IBC 2003 Snow Loads

- Section 1608 Snow Loads
  - Use ASCE 7-02, Section 7
  - Flat roof snow loads, C_e, C_t, p_g, I_s, balanced loads, unbalanced loads, rain-on-snow surcharge, roof projections, sliding snow, snow drift, …
  - Use ASCE 7-02, Section 7

ASCE 7 Snow Loads

- Flat roof snow load (check minimum) - 7.3
- Sloped roof snow load - 7.4
- Partial loading - 7.5
- Unbalanced roof snow loads – 7.6
- Drifts on lower roofs – 7.7
- Roof projections – 7.8
- Sliding snow – 7.9
- Rain-on-snow surcharge – 7.10
- Ponding instability – 7.11
- Existing roofs – 7.12

Flat Roof Snow Load

- Flat roof : slopes less than 5 degrees
  - (5 degrees = 1.05”/foot)
- $p_f = 0.7\ C_e\ C_t\ I_s\ p_g$ (Eq. 7-1)
  - Minimum $p_f = p_g\ I_s$
  - or $p_f = 20\ I_s$
  - Concern is with single major storms which Eq. 7-1, C_e, and C_t *may* underestimate.

Flat Roof Snow Load (cont.)

- Minimum p_f often controls
  - For p_g equal to or less than 20 psf:
    - Minimum $p_f = p_g I_s$ almost always controls
    - with C_e=1.3, C_t=1.2 (maximum values)
      - p_f (max) = 1.092 $p_g I_s$ (Eq. 7-1)
  - For p_g greater than 20 psf:
    - Minimum $p_f = 20I_s$
    - almost always controls, for p_g less than 30 psf
    - For p_g greater than 25 psf, Eq. 7-1 usually controls

Flat Roof Snow Load (cont.)

- Minimum p_f applies for all flat roofs by definition:
  - Monoslope roofs with slopes less than 15 degrees
  - Hip and gable roofs with slopes less than (70/W) + 0.5 (degrees?)
    - W is horizontal distance from eave to ridge
  - Curved roofs where the chord slope (eaves to crown) is less than 10 degrees.
- p_f = larger of p_f and $p_{f(minimum)}$

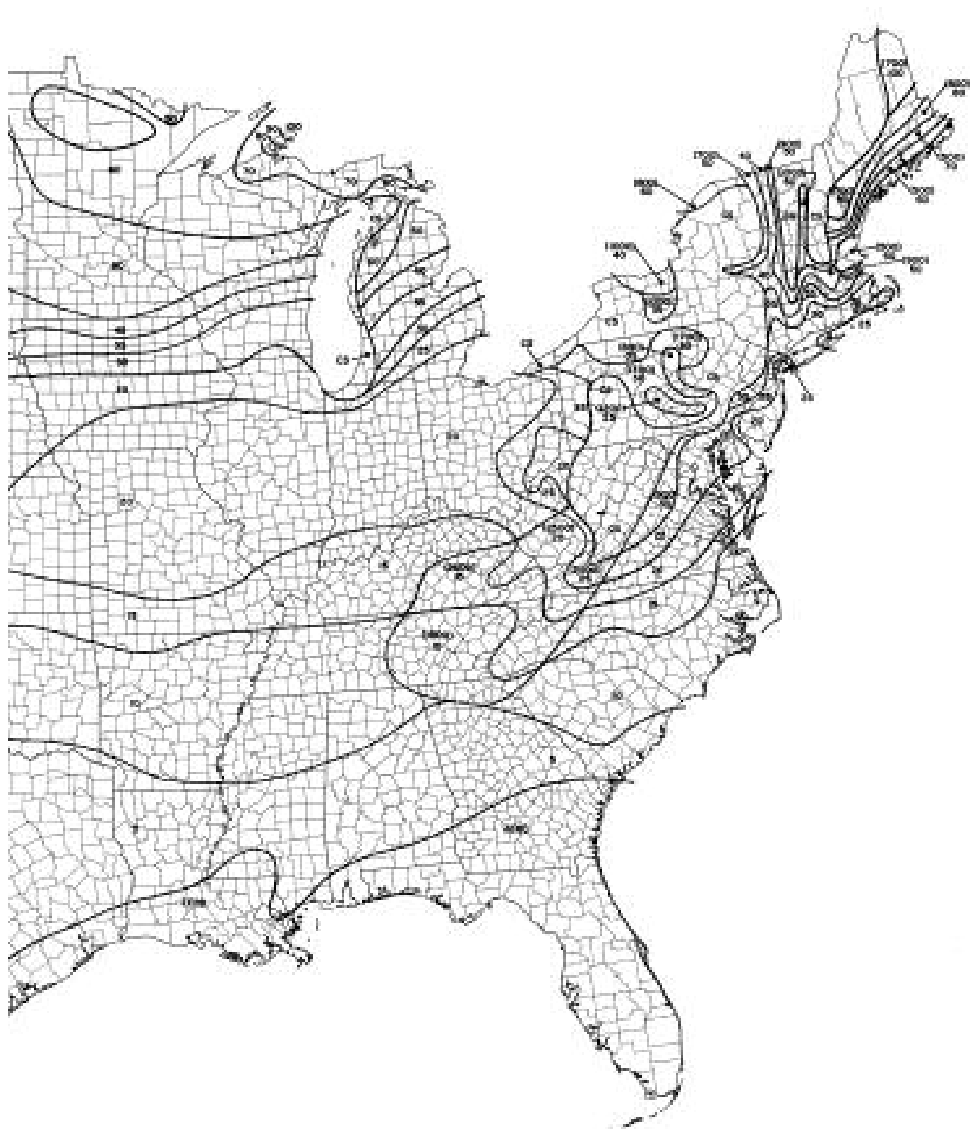
Flat & Sloped Roof Snow Loads

- For calculations, we need to find the flat roof snow load (and possibly the minimum flat roof snow load) for flat and for sloped roofs.
- The sloped roof snow load is the flat roof snow load (or the minimum if it applies), modified by the factor C_s.
- $p_s = C_s\, p_f$ (Eq. 7-2)

Flat Roof Snow Loads (cont.)

- $p_f = 0.7\ C_e\ C_t\ I_s\ \boldsymbol{p_g}$ (Eq. 7-1)
- P_g from maps : log normal distribution was used to estimate ground snow loads with a 2% annual probability of being exceeded (50-year mean recurrence interval)
- Measured at 204 ‘first order’ stations (see Table C7-1) and at 9,200 other stations.

Flat Roof Snow Loads (cont.)



Flat Roof Snow Loads (cont.)

- St. Louis was a ‘first order’ station:
  - 37 years of records through 1992, maximum ground snow load observed, 28 psf.
  - 2% annual probability: 21 psf

Flat Roof Snow Loads (cont.)

- Look at possibility of excess load in St. Louis, with a light roof:
  - 15 psf dead load + 20 psf minimum snow load = 35 psf total design load
  - 50% excess snow = 30 psf snow load
    - 15 psf dead load + 30 psf snow load = 45 psf total
    - = 29% overstress
  - Maximum recorded snow = 28 psf snow load
    - 15 psf dead load + 28 psf snow load = 43 psf load
    - = 22% overstress

Flat Roof Snow Loads (cont.)

- Look at possibility of excess load in areas with higher ground snow loads with a light roof:
  - 15 psf dead load + 35 psf snow load = 50 psf total design load
  - 50% excess snow = 52 psf snow load
    - 15 psf dead load + 52 psf snow load = 67 psf total = 34% overstress
  - Maximum recorded snow = 55 psf snow load (Duluth, Minnesota)
    - 15 psf dead load + 55 psf snow load = 70 psf total = 40% overstress

Flat Roof Snow Loads (cont.)

- p_f = $\mathbf{0.7}\ \boldsymbol{C_e}\, C_t\, I_s\, p_g$ (Eq. 7-1)
  - 0.7 is a basic exposure factor.
  - Exposure Factor, C_e,from Table 7-2 is a secondary exposure factor.
  - Two step process varies the total exposure factor from a minimum of 0.49 to a maximum of 0.91
  - Less snow is present on roofs than on the ground.

Flat Roof Snow Loads (cont.)

- Exposure Factor, C_e (cont.)
  - Terrain category, similar to wind terrain.
  - Fully exposed: no shelter, no parapets, few pieces of mechanical equipment
    - Shelter: obstructions (terrain, higher structures, trees) within a distance $10h_o$, h_o=height above roof.
  - Sheltered: tight conifers qualifying as obstructions.

Flat Roof Snow Loads (cont.) Section 1609.4, Terrain

- Exposure A : Large city centers, 50% of buildings over 70 feet. (no longer used)
- Exposure B : urban, suburban, wooded areas. Usually assumed.
- Exposure C : open terrain, flat open country, grasslands, shorelines
- Exposure D : flat, unobstructed, exposed to wind flowing over open water for at least a mile.

Flat Roof Snow Loads (cont.) Table 7-2

TABLE 7-2
EXPOSURE FACTOR, C_e

Terrain Category	Fully Exposed	Exposure of Roof* Partially Exposed	Sheltered
A (see Section 6.5.6)	N/A	1.1	1.3
B (see Section 6.5.6)	0.9	1.0	1.2
C (see Section 6.5.6)	0.9	1.0	1.1
D (see Section 6.5.6)	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.

***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 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.

**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 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.

Flat Roof Snow Loads (cont.)

- $p_f = 0.7\ C_e\ \boldsymbol{C_t}\ I_s\ p_g$ (Eq. 7-1)
  - Thermal Factor, C_t, from Table 7-3.
  - Use C_t = 1.2 for unheated structures and those intentionally kept below freezing.
    - Some buildings may be unused in the winter and may have a larger C_t of 1.2, but are unoccupied, and have I_s=0.8 The total effect (0.96) is similar to that of an occupied building with a C_t=1.0, I_s=1.0

Flat Roof Snow Loads (cont.)

- Thermal Factor, C_t (cont.)
  - Use $C_t = 1.1$ for structures kept just above freezing and for cold, ventilated roofs (attics) with insulation between the ventilated space and the heated space (insulation in the ceiling of the space below) greater than an R-value of 25 (not most attics).

Flat Roof Snow Loads (cont.)

- Thermal Factor, C_t (cont.)
  - Use $C_t = 0.85$ for continuously heated greenhouses, with an R-value in the roof less than 2.0.
    - Continuously heated: 50 degrees at 3 feet above the floor and either an attendant or an alarm system to warn of a failure of the heating system.

Flat Roof Snow Loads (cont.) Table 7-3

TABLE 7-3
THERMAL FACTOR, C_t

Thermal Condition*	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°·hr·sq ft/Btu (4.4 K·m^2/W)	1.1
Unheated structures and structures intentionally kept below freezing	1.2
Continuously heated greenhouses** with a roof having a thermal resistance (R-value) less than 2.0 F°·hr·ft^2/Btu(0.4 K·m^2/W)	0.85

*These conditions shall be representative of the anticipated conditions during winters for the life of the structure.

**Greenhouses 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.

Flat Roof Snow Loads (cont.)

- $p_f = 0.7\ C_e\ C_t\ \boldsymbol{I_s}\ p_g$ (Eq. 7-1)
  - Importance Factor, I_s, from Table 1604.5.
  - Category I ‘agricultural’ : $I_s = 0.8$
  - Category II ‘remainder’ : $I_s = 1.0$
  - Category III ‘lot of people’: $I_s = 1.1$
  - Category IV ‘essential’ : $I_s = 1.2$
  - Greenhouses not open to the public are Category I, which means that if they are open to the public, they must be II or III

Flat Roof Snow Loads (cont.) Section 1604.5

TABLE 1604.5
CLASSIFICATION OF BUILDINGS AND OTHER STRUCTURES FOR IMPORTANCE FACTORS

CATEGORY[a]	NATURE OF OCCUPANCY	SEISMIC FACTOR I_E	SNOW FACTOR I_S	WIND FACTOR I_W
I	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	1.00	0.8	0.87[b]
II	Buildings and other structures except those listed in Categories I, III and IV	1.00	1.0	1.00
III	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 elementary school, secondary school or day care facilities with an occupant load greater than 250 • Buildings and other structures with an occupant load greater than 500 for colleges or adult education facilities • Health care facilities with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities • Jails and detention facilities • Any other occupancy with an occupant load greater than 5,000 • Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Category IV • Buildings and other structures not included in Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released	1.25	1.1	1.15
IV	Buildings and other structures designed 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 • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power-generating stations and other public utility facilities required as emergency backup facilities for Category IV structures • Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.7(2) • Aviation control towers, air traffic control centers and emergency aircraft hangars • Buildings and other structures having critical national defense functions • Water treatment facilities required to maintain water pressure for fire suppression	1.50	1.2	1.15

a. For the purpose of Section 1616.2, Categories I and II are considered Seismic Use Group I, Category III is considered Seismic Use Group II and Category IV is equivalent to Seismic Use Group III.

b. In hurricane-prone regions with $V > 100$ miles per hour, I_w shall be 0.77.

Sloped Roof Snow Load

- $p_s = C_s\, p_f$ (Eq. 7-2)
- C_s modifies the flat roof load, p_f
- C_s is always less than or equal to 1.0
- C_s depends upon whether snow can slide off a roof (is it “slippery”), and on whether it is warm or not.
- Warm slippery roofs have less snow load.

Sloped Roof Snow Load (cont.)

- Roofs that allow snow to slide off will have lower roof snow loads.
- Roof must be unobstructed, and must have sufficient space below the eaves to accept the sliding snow.
- Intermittent melting and re-freezing may either form ice dam obstructions or may ‘lock-in’ snow on the roof.

Sloped Roof Snow Load (cont.)

- ‘Slippery’ roofs that allow snow to slide off will have lower roof snow loads, and should use the dashed lines in figures 7-2a, 7-2b, and 7-2c.
- Other roofs must use the solid lines.

Sloped Roof Snow Load (cont.)

- Warm roofs are roofs with C_t <= 1.0
- Warm ventilated roofs with an R-value >= 20, and non-ventilated roofs with an R-value >= 30 have lower C_s values (??)
- (??) Warm roofs with too little insulation can cause intermittent melting and the formation of ice dams, which stop snow sliding.

Sloped Roof Snow Load (cont.) Figure 7-2 (a, b, & c)

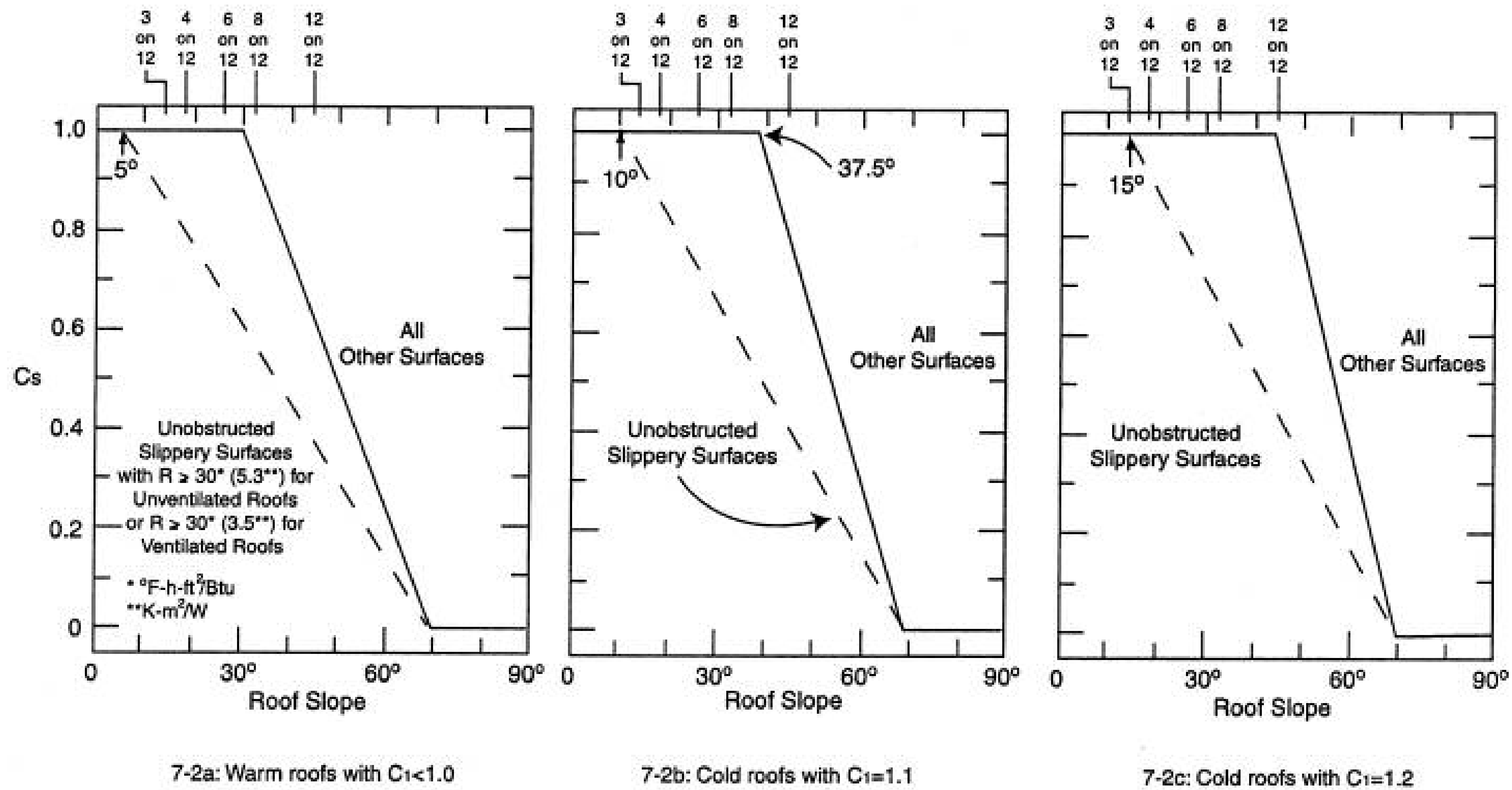


FIGURE 7-2
GRAPHS FOR DETERMINING ROOF SLOPE FACTOR C, FOR WARM AND COLD ROOFS (SEE TABLE 7-3 FOR C_1 DEFINITIONS)

Computer Aids

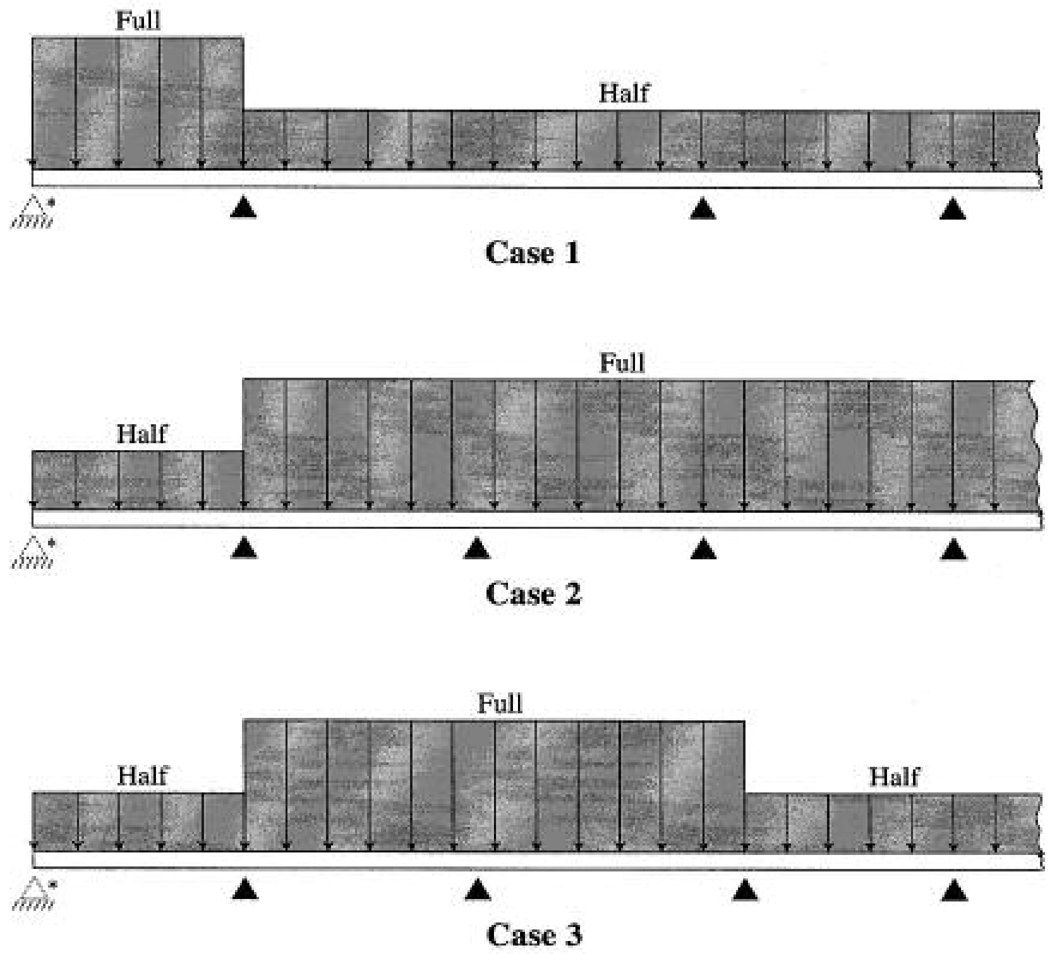
- Excel Spreadsheet
- Commercial Programs
  - Archon ($35)

Snow Loads & Snow Drift - ASCE 7-02		
Project : Project # : Date		
Monoslope roof, Hip/Gable roof, or Curved roof (M, HG, C)		input roof type
hip/gable roof - horizontal distance from eave to ridge, W (ft)		
curved roof - vertical angle from eaves to crown (degrees)		
ground snow load, pg (psf)		figure 7-1 or site-specific
snow density, lambda (pcf)	14.00	
exposure factor, Ce		table 7-2
thermal factor, Ct		table 7-3
importance factor, I		
roof slope (degrees)		input either degrees OR inches per foot, NOT both
roof slope (inches per foot)		
roof slope (degrees)	0.000	
roof slope (inches per foot)	0.000	
Use flat roof snow load (section 7.3)		
flat roof snow load, pf (min)	0.00	section 7.3.4
flat roof snow load, pf (calculated)	0.00	Eq. 7.1
rain-on-snow surcharge (psf)	5.00	section 7.10
flat roof snow load, pf (psf)	0.00	including rain-on-snow
minimum roof snow load (psf)	0.00	
flat roof snow load or minimum roof snow load, whichever is larger, psf	0.00	
R-value of roof (thermal resistance) (sq ft hr F/Btu)		required only for Ct<=1.0 and sloped roof
is roof ventilated ? (can exterior air flow from eave to ridge ?) (Y/N)		
slippery or rough roof surface (S/R)		Metal, slate, glass & rubber : smooth. Embedded granules, wood shingles : rough.
unobstructed roof ? (meaning snow can slide off ?) (Y/N)		
Use Table 7-2a : solid line		
slope factor, Cs	1.000	see tables 7-2a, 7-2b, and 7-2c
sloped roof snow load, ps (psf)	0.000	= Cs * pf
sloped roof snow load or min roof snow load (if slope<15 degrees), psf	0.000	See 7.3.4 : min applies if slope<15 degrees
length of high roof, lu (ft)		perpendicular to roof edge
length of low roof, ll (ft)		perpendicular to roof edge
difference in roof height, hc (ft)		
depth of flat or sloped roof snow load, hb (ft)	0.00	flat snow load / snow density
No snow drift is required.		
leeward drift height, hd (ft)	0.74	
windward drift height, hd (ft)	0.18	
drift height to use, hd (ft)	0.74	
snow height at high point of drift (ft)	0.74	hb + hd
snow load at high point of drift (psf)	10.30	(pd + pf) or (pd + ps)
slope of snow load (psf/ft)	0.00	based on a 'long' low roof dimension
width of snow drift, W (ft)	0.00	as calculated, but <= than low roof length
snow load at lower side of drift (psf)	10.30	pf, ps, or truncated load (if low roof is 'short')
Truncated snow drift at edge of low roof.		

Partial Snow Loading

- Continuous beam systems (including cantilevers) shall be checked for three different loadings:
  - Full snow on exterior spans, half snow all on interior spans.
  - Half snow on exterior spans, full snow all on interior spans.
  - Full snow on <u>any</u> two adjacent spans, half snow all on other spans.

Partial Snow Loading
Figure 7-4



* The left supports are dashed since they would not exist when a cantilever is present.

Unbalanced Roof Snow Loads Hip & Gable

- Required for slopes greater than 70/W +0.5 and less than 70 degrees
- Need to find Beta if W>20 ft. (larger roofs) See Fig. 7-5
  - p_g<=20 Beta=1
  - 20<p_g<=40 Beta=1.5-0.025p_g
  - 40<p_g Beta=0.5
  - Smaller Beta = smaller unbalanced load

Unbalanced Roof Snow Loads Hip & Gable Fig. 7-5

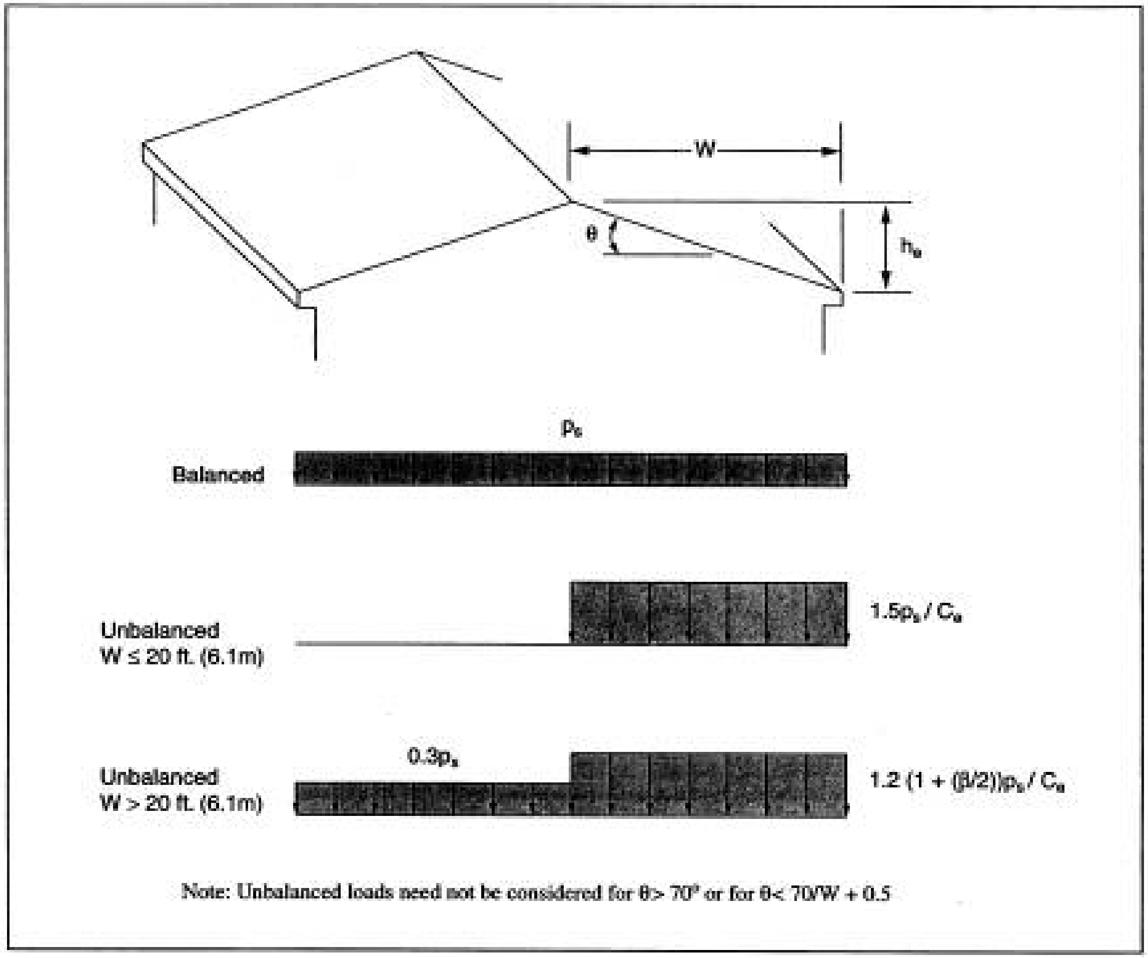


FIGURE 7-5
BALANCED AND UNBALANCED SNOW LOADS FOR HIP AND GABLE ROOFS

Unbalanced Roof Snow Loads Curved Roofs

- Portions of roof sloped greater than 70 degrees are free of snow.
- If angle of the slope from eave to crown is less than 10 degrees, unbalanced loads shall not apply.
- See Fig. 7-3.
- Maintain 30 degree load if ground or adjacent roof is within 3 feet of eave.

Unbalanced Roof Snow Loads Curved Roofs Fig. 7-3

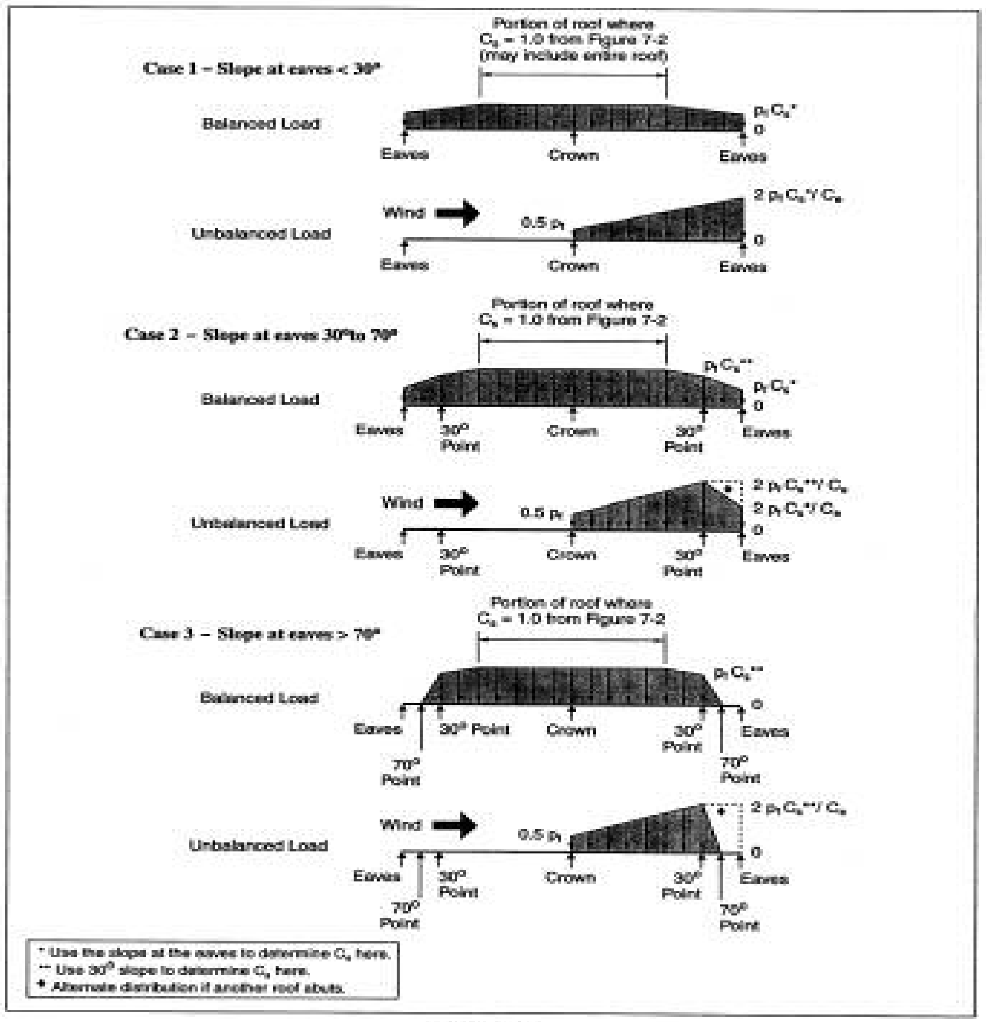
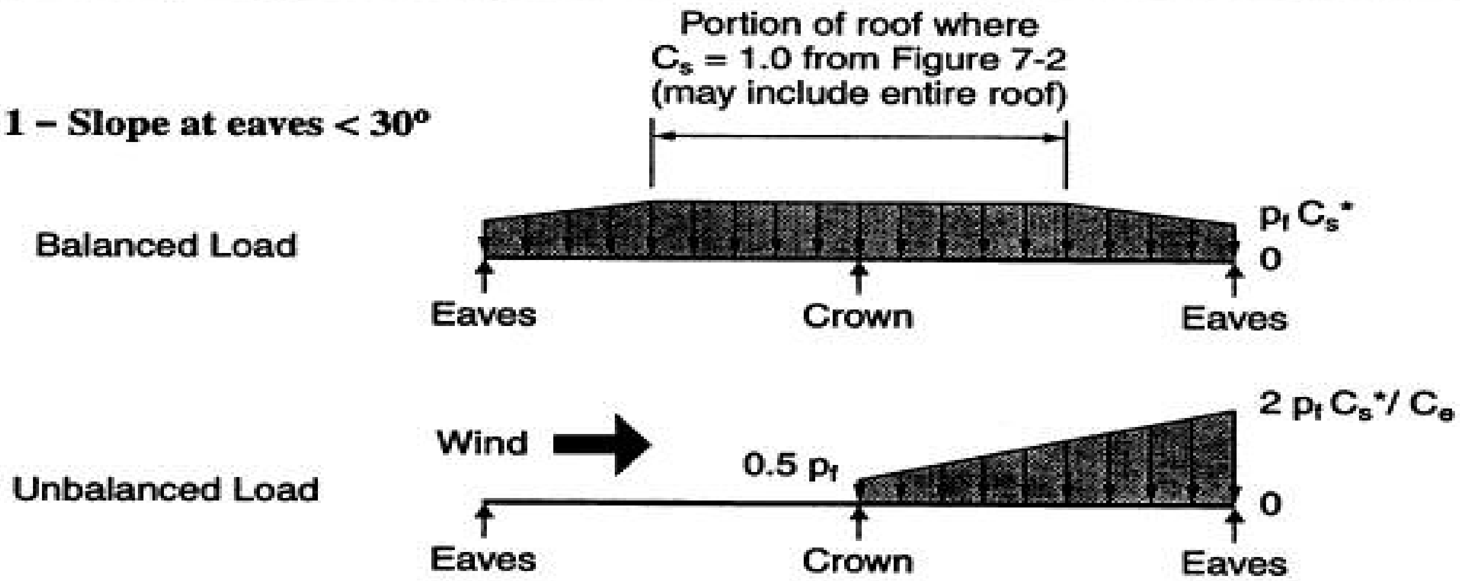
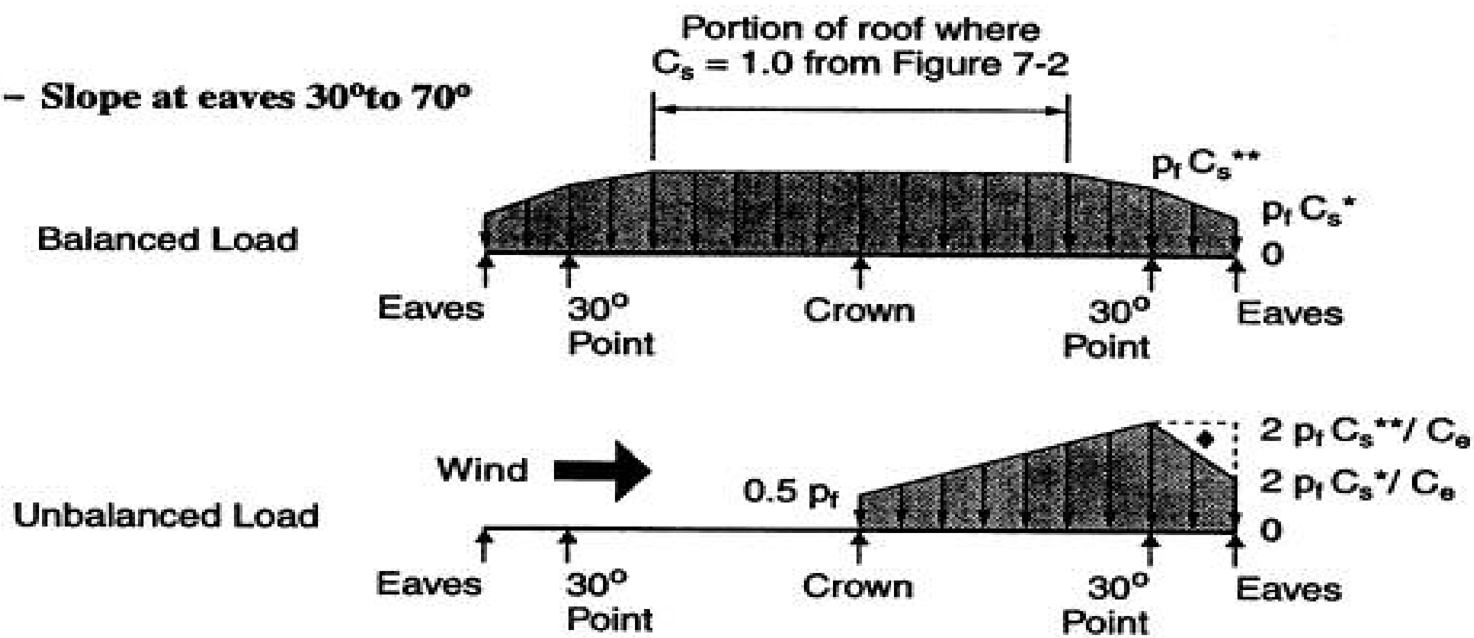


FIGURE 7-3
BALANCED AND UNBALANCED LOADS FOR CURVED ROOFS

Case 1 – Slope at eaves < 30°



Case 2 – Slope at eaves 30° to 70°



Portion of roof where
C_s = 1.0 from Figure 7-2

Case 3 – Slope at eaves > 70°

Sloped Roof Snow Load (cont.) Figure 7-2 (a, b, & c)

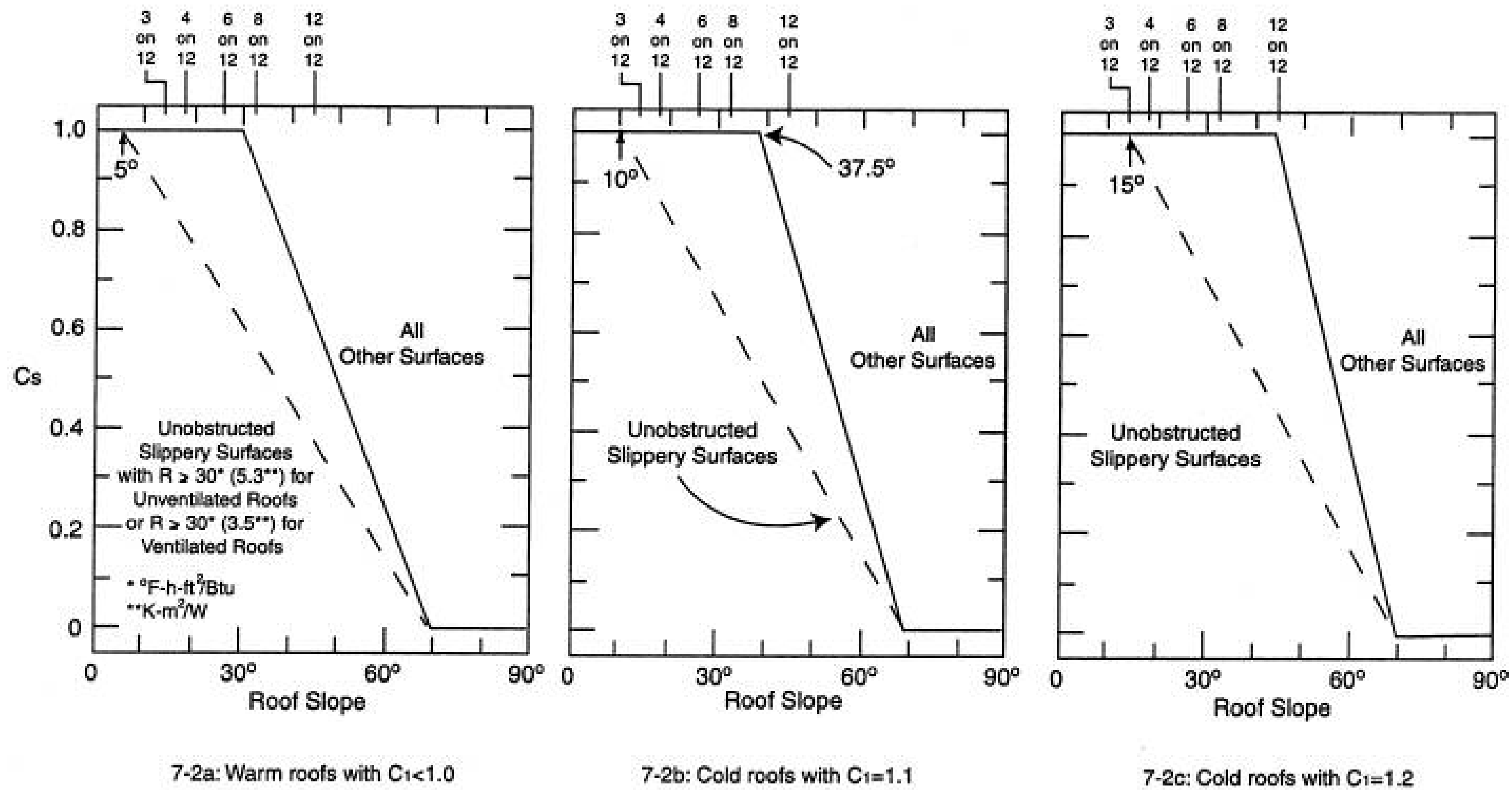


FIGURE 7-2
GRAPHS FOR DETERMINING ROOF SLOPE FACTOR C, FOR WARM AND COLD ROOFS (SEE TABLE 7-3 FOR C_1 DEFINITIONS)

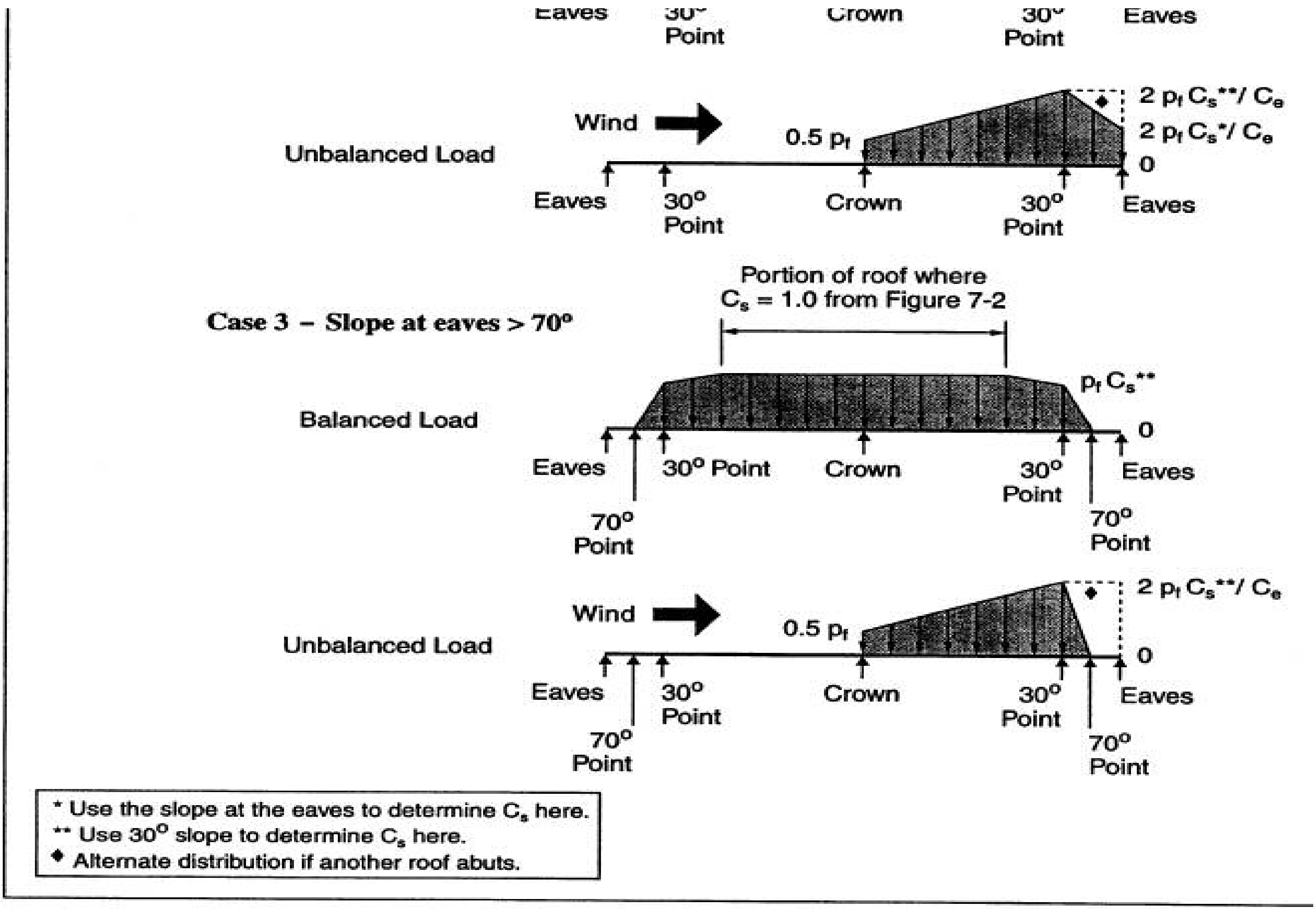
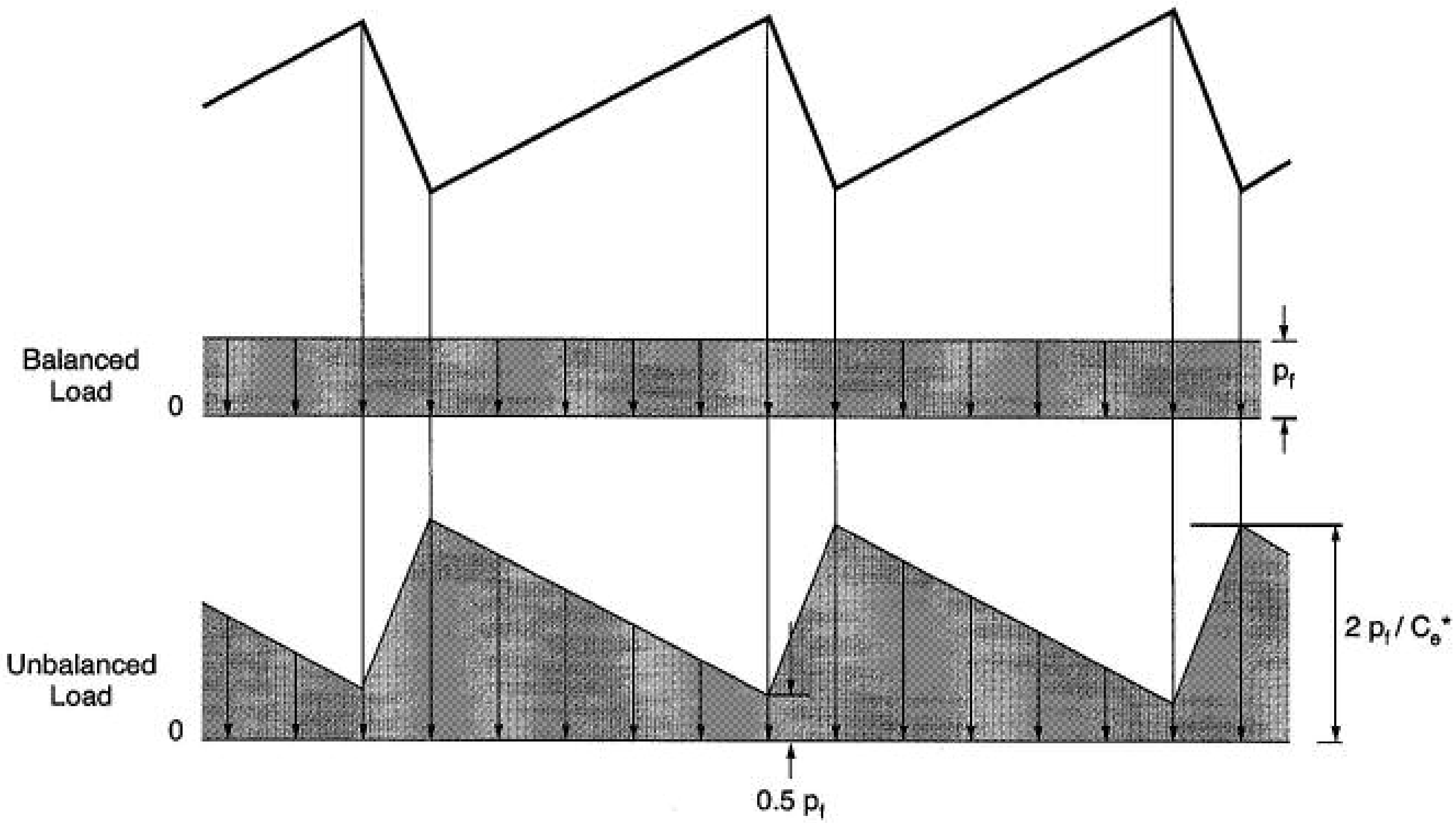


FIGURE 7-3
BALANCED AND UNBALANCED LOADS FOR CURVED ROOFS

Unbalanced Roof Snow Loads
Multiple Roofs

- For folded plate, sawtooth, and barrel-vaulted multiple roofs with a slope exceeding 3/8” per foot.
- See Fig. 7-6
- Snow surface at valley need not be higher than snow surface above ridge.
  - $\text{load}_{valley} <= \text{density}\ (h_{ridge}+(p_f/2)/\text{density}))$
  - $\text{density} = 0.13p_g+14$ pcf Eq. 7-4

Unbalanced Roof Snow Loads Multiple Roofs Fig. 7-6

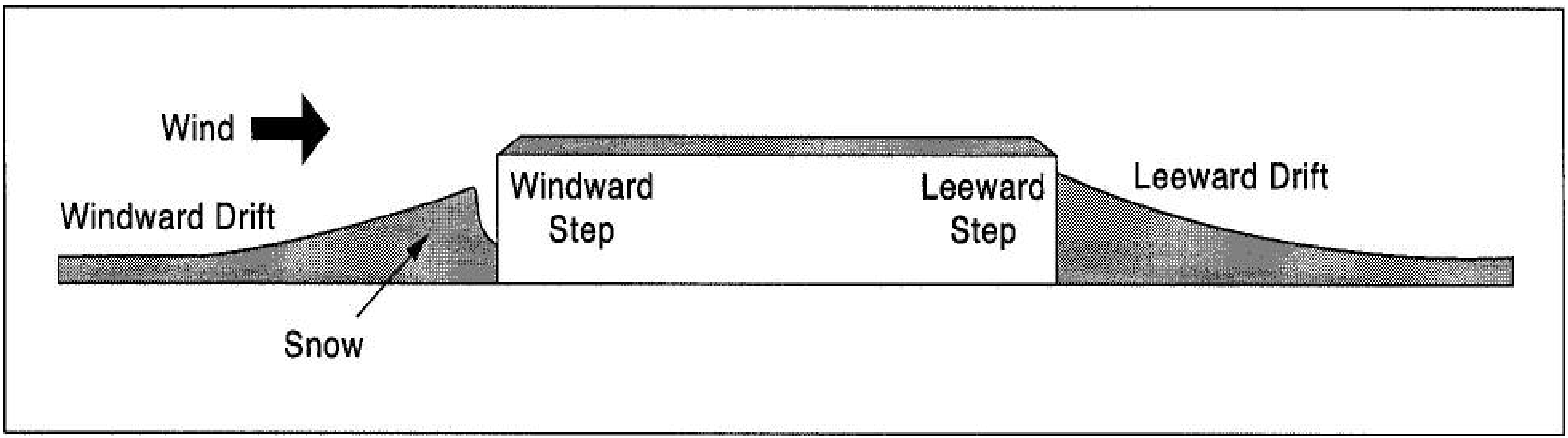


* May be somewhat less; see Section 7.6.3.

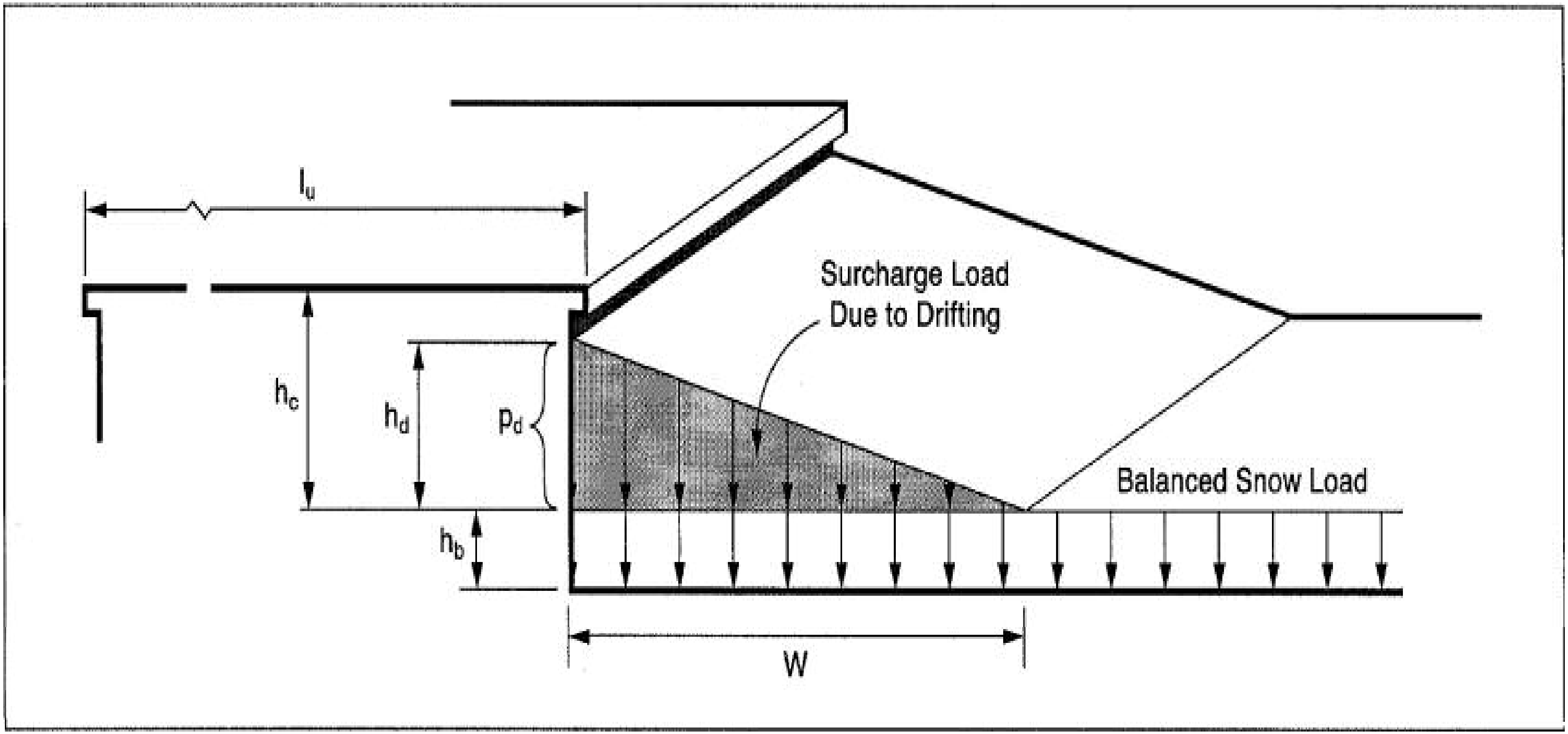
Drifts on Lower Roofs

- Drifts can occur on lower roofs when an upper roof, a higher structure, or a terrain feature is 20 feet or less away from the edge of the lower roof.
- Drifts can be ‘leeward’ or ‘windward’
  - Leeward : snow blown off a high roof onto a lower roof.
  - Windward : snow blown against a projection or wall below a high roof.

Drifts on Lower Roofs (cont.)



Drifts on Lower Roofs (cont.) Roof Projections Fig. 7-8



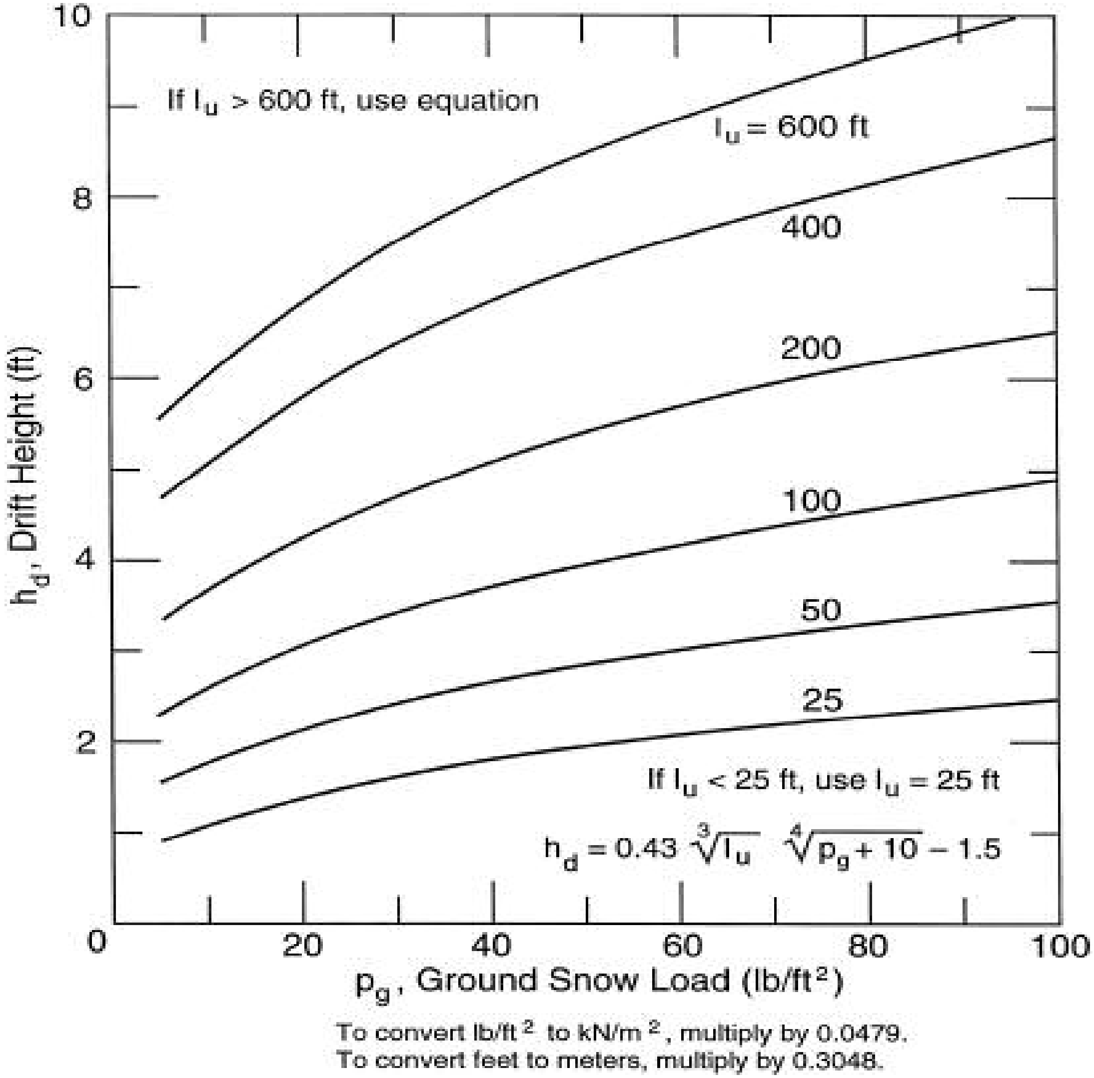
Drifts on Lower Roofs

- If $h_c/h_b < 0.2$ :: $h_c<20\%$ of h_b then a snow drift need not be applied
- To calculate snow drift, determine:
  - Height of snow drift, h_d
  - Density of snow
  - Width of snow drift, W
  - Separation between the low roof edge and the high roof, or obstruction

Drifts on Lower Roofs

- Height of snow drift, h_d
- Use, for h_d the larger of h_d calculated for leeward drifts and 75% of h_d calculated for windward drifts
- $h_d = [0.43\,(l_u)^{1/3}\,(p_g+10)^{1/4}] - 1.5$
  - l_u : length of upper roof for leeward
  - l_u : length of lower roof for windward

Drifts on Lower Roofs (cont.) Graph/Equations Fig. 7-9



Drifts on Lower Roofs

- Density of snow (pcf):
  - density = 0.13 p_g + 14 <= 30 (Eq. 7-4)
- This is used in calculating heights of snow when the load is known, or for calculating the load (psf) when the height (ft) is known.
- For instance, $h_b = p_f$ /(density)
- or, $p_d = h_d$ (density)

Drifts on Lower Roofs

- Drift loads shall be reduced by the factor (20-*s*)/20, where s is the spacing between the low and high roofs. The geometry of the drift should be calculated in the same manner.
- Reduce the calculated h_d so that $h_d = h_d\,(20\text{-}s)/20$

Drifts on Lower Roofs

- If h_d is equal to or less than h_c then $W=4h_d$, and drift height=h_d (there's room below the eave for the drift)
- If h_d is greater than h_c then $h_d = h_c$ and $W=[4(h_d)^2 / h_c]$ (cut the drift off at the high roof and spread it out)
- W shall not exceed 8 h_c nor shall it extend past the edge of the low roof.

Drifts on Lower Roofs

- As said previously, $p_d = h_d$(density)
- p_d is the superimposed drift load.
- p_d is to be added to the flat or sloped roof load found previously.

Drifts on Roof Projections and Parapet Walls

- Use same method as for drifts on lower roofs, <u>except</u> …
  - Use 0.75 h_d
    - *this is a windward drift, after all*
  - l_u = length of roof upwind from projection or parapet wall
    - check wind in all directions
  - If side of roof projection is less than 15 feet long, drift load is not required.

Sliding Snow From a Sloped Roof Onto a Lower Roof

- Calculate sliding snow load & superimpose onto loads on lower roof, for:
  - Slippery upper roofs with slope > ¼" / ft.
  - Non-slippery upper roofs with slope > 2" / ft.
- Total load on lower roof, per foot of eave length, is 0.4 p_f W, distributed on the lower roof over a 15 foot distance from the upper roof eave.
  - p_f and W are measured on the upper roof.

Sliding Snow From a Sloped Roof Onto a Lower Roof

- If width of lower roof is less than 15 feet, reduce load proportionately. (Keep same load per sq ft, however)
- May reduce load if upper roof snow is blocked by snow already on the lower roof (could happen if roofs are close together - use height difference times density for maximum load)
- May reduce load if sliding snow will slide clear of lower roof.

Rain-on-Snow Surcharge

- Calculate for 0< p_g <= 20 psf, and slope < ½" / ft.:
  - Add 5 psf to snow load.
  - Where $p_{f(minimum)} > p_{f(Eq.\ 7\text{-}1)}$, reduce the rain-on-snow surcharge by the difference between the two, but the reduction must not exceed 5 psf.
- Add surcharge to all snow loads, balanced, unbalanced, drifts, etc.

Ponding Instability

- Roof with a slope of less than ¼” per foot shall be investigated for ponding instability from rain-on-snow surcharge loads and from snow meltwater.
- See section 8.4

Existing Roofs

- Additions and alterations may create snow loads higher than the original design snow loads.
- Advise owners of existing lower roofs of the possibility when the roof is closer than 20 feet to an existing roof.
- Advise owners of existing roofs when a new building creates a ‘shelter’ and changes the exposure factor, C_e.

IBC 2003 Snow Loads

- Questions ??
- **Answers ??**

Questions?