Design Loads

ASCE 7-16

- Referenced standards
- Referencing Codes
- 7-22 is now out $310

1 General

2 Load Combinations

3 Dead Load

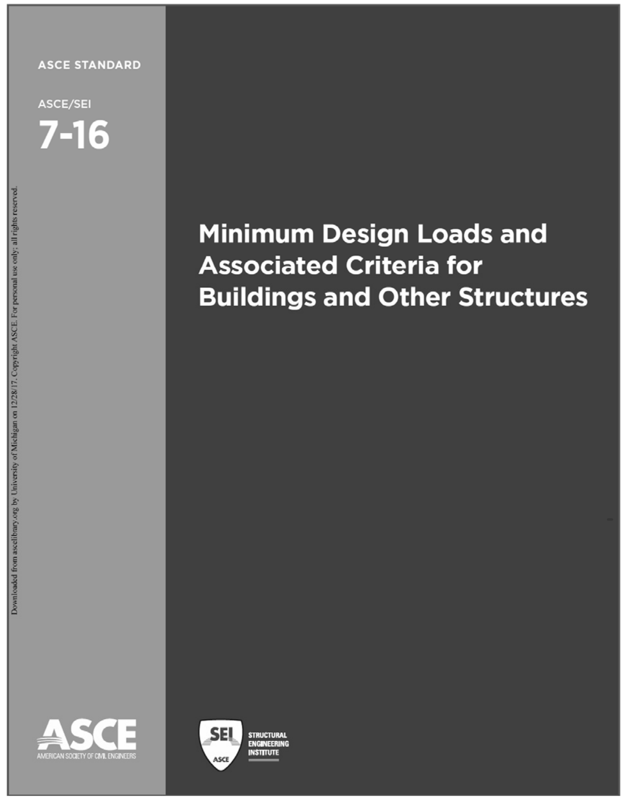
4 Live Load

- Occupancy
- Roof

7 Snow

- Flat
- Sloped

26 – 31 Wind



General 1.0

Building Classification

- Risk catagory
- Used for Importance factor

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.15	1.00	1.25
IV	1.20	1.25	1.00	1.50

Note: The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it depends on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent low risk to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life	III
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure	
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures designated as essential facilities	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community	
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released[a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures	

[a]Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the Authority Having Jurisdiction by a hazard assessment as described in Section 1.5.3 that a release of the substances is commensurate with the risk associated with that Risk Category.

General 1.0

Risk Category I

- usually unoccupied
- low risk to public
- barns, storage, gatehouse

Risk Category II

- vast majority of structures
- residential, commercial, industrial
- “all others” not in I, III, or IV

Risk Category III

- large number of people together
- theaters, lecture halls
- contain persons not mobile
- elementary schools, prisons, health-care
- importance to community, would disrupt life
- power stations, water treatment, telecommunications

Risk Category III

- buildings needed in an emergency
- police, fire stations, hospitals. emergency communications
- extremely hazardous material

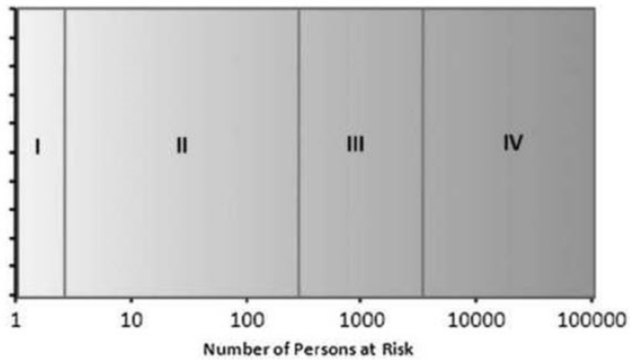
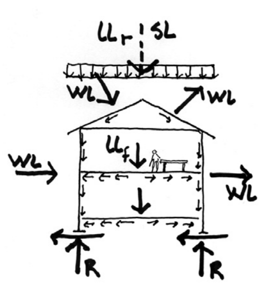


FIGURE C1.5-1 Approximate Relationship between Number of Lives Placed at Risk by a Failure and Occupancy Category

Combinations of Loads – Ch. 2

Strength and Allowable Stress Design

- Each combination separately
- Combine to give worst affect



2.2 SYMBOLS

A_k = load or load effect arising from extraordinary event A
D = dead load
D_i = weight of ice
E = earthquake load
F = load caused by fluids with well-defined pressures and maximum heights
F_a = flood load
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L = live load
L_r = roof live load
N = notional load for structural integrity, Section 1.4
R = rain load
S = snow load
T = cumulative effect of self-straining forces and effects arising from contraction or expansion resulting from environmental or operational temperature changes, shrinkage, moisture changes, creep in component materials, movement caused by differential settlement, or combinations thereof
W = wind load
W_i = wind-on-ice determined in accordance with Chapter 10

2.3 LOAD COMBINATIONS FOR STRENGTH DESIGN

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4. $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $0.9D + 1.0W$

2.4 LOAD COMBINATIONS FOR ALLOWABLE STRESS DESIGN

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W)$
6. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$
7. $0.6D + 0.6W$

Dead Loads – Ch. 3

Weight of material

- Table C3.1-1 in commentary

TABLE C3-1
MINIMUM DESIGN DEAD LOADS*

Component	Load (psf)	Component	Load (psf)
CEILINGS		Decking, 2-in. wood (Douglas fir)	5
Acoustical Fiber Board	1	Decking, 3-in. wood (Douglas fir)	8
Gypsum board (per mm thickness)	0.55	Fiberboard, 1/2-in.	0.75
Mechanical duct allowance	4	Gypsum sheathing, 1/2-in.	2
Plaster on tile or concrete	5	Insulation, roof boards (per inch thickness)	
Plaster on wood lath	8	Cellular glass	0.7
Suspended steel channel system	2	Fibrous glass	1.1
Suspended metal lath and cement plaster	15	Fiberboard	1.5
Suspended metal lath and gypsum plaster	10	Perlite	0.8
Wood furring suspension system	2.5	Polystyrene foam	0.2
COVERINGS, ROOF, AND WALL		Urethane foam with skin	0.5
Asbestos-cement shingles	4	Plywood (per 1/8-in. thickness)	0.4
Asphalt shingles	2	Rigid insulation, 1/2-in.	0.75
Cement tile	16	Skylight, metal frame, 3/8-in. wire glass	8
Clay tile (for mortar add 10 psf)		Slate, 3/16-in.	7
Book tile, 2-in.	12	Slate, 1/4-in.	10
Book tile, 3-in.	20	Waterproofing membranes:	
Ludowici	10	Bituminous, gravel-covered	5.5
Roman	12	Bituminous, smooth surface	1.5
Spanish	19	Liquid applied	1
Composition:		Single-ply, sheet	0.7
Three-ply ready roofing	1	Wood sheathing (per inch thickness)	3
Four-ply felt and gravel	5.5	Wood shingles	3
Five-ply felt and gravel	6	FLOOR FILL	
Copper or tin	1	Cinder concrete, per inch	9
Corrugated asbestos-cement roofing	4	Lightweight concrete, per inch	8
Deck, metal, 20 gage	2.5	Sand, per inch	8
Deck, metal, 18 gage	3	Stone concrete, per inch	12

Dead Loads – Ch. 3

Weight of material

- Table C3.1-2 in commentary
- Raw materials
- Also Steel manual

TABLE C3-2
MINIMUM DENSITIES FOR DESIGN LOADS FROM MATERIALS

Material	Load (lb/ft^3)	Material	Load (lb/ft^3)
Aluminum	170	Earth (submerged)	
Bituminous products		Clay	80
Asphaltum	81	Soil	70
Graphite	135	River mud	90
Paraffin	56	Sand or gravel	60
Petroleum, crude	55	Sand or gravel and clay	65
Petroleum, refined	50	Glass	160
Petroleum, benzine	46	Gravel, dry	104
Petroleum, gasoline	42	Gypsum, loose	70
Pitch	69	Gypsum, wallboard	50
Tar	75	Ice	57
Brass	526	Iron	
Bronze	552	Cast	450
Cast-stone masonry (cement, stone, sand)	144	Wrought	48
Cement, portland, loose	90	Lead	710
Ceramic tile	150	Lime	
Charcoal	12	Hydrated, loose	32
Cinder fill	57	Hydrated, compacted	45
Cinders, dry, in bulk	45	Masonry, Ashlar stone	
Coal		Granite	165
Anthracite, piled	52	Limestone, crystalline	165
Bituminous, piled	47	Limestone, oolitic	135
Lignite, piled	47	Marble	173
Peat, dry, piled	23	Sandstone	144
Concrete, plain		Masonry, brick	
Cinder	108	Hard (low absorbtion)	130
Expanded-slag aggregate	100	Medium (medium absorbtion)	115
Haydite (burned-clay aggregate)	90	Soft (high absorbtion)	100
Slag	132	Masonry, concrete*	
Stone (including gravel)	144	Lightweight units	105
Vermiculite and perlite aggregate, non–load-bearing	25–50	Medium weight units	125
Other light aggregate, load-bearing	70–105	Normal weight units	135
Concrete, reinforced		Masonry grout	140
Cinder	111	Masonry, rubble stone	
Slag	138	Granite	153
Stone (including gravel)	150	Limestone, crystalline	147
Copper	556	Limestone, oolitic	138
Cork, compressed	14	Marble	156
Earth (not submerged)		Sandstone	137
Clay, dry	63	Mortar, cement or lime	130
Clay, damp	110	Particleboard	45
Clay and gravel, dry	100	Plywood	36
Silt, moist, loose	78	Riprap (Not submerged)	
Silt, moist, packed	96	Limestone	83
Silt, flowing	108	Sandstone	90
Sand and gravel, dry, loose	100	Sand	
Sand and gravel, dry, packed	110	Clean and dry	90
Sand and gravel, wet	120	River, dry	106

Dead Load of Lumber

Using specific gravity, G

- Neglecting Moisture Content

$$D = G \times 62.428 \text{ PCF}$$

- Including Moisture Content

$$D = 62.428\left[\frac{G}{1+G(0.009)(m.c.)}\right]\times\left[1+\frac{m.c.}{100}\right]$$

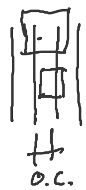
G = specific gravity (unitless)

D = density (e.g. PCF)

m.c. = the % moisture content (e.g. 18)

Section Dead Load:

$$PLF = D \times \frac{Area}{144}$$



Member Dead Load:

$$LBS = D \times \frac{Area}{144} \times Length$$

Floor Dead Load

$$PSF = D \times \frac{Area}{144} \times \frac{12}{o.c.}$$

Table 4A Reference Design Values for Visually Graded Dimension Lumber (2" - 4" thick)[1,2,3]

(All species except Southern Pine—see Table 4B) (Tabulated design values are for normal load duration and dry service conditions. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4A ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	Modulus of Elasticity E_{min}	Specific Gravity[4] G	Grading Rules Agency
ALASKA CEDAR										
Select Structural	2" & wider	1,150	625	165	525	1,000	1,400,000	510,000	0.47	WCLIB
No. 1		975	525	165	525	900	1,300,000	470,000		
No. 2		800	425	165	525	750	1,200,000	440,000		
No. 3		450	250	165	525	425	1,100,000	400,000		
Stud	2" & wider	625	350	165	525	475	1,100,000	400,000		
Construction	2" - 4" wide	900	500	165	525	950	1,200,000	440,000		
Standard		500	275	165	525	775	1,100,000	400,000		
Utility		250	125	165	525	500	1,000,000	370,000		
ALASKA HEMLOCK										
Select Structural	2" & wider	1,300	825	185	440	1,200	1,700,000	620,000	0.46	WWPA
No. 1		900	550	185	440	1,100	1,600,000	580,000		
No. 2		825	475	185	440	1,050	1,500,000	550,000		
No. 3		475	275	185	440	600	1,400,000	510,000		
Stud	2" & wider	650	375	185	440	650	1,400,000	510,000		
Construction	2" - 4" wide	950	550	185	440	1,250	1,400,000	510,000		
Standard		525	300	185	440	1,050	1,300,000	470,000		
Utility		250	150	185	440	700	1,200,000	440,000		
ALASKA SPRUCE										
Select Structural	2" & wider	1,400	900	160	330	1,200	1,600,000	580,000	0.41	WWPA
No. 1		950	600	160	330	1,100	1,500,000	550,000		
No. 2		875	500	160	330	1,050	1,400,000	510,000		
No. 3		500	300	160	330	600	1,300,000	470,000		
Stud	2" & wider	675	400	160	330	675	1,300,000	470,000		
Construction	2" - 4" wide	1,000	575	160	330	1,250	1,300,000	470,000		
Standard		550	325	160	330	1,050	1,200,000	440,000		
Utility		275	150	160	330	700	1,100,000	400,000		
ALASKA YELLOW CEDAR										
Select Structural	2" & wider	1,350	800	225	510	1,200	1,500,000	550,000	0.46	WCLIB WWPA
No. 1		900	525	225	510	1,050	1,400,000	510,000		
No. 2		800	450	225	510	1,000	1,300,000	470,000		
No. 3		475	250	225	510	575	1,200,000	440,000		
Stud	2" & wider	625	350	225	510	625	1,200,000	440,000		
Construction	2" - 4" wide	925	500	225	510	1,250	1,300,000	470,000		
Standard		500	275	225	510	1,050	1,100,000	400,000		
Utility		250	125	225	510	675	1,100,000	400,000		
ASPEN										
Select Structural	2" & wider	875	500	120	265	725	1,100,000	400,000	0.39	NELMA WWPA
No. 1		625	375	120	265	600	1,100,000	400,000		
No. 2		600	350	120	265	450	1,000,000	370,000		
No. 3		350	200	120	265	275	900,000	330,000		
Stud	2" & wider	475	275	120	265	300	900,000	330,000		
Construction	2" - 4" wide	700	400	120	265	625	900,000	330,000		
Standard		375	225	120	265	475	900,000	330,000		
Utility		175	100	120	265	300	800,000	290,000		
BALDCYPRESS										
Select Structural	2" & wider	1,200	650	160	615	1,200	1,400,000	510,000	0.47	SPIB
No. 1		1,000	550	160	615	1,050	1,400,000	510,000		
No. 2		825	450	160	615	900	1,300,000	470,000		
No. 3		475	250	160	615	525	1,200,000	440,000		
Stud	2" & wider	650	350	160	615	575	1,200,000	440,000		
Construction	2" - 4" wide	925	500	160	615	1,100	1,200,000	440,000		
Standard		525	275	160	615	925	1,100,000	400,000		
Utility		250	125	160	615	600	1,000,000	370,000		

4 REFERENCE DESIGN VALUES

Live Loads – Ch. 4

Concentrated

- 200 to 8000 LBS by occupancy over 2.5 FT x 2.5 FT area
- Handrail 200 LBS

Floor

- By occupancy
- Reduction with area > 400 SF
- Table 4.3-1

4.7.2 Reduction in Uniform Live Loads. Subject to the limitations of Sections 4.7.3 through 4.7.6, members for which a value of $K_{LL}A_T$ is 400 ft² (37.16 m²) or more are permitted to be designed for a reduced live load in accordance with the following formula:

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right) \quad (4.7\text{-}1)$$

TABLE 4.7-1

Roof

- Minimum Lr between 12 PSF and 20 PSF
- Lr = 20 R1 R2
- See 4.8.1

Table 4.3-1 Minimum Uniformly Distributed Live Loads, L_o, and Minimum Concentrated Live Loads

Occupancy or Use	Uniform, L_o psf (kN/m²)	Live Load Reduction Permitted? (Sec. No.)	Multiple-Story Live Load Reduction Permitted? (Sec. No.)	Concentrated lb (kN)	Also See Section
Apartments (See Residential)					
Access floor systems					
Office use	50 (2.40)	Yes (4.7.2)	Yes (4.7.2)	2,000 (8.90)	
Computer use	100 (4.79)	Yes (4.7.2)	Yes (4.7.2)	2,000 (8.90)	
Armories and drill rooms	150 (7.18)	No (4.7.5)	No (4.7.5)		
Assembly areas					
Fixed seats (fastened to floors)	60 (2.87)	No (4.7.5)	No (4.7.5)		
Lobbies	100 (4.79)	No (4.7.5)	No (4.7.5)		
Movable seats	100 (4.79)	No (4.7.5)	No (4.7.5)		
Platforms (assembly)	100 (4.79)	No (4.7.5)	No (4.7.5)		
Stage floors	150 (7.18)	No (4.7.5)	No (4.7.5)		
Reviewing stands, grandstands, and bleachers	100 (4.79)	No (4.7.5)	No (4.7.5)		4.14
Stadiums and arenas with fixed seats (fastened to the floor)	60 (2.87)	No (4.7.5)	No (4.7.5)		4.14
Other assembly areas	100 (4.79)	No (4.7.5)	No (4.7.5)		
Balconies and decks	1.5 times the live load for the area served. Not required to exceed 100 psf (4.79 kN/m²)	Yes (4.7.2)	Yes (4.7.2)		
Catwalks for maintenance access	40 (1.92)	Yes (4.7.2)	Yes (4.7.2)	300 (1.33)	
Corridors					
First floor	100 (4.79)	Yes (4.7.2)	Yes (4.7.2)		
Other floors	Same as occupancy served except as indicated				
Dining rooms and restaurants	100 (4.79)	No (4.7.5)	No (4.7.5)		
Dwellings (See Residential)					
Elevator machine room grating (on area of 2 in. by 2 in. (50 mm by 50 mm))		—	—	300 (1.33)	
Finish light floor plate construction (on area of 1 in. by 1 in. (25 mm by 25 mm))		—	—	200 (0.89)	
Fire escapes	100 (4.79)	Yes (4.7.2)	Yes (4.7.2)		
On single-family dwellings only	40 (1.92)	Yes (4.7.2)	Yes (4.7.2)		
Fixed ladders		—	—	See Sec. 4.5.4	
Garages (See Section 4.10)					
Passenger vehicles only	40 (1.92)	No (4.7.4)	Yes (4.7.4)	See Sec. 4.10.1	
Trucks and buses	See Sec. 4.10.2	—	—	See Sec. 4.10.2	
Handrails and Guardrails	See Sec. 4.5.1	—	—	See Sec. 4.5.1	
Grab bars		—	—	See Sec. 4.5.2	
Helipads (See Section 4.11)					
Helicopter takeoff weight 3,000 lb (13.35 kN) or less	40 (1.92)	No (4.11.1)	—	See Sec. 4.11.2	
Helicopter takeoff weight more than 3,000 lb (13.35 kN)	60 (2.87)	No (4.11.1)	—	See Sec. 4.11.2	
Hospitals					
Operating rooms, laboratories	60 (2.87)	Yes (4.7.2)	Yes (4.7.2)	1,000 (4.45)	
Patient rooms	40 (1.92)	Yes (4.7.2)	Yes (4.7.2)	1,000 (4.45)	
Corridors above first floor	80 (3.83)	Yes (4.7.2)	Yes (4.7.2)	1,000 (4.45)	
Hotels (See Residential)					
Libraries					
Reading rooms	60 (2.87)	Yes (4.7.2)	Yes (4.7.2)	1,000 (4.45)	
Stack rooms	150 (7.18)	No (4.7.3)	Yes (4.7.3)	1,000 (4.45)	4.13
Corridors above first floor	80 (3.83)	Yes (4.7.2)	Yes (4.7.2)	1,000 (4.45)	
Manufacturing					
Light	125 (6.00)	No (4.7.3)	Yes (4.7.3)	2,000 (8.90)	
Heavy	250 (11.97)	No (4.7.3)	Yes (4.7.3)	3,000 (13.35)	
Office buildings					
File and computer rooms shall be designed for heavier loads based on anticipated occupancy					
Lobbies and first-floor corridors	100 (4.79)	Yes (4.7.2)	Yes (4.7.2)	2,000 (8.90)	
Offices	50 (2.40)	Yes (4.7.2)	Yes (4.7.2)	2,000 (8.90)	
Corridors above first floor	80 (3.83)	Yes (4.7.2)	Yes (4.7.2)	2,000 (8.90)	

continues

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Live Loads – Ch. 4

Roof

- Minimum L_r between 12 PSF and 20 PSF
- $L_r = 20\, R_1 R_2$
- See 4.9.1

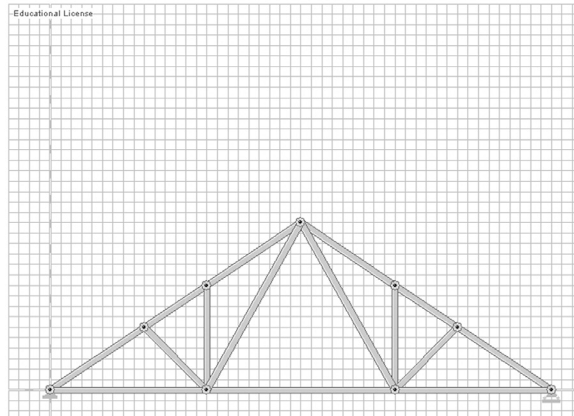
$$R_1 = \begin{cases} 1 & \text{for } A_t \le 200 \text{ ft}^2 (18.58 \text{ m}^2) \\ 1.2 - 0.001 A_t & \text{for } 200 \text{ ft}^2 < A_t < 600 \text{ ft}^2 \\ 0.6 & \text{for } A_t \ge 600 \text{ ft}^2 (55.74 \text{ m}^2) \end{cases}$$

where A_t = tributary area in ft^2 (m^2) supported by any structural member and

$$R_2 = \begin{cases} 1 & \text{for } F \le 4 \\ 1.2 - 0.05\,F & \text{for } 4 < F < 12 \\ 0.6 & \text{for } F \ge 12 \end{cases}$$

where, for a pitched roof, F = number of inches of rise per ft.

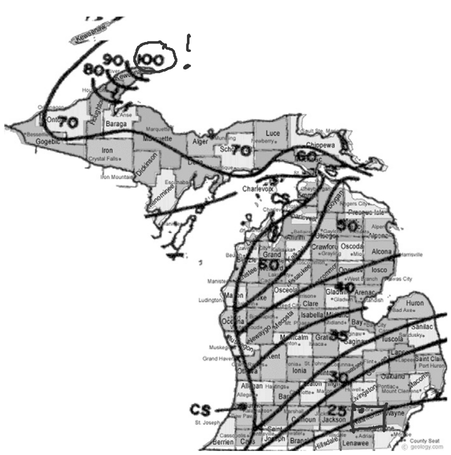
for an arch or dome, F = rise-to-span ratio multiplied by 32.



Snow Load – Ch. 7

p_g - Ground snow load

- from map fig 7-1
- PSF
- Based on 50 year mean (2% probability of being exceeded)



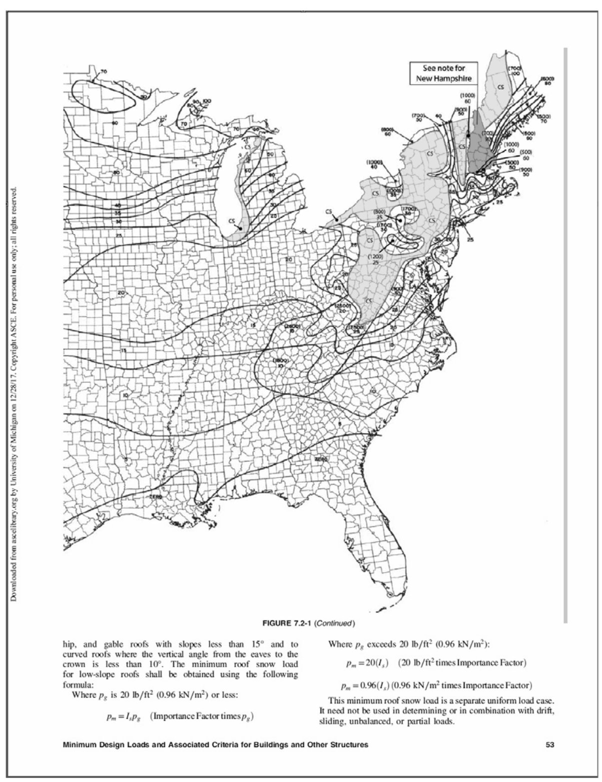


FIGURE 7.2-1 (*Continued*)

hip, and gable roofs with slopes less than 15° and to curved roofs where the vertical angle from the eaves to the crown is less than 10°. The minimum roof snow load for low-slope roofs shall be obtained using the following formula:

Where p_g is 20 lb/ft² (0.96 kN/m²) or less:

$$p_m = I_s p_g \quad \text{(Importance Factor times } p_g\text{)}$$

Where p_g exceeds 20 lb/ft² (0.96 kN/m²):

$$p_m = 20(I_s) \quad (20 \text{ lb/ft}^2 \text{ times Importance Factor})$$

$$p_m = 0.96(I_s) \quad (0.96 \text{ kN/m}^2 \text{ times Importance Factor})$$

This minimum roof snow load is a separate uniform load case. It need not be used in determining or in combination with drift, sliding, unbalanced, or partial loads.

Minimum Design Loads and Associated Criteria for Buildings and Other Structures 53

Snow Load – Ch. 7

p_f - flat roof snow load

$p_f = 0.7\ C_e\ C_t\ I_s\ p_g$

- Eq. 7.3-1

Minimum for Low Slope Roofs, p_m

- Minimum where $p_g \leqq 20$ $p_m = I_S\ p_g$ PSF
- Minimum where $p_g > 20$ $p_m = I_S\ 20$ PSF

Low Slope Roofs

- Monoslope, hip or gable < 15°

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.15	1.00	1.25
IV	1.20	1.25	1.00	1.50

Note: The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it depends on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

7.3 FLAT ROOF SNOW LOADS, p_f

The flat roof snow load, p_f, shall be calculated in lb/ft² (kN/m²) using the following formula:

$$p_f = 0.7 C_e C_t I_s p_g \qquad (7.3\text{-}1)$$

7.3.1 Exposure Factor, C_e
The value for C_e shall be determined from Table 7-2.

7.3.2 Thermal Factor, C_t
The value for C_t shall be determined from Table 7-3.

7.3.3 Importance Factor, I_s
The value for I_s shall be determined from Table 1.5-2 based on the Risk Category from Table 1.5-1.

7.3.4 Minimum Snow Load for Low-Slope Roofs, p_m
A minimum roof snow load, p_m, shall only apply to monoslope, hip and gable roofs with slopes less than 15°, and to curved roofs where the vertical angle from the eaves to the crown is less than 10°. The minimum roof snow load for low-slope roofs shall be obtained using the following formula:

Where p_g is 20 lb/ft² (0.96 kN/m²) or less:

$$p_m = I_s p_g \qquad \text{(Importance Factor times } p_g\text{)}$$

Where p_g exceeds 20 lb/ft² (0.96 kN/m²):

$$p_m = 20\ (I_s) \qquad \text{(20 lb/ft}^2\text{ times Importance Factor)}$$

This minimum roof snow load is a separate uniform load case. It need not be used in determining

Snow Load – Ch. 7

C_e – Exposure Factor

- Table 7-2

Table 7-2 Exposure Factor, C_e

Terrain Category	Exposure of Roof[a]: Fully Exposed	Partially Exposed	Sheltered
B (see Section 26.7)	0.9	1.0	1.2
C (see Section 26.7)	0.9	1.0	1.1
D (see Section 26.7)	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

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.

[a]Definitions: Partially Exposed: All roofs except as indicated in the following text. Fully Exposed: Roofs exposed on all sides with no shelter[b] afforded by terrain, higher structures, or trees. Roofs that contain several large pieces of mechanical equipment, parapets that 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.

[b]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 that are leafless in winter, the "fully exposed" category shall be used. Note that these are heights above the roof. Heights used to establish the Exposure Category in Section 26.7 are heights above the ground.

Exposure Categories

- Commentary 26
- Used for wind and snow

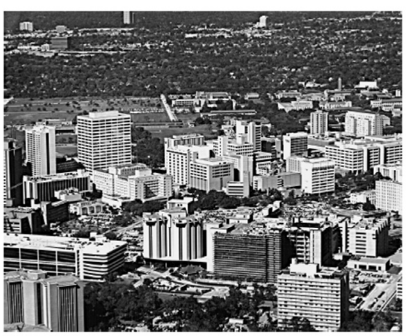
B

EXPOSURE B
SUBURBAN RESIDENTIAL AREA WITH MOSTLY SINGLE-FAMILY DWELLINGS. STRUCTURES IN THE CENTER OF THE PHOTOGRAPH HAVE SITES DESIGNATED AS EXPOSURE B WITH SURFACE ROUGHNESS CATEGORY B TERRAIN AROUND THE SITE FOR A DISTANCE GREATER THAN 1500 FT OR TEN TIMES THE HEIGHT OF THE STRUCTURE, WHICHEVER IS GREATER, IN ANY WIND DIRECTION

B

EXPOSURE B
URBAN AREA WITH NUMEROUS CLOSELY SPACED OBSTRUCTIONS HAVING THE SIZE OF SINGLE-FAMILY DWELLINGS OR LARGER. FOR ALL STRUCTURES SHOWN, TERRAIN REPRESENTATIVE OF SURFACE ROUGHNESS CATEGORY B EXTENDS MORE THAN TEN TIMES THE HEIGHT OF THE STRUCTURE OR 800 M, WHICHEVER IS GREATER, IN THE UPWIND DIRECTION

B



EXPOSURE B
STRUCTURES IN THE FOREGROUND ARE LOCATED IN EXPOSURE B. STRUCTURES IN THE CENTER TOP OF THE PHOTOGRAPH ADJACENT TO THE CLEARING TO THE LEFT, WHICH IS GREATER THAN 200 M IN LENGTH, ARE LOCATED IN EXPOSURE C WHEN WIND COMES FROM THE LEFT OVER THE CLEARING (SEE FIGURE C6-5)

C

EXPOSURE C
FLAT OPEN GRASSLAND WITH SCATTERED OBSTRUCTIONS HAVING HEIGHTS GENERALLY LESS THAN 30 FT

C

EXPOSURE C
OPEN TERRAIN WITH SCATTERED OBSTRUCTIONS HAVING HEIGHTS GENERALLY LESS THAN 30 FT FOR MOST WIND DIRECTIONS, ALL 1-STORY STRUCTURES WITH A MEAN ROOF HEIGHT LESS THAN 30 FT IN THE PHOTOGRAPH ARE LESS THAN 1500 FT OR TEN TIMES THE HEIGHT OF THE STRUCTURE, WHICHEVER IS GREATER, FROM AN OPEN FIELD THAT PREVENTS THE USE OF EXPOSURE B

D

EXPOSURE D
A BUILDING AT THE SHORELINE (EXCLUDING SHORELINES IN HURRICANE-PRONE REGIONS) WITH WIND FLOWING OVER OPEN WATER 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

Snow Load – Ch. 7

C_t – Thermal Factor

- Table 7.3-2

I_s – Importance Factor

- Table 1.5-2

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.15	1.00	1.25
IV	1.20	1.25	1.00	1.50

Note: The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it depends on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Table 7.3-2 Thermal Factor, C_t

Thermal Condition[a]	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 and open air structures	1.2
Freezer building	1.3
Continuously heated greenhouses[b] with a roof having a thermal resistance (R-value) less than 2.0°F × h × ft²/Btu (0.4 K × m²/W)	0.85

[a]These conditions shall be representative of the anticipated conditions during winters for the life of the structure.
[b]Greenhouses with a constantly maintained interior temperature of 50°F (10°C) or more at any point 3 ft (0.9 m) 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.

Snow Load – Ch. 7

p_s – sloped roof snow load

$p_s = C_s p_f$

- Eq. 7.4-1

C_s – Roof Slope Factor

- Figure 7-2
- $C_1 = C_t$
- Equations given in commentary C7.4

p_s is a projected load (based on the horizontal plan area.

It is calculated using roof pitch and insulation factor, C_t

Snow Load – Ch. 7

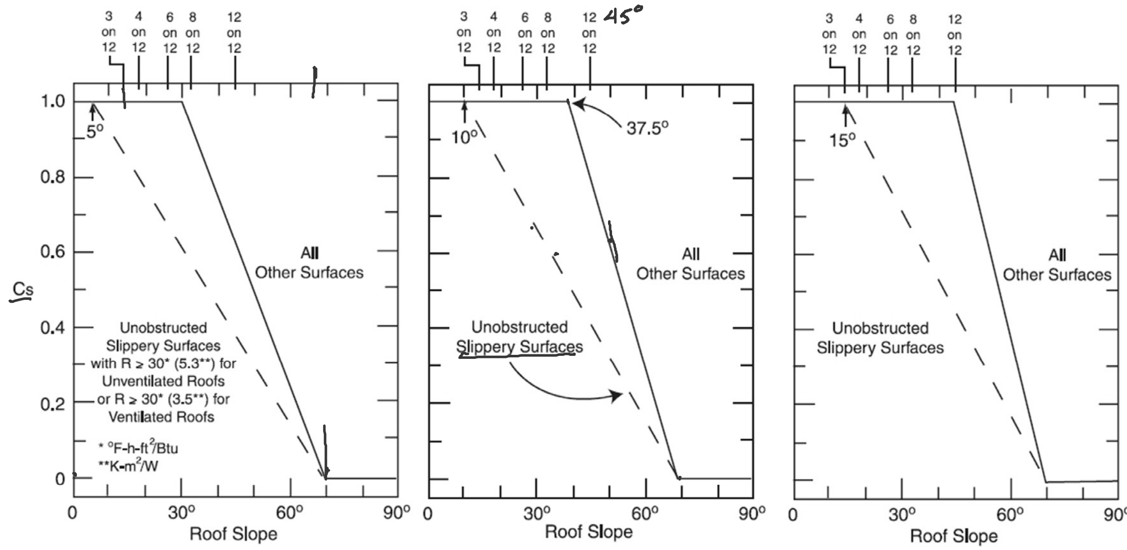
p_s – sloped roof snow load

$p_s = C_s\, p_f$

- Eq. 7.4-1

C_s – Roof Slope Factor

- Figure 7-2
- $C_1 = C_t$
- Equations given in commentary C7-4



7-2a: Warm roofs with $C_1 < 1.0$ 7-2b: Cold roofs with $C_1 = 1.1$ 7-2c: Cold roofs with $C_1 = 1.2$ or larger

Snow Load – Ch. 7

Balanced

- p_s

Unbalanced

For W ≤ 20FT

- $I_s \times p_g$

For W > 20FT

- See Fig. 7.6-2

Unbalanced Gable Roof Loads

- **Not** for F > 7 on 12 (30.2°)
- **Not** for F < ½ on 12 (2.38°)

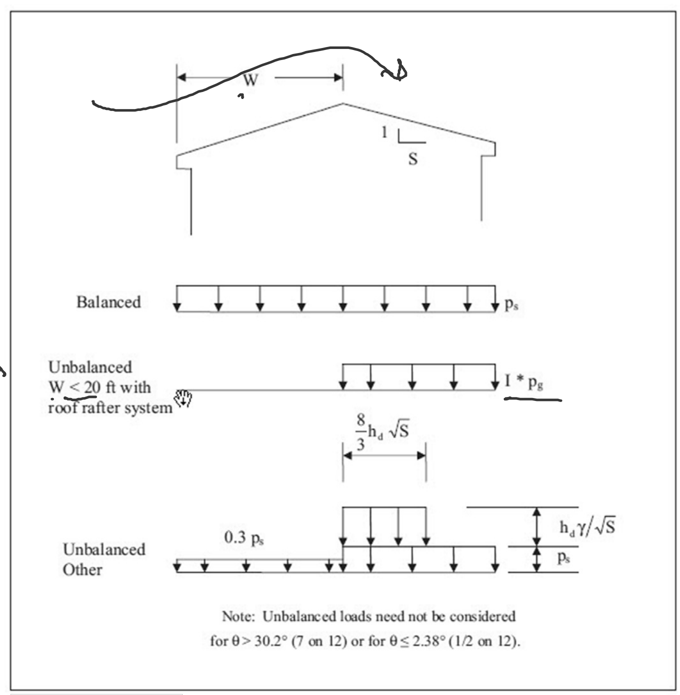


FIGURE 7.6-2 **Balanced and Unbalanced Snow Loads for Hip and Gable Roofs.**

Snow Load – Ch. 7

Other considerations

- Drifts 7.7
- Projections 7.8
- Sliding Snow 7.9

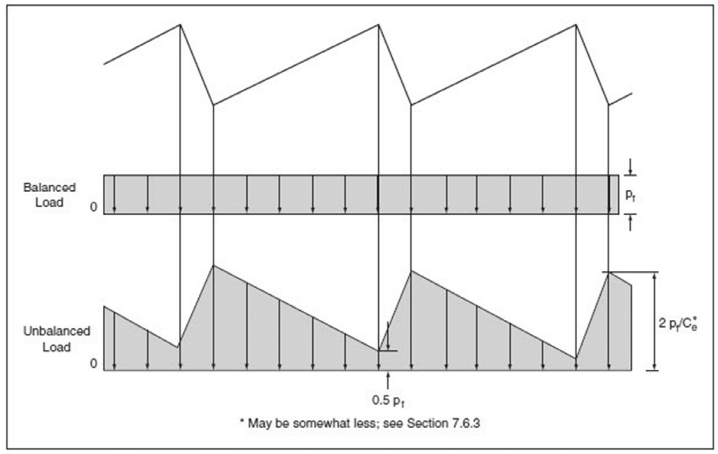


FIGURE 7-6 Balanced and Unbalanced Snow Loads for a Sawtooth Roof.

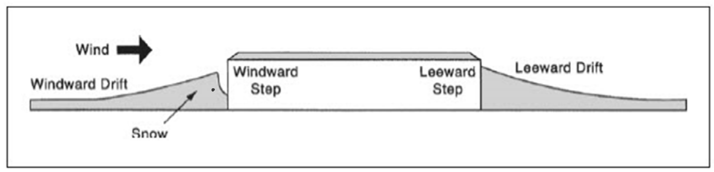


FIGURE 7-7 Drifts Formed at Windward and Leeward Steps.

Snow Load – Ch. 7

Other considerations

- Drifts 7.7
- Projections 7.8
- Sliding Snow 7.9

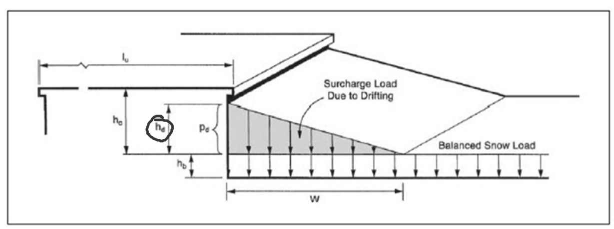
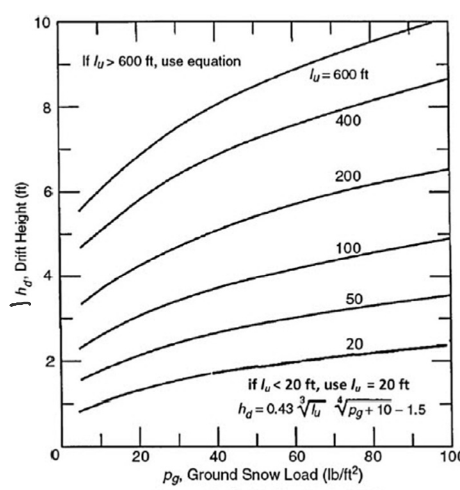


FIGURE 7-8 Configuration of Snow Drifts on Lower Roofs.



To convert lb/ft² to kN/m², multiply by 0.0479.
To convert ft to m, multiply by 0.3048.

FIGURE 7-9 Graph and Equation for Determining Drift Height, h_d.

Snow Load – Ch. 7

Snow Drifts

- Drifts 7-7

Snow Load – Ch. 7

Slope

24 on 12 = 63.4°

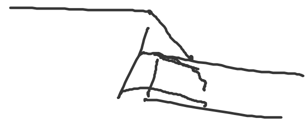
Snow Load – Ch. 7

- Drifts 7-7

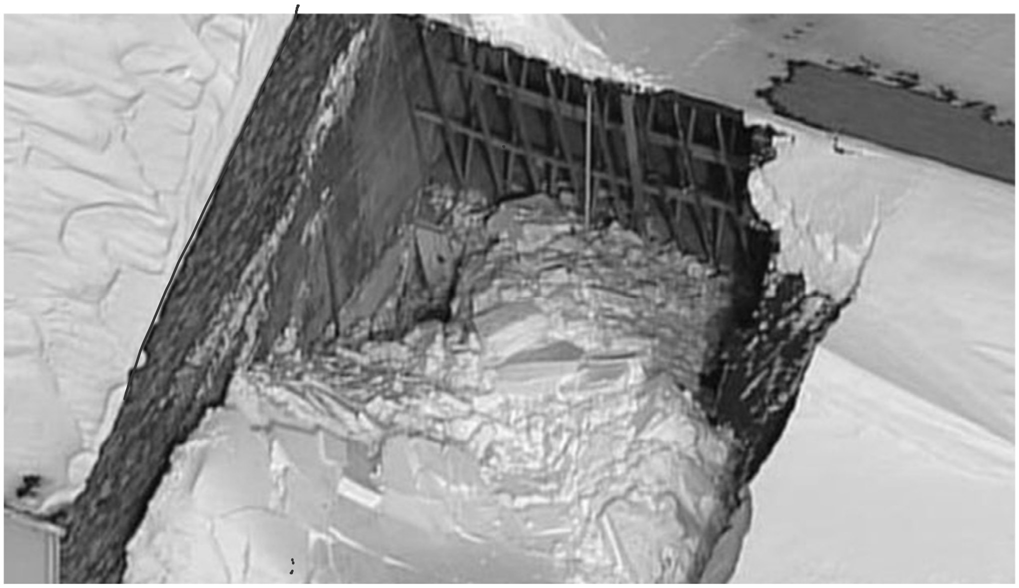
Snow Load – Ch. 7

- Michigan UP, Houghton

Snow Load – Ch. 7



- roof failure due to drift load



Sutton, Massachusetts

Other Loads

Flood, Soil and Hydrostatic
- Ch. 5

Tsunami
- Ch. 6

Rain
- Ch. 8

Ice
- Ch. 10

Seismic
- Ch. 11 - 23

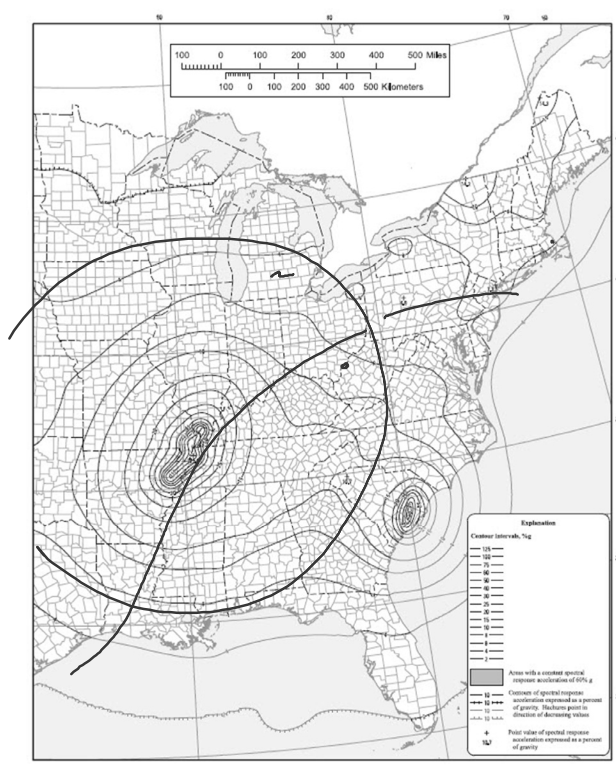


FIGURE 22-2 (*Continued*)

Wind Loads – Chs. 26 - 31

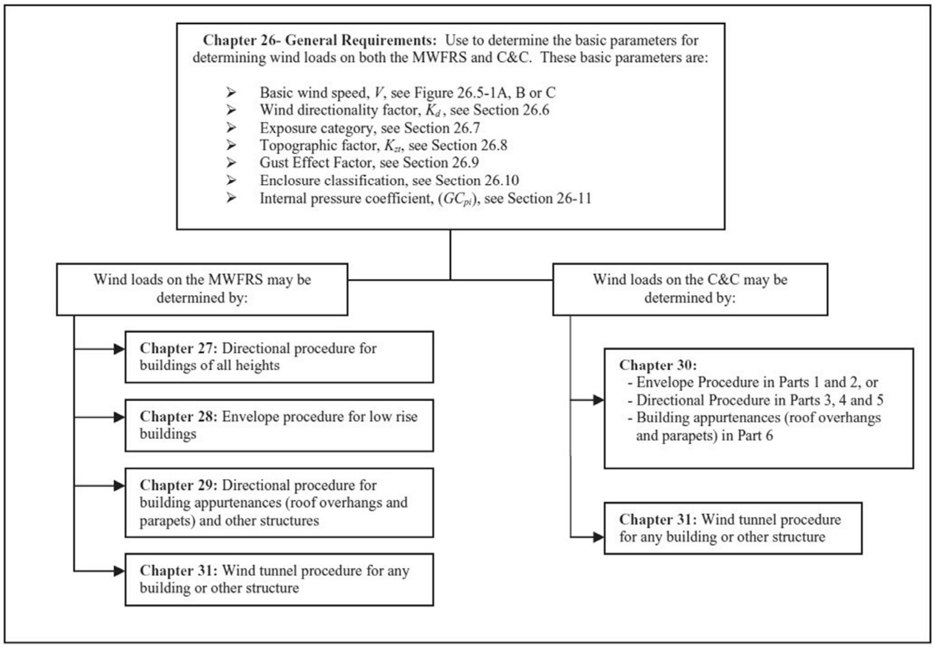


FIGURE 26.1-1 Outline of Process for Determining Wind Loads. Additional outlines and User Notes are provided at the beginning of each chapter for more detailed step-by-step procedures for determining the wind loads.

Wind – General Requirements - Ch. 26

Minimum force

- 16 psf (27.4.7)

Basic pressure equation

$$q = \tfrac{1}{2} \times \gamma \times v^2$$

ASCE equation

- Sec. 26.10.2 eq. 26.10-1

$$q_z = 0.00256 \times \mathrm{K_z K_{zt} K_d K_e} \times V^2$$

- Velocity V is in MPH
- 0.00256 accounts for air density/2 and dimensional conversions

26.10.2 Velocity Pressure. Velocity pressure, q_z, evaluated at height z above ground shall be calculated by the following equation:

$$q_z = 0.00256 K_z K_{zt} K_d K_e V^2 \text{ (lb/ft}^2\text{); } V \text{ in mi/h} \qquad (26.10\text{-}1)$$

$$q_z = 0.613 K_z K_{zt} K_d K_e V^2 \text{ (N/m}^2\text{); } V \text{ in m/s} \qquad (26.10\text{-}1.\text{si})$$

where

K_z = velocity pressure exposure coefficient, see Section 26.10.1.
K_{zt} = topographic factor, see Section 26.8.2.
K_d = wind directionality factor, see Section 26.6.
K_e = ground elevation factor, see Section 26.9.
V = basic wind speed, see Section 26.5.
q_z = velocity pressure at height z.

Wind – Directional Procedure

V - Basic Wind Speed

- 3 sec. gust speed in MPH (m/s)
- 33 FT height
- Includes importance factor in map
- Gray zones by local data

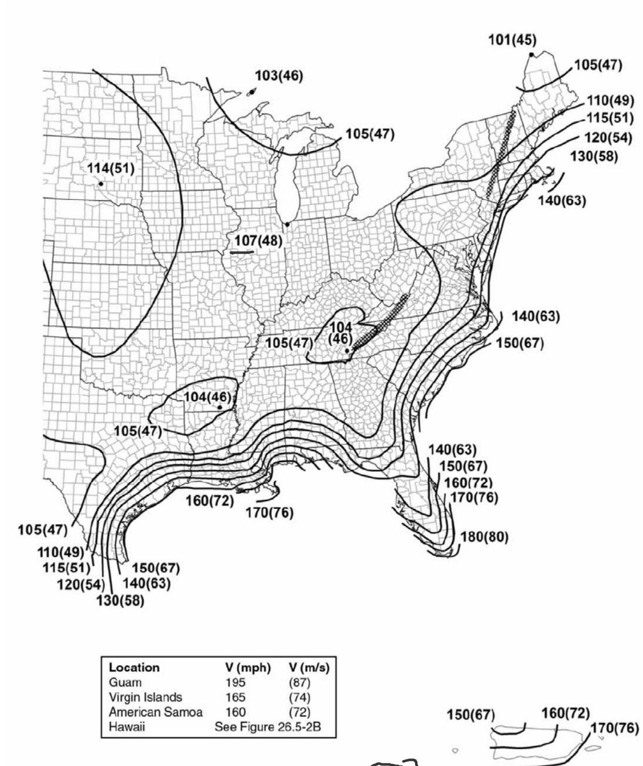


FIGURE 26.5-1B (*Continued*). Basic Wind Speeds for Risk Category II Buildings and Other Structures

Wind – General Requirements - Ch. 26

Kz – Velocity Pressure Exposure Coefficient

- Accounts for wind speed increase with height
- Kz is at elevation z
- Kh is at mean roof height (average roof height)
- Based on Exposure Categories B, C, D

Table 26.10-1 Velocity Pressure Exposure Coefficients, K_h and K_z

Height above Ground Level, z		Exposure		
ft	m	B	C	D
0–15	0–4.6	0.57 (0.70)[a]	0.85	1.03
20	6.1	0.62 (0.70)[a]	0.90	1.08
25	7.6	0.66 (0.70)[a]	0.94	1.12
30	9.1	0.70	0.98	1.16
40	12.2	0.76	1.04	1.22
50	15.2	0.81	1.09	1.27
60	18.0	0.85	1.13	1.31
70	21.3	0.89	1.17	1.34
80	24.4	0.93	1.21	1.38
90	27.4	0.96	1.24	1.40
100	30.5	0.99	1.26	1.43
120	36.6	1.04	1.31	1.48
140	42.7	1.09	1.36	1.52
160	48.8	1.13	1.39	1.55
180	54.9	1.17	1.43	1.58
200	61.0	1.20	1.46	1.61
250	76.2	1.28	1.53	1.68
300	91.4	1.35	1.59	1.73
350	106.7	1.41	1.64	1.78
400	121.9	1.47	1.69	1.82
450	137.2	1.52	1.73	1.86
500	152.4	1.56	1.77	1.89

[a]Use 0.70 in Chapter 28, Exposure B, when $z < 30$ ft (9.1 m).

Notes

1. The velocity pressure exposure coefficient K_z may be determined from the following formula:
   For 15 ft (4.6 m) $\le z \le z_g$ $\quad K_z = 2.01(z/z_g)^{2/\alpha}$
   For $z < 15$ ft (4.6 m) $\quad K_z = 2.01(15/z_g)^{2/\alpha}$
2. α and z_g are tabulated in Table 26.11-1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 26.7.

Wind – Directional Procedure

Exposure Categories

- Commentary 26

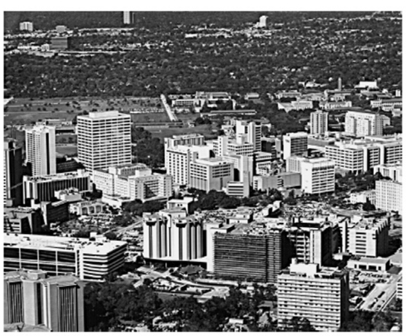
B

EXPOSURE B
SUBURBAN RESIDENTIAL AREA WITH MOSTLY SINGLE-FAMILY DWELLINGS. STRUCTURES IN THE CENTER OF THE PHOTOGRAPH HAVE SITES DESIGNATED AS EXPOSURE B WITH SURFACE ROUGHNESS CATEGORY B TERRAIN AROUND THE SITE FOR A DISTANCE GREATER THAN 1500 FT OR TEN TIMES THE HEIGHT OF THE STRUCTURE, WHICHEVER IS GREATER, IN ANY WIND DIRECTION

B

EXPOSURE B
URBAN AREA WITH NUMEROUS CLOSELY SPACED OBSTRUCTIONS HAVING THE SIZE OF SINGLE-FAMILY DWELLINGS OR LARGER. FOR ALL STRUCTURES SHOWN, TERRAIN REPRESENTATIVE OF SURFACE ROUGHNESS CATEGORY B EXTENDS MORE THAN TEN TIMES THE HEIGHT OF THE STRUCTURE OR 800 M, WHICHEVER IS GREATER, IN THE UPWIND DIRECTION

B



EXPOSURE B
STRUCTURES IN THE FOREGROUND ARE LOCATED IN EXPOSURE B. STRUCTURES IN THE CENTER TOP OF THE PHOTOGRAPH ADJACENT TO THE CLEARING TO THE LEFT, WHICH IS GREATER THAN 200 M IN LENGTH, ARE LOCATED IN EXPOSURE C WHEN WIND COMES FROM THE LEFT OVER THE CLEARING (SEE FIGURE C6-5)

C

EXPOSURE C
FLAT OPEN GRASSLAND WITH SCATTERED OBSTRUCTIONS HAVING HEIGHTS GENERALLY LESS THAN 30 FT

C

EXPOSURE C
OPEN TERRAIN WITH SCATTERED OBSTRUCTIONS HAVING HEIGHTS GENERALLY LESS THAN 30 FT FOR MOST WIND DIRECTIONS, ALL 1-STORY STRUCTURES WITH A MEAN ROOF HEIGHT LESS THAN 30 FT IN THE PHOTOGRAPH ARE LESS THAN 1500 FT OR TEN TIMES THE HEIGHT OF THE STRUCTURE, WHICHEVER IS GREATER, FROM AN OPEN FIELD THAT PREVENTS THE USE OF EXPOSURE B

D

EXPOSURE D
A BUILDING AT THE SHORELINE (EXCLUDING SHORELINES IN HURRICANE-PRONE REGIONS) WITH WIND FLOWING OVER OPEN WATER 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

Wind – General Requirements - Ch. 26

Kzt – Topographic Factor

- Accounts for wind speed increase over hilltop

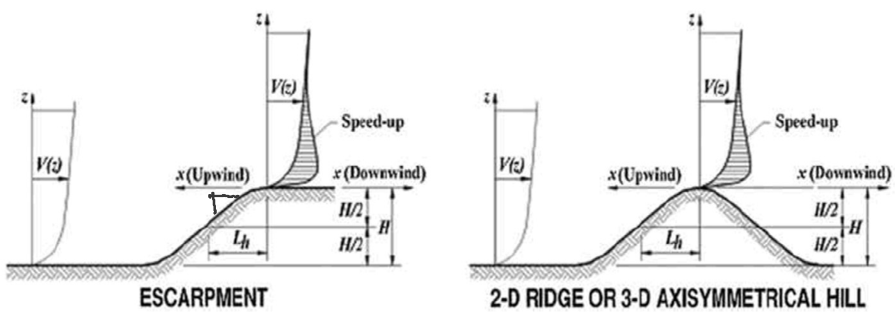
26.8.2 Topographic Factor. The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}:

$$K_{zt} = (1 + K_1 K_2 K_3)^2 \qquad (26.8\text{-}1)$$

where K_1, K_2, and K_3 are given in Fig. 26.8-1.

If site conditions and locations of buildings and other structures do not meet all the conditions specified in Section 26.8.1, then $K_{zt} = 1.0$.

Diagrams



Topographic Multipliers for Exposure $C^{a,b,c}$

Wind – General Requirements - Ch. 26

Kzt – Topographic Factor

- Accounts for wind speed increase over hilltop
- All five of the following conditions need to be met in order to use Kzt – otherwise Kzt = 1.0

1. The hill, ridge, or escarpment is isolated and unobstructed upwind by other similar topographic features of comparable height for 100 times the height of the topographic feature ($100H$) or 2 mi (3.22 km), whichever is less. This distance shall be measured horizontally from the point at which the height H of the hill, ridge, or escarpment is determined.
2. The hill, ridge, or escarpment protrudes above the height of upwind terrain features within a 2-mi (3.22-km) radius in any quadrant by a factor of 2 or more.
3. The building or other structure is located as shown in Fig. 26.8-1 in the upper one-half of a hill or ridge or near the crest of an escarpment.
4. $H/L_h \geq 0.2$.
5. H is greater than or equal to 15 ft (4.5 m) for Exposure C and D and 60 ft (18 m) for Exposure B.

Wind – Directional Procedure

K_d - Wind Directionality Factor

- Table 26.6-1

Table 26.6-1 Wind Directionality Factor, K_d

Structure Type	Directionality Factor K_d
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Circular Domes	1.0[a]
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Octagonal	1.0[a]
Round	1.0[a]
Solid Freestanding Walls, Roof Top Equipment, and Solid Freestanding and Attached Signs	0.85
Open Signs and Single-Plane Open Frames	0.85
Trussed Towers	
Triangular, square, or rectangular	0.85
All other cross sections	0.95

[a]Directionality factor $K_d = 0.95$ shall be permitted for round or octagonal structures with nonaxisymmetric structural systems.

Wind – Directional Procedure

K_e – Ground Elevation Factor

- To adjust air density at high elevations
- Ke may concervatively be taken as 1.0

26.9 GROUND ELEVATION FACTOR

The ground elevation factor to adjust for air density, K_e, shall be determined in accordance with Table 26.9-1. It is permitted to take $K_e = 1$ for all elevations.

Table 26.9-1 Ground Elevation Factor, K_e

Ground Elevation above Sea Level: ft	Ground Elevation above Sea Level: m	Ground Elevation Factor K_e
<0	<0	See note 2
0	0	1.00
1,000	305	0.96
2,000	610	0.93
3,000	914	0.90
4,000	1,219	0.86
5,000	1,524	0.83
6,000	1,829	0.80
>6,000	>1,829	See note 2

Notes

1. The conservative approximation $K_e = 1.00$ is permitted in all cases.
2. The factor K_e shall be determined from the above table using interpolation or from the following formula for all elevations:
   $K_e = e^{-0.0000362 z_g}$ (z_g = ground elevation above sea level in ft).
   $K_e = e^{-0.000119 z_g}$ (z_g = ground elevation above sea level in m).
3. K_e is permitted to be take as 1.00 in all cases.

Wind – Directional Procedure Chapter 27

Design Pressure Equations

- Take shape of structure into account
- Interior pressure + or –
- Sec. 27.4.1 eq. 27.4-1 or -2 or -3

EXT INT

$$p = q\,G\,C_p - q_i\left(GC_{pi}\right)$$

- q windward = qz
- q leeward = qh
- Conservatively use qi = qh

27.3.1 Enclosed and Partially Enclosed Rigid and Flexible Buildings. Design wind pressures for the MWFRS of buildings of all heights in lb/ft^2 (N/m^2), shall be determined by the following equation:

$$p = qGC_p - q_i(GC_{pi}) \qquad (27.3\text{-}1)$$

where

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

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

$q_i = q_h$ for windward walls, sidewalls, 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 that is not impact-resistant or protected with an impact-resistant covering shall be treated as an opening in accordance with Section 26.12.3. For positive internal pressure evaluation, q_i may conservatively be evaluated at height $h(q_i = q_h)$.

G = gust-effect factor; see Section 26.11. For flexible buildings, G_f determined in accordance with Section 26.11.5 shall be substituted for G.

C_p = external pressure coefficient from Figs. 27.3-1, 27.3-2, and 27.3-3.

(GC_{pi}) = internal pressure coefficient from Table 26.13-1.

Both q and q_i shall be evaluated using exposure defined in Section 26.7.3. Pressure shall be applied simultaneously on windward and leeward walls and on roof surfaces as defined in Figs. 27.3-1, 27.3-2, and 27.3-3.

Wind – Directional Procedure

G – Gust Factor

- Sec. 26.11
- **Use 0.85**

26.11.1 Gust-Effect Factor. The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85.

26.11.4 Rigid Buildings or Other Structures. For rigid buildings or other structures as defined in Section 26.2, the gust-effect factor shall be taken as 0.85 or calculated by this formula:

$$G = 0.925\left(\frac{1 + 0.7g_Q I_{\bar{z}} Q}{1 + 0.7g_v I_{\bar{z}}}\right) \qquad (26.11\text{-}6)$$

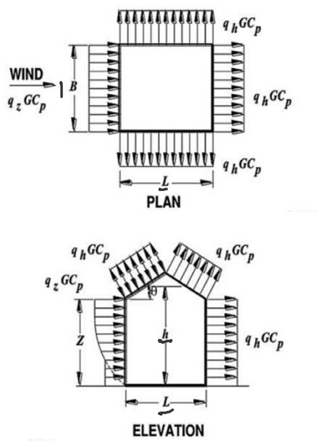
$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} \qquad (26.11\text{-}7)$$

$$I_{\bar{z}} = c\left(\frac{10}{\bar{z}}\right)^{1/6} \qquad (26.11\text{-}7.si)$$

Wind – Directional Procedure

C_p – External Pressure Coefficient

- Fig. 27.3-1 through - 8
- Or supplied by wind tunnel test
- Walls – windward, leeward, and side
- Roofs – sloped or flat
- Special roof shapes see later figures.



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	q_h
	≥4	−0.2	q_h
Sidewall	All values	−0.7	q_h

Roof Pressure Coefficients, C_p, for use with q_h

Wind Direction	h/L	Windward: Angle, θ (degrees) 10	15	20	25	30	35	45	≥60[c]	Leeward: Angle, θ (degrees) 10	15	≥20
Normal to Ridge for θ ≥ 10°	≤0.25	−0.7	−0.5	−0.3	−0.2	−0.2	0.0[a]					
		−0.18	0.0[a]	0.2	0.3	0.3	0.4	0.4	0.01 θ	−0.3	−0.5	−0.6
	0.5	−0.9	−0.7	−0.4	−0.3	−0.2	−0.2	0.0[a]				
		−0.18	−0.18	0.0[a]	0.2	0.2	0.3	0.4	0.01 θ	−0.5	−0.5	−0.6
	≥1.0	−1.3[b]	−1.0	−0.7	−0.5	−0.3	−0.2	0.0[a]				
		−0.18	−0.18	−0.18	0.0[a]	0.2	0.2	0.3	0.01 θ	−0.7	−0.6	−0.6

Wind Direction	h/L	Horizontal 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, −0.18
		h/2 to h	−0.9, −0.18
		h to 2h	−0.5, −0.18
		>2h	−0.3, −0.18
	≥1.0	0 to h/2	−1.3[b], −0.18
		>h/2	−0.7, −0.18

[a]Value is provided for interpolation purposes.
[b]Value can be reduced linearly with area over which it is applicable as follows:
[c]For roof slopes greater than 80°, use $C_p = 0.8$.

Area, ft²	Area, m²	Reduction Factor
≤100	≤9.3	1.0
250	23.2	0.9
≥1,000	≥92.9	0.8

Notes

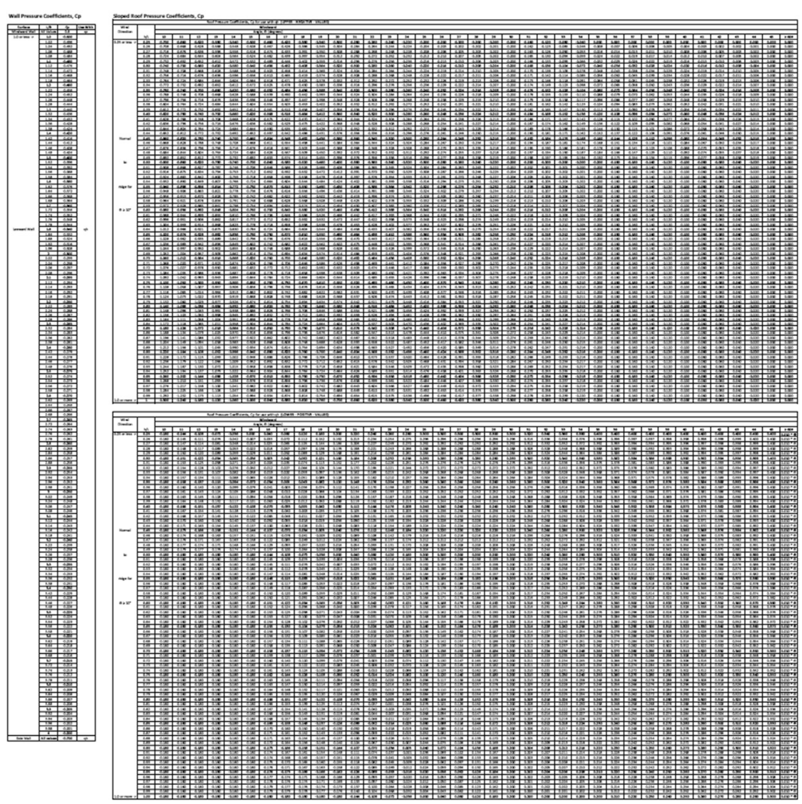
1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. Linear interpolation is permitted for values of L/B, h/L, and θ other than shown. Interpolation shall only be carried out between values of the same sign. Where no value of the same sign is given, assume 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. Refer to Fig. 27.3-2 for domes and Fig. 27.3-3 for arched roofs.
6. For mansard roofs, the top horizontal surface and leeward inclined surface shall be treated as leeward surfaces from the table.
7. Except for MWFRSs at the roof consisting of moment-resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.

FIGURE 27.3-1 (*Coninued*). Main Wind Force Resisting System, Part 1 (All Heights): External Pressure Coefficients, C_p, for Enclosed and Partially Enclosed Buildings—Walls and Roofs

Wind – Directional Procedure

expanded C_p charts

1. walls
2. upper C_p
3. lower C_p

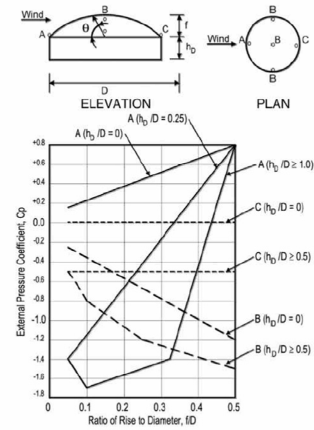


Wind – Directional Procedure

C_p for domed roofs

Diagrams

External Pressure Coefficients for Domes with Circular Base



Notation

f = Dome rise, in ft (m).
h_D = Height to base of dome, in ft (m).
D = Diameter, in ft (m).
θ = Angle of plane of roof from horizontal, in degrees.

Notes

1. Two load cases shall be considered:
   Case A: C_p values between A and B and between B and C shall be determined by linear interpolation along arcs on the dome parallel to the wind direction;
   Case B: C_p shall be the constant value of A for $\theta \leq 25$ degrees and shall be determined by linear interpolation from 25 degrees to B and from B to C.
2. Values denote C_p to be used with $q_{(hD+f)}$ where h_{D+f} is the height at the top of the dome.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. C_p is constant on the dome surface for arcs of circles perpendicular to the wind direction; for example, the arc passing through $B-B-B$ and all arcs parallel to $B-B-B$.
5. For values of $h_{D/D}$ between those listed on the graph curves, linear interpolation shall be permitted.
6. $\theta = 0$ degrees on dome springline, $\theta = 90$ degrees at dome center top point. f is measured from springline to top.
7. The total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
8. For f/D values less than 0.05, use Fig. 27.3-1.

FIGURE 27.3-2 Main Wind Force Resisting System, Part 1 (All Heights): External Pressure Coefficients, C_p, for Enclosed and Partially Enclosed Buildings and Structures—Domed Roofs with a Circular Base

Wind – Directional Procedure

GC_{pi}
Internal Pressure Coefficient

- Table 26.13-1
- Combine with GC_p to give worst case

$$p = q\ G\ C_p - q_i(GC_{pi})$$

Table 26.13-1 Main Wind Force Resisting System and Components and Cladding (All Heights): Internal Pressure Coefficient, (GC_{pi}), for Enclosed, Partially Enclosed, Partially Open, and Open Buildings (Walls and Roof)

Enclosure Classification	Criteria for Enclosure Classification	Internal Pressure	Internal Pressure Coefficient, (GC_{pi})
Enclosed buildings	A_o is less than the smaller of $0.01A_g$ or 4 sq ft (0.37 m) and $A_{oi}/A_{gi} \leq 0.2$	Moderate	+0.18 −0.18
Partially enclosed buildings	$A_o > 1.1A_{oi}$ and $A_o >$ the lesser of $0.01A_g$ or 4 sq ft (0.37 m) and $A_{oi}/A_{gi} \leq 0.2$	High	+0.55 −0.55
Partially open buildings	A building that does not comply with Enclosed, Partially Enclosed, or Open classifications	Moderate	+0.18 −0.18
Open buildings	Each wall is at least 80% open	Negligible	0.00

Notes

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of (GC_{pi}) shall be used with q_z or q_h as specified.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:
   a. A positive value of (GC_{pi}) applied to all internal surfaces, or
   b. A negative value of (GC_{pi}) applied to all internal surfaces.

GC_{pi}
Internal Pressure Coefficient

- Table 26.13-1
- Combine with GC_p to give worst case

GCpi ± 0.55

BUILDING, PARTIALLY ENCLOSED: A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%.
2. The total area of openings in a wall that receives positive external pressure exceeds 4 ft² (0.37 m²) or 1% of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20%.

These conditions are expressed by the following equations:

$$A_o > 1.10A_{oi}$$

$A_o > 4\ \text{ft}^2 (0.37\ \text{m}^2)$ or

$> 0.01A_g$, whichever is smaller, and $A_{oi}/A_{gi} \le 0.20$

where A_o and A_g are as defined for Open Building;

A_{oi} = sum of the areas of openings in the building envelope (walls and roof) not including A_o, in ft² (m²); and

A_{gi} = sum of the gross surface areas of the building envelope (walls and roof) not including A_g, in ft² (m²).

GCpi ± 0.18

BUILDING, ENCLOSED: A building that has the total area of openings in each wall, that receives positive external pressure, less than or equal to 4 sq ft (0.37 m²) or 1% of the area of that wall, whichever is smaller. This condition is expressed for each wall by the following equation:

$A_o < 0.01A_g$, or 4 sq ft (0.37 m²), whichever is smaller,

where A_o and A_g are as defined for Open Buildings.

GCpi ± 0.18

BUILDING, PARTIALLY OPEN: A building that does not comply with the requirements for open, partially enclosed, or enclosed buildings.

GCpi = 0.0

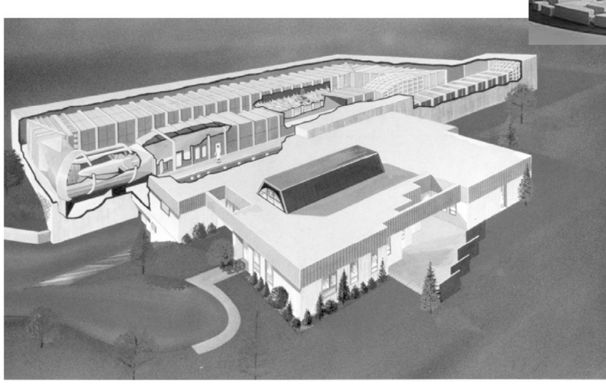
BUILDING, OPEN: A building that has each wall at least 80% open. This condition is expressed for each wall by the equation $A_o \ge 0.8A_g$, where

A_o = total area of openings in a wall that receives positive external pressure, in ft² (m²); and

A_g = the gross area of that wall in which A_o is identified, in ft² (m²).

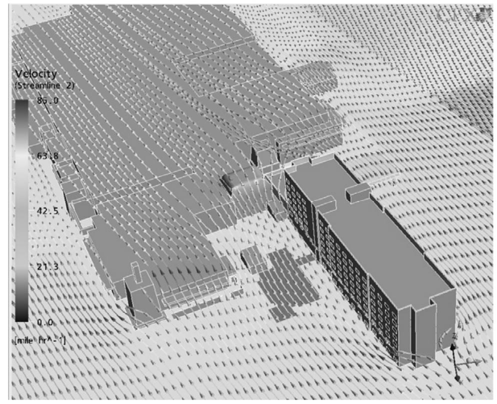
Wind – wind tunnel testing

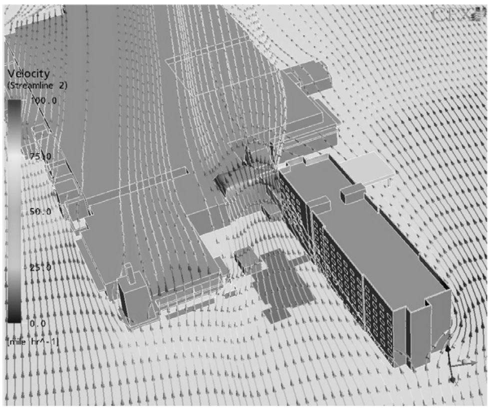
Boundary Layer Wind Tunnel



Wind – CFD

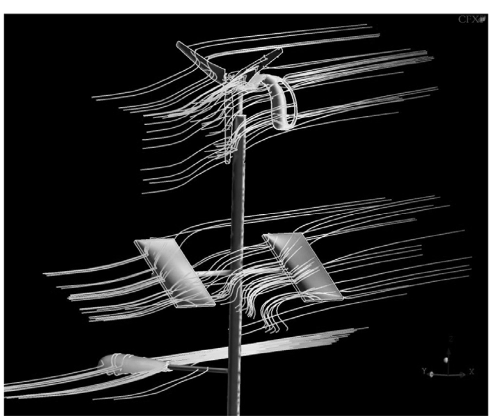
Computational Fluid Dynamics





Wind – CFD

Computational Fluid Dynamics

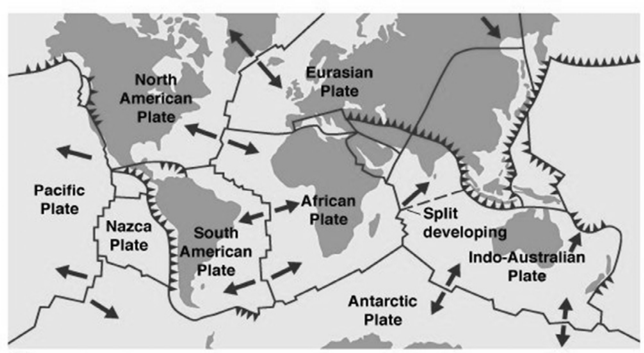


Earthquake Loads

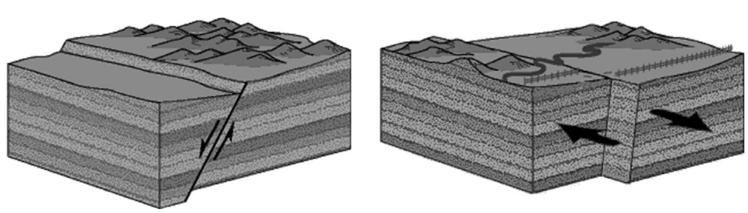
- Ground Motion
- Measurement
- Amplification
- Building Resistance

Geologic Background

Plate Tectonics



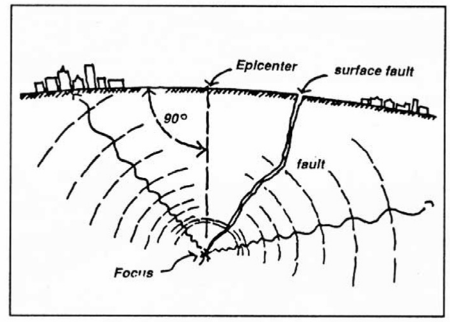
Geologic Faults



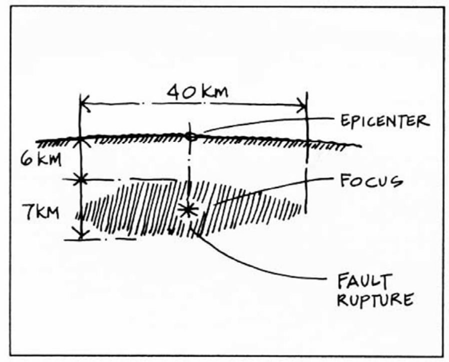
Geologic Background

Fault Location

- Focus (hypocenter)
- Epicenter



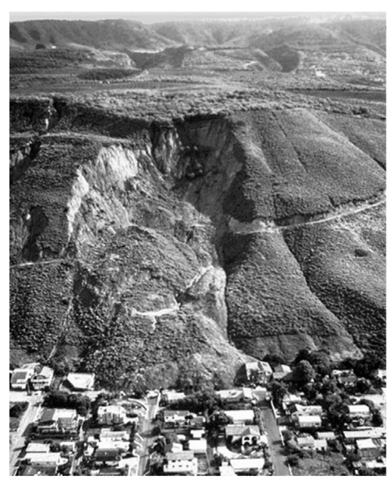
Earthquake location



The Loma Prieta fault rupture, 1989

Ground Failure

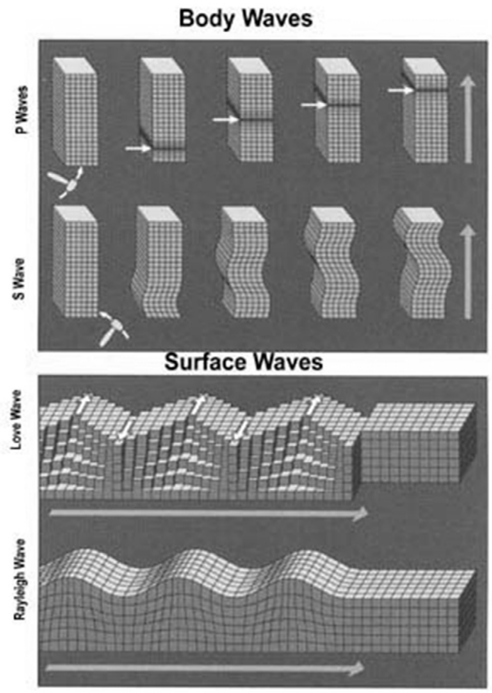
- Landslides
- Liquefaction
- Subsidence



Ground Motion

Primary
- P wave
- hits first
- pressure hammer

Secondary (Shear)
- S wave
- back and forth
- adds to P wave



Ground Motion

Acceleration
- Measured in g's (1 g = 32 ft/sec2)
- 0.001 g limit of perception
- 0.1 g weak construction fails
- 0.2 g hard to stand up
- 0.5 g very sever for earthquake

San Francisco, 1906 approximately 0.7g

Measurement

Magnitude

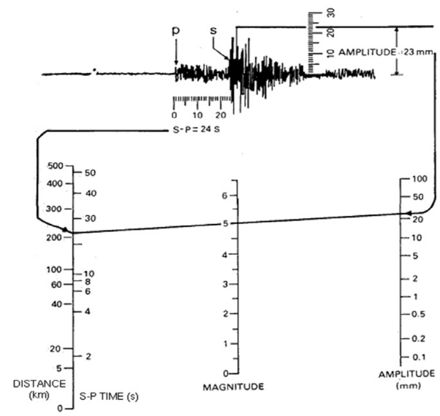
- Richter scale 0 to ~9.5
- Size of the wave
- Accounts for attenuation
- Logarithmic (base 10)

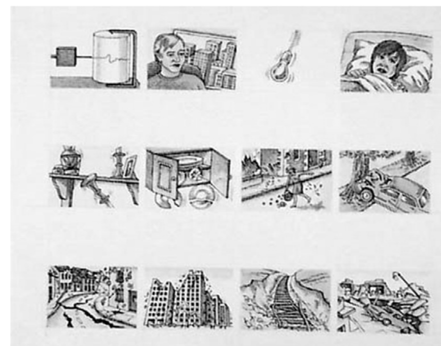
Intensity

- Modified Mercalli scale I to XII
- Relates to effects
- Includes duration
- Differs with location

Other measured parameters

- Peak Ground Acceleration (PGA)
- Design Basis Earthquake Ground Motion (DBEGM)

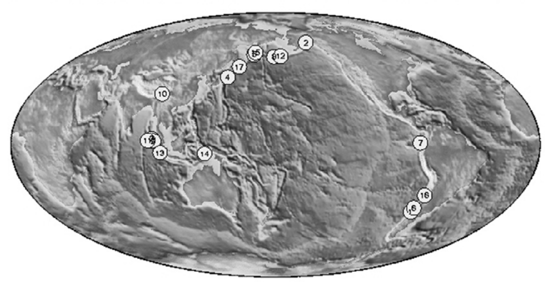




Latest Earthquakes
Real-time Feeds & Notifications
Significant EQ Archive
Search EQ Archives
"Top 10" Lists & Map
Info by Region

Largest Earthquakes in the World Since 1900

This webpage is updated in January of each year to incorporate any relevant data from the previous year.



USGS National Earthquake Information Center

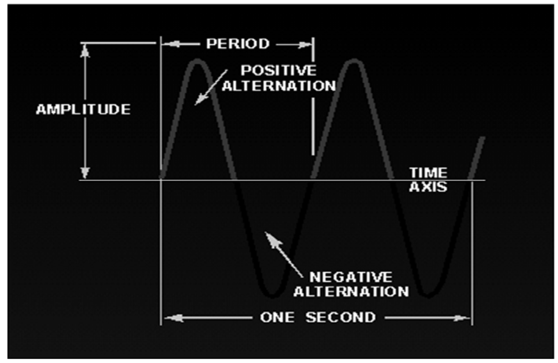
Google Earth KML
(requires Google Earth)

	Location	Date UTC	Magnitude	Lat.	Long.	Reference
1.	Chile	1960 05 22	9.5	-38.29	-73.05	Kanamori, 1977
2.	1964 Great Alaska Earthquake	1964 03 28	9.2	61.02	-147.65	Kanamori, 1977
3.	Off the West Coast of Northern Sumatra	2004 12 26	9.1	3.30	95.78	Park et al., 2005
4.	Near the East Coast of Honshu, Japan	2011 03 11	9.0	38.322	142.369	PDE
5.	Kamchatka	1952 11 04	9.0	52.76	160.06	Kanamori, 1977
6.	Offshore Maule, Chile	2010 02 27	8.8	-35.846	-72.719	PDE
7.	Off the Coast of Ecuador	1906 01 31	8.8	1.0	-81.5	Kanamori, 1977
8.	Rat Islands, Alaska	1965 02 04	8.7	51.21	178.50	Kanamori, 1977
9.	Northern Sumatra, Indonesia	2005 03 28	8.6	2.08	97.01	PDE
10.	Assam - Tibet	1950 08 15	8.6	28.5	96.5	Kanamori, 1977
11.	Off the west coast of northern Sumatra	2012 04 11	8.6	2.311	93.063	PDE
12.	Andreanof Islands, Alaska	1957 03 09	8.6	51.56	-175.39	Johnson et al., 1994
13.	Southern Sumatra, Indonesia	2007 09 12	8.5	-4.438	101.367	PDE
14.	Banda Sea, Indonesia	1938 02 01	8.5	-5.05	131.62	Okal and Reymond, 2003
15.	Kamchatka	1923 02 03	8.5	54.0	161.0	Kanamori, 1988
16.	Chile-Argentina Border	1922 11 11	8.5	-28.55	-70.50	Kanamori, 1977

Characteristics of Period

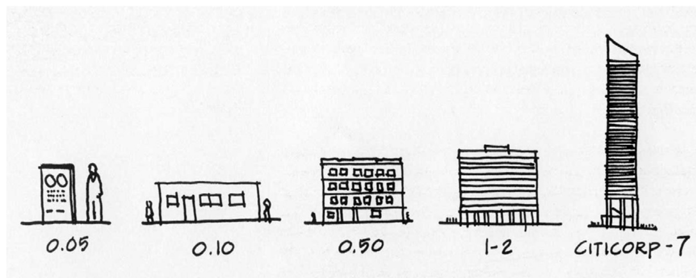
Frequency
- Cycles / second (Hz)

Period
- Inverse of frequency



Fundamental Period
- measure in seconds
- approx. = stories/10

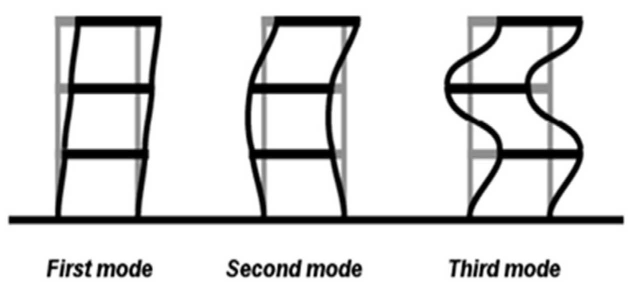
Soil approx. 0.5 ~ 2.0



20 Hz 10 Hz 2 Hz 1 – 0.5 Hz 0.14 Hz

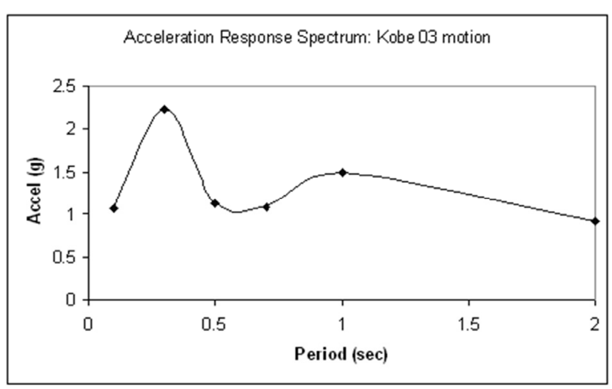
Amplification

Fundamental Period
- Modes
- Modal shapes
- Modal frequency



Resonance

Response Spectrum
- Fundamental period of soil
- 0.4 to 1.5 (or 2.0)
- Harder is shorter (rock)
- Softer is longer (soil)

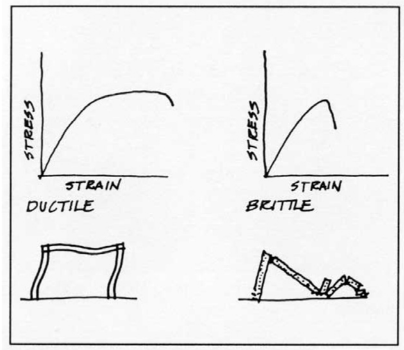


Building Resistance

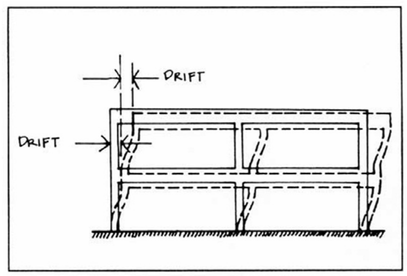
Damping
- Material
- Partitions

Ductility
- connections

Strength and stiffness
- drift



Ductile materials undergo considerable permanent deformation before failure.



Story-to-story drift

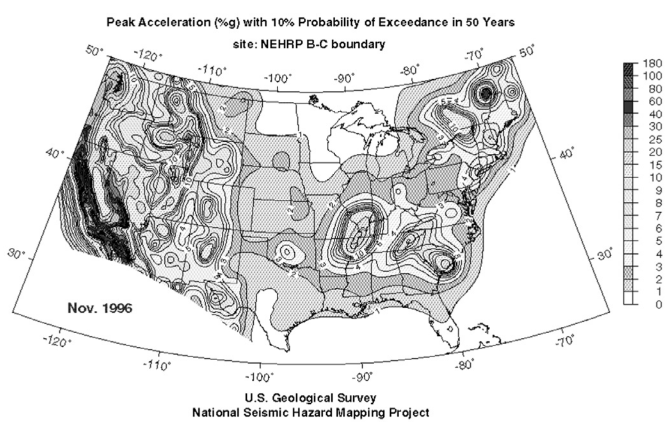
Provisions and Codes

National Earthquake Hazards Reduction Program (NEHRP)

not a code but "provisions"

ASCE 7 Section 9

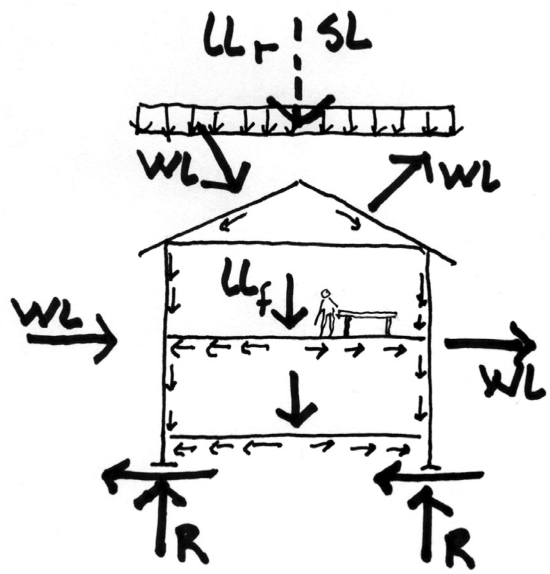
code based on NEHRP



Load Combinations

Load Types

- Dead Load - D
- Roof Live Load - Lr
- Floor Live Load - L
- Snow Load - S
- Wind Load - W
- Earthquake - E



Load Combinations

Allowable Stress Design (ASD)

- D + L
- D + (Lr or S)
- D + 0.75 L + 0.75 (Lr or S)
- D + (W or 0.7 E)

Strength Design (LRFD)

- 1.4 D
- 1.2 D + 1.6 Lr + 0.5(Lr or S)
- 1.2 D + 1.6(Lr or S) + (L or 0.8W)
- 1.2 D + 1.6W + L + 0.5(Lr or S)
- 1.2 D + 1.6E + L + 0.2S