln (R/Q), the larger β is, the smaller is the probability of exceeding a limit state. The relationship between the safety index β and the probability of failure P_f, on the assumption that Q and R are distributed normally, is given in Table W4.4.1.

TABLE W4.4.1: Probability of Failure as a Function of Safety Index

After some lengthy transformations and simplifications, Eq.W4.4.4 yields [Galambos and Ravindra, 1976; Lind, 1971]:

$$\left[\frac{R_m}{R_n} e^{-0.55\,\beta V_R}\right] R_n \quad \geq \quad \left[\frac{Q_m}{Q_n} e^{0.55\,\beta V_Q}\right] Q_n \tag{W4.4.5a}$$

or

$$\phi R_n \quad \geq \quad \gamma Q_n \tag{W4.4.5b}$$

where R_n = nominal or theoretical value of the resistance R

Q_n = nominal value of the load Q

R_m = mean value of the resistance R

Q_m = mean value of the load Q

V_R = coefficient of variation of the resistance R

V_Q = coefficient of variation of the load Q

β = safety index

ϕ = resistance factor

γ = load factor

The objective of a good design specification is to ensure that the probability (risk) of failure is comparable with other risks an occupant of the building designed using the specification, has to face in a modern society. That is, a level too high means unsafe design, whereas a level too low means over design and waste. The model briefly described above, is known as a ***First-Order Second-Moment (FOSM) Probabilistic Model***, where only the first two moments (mean and standard deviation) of the random variables are used to develop the statistical properties of resistance, load, and structural safety.

The load combinations and load factors were developed by Ellingwood et al. [1982]. The target reliability indices, β, underlying the load factors are: 3.0 for combinations with gravity loads only (dead, live, rain, and snow loads), 2.5 for combinations with wind included, and 1.75 for combinations with earthquake loads (see Table W4.4.1 for the corresponding probabilities of failure).

The target value for the safety index β used in LRFDS is 3 for all members (tension members, beams, columns, and beam-columns), while a higher value of 4.5 is used for connections. From Table W4.4.1, we observe that the probability of reaching a limit state is, therefore, much smaller for connections than the members, translating the design philosophy in existence over the last 80 years; that the connections should be stronger than the members that they connect. The basis of determining ϕ has been described by Galambos and Ravindra [1976].

TABLE W4.4.2: Typical Resistance Factors

References

W4.1 AISC [1999]: *Load and Resistance Factor Design Specifications for Structural Steel Buildings,* American Institute of Steel Construction, Chicago, IL. (Also referred to as **LRFDS** in this book.)

W4.2 ASCE [1965]: "Wind Forces on Structures," *Journal of the Structural Division,* ASCE, vol. 91, ST3.

W4.3 ASCE [2000]: *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-98, American Society of Civil Engineers. (Also referred to as **ASCES** in this book.)

W4.4 ASCE [2003]: *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-02, American Society of Civil Engineers.

W4.5 Cornell, C. A. [1969]: "A Probability-Based Structural Code," *Journal American Concrete Institute,* vol. 55, no. 12, December, pp. 974-985.

W4.6 Davenport, A. G. [1968]: "A Rationale for the Determination of Design Wind Velocities," *Journal of the Structural Division,* ASCE, vol. 94, ST6, June.

W4.7 Ellingwood, B. E., McGregor, J. G., Galambos, T. V., and Cornell, C. A. [1982]: "Probability-Based Load Criteria: Load Factors and Load Combinations," *Journal of the Structural Division,* ASCE, vol. 108, no. 5, pp. 978-997.

W4.8 Galambos, T. V., and Ravindra, M. K. [1976]: "Proposed Criterion for Load and Resistance Factor Design of Steel Building Structures," Research Report No. 45, Civil Engineering Department, Washington University, St. Louis, MO, May.

W4.9 Lind, N. C. [1971]: "Consistent Partial Safety Factors," *Journal of the Structural Division,* ASCE, vol. 97, ST6, Proc. Paper 8166, June, pp. 1651-1669.

TABLE W4.4.1: Probability of Failure as a Function of Safety Index

β	1.0	2.0	3.0	4.0	5.0
P_f	1.58×10^{-1}	2.27×10^{-2}	1.35×10^{-3}	3.16×10^{-5}	2.86×10^{-7}
β = safety index; P_f = probability of failure					

TABLE W4.4.2: Typical Resistance Factors

ϕ	Application
1.00	Slip resistant bolt shear values, standard holes; web local yielding under concentrated loads
0.90	Yielding in the gross section of tension members; bending strength of beams; shear strength of webs of beams; base metal in grove welds; shear yielding or tension yielding of the connecting elements; flange local bending; web compression buckling; web panel-zone shear
0.85	Column strength in flexural buckling and flexural torsional buckling; axial strength of composite columns: steel area; flexural strength of composite beams; web sidesway buckling
0.80	Shear on effective area of complete-joint-penetration grove welds; tension normal to effective area of partial-joint-penetration grove welds
0.75	Fracture in the net section of tension members; pin connected members in tension or shear; fillet welds: shear on effective throat area; plug and slot welds shear parallel to faying surface; partial-joint-penetration grove welds: shear parallel to axis of weld; tension, shear, or combined shear and tension on bolts; tension rupture of the connection elements; block shear rupture strength; bearing strength of bolts; bearing of pins, rollers and rockers; web crippling
0.70	Slip resistance for bolts in long-slotted holes when holes are parallel to the direction of load
0.60	Bearing on concrete foundations; slip resistance for bolts in long-slotted holes when holes are transverse to the direction of load

TABLE 1-1. Classification of Buildings and Other Structures for Flood, Wind, Snow, and Earthquake Loads

Nature of Occupancy	Category
Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Categories I, III and IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with day-care facilities with capacity greater than 150 • Buildings and other structures with elementary or secondary school facilities with capacity greater than 150 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities • Jails and detention facilities • Power generating stations and other public utility facilities not included in Category IV Buildings and other structures containing sufficient quantities of toxic, explosive or other hazardous substances to be dangerous to the public if released including, but not limited to: • Petrochemical facilities • Fuel storage facilities • Manufacturing or storage facilities for hazardous chemicals • Manufacturing or storage facilities for explosives	III
Buildings and other structures that are equipped with secondary containment of toxic, explosive or other hazardous substances (including, but not limited to double wall tank, dike of sufficient size to contain a spill, or other means to contain a spill or a blast within the property boundary of the facility and prevent release of harmful quantities of contaminants to the air, soil, ground water, or surface water) or atmosphere (where appropriate) shall be eligible for classification as a Category II structure. In hurricane prone regions, buildings and other structures that contain toxic, explosive, or other hazardous substances and do not qualify as Category IV structures shall be eligible for classification as Category II structures for wind loads if these structures are operated in accordance with mandatory procedures that are acceptable to the authority having jurisdiction and which effectively diminish the effects of wind on critical structural elements or which alternatively protect against harmful releases during and after hurricanes. Buildings and other structures designated as essential facilities including, but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities • Fire, rescue and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Communications centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Ancillary structures (including, but not limited to communication towers, fuel storage tanks, cooling towers, electrical substation structures, fire water storage tanks or other structures housing or supporting water or other fire-suppression material or equipment) required for operation of Category IV structures during an emergency • Aviation control towers, air traffic control centers and emergency aircraft hangars • Water storage facilities and pump structures required to maintain water pressure for fire suppression • Buildings and other structures having critical national defense functions	IV

ASCES Table 1-1

TABLE C3-1. Minimum Design Dead Loads* (English Units)

Component	Load (psf)
CEILINGS	
Acoustical Fiber Board	1
Gypsum board (per mm thickness)	0.55
Mechanical duct allowance	4
Plaster on tile or concrete	5
Plaster on wood lath	8
Suspended steel channel system	2
Suspended metal lath and cement plaster	15
Suspended metal lath and gypsum plaster	10
Wood furring suspension system	2.5
COVERINGS, ROOF, AND WALL	
Asbestos-cement shingles	4
Asphalt shingles	2
Cement tile	16
Clay tile (for mortar add 10 psf)	
Book tile, 2-in.	12
Book tile, 3-in.	20
Ludowici	10
Roman	12
Spanish	19
Composition:	
Three-ply ready roofing	1
Four-ply felt and gravel	5.5
Five-ply felt and gravel	6
Copper or tin	1
Corrugated asbestos-cement roofing	4
Deck, metal, 20 gage	2.5
Deck, metal, 18 gage	3
Decking, 2-in. wood (Douglas fir)	5
Decking, 3-in. (Douglas fir)	8
Fiberboard, 1/2-in.	0.75
Gypsum sheathing, 1/2-in.	2
Insulation, roof boards (per in. thickness)	
Cellular glass	0.7
Fibrous glass	1.1
Fiberboard	1.5
Perlite	0.8
Polystyrene foam	0.2
Urethane foam with skin	0.5
Plywood (per 1/8-in. thickness)	0.4
Rigid insulation, 1/2-in.	0.75
Skylight, metal frame, 3/8-in. wire glass	8
Slate, 3/16-in.	7
Slate, 1/4-in.	10
Waterproofing membranes:	
Bituminous, gravel-covered	5.5
Bituminous, smooth surface	1.5
Liquid applied	1
Single-ply, sheet	0.7
Wood sheathing (per in. thickness)	3
Wood shingles	3

Component	Load (psf)
FLOOR FILL	
Cinder concrete, per inch	9
Lightweight concrete, per inch	8
Sand, per inch	8
Stone concrete, per inch	12
FLOORS AND FLOOR FINISHES	
Asphalt block (2-in.), 1/2-in. mortar	30
Cement finish (1-in.) on stone-concrete fill	32
Ceramic or quarry tile (3/4-in.) on 1/2-in. mortar bed	16
Ceramic or quarry tile (3/4-in.) on 1-in. mortar bed	23
Concrete fill finish (per inch thickness)	12
Hardwood flooring, 7/7-in.	4
Linoleum or asphalt tile, 1/4-in.	1
Marble and mortar on stone-concrete fill	33
Slate (per mm thickness)	15
Solid flat tile on 1-in. mortar base	23
Subflooring, 3/4-in.	3
Terrazzo (1-1/2-in.) directly on slab	19
Terrazzo (1-in.) on stone-concrete fill	32
Terrazzo (1-in.), 2-in. stone concrete	32
Wood block (3-in.) on mastic, no fill	10
Wood block (3-in.) on 1/2-in. mortar base	16
FLOORS, WOOD-JOIST (NO PLASTER)	
DOUBLE WOOD FLOOR	

Joist sizes (in.):	12-in. spacing (lb/ft²)	16-in. spacing (lb/ft²)	24-in. spacing (lb/ft²)
2 × 6	6	5	5
2 × 8	6	6	5
2 × 10	7	6	6
2 × 12	8	7	6

Component	Load (psf)
FRAME PARTITIONS	
Movable steel partitions	4
Wood or steel studs, 1/2-in. gypsum board each side	8
Wood studs, 2 × 4, unplastered	4
Wood studs, 2 × 4, plastered one side	12
Wood studs, 2 × 4, plastered two sides	20
FRAME WALLS	
Exterior stud walls:	
2 × 4 @ 16-in., 5/8-in. gypsum, insulated, 3/8-in. siding	11
2 × 6 @ 16-in., 5/8-in. gypsum, insulated, 3/8-in. siding	12
Exterior stud walls with brick veneer	48
Windows, glass, frame and sash	8

Component					Load (psf)
Clay brick wythes:					
4 in.					39
8 in.					79
12 in.					115
16 in.					155
Hollow concrete masonry unit wythes:					
Wythe thickness (in inches)	4	6	8	10	12
Density of unit (16.49 kN/m³)					
No grout	22	24	31	37	43
48″ o.c.		29	38	47	55
40″ o.c. grout		30	40	49	57
32″ o.c. spacing		32	42	52	61
24″ o.c.		34	46	57	67
16″ o.c.		40	53	66	79
Full grout		55	75	95	115
Density of unit (125 pcf):					
No grout	26	28	36	44	50
48″ o.c.		33	44	54	62
40″ o.c. grout		34	45	56	65
32″ o.c. spacing		36	47	58	68
24″ o.c.		39	51	63	75
16″ o.c.		44	59	73	87
Full Grout		59	81	102	123
Density of Unit (21.21 kN/m³)					
No grout	29	30	39	47	54
48″ o.c.		36	47	57	66
40″ o.c. grout		37	48	59	69
32″ o.c. spacing		38	50	62	72
24″ o.c.		41	54	67	78
16″ o.c.		46	61	76	90
Full grout		62	83	105	127
Solid concrete masonry unit wythes (incl. concrete brick):					
Wythe thickness (in mm)	4	6	8	10	12
Density of unit (105 pcg):	32	51	69	87	105
Density of unit (125 pcf):	38	60	81	102	124
Density of unit (135 pcf:)	41	64	87	110	133

*Weights of masonry include mortar but not plaster. For plaster, add 5 lb/ft² for each face plastered. Values given represent averages. In some cases there is a considerable range of weight for the same construction.

ASCES Table C3-1

TABLE C3-2. Minimum Densities for Design Loads from Materials (English Units)

Material	Load (lb/ft³)	Material	Load (lb/ft³)
Aluminum	170	Lead	710
Bituminous products		Lime	
Asphaltum	81	Hydrated, loose	32
Graphite	135	Hydrated, compacted	45
Parafin	56	Masonry, Ashlar Stone	
Petroleum, crude	55	Granite	165
Petroleum, refined	50	Limestone, crystalline	165
Petroleum, benzine	46	Limestone, oolitic	135
Petroleum, gasoline	42	Marble	173
Pitch	69	Sandstone	144
Tar	75	Masonry, Brick	
Brass	526	Hard (low absorption)	130
Bronze	552	Medium (medium absorption)	115
Cast-stone masonry (cement, stone, sand)	144	Soft (high absorption)	100
Cement, portland, loose	90	Masonry, Concrete	
Ceramic tile	150	Lightweight units	105
Charcoal	12	Medium weight units	125
Cinder fill	57	Normal weight units	135
Cinders, dry, in bulk	45	Masonry Grout	140
Coal		Masonry, Rubble Stone	
Anthracite, piled	52	Granite	153
Bituminous, piled	47	Limestone, crystalline	147
Lignite, piled	47	Limestone, oolitic	138
Peat, dry, piled	23	Marble	156
Concrete, plain		Sandstone	137
Cinder	108	Mortar, cement or lime	130
Expanded-slag aggregate	100	Particleboard	45
Haydite (burned-clay aggregate)	90	Plywood	36
Slag	132	Riprap (Not submerged)	
Stone (including gravel)	144	Limestone	83
Vermiculite and perlite aggregate, nonload-bearing	25–50	Sandstone	90
Other light aggregate, load-bearing	70–105	Sand	
Concrete, Reinforced		Clean and dry	90
Cinder	111	River, dry	106
Slag	138	Slag	
Stone (including gravel)	150	Bank	70
Copper	556	Bank screenings	108
Cork, compressed	14	Machine	96
Earth (not submerged)		Sand	52
Clay, dry	63	Slate	172
Clay, damp	110	Steel, cold-drawn	492
Clay and gravel, dry	100	Stone, Quarried, Piled	
Silt, moist, loose	78	Basalt, granite, gneiss	96
Silt, moist, packed	96	Limestone, marble, quartz	95
Silt, flowing	108	Sandstone	82
Sand and gravel, dry, loose	100	Shale	92
Sand and gravel, dry, packed	110	Greenstone, hornblende	107
Sand and gravel, wet	120	Terra Cotta, Architectural	
Earth (submerged)		Voids filled	120
Clay	80	Voids unfilled	72
Soil	70	Tin	459
River mud	90	Water	

ASCES Table C3-2

TABLE C3-2. Minimum Densities for Design Loads from Materials (English Units) (*Continued*)

Material	Load (lb/ft³)	Material	Load (lb/ft³)
Sand or gravel	60	Fresh	62
Sand or gravel and clay	65	Sea	64
Glass	160	Wood, Seasoned	
Gravel, dry	104	Ash, commercial white	41
Gypsum, loose	70	Cypress, southern	34
Gypsum, wallboard	50	Fir, Douglas, coast region	34
Ice	57	Hem fir	28
Iron		Oak, commercial reds and whites	47
Cast	450	Pine, southern yellow	37
Wrought	480	Redwood	28
		Spruce, red, white, and Stika	29
		Western hemlock	32
		Zinc, rolled sheet	449

[1]Tabulated values apply to solid masonry and to the solid portion of hollow masonry.

ASCES Table C3-2

TABLE 4-1. Minimum Uniformly Distributed Live Loads, L_o and Minimum Concentrated Live Loads

Occupancy or Use	Uniform psf (kN/m²)	Concentration lb (kN)
Apartments (see residential)		
Access floor systems		
Office use	50 (2.4)	2,000 (8.9)
Computer use	100 (4.79)	2,000 (8.9)
Armories and drill rooms	150 (7.18)	
Assembly areas and theaters		
Fixed seats (fastened to floor)	60 (2.87)	
Lobbies	100 (4.79)	
Movable seats	100 (4.79)	
Platforms (assembly)	100 (4.79)	
Stage floors	150 (7.18)	
Balconies (exterior)	100 (4.79)	
On one- and two-family residences only, and not exceeding 100 ft² (9.3 m²)	60 (2.87)	
Bowling alleys, poolrooms and similar recreational areas	75 (3.59)	
Catwalks for maintenance access	40 (1.92)	300 (1.33)
Corridors		
First floor	100 (4.79)	
Other floors, same as occupancy served except as indicated		
Dance halls and ballrooms	100 (4.79)	
Decks (patio and roof)		
Same as area served, or for the type of occupancy accommodated		
Dining rooms and restaurants	100 (4.79)	
Dwellings (see residential)		
Elevator machine room grating [on area of 4 in.² (2,580 mm²)]		300 (1.33)
Finish light floor plate construction [on area of 1 in.² (645 mm²)]		200 (0.89)
Fire escapes	100 (4.79)	
On single-family dwellings only	40 (1.92)	
Fixed Ladders		See Section 4.4
Garages (passenger cars only)	50 (2.40)	—[1]
Trucks and buses	—[2]	
Grandstands (see stadium and arena bleachers)		
Gymnasiums, main floors and balconies	100 (4.79)[1]	
Handrails, guardrails and grab bars	See Section 4.4	
Hospitals		
Operating rooms, laboratories	60 (2.87)	1,000 (4.45)
Private rooms	40 (1.92)	1,000 (4.45)
Wards	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Hotels (see residential)		
Libraries		
Reading rooms	60 (2.87)	1,000 (4.45)
Stack rooms	150 (7.18)[3]	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
Manufacturing		
Light	125 (6.00)	2,000 (8.90)
Heavy	250 (11.97)	3,000 (13.40)
Marquees and Canopies	75 (3.59)	
Office Buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first floor corridors	100 (4.79)	2,000 (8.90)
Offices	50 (2.40)	2,000 (8.90)
Corridors above first floor	80 (3.83)	2,000 (8.90)

ASCES Table 4-1

TABLE 4-1. Minimum Uniformly Distributed Live Loads, L_o, and Minimum Concentrated Live Loads (*Continued*)

Occupancy or Use	Uniform psf (kN/m²)	Concentration lb (kN)
Penal Institutions		
Cell blocks	40 (1.92)	
Corridors	100 (4.79)	
Residential		
Dwellings (one- and two-family)		
Uninhabitable attics without storage	10 (0.48)	
Uninhabitable attics with storage	20 (0.96)	
Habitable attics and sleeping areas	30 (1.44)	
All other areas except stairs and balconies	40 (1.92)	
Hotels and multifamily houses		
Private rooms and corridors serving them	40 (1.92)	
Public rooms and corridors serving them	100 (4.79)	
Reviewing stands, grandstands and bleachers	100 (4.79)[4]	
Roofs	See Sections 4.3 and 4.9	
Schools		
Classrooms	40 (1.92)	1,000 (4.45)
Corridors above first floor	80 (3.83)	1,000 (4.45)
First floor corridors	100 (4.79)	1,000 (4.45)
Scuttles, skylight ribs, and accessible ceilings		200 (9.58)
Sidewalks, vehicular driveways, and yards, subject to trucking	250 (11.97)[5]	8,000 (35.60)[6]
Stadiums and Arenas		
Bleachers	100 (4.79)[4]	
Fixed Seats (fastened to floor)	60 (2.87)[4]	
Stairs and exitways	100 (4.79)	—[7]
One- and two-family residences only	40 (1.92)	
Storage areas above ceilings	20 (0.96)	
Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Light	125 (6.00)	
Heavy	250 (11.97)	
Stores		
Retail		
First floor	100 (4.79)	1,000 (4.45)
Upper floors	73 (3.59)	1,000 (4.45)
Wholesale, all floors	125 (6.00)	1,000 (4.45)
Vehicle barriers	See Section 4.4	
Walkways and elevated platforms (other than exitways)	60 (2.87)	
Yards and terraces, pedestrians	100 (4.79)	

[1]Floors in garages or portions of building used for the storage of motor vehicles shall be designed for the uniformly distributed live loads of Table 4-1 or the following concentrated load: (1) for passenger cars accommodating not more than nine passengers, 2,000 lb (8.90 kN) acting on an area of 20 in.^{2} (12,900 mm^2); (2) mechanical parking structures without slab or deck, passenger car only, 1,500 lb (6.70 kN) per wheel.

[2]Garages accommodating trucks and buses shall be designed in accordance with an approved method which contains provisions for truck and bus loadings.

[3]The weight of books and shelving shall be computed using an assumed density of 65 lb/ft^3 (pounds per cubic foot, sometimes abbreviated pcf) (10.21 kN/m^3) and converted to a uniformly distributed load; this load shall be used if it exceeds 150 lb/ft^2 (7.18 kN/m^2).

[4]In addition to the vertical live loads, horizontal swaying forces parallel and normal to the length of seats shall be included in the design according to the requirements of ANSI/NFPA 102 [3].

[5]Other uniform loads in accordance with an approved method which contains provisions for truck loadings shall also be considered where appropriate.

[6]The concentrated wheel load shall be applied on an area of 20 in.^{2} (12,900 mm^2).

[7]Minimum concentrated load on stair treads [on area of 4 in.^{2} (2,580 mm^2)] is 300 lb (1.33 kN).

ASCES Table 4-1

TABLE 4-2. Live Load Element Factor, K_{LL}

Element	K_{LL}[1]
Interior columns	4
Exterior columns without cantilever slabs	4
Edge columns with cantilever slabs	3
Corner columns with cantilever slabs	2
Edge beams without cantilever slabs	2
Interior beams	2
All other members not identified above including:	1
Edge beams with cantilever slabs	
Cantilever beams	
Two way slabs	
Members without provisions for continuous shear transfer normal to their span	

[1]In lieu of the values above, K_{LL} is permitted to be calculated.

ASCES Table 4-2

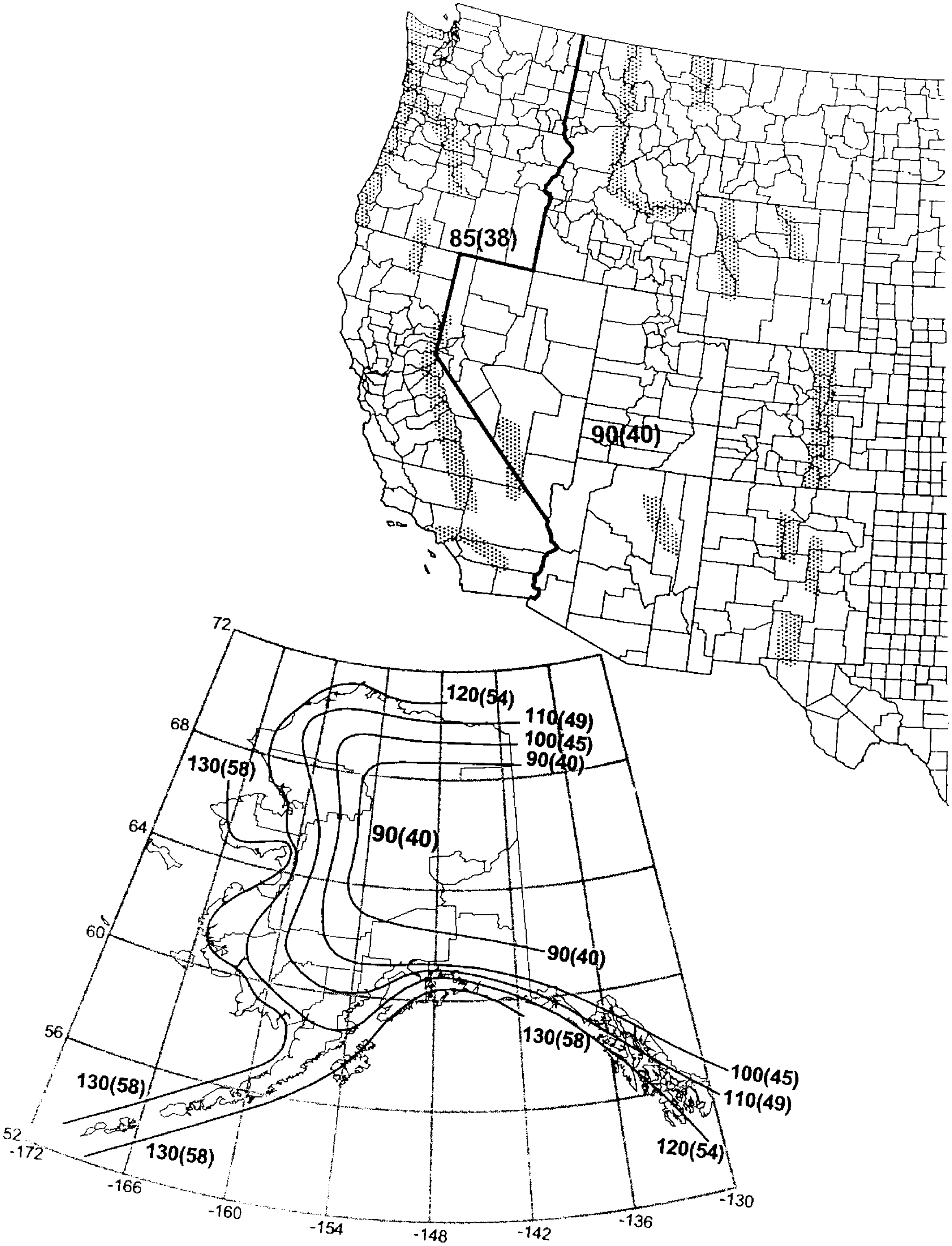
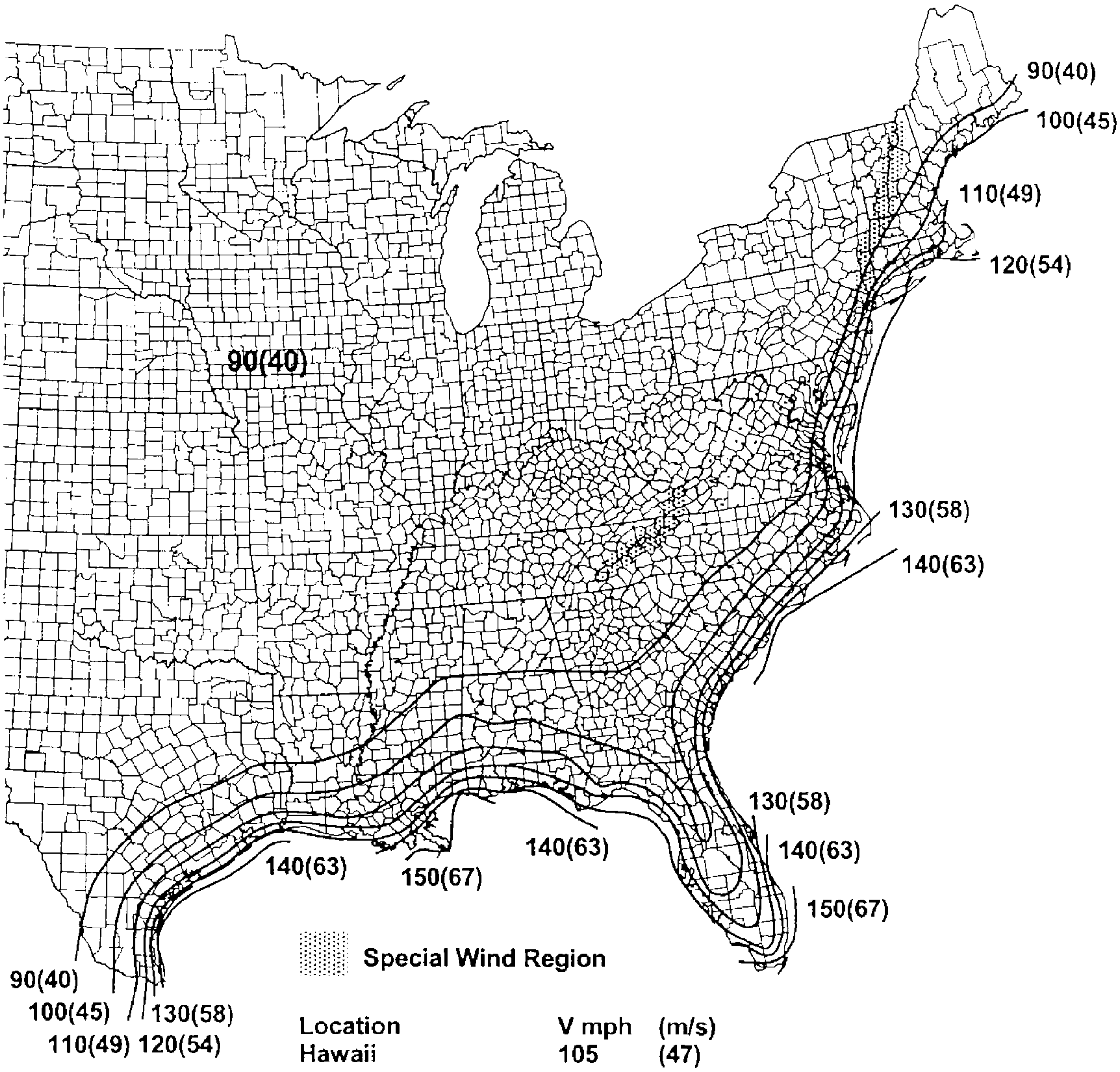


FIGURE 6-1. Basic Wind Speed

ASCES Figure 6-1



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

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

FIGURE 6-1. *(Continued)*

ASCES Figure 6-1

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.

ASCES Table 6-1

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. $< z \leq z_g$ For $z < 15$ ft.

   $K_z = 2.01\,(z/z_g)^{2/\alpha}$ $K_z = 2.01\,(15/z_g)^{2/\alpha}$

   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.

ASCES Table 6-5

Wind Directionality Factor, K_d

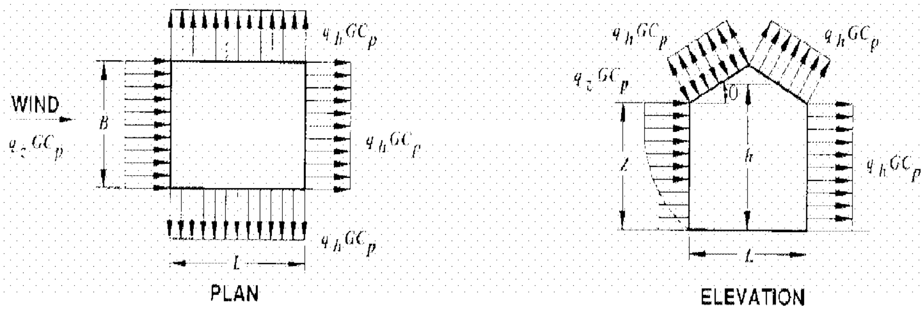
Table 6-6

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

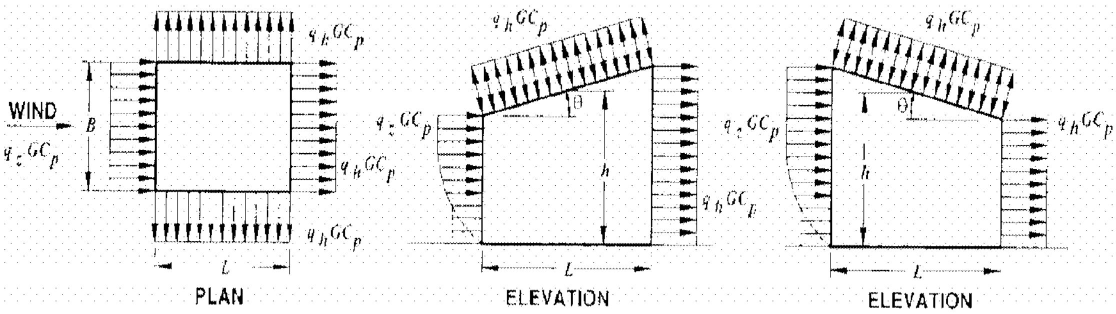
*Directionality Factor K_d has been calibrated with combinations of loads specified in Section 2. This factor shall only be applied when used in conjunction with load combinations specified in 2.3 and 2.4.

ASCES Table 6-6

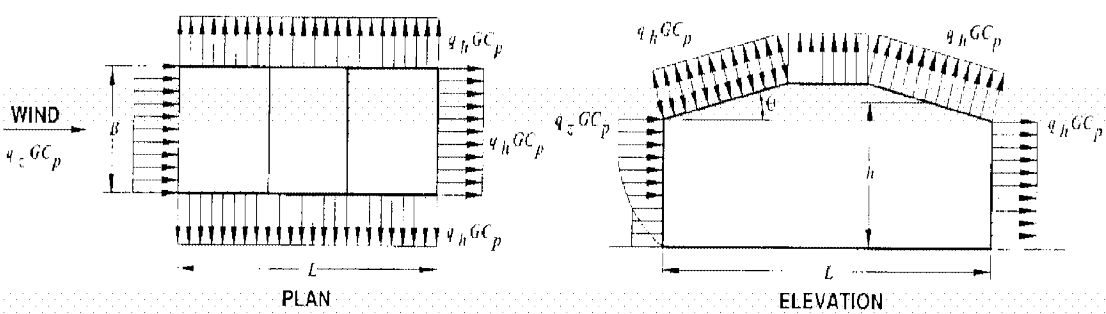
Main Wind Force Resisting System		All h
Figure 6-3	External Pressure Coefficients, C_p	Walls & Roofs
Enclosed, Partially Enclosed Buildings		



GABLE, HIP ROOF



MONOSLOPE ROOF (NOTE 4)



MANSARD ROOF (NOTE 8)

ASCES Figure 6-3

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

ASCES Figure 6-3

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

ASCES Table 6-7

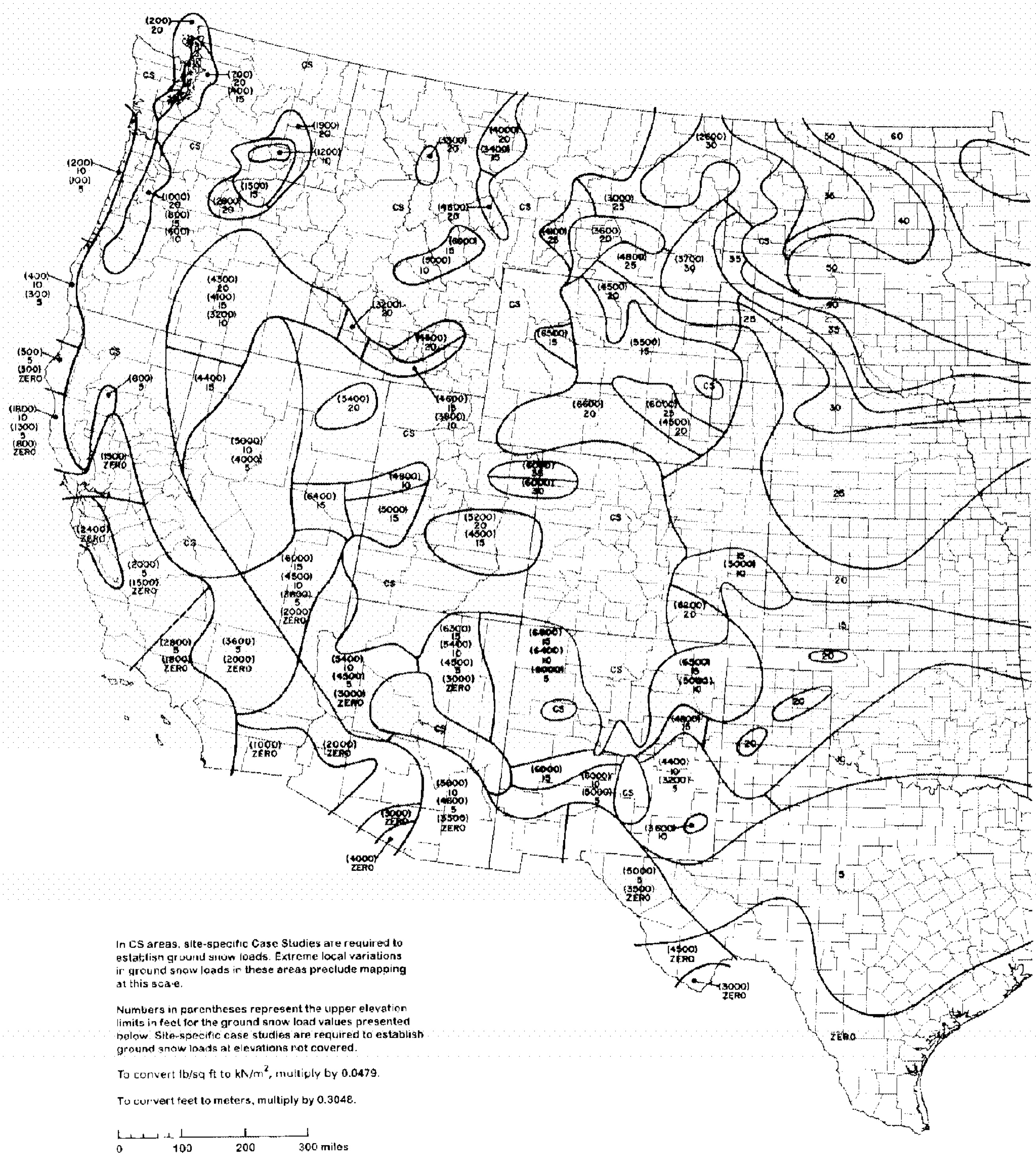


FIGURE 7-1. Ground Snow Loads, p_g for the United States (lb/ft^2)

ASCES Figure 7-1

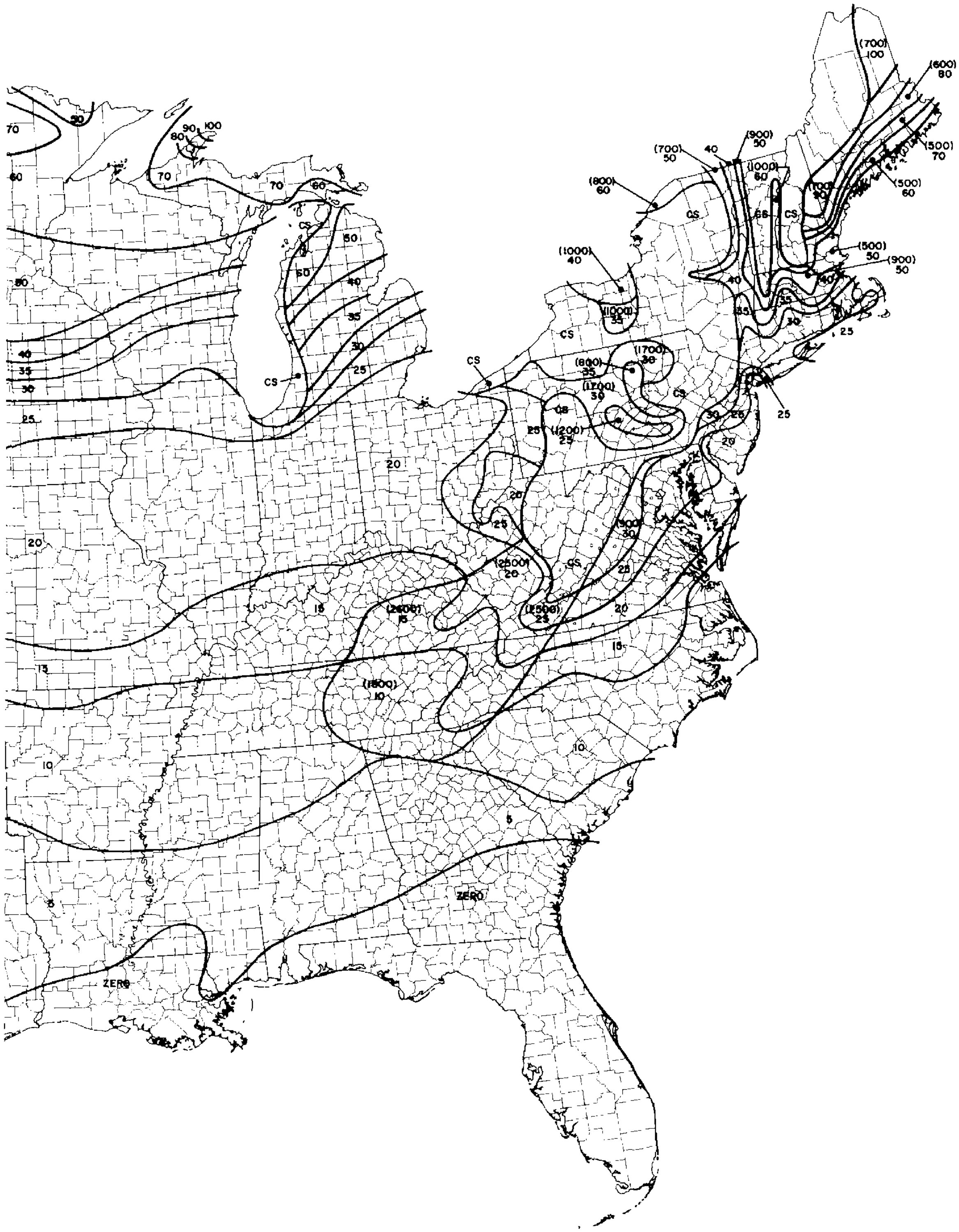


FIGURE 7-1. (*Continued*)

ASCES Figure 7-1

TABLE 7-2. Exposure Factor, C_e

Terrain Category	Exposure of Roof[1] Fully Exposed	Partially Exposed	Sheltered
A (see Section 6.5.3)	N/A	1.1	1.3
B (see Section 6.5.3)	0.9	1.0	1.2
C (see Section 6.5.3)	0.9	1.0	1.1
D (see Section 6.5.3)	0.8	0.9	1.0
Above the treeline in windswept mountainous areas.	0.7	0.8	N/A
In Alaska, in areas where trees do not exist within a 2-mile (3-km) radius of the site.	0.7	0.8	N/A

Notes: The terrain category and roof exposure condition chosen shall be representative of the anticipated conditions during the life of the structure. An exposure factor shall be determined for each roof of a structure.

[1]Definitions:

Partially Exposed: All roofs except as indicated below.

Fully Exposed: Roofs exposed on all sides with no shelter* afforded by terrain, higher structures or trees. Roofs that contain several large pieces of mechanical equipment, parapets which extend above the height of the balanced snow load (h_b), or other obstructions are not in this category.

Sheltered: Roofs located tight in among conifers that qualify as obstructions.

*Obstructions within a distance of $10h_o$ provide "shelter," where h_o is the height of the obstruction above the roof level. If the only obstructions are a few deciduous trees which are leafless in winter, the "fully exposed" category shall be used except for terrain Category "A." Note that these are heights above the roof. Heights used to establish the Terrain Category in Section 6.5.3 are heights above the ground.

ASCES Table 7-2

TABLE 7-3. Thermal Factor, C_t

Thermal Condition[1]	C_t
All structures except as indicated below.	1.0
Structures kept just above freezing and others with cold, ventilated roofs in which the thermal resistance (*R*-value) between the ventilated space and the heated space exceeds 25°F · h · ft²/Btu (4.4 K · m²/*W*).	1.1
Unheated structures and structures intentionally kept below freezing.	1.2
Continuously heated greenhouses[2] with a roof having a thermal resistance (*R*-value) less than 2.0°F · h · ft²/Btu (0.4 K · m².*W*).	0.85

[1]These conditions shall be representative of the anticipated conditions during winters for the life of the structure.

[2]Green houses with a constantly maintained interior temperature of 50°F (10°C) or more at any point 3 ft above the floor level during winters and having either a maintenance attendant on duty at all times or a temperature alarm system to provide warning in the event of a heating failure.

TABLE 7-4. Importance Factor, *I*, (Snow Loads)

Category[1]	*I*
I	0.8
II	1.0
III	1.1
IV	1.2

[1]See Section 1.5 and Table 1-1.

ASCES Tables 7-3 and 7-4

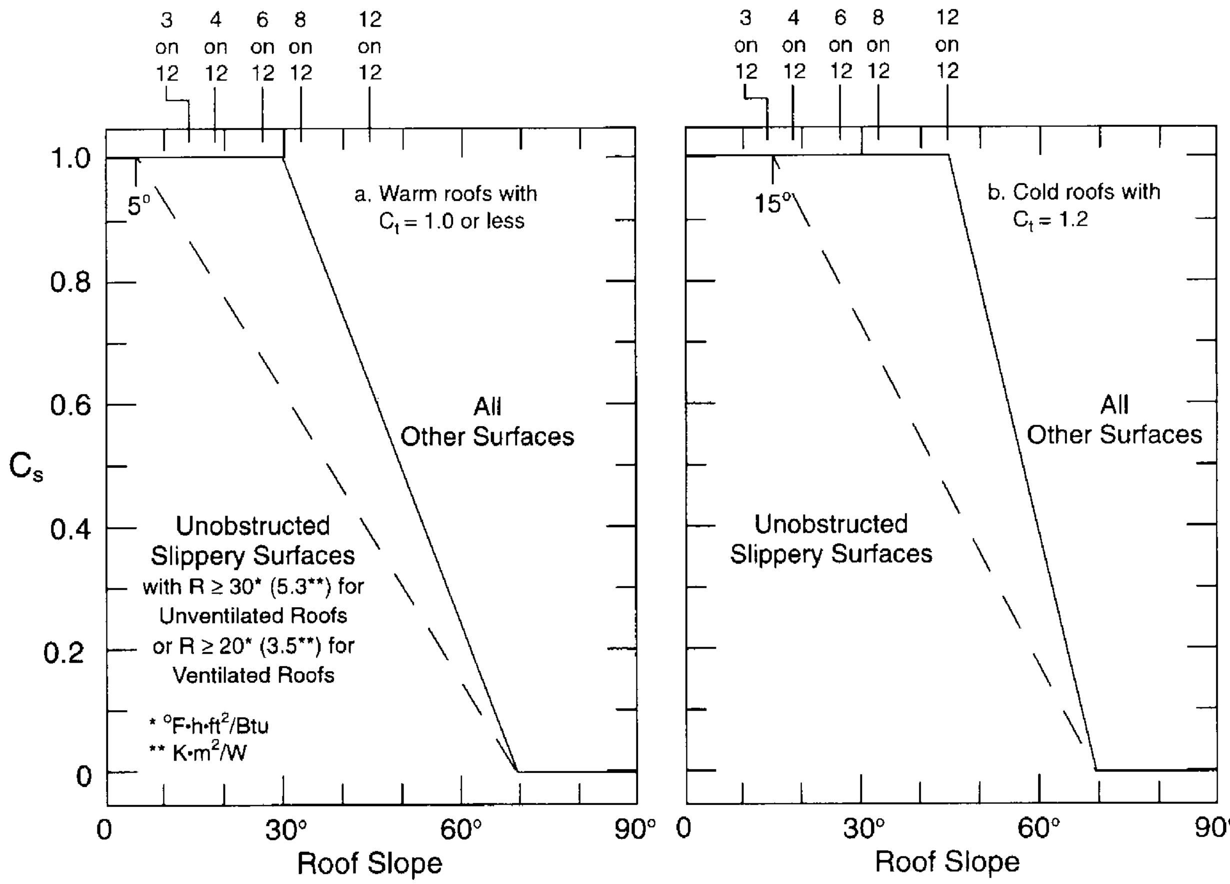


FIGURE 7-2. Graphs for Determining Roof Slope Factor C_s for Warm and Cold Roofs

ASCES Figure 7-2

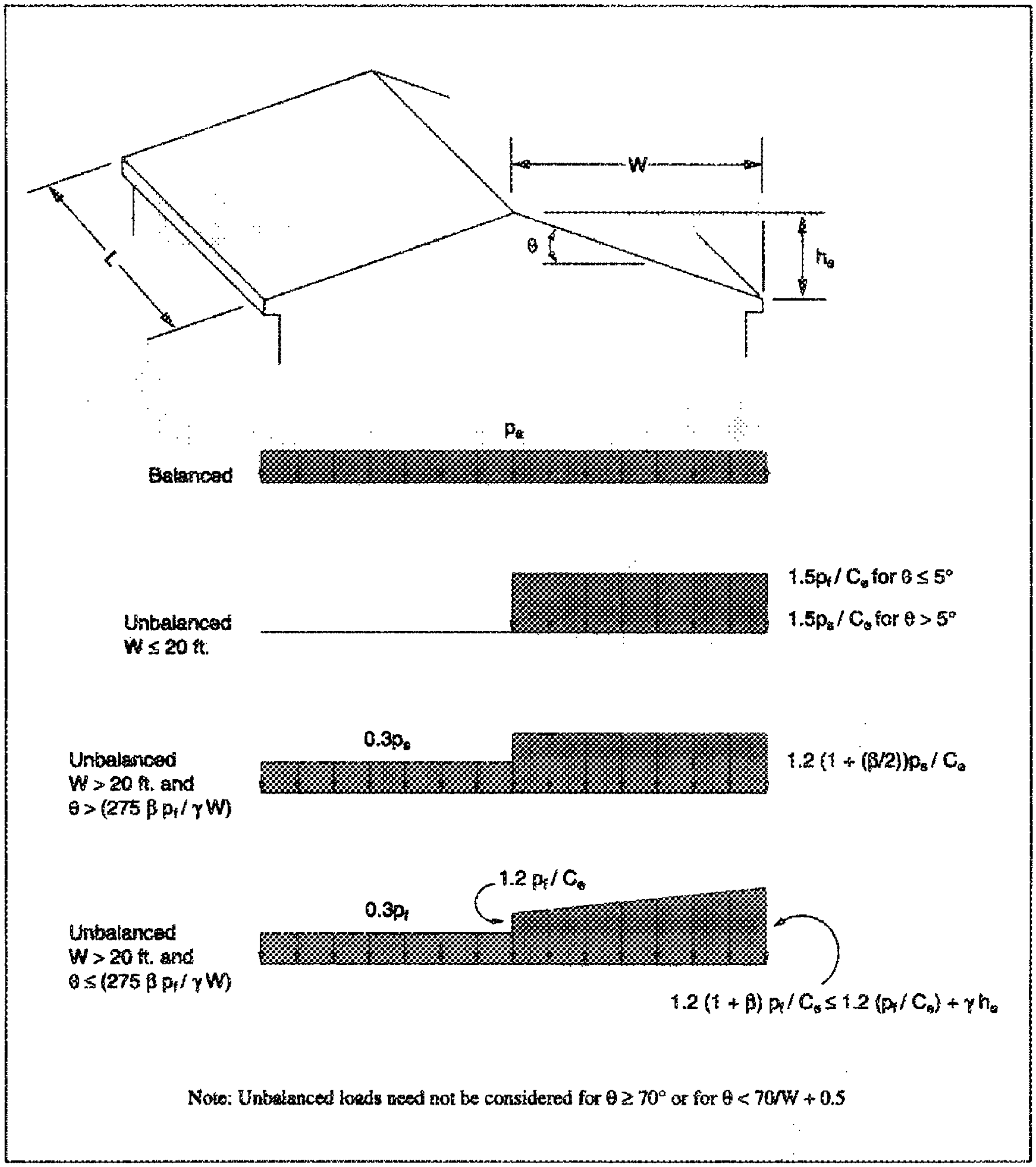


FIGURE 7-5. Balanced and Unbalanced Snow Loads for Hip and Gable Roofs

ASCES Figure 7-5

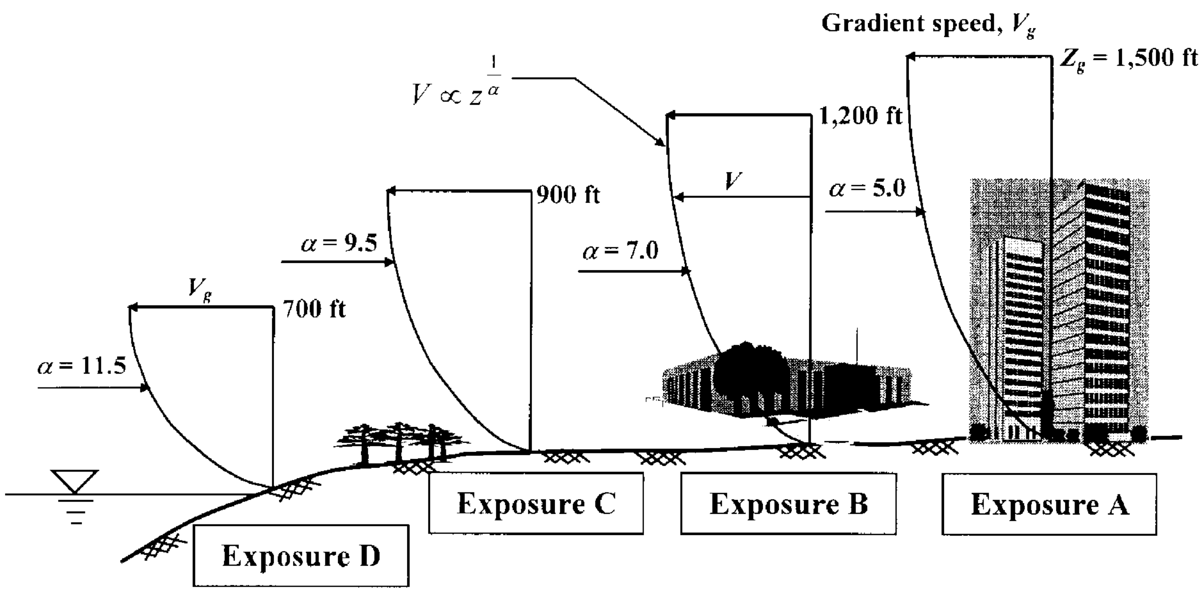
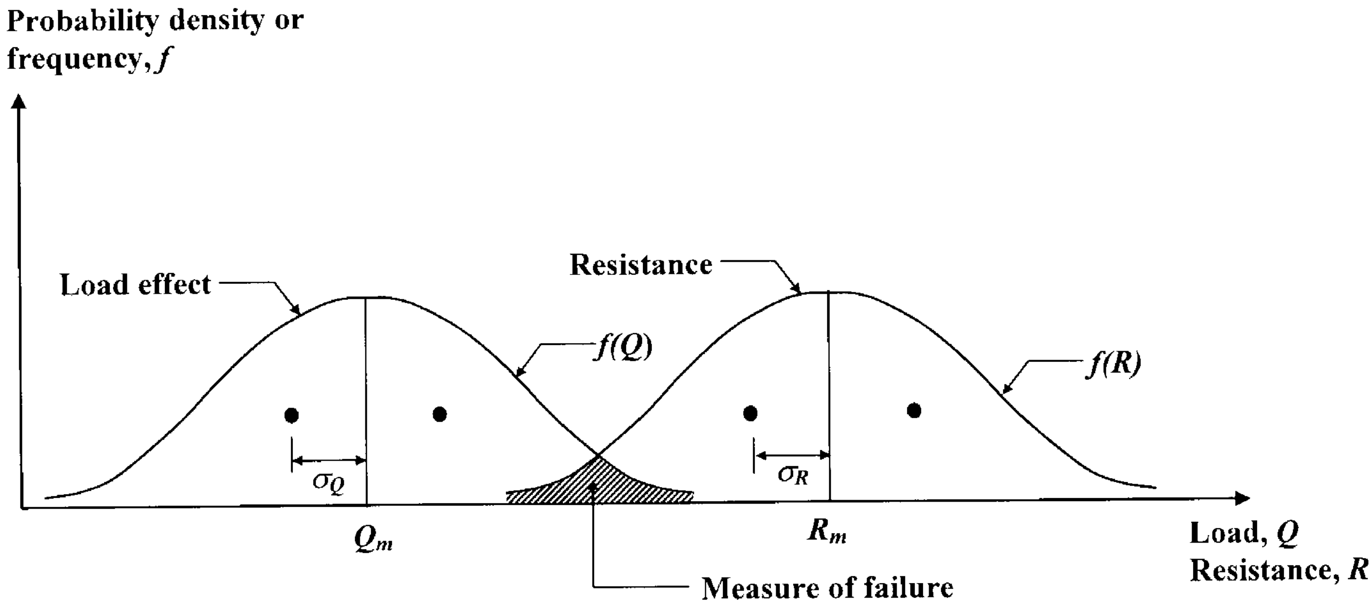
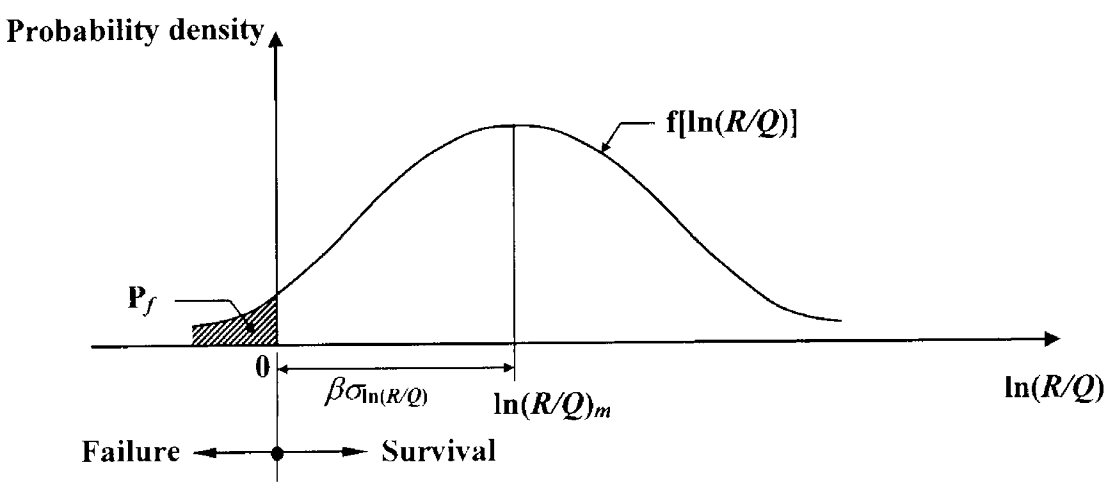


Figure W4.2.1: Variation of wind speed with height and terrain.



Frequency distribution of load effect Q and resistance R
(*a*)



Definitions of the safety index
(*b*)

Figure W4.4.1: Definitions of structural safety in LRFD.