Snow Loads in ASCE 7-22 – What’s New

Mike O’Rourke

Prof. Emeritus Civil Engineering

Rensselaer

Outline

Ground Snow Loads

Winter Wind Parameter

Windward Drifts

Roof Thermal Factor

Snow Capture Walls

Ground Snow Loads

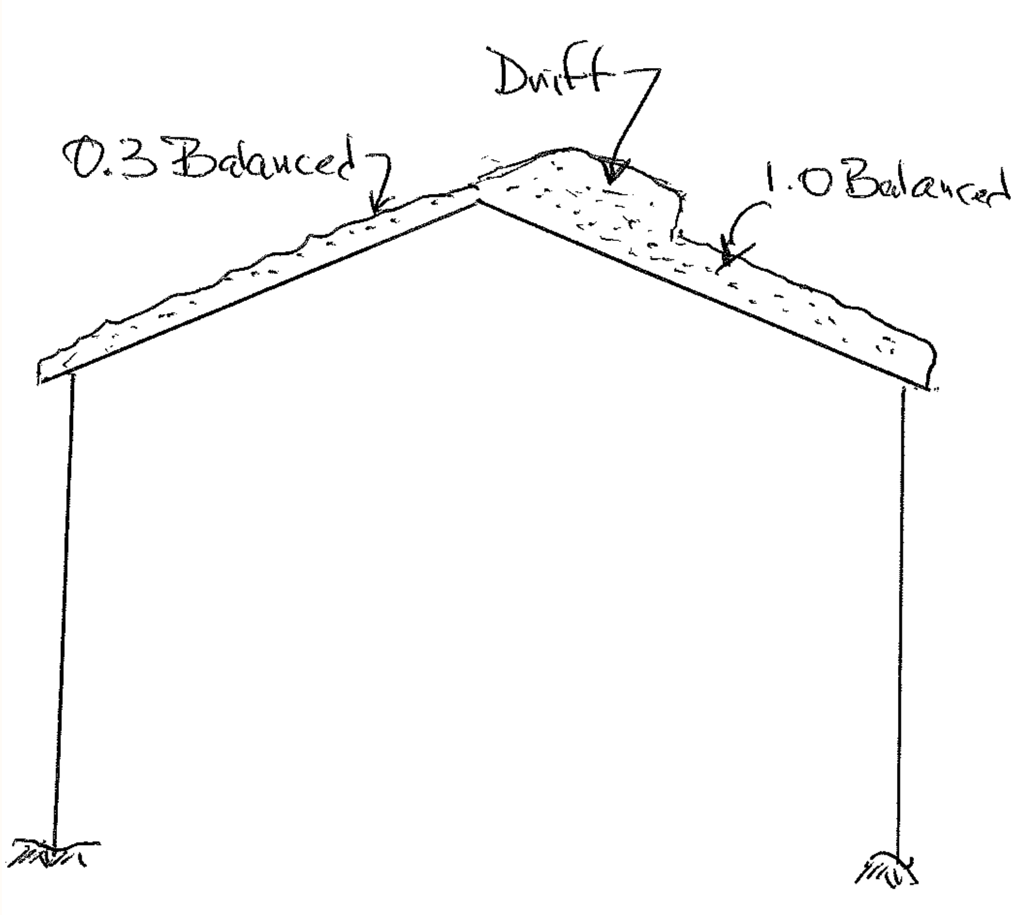
* Pg is the basis for most all roof snow loads in ASCE 7

* **Balanced** load in ASCE 7-16

$$P_s = 0.7\ C_e\ C_t\ C_s\ I_s\ \mathbf{P_g}$$

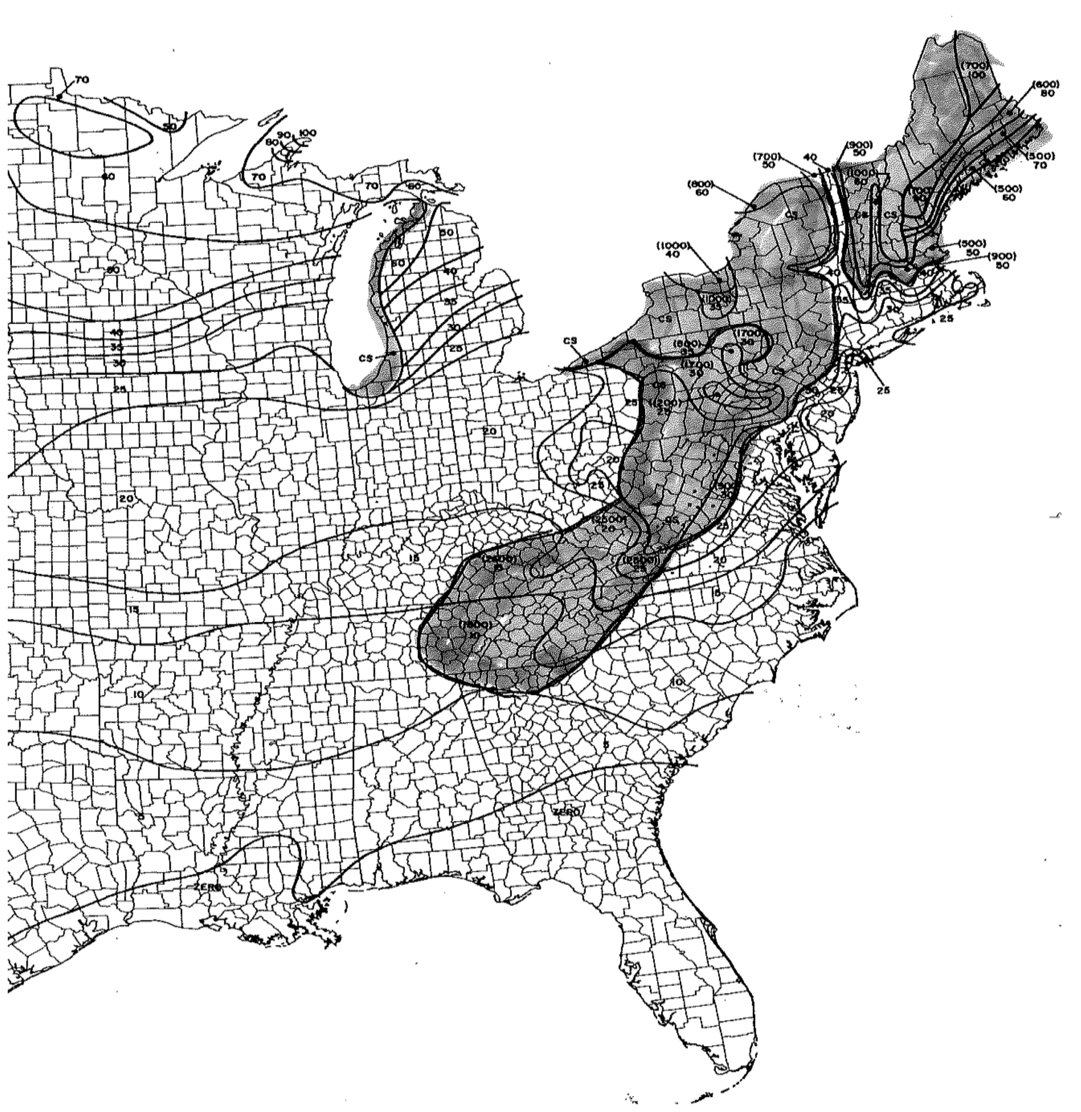
* **Drift** loads in ASCE 7-16

$$h_d = (I_s)^{0.5}\ (\ 0.43\ (L_u)^{0.33}\ (\mathbf{P_g} + 10)^{0.25}\ -1.5)$$



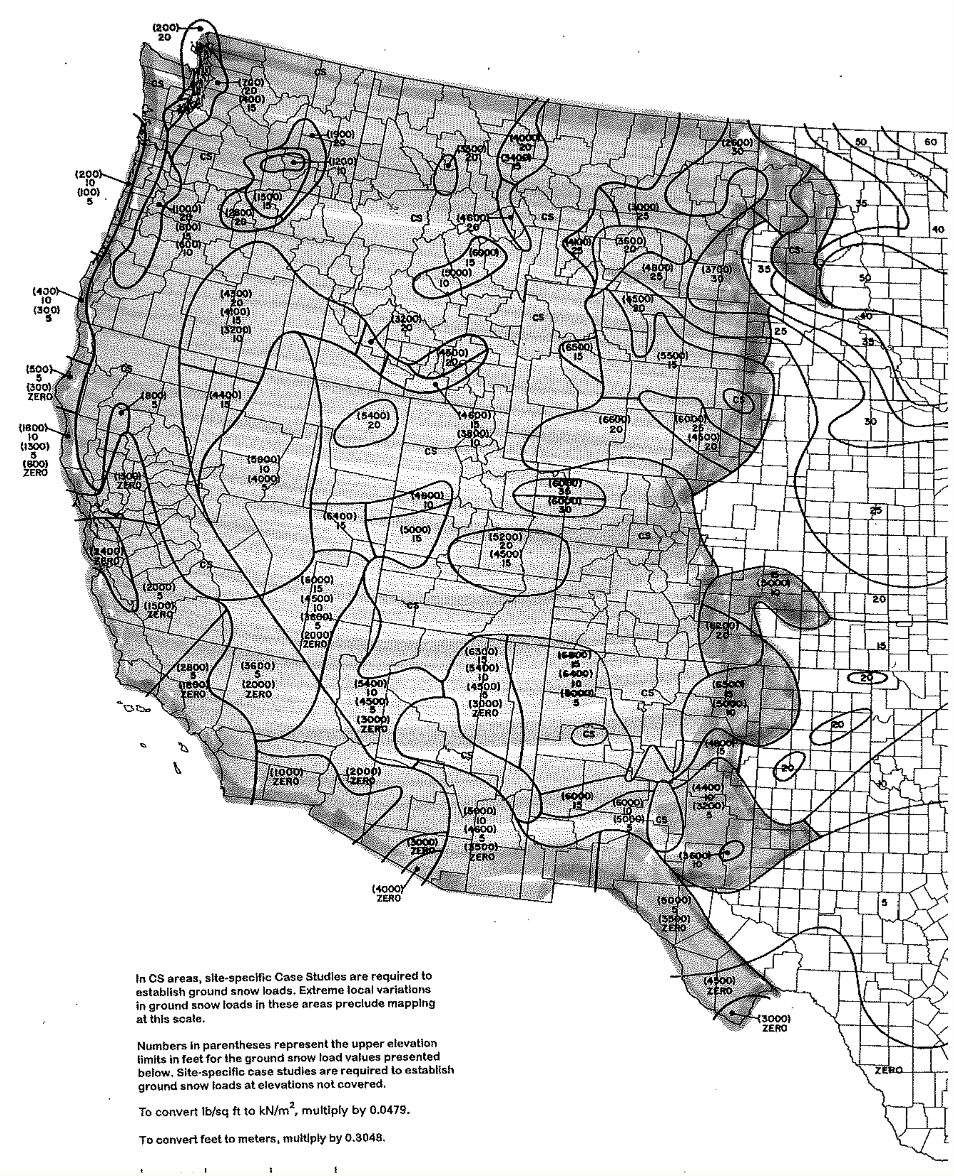
Ground Snow Loads

- Prior to ASCE 7-16 , area or zone maps of P_g
- East of the Mississippi, CS areas (or CS required above a listed elevation) along the Appalachian Trail , East of Lake Michigan , and all of New York except the Hudson River Valley



Ground Snow Loads

- Again prior to ASCE 7-16, West of the Mississippi, CS or CS above a listed elevation needed nominally everywhere West of Denver



In CS areas, site-specific Case Studies are required to establish ground snow loads. Extreme local variations in ground snow loads in these areas preclude mapping at this scale.

Numbers in parentheses represent the upper elevation limits in feet for the ground snow load values presented below. Site-specific case studies are required to establish ground snow loads at elevations not covered.

To convert lb/sq ft to kN/m^2, multiply by 0.0479.

To convert feet to meters, multiply by 0.3048.

Ground Snow Loads

- In ASCE 7-16 , Engineer-friendly State P_g tables introduced for CO , ID, MT, NH, NM, **OR** & WA

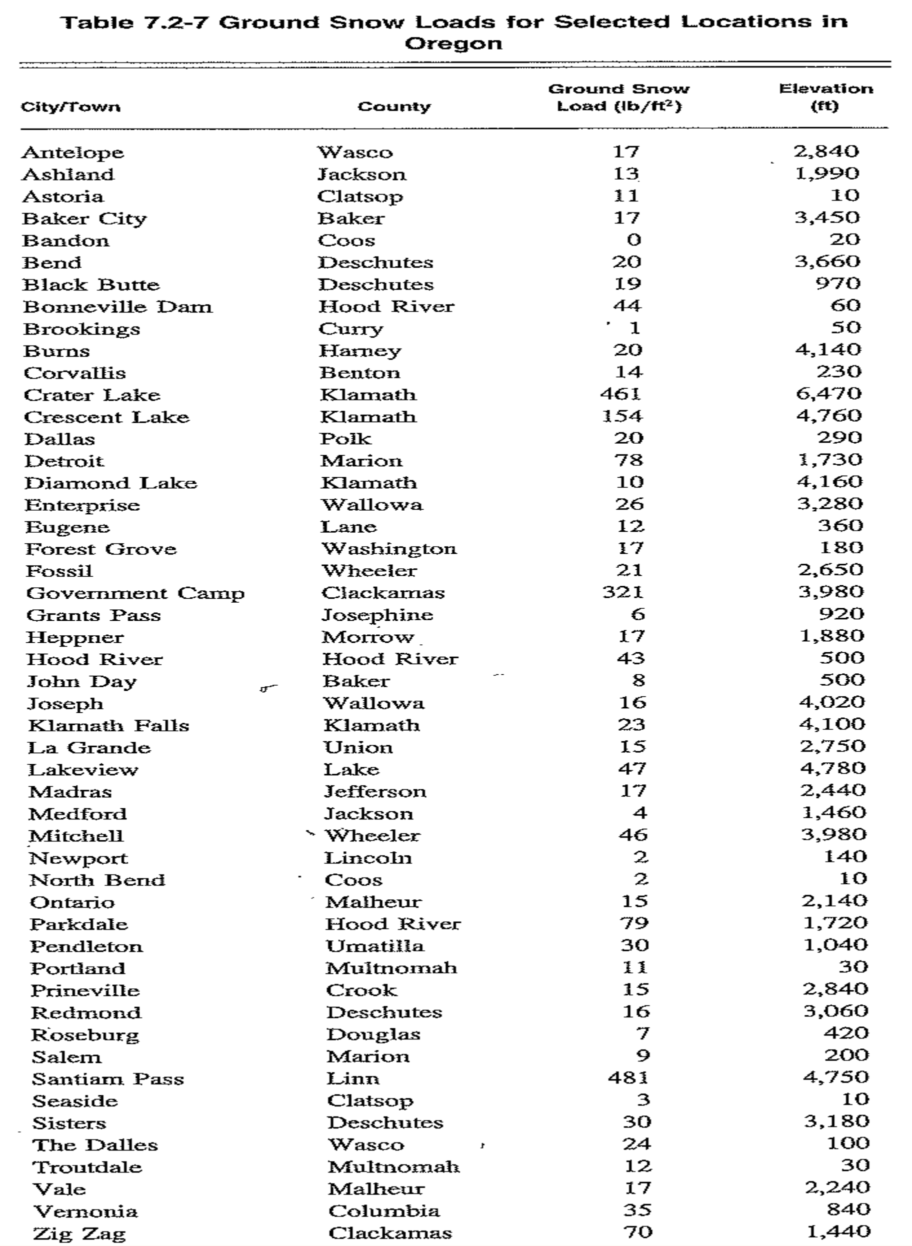


Table 7.2-7 Ground Snow Loads for Selected Locations in Oregon

City/Town	County	Ground Snow Load (lb/ft²)	Elevation (ft)
Antelope	Wasco	17	2,840
Ashland	Jackson	13	1,990
Astoria	Clatsop	11	10
Baker City	Baker	17	3,450
Bandon	Coos	0	20
Bend	Deschutes	20	3,660
Black Butte	Deschutes	19	970
Bonneville Dam	Hood River	44	60
Brookings	Curry	1	50
Burns	Harney	20	4,140
Corvallis	Benton	14	230
Crater Lake	Klamath	461	6,470
Crescent Lake	Klamath	154	4,760
Dallas	Polk	20	290
Detroit	Marion	78	1,730
Diamond Lake	Klamath	10	4,160
Enterprise	Wallowa	26	3,280
Eugene	Lane	12	360
Forest Grove	Washington	17	180
Fossil	Wheeler	21	2,650
Government Camp	Clackamas	321	3,980
Grants Pass	Josephine	6	920
Heppner	Morrow	17	1,880
Hood River	Hood River	43	500
John Day	Baker	8	500
Joseph	Wallowa	16	4,020
Klamath Falls	Klamath	23	4,100
La Grande	Union	15	2,750
Lakeview	Lake	47	4,780
Madras	Jefferson	17	2,440
Medford	Jackson	4	1,460
Mitchell	Wheeler	46	3,980
Newport	Lincoln	2	140
North Bend	Coos	2	10
Ontario	Malheur	15	2,140
Parkdale	Hood River	79	1,720
Pendleton	Umatilla	30	1,040
Portland	Multnomah	11	30
Prineville	Crook	15	2,840
Redmond	Deschutes	16	3,060
Roseburg	Douglas	7	420
Salem	Marion	9	200
Santiam Pass	Linn	481	4,750
Seaside	Clatsop	3	10
Sisters	Deschutes	30	3,180
The Dalles	Wasco	24	100
Troutdale	Multnomah	12	30
Vale	Malheur	17	2,240
Vernonia	Columbia	35	840
Zig Zag	Clackamas	70	1,440

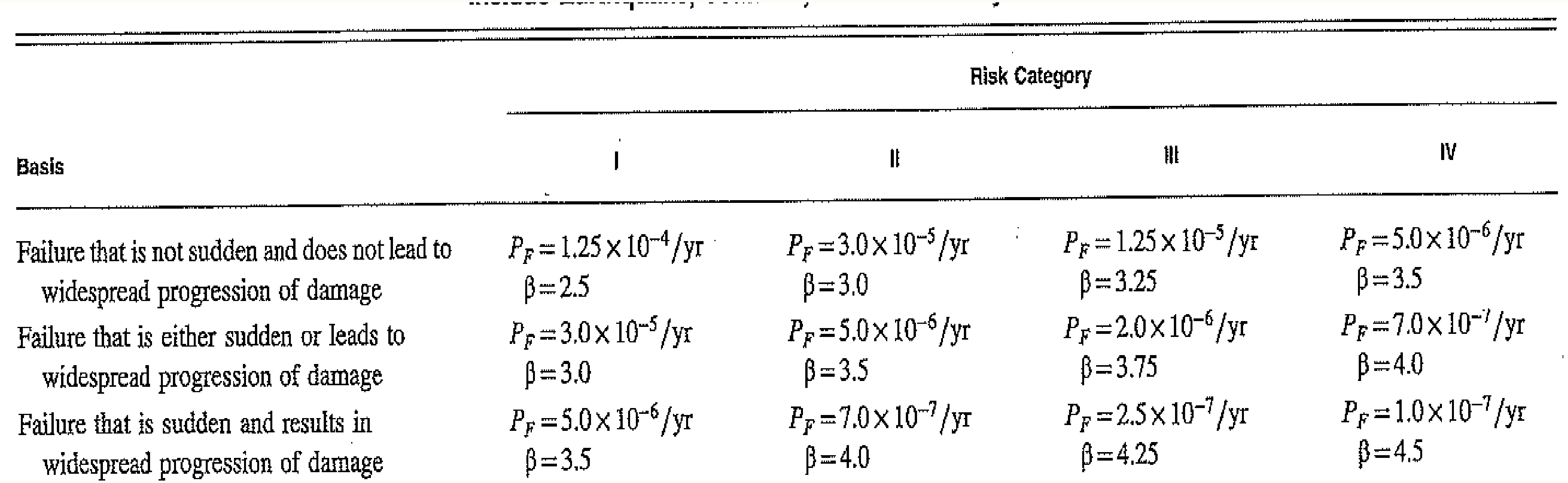
Ground Snow Loads

- In ASCE 7-16 the Importance Factor was a function of the risk category , but not Pg or location.
- The **hazard** level for a structure of ordinary importance, was the **50 year** ground snow load (2 % chance of being exceeded any winter)

Risk Category	I_s	Return Period
I	0.8	~ 25 yrs.
II	1.0	50 yrs.
III	1.1	~ 75 yrs.
IV	1.2	~100 yrs.

Ground Snow Loads

- In ASCE 7-22 , Scott Russel (NUCOR) managed a project to improve ground snow load information. Work performed by Brennan Bean (Utah State) and Marc McGuire (Nebraska)
- Intended to be consistent with the **ASCE 7 Risk Table** – not necessarily the 50 year MRI hazard



Basis	Risk Category I	II	III	IV
Failure that is not sudden and does not lead to widespread progression of damage	$P_F = 1.25 \times 10^{-4}/\text{yr}$ $\beta = 2.5$	$P_F = 3.0 \times 10^{-5}/\text{yr}$ $\beta = 3.0$	$P_F = 1.25 \times 10^{-5}/\text{yr}$ $\beta = 3.25$	$P_F = 5.0 \times 10^{-6}/\text{yr}$ $\beta = 3.5$
Failure that is either sudden or leads to widespread progression of damage	$P_F = 3.0 \times 10^{-5}/\text{yr}$ $\beta = 3.0$	$P_F = 5.0 \times 10^{-6}/\text{yr}$ $\beta = 3.5$	$P_F = 2.0 \times 10^{-6}/\text{yr}$ $\beta = 3.75$	$P_F = 7.0 \times 10^{-7}/\text{yr}$ $\beta = 4.0$
Failure that is sudden and results in widespread progression of damage	$P_F = 5.0 \times 10^{-6}/\text{yr}$ $\beta = 3.5$	$P_F = 7.0 \times 10^{-7}/\text{yr}$ $\beta = 4.0$	$P_F = 2.5 \times 10^{-7}/\text{yr}$ $\beta = 4.25$	$P_F = 1.0 \times 10^{-7}/\text{yr}$ $\beta = 4.5$

Ground Snow Loads

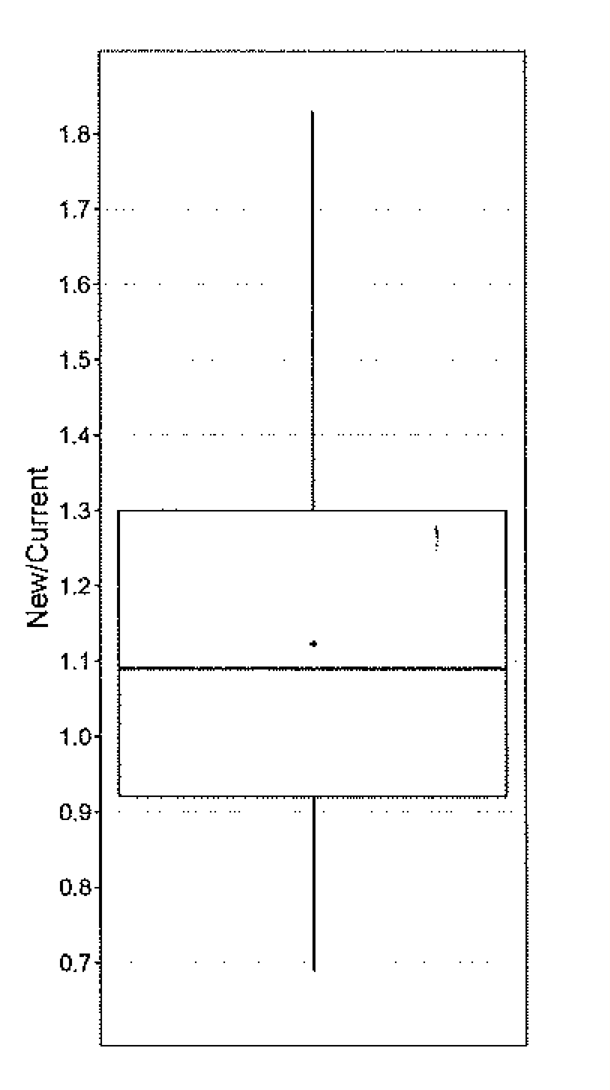
- In ASCE 7-22, **line** map , also available via the ASCE Hazard Tool
- Risk based – Prob of failure for WF shape subject to **uniform/balanced snow** loads
- **Separate** map for each risk category
- 1.0 $S_{7\text{-}22}$ as opposed to 1.6 $S_{7\text{-}16}$

FIGURE 7.2-1B Ground Snow Loads, p_g, for Risk Category II for the conterminous United States (*lb/ft²*)

Notes:
1. This figure is a representation of the Ground Snow Load Geodatabase of geocoded design ground snow load values, available at [https://asce7hazardtool.online/].
2. Values for specific locations can most–accurately be determined by accessing the Geodatabase.

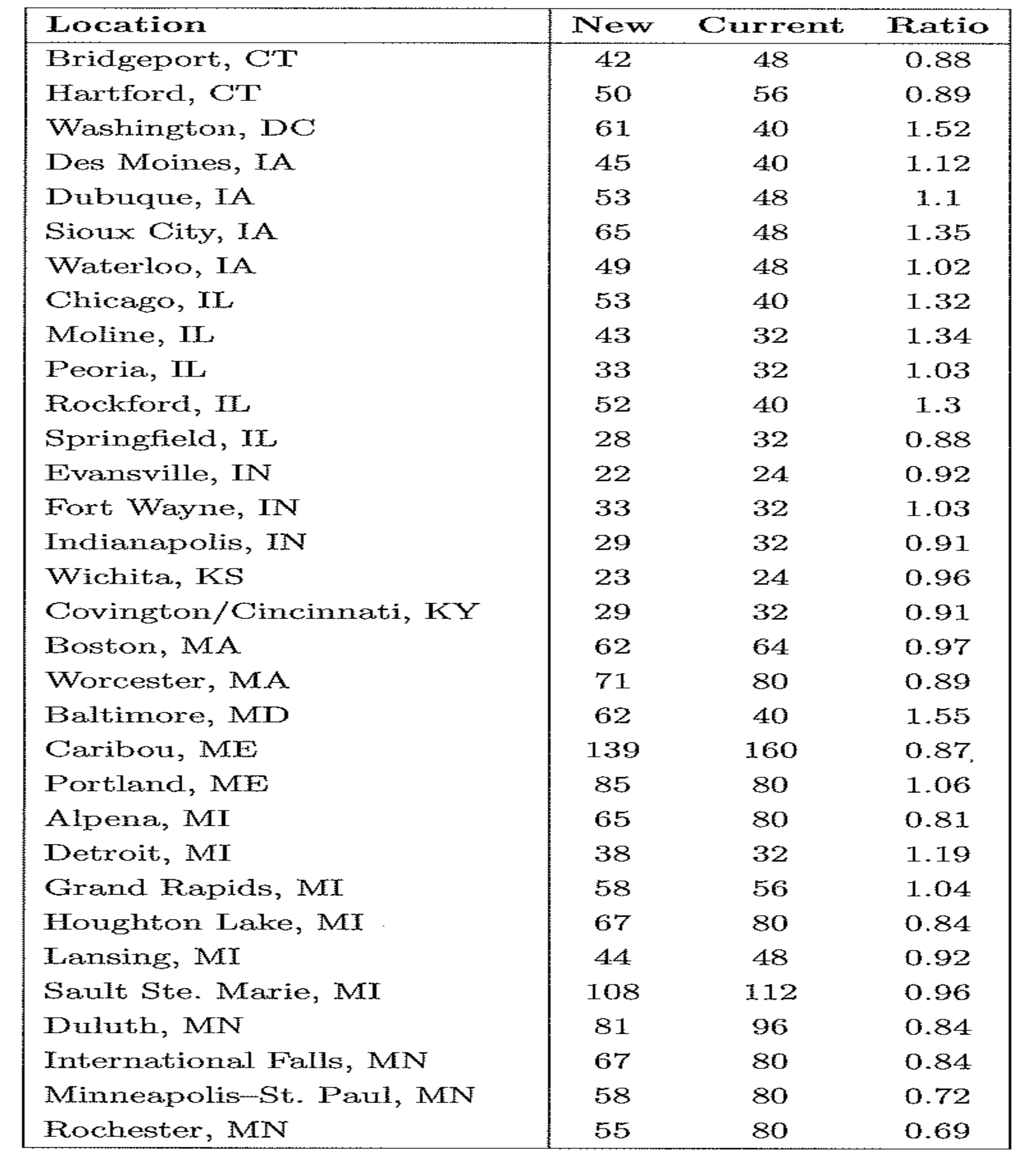
Ground Snow Loads

- Some sites have reduced Pg values , most have increased
- For 65 US cities, “new/current” means 1.0 $S_{7\text{-}22}$/1.6 $S_{7\text{-}16}$
- Mean new/current = 1.12 with a standard deviation = 0.26
- Reduction in load typically for heavy snow locations , increase in load for light snow locations
- Average $S_{7\text{-}16}$ of 49 psf for new/current 0.7 to 0.9 , average $S_{7\text{-}16}$ of 21 psf for new/current 1.3 to 1.8



Ground Snow Loads

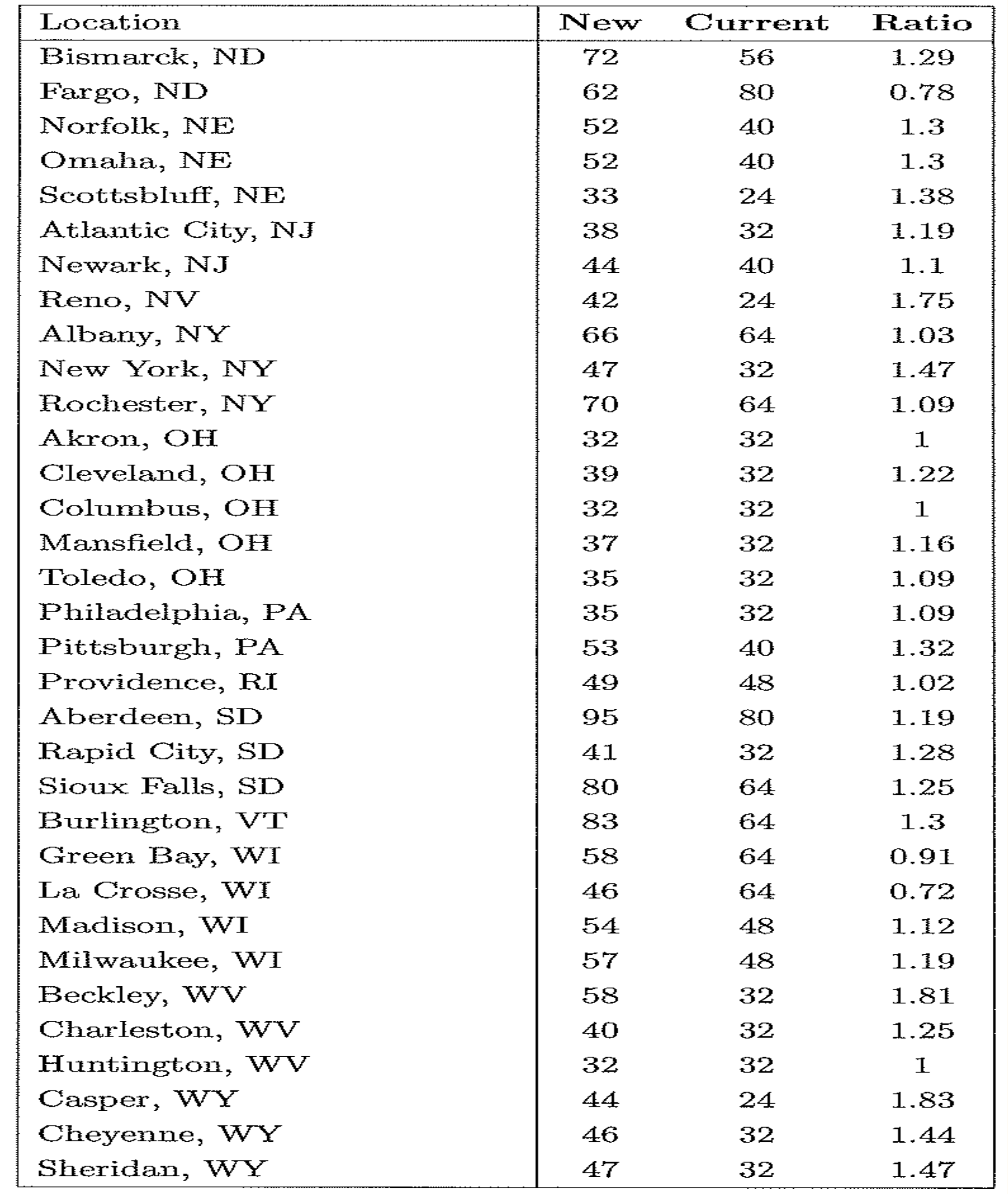
- Listed alphabetically by State CT to MN
- “New” =1.0 $S_{7\text{-}22}$, “Current” = 1.6 $S_{7\text{-}16}$
- $(P_g)_{50}$ = 30 psf for Bridgeport CT (Current = 1.6 x 30 = 48 psf)



Location	New	Current	Ratio
Bridgeport, CT	42	48	0.88
Hartford, CT	50	56	0.89
Washington, DC	61	40	1.52
Des Moines, IA	45	40	1.12
Dubuque, IA	53	48	1.1
Sioux City, IA	65	48	1.35
Waterloo, IA	49	48	1.02
Chicago, IL	53	40	1.32
Moline, IL	43	32	1.34
Peoria, IL	33	32	1.03
Rockford, IL	52	40	1.3
Springfield, IL	28	32	0.88
Evansville, IN	22	24	0.92
Fort Wayne, IN	33	32	1.03
Indianapolis, IN	29	32	0.91
Wichita, KS	23	24	0.96
Covington/Cincinnati, KY	29	32	0.91
Boston, MA	62	64	0.97
Worcester, MA	71	80	0.89
Baltimore, MD	62	40	1.55
Caribou, ME	139	160	0.87
Portland, ME	85	80	1.06
Alpena, MI	65	80	0.81
Detroit, MI	38	32	1.19
Grand Rapids, MI	58	56	1.04
Houghton Lake, MI	67	80	0.84
Lansing, MI	44	48	0.92
Sault Ste. Marie, MI	108	112	0.96
Duluth, MN	81	96	0.84
International Falls, MN	67	80	0.84
Minneapolis–St. Paul, MN	58	80	0.72
Rochester, MN	55	80	0.69

Ground Snow Loads

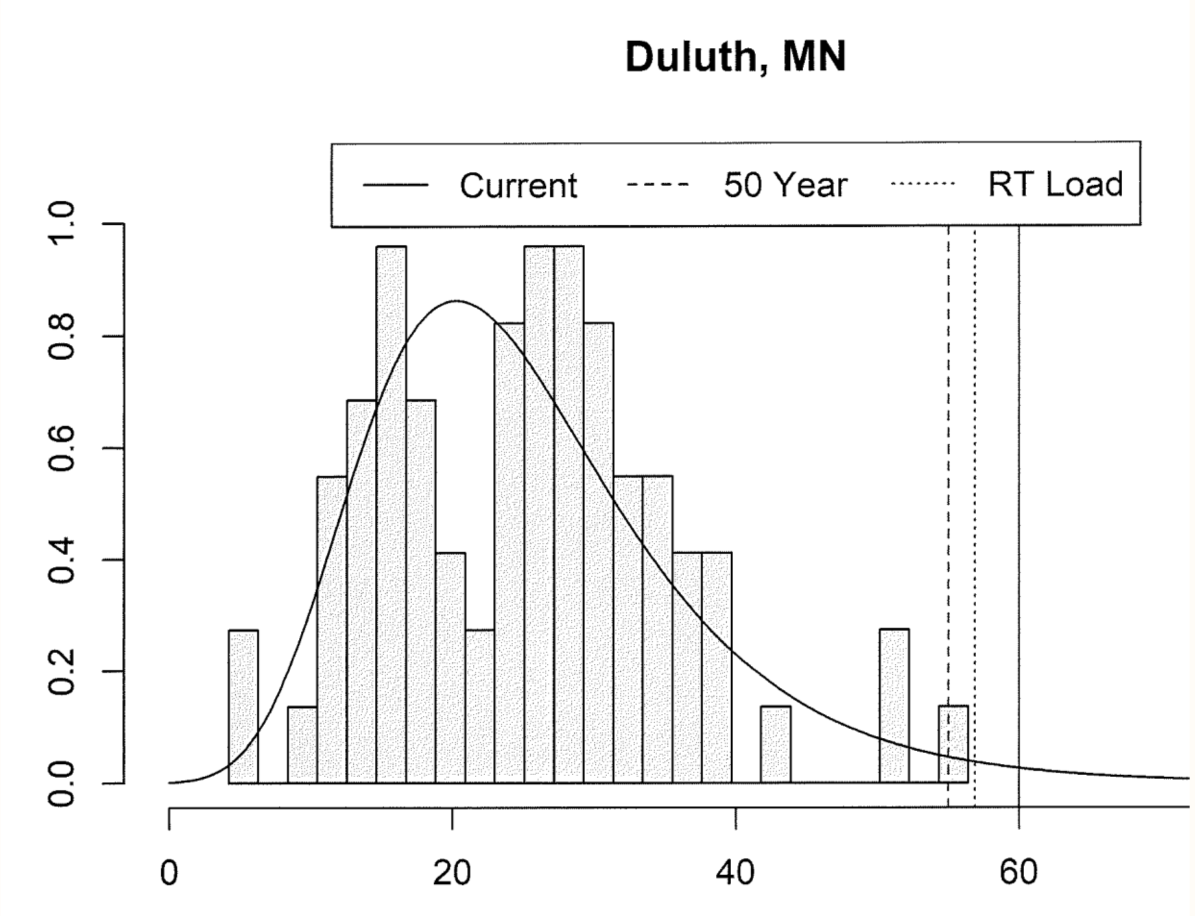
- Alphabetically by State ND to WY
- “New” =1.0 $S_{7\text{-}22}$, “Current” = 1.6 $S_{7\text{-}16}$



Location	New	Current	Ratio
Bismarck, ND	72	56	1.29
Fargo, ND	62	80	0.78
Norfolk, NE	52	40	1.3
Omaha, NE	52	40	1.3
Scottsbluff, NE	33	24	1.38
Atlantic City, NJ	38	32	1.19
Newark, NJ	44	40	1.1
Reno, NV	42	24	1.75
Albany, NY	66	64	1.03
New York, NY	47	32	1.47
Rochester, NY	70	64	1.09
Akron, OH	32	32	1
Cleveland, OH	39	32	1.22
Columbus, OH	32	32	1
Mansfield, OH	37	32	1.16
Toledo, OH	35	32	1.09
Philadelphia, PA	35	32	1.09
Pittsburgh, PA	53	40	1.32
Providence, RI	49	48	1.02
Aberdeen, SD	95	80	1.19
Rapid City, SD	41	32	1.28
Sioux Falls, SD	80	64	1.25
Burlington, VT	83	64	1.3
Green Bay, WI	58	64	0.91
La Crosse, WI	46	64	0.72
Madison, WI	54	48	1.12
Milwaukee, WI	57	48	1.19
Beckley, WV	58	32	1.81
Charleston, WV	40	32	1.25
Huntington, WV	32	32	1
Casper, WY	44	24	1.83
Cheyenne, WY	46	32	1.44
Sheridan, WY	47	32	1.47

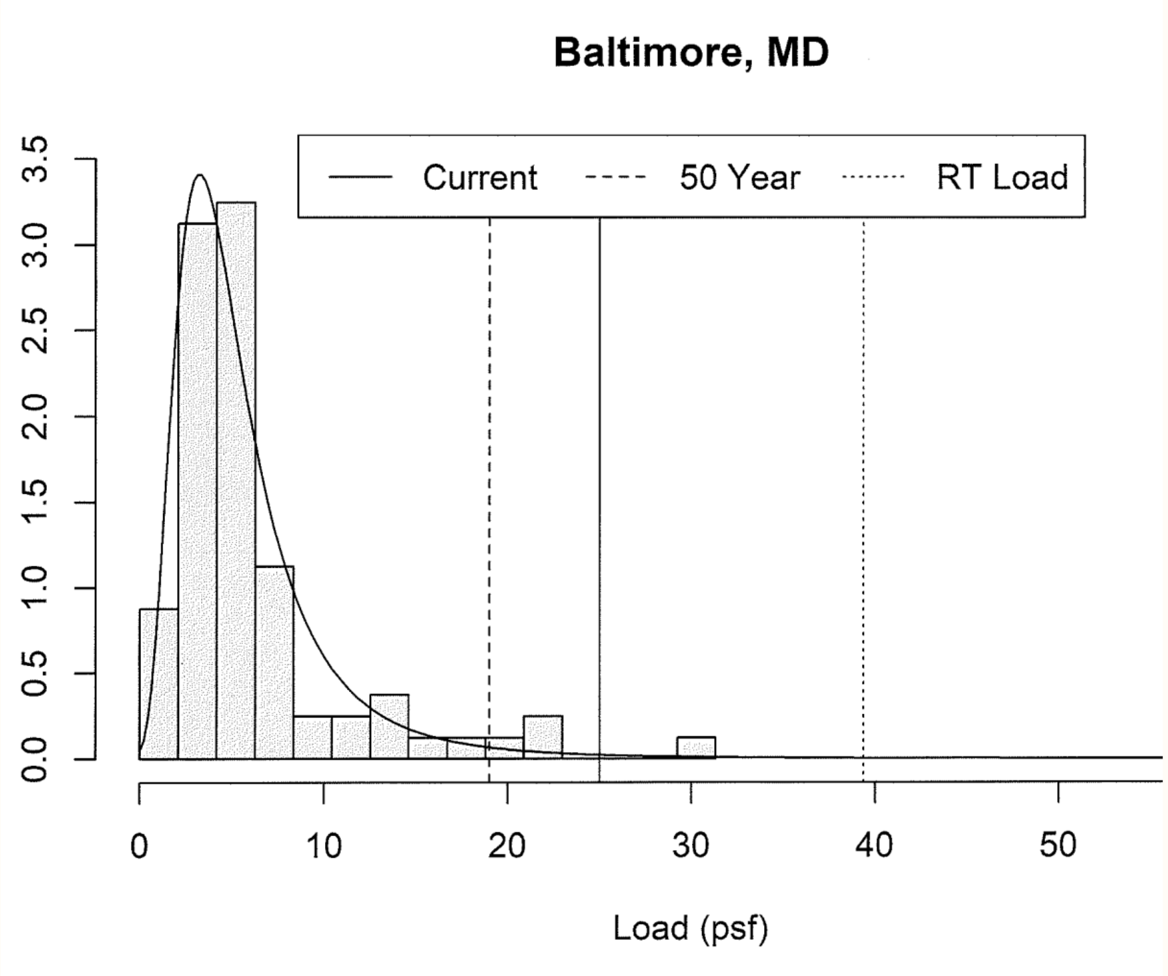
Ground Snow Loads

- Duluth MN
- Number of snow events –little or no melting between storms
- RT = 1.0 $S_{7\text{-}22}$/1.6 = 51 psf
- Typical annual value ~ 20 psf
- 50 year ~ 55 psf taken to be 60 psf
- Max observed ~ 56 psf
- **Reduction** due to **short** tail



Ground Snow Loads

- Baltimore MD
- Few snow events – melting between snow events
- RT = 1.0 $S_{7\text{-}22}$ /1.6 = 39 psf
- Typical value ~ 6 psf
- 50 year ~ 19 psf taken to be 25 psf
- Max. observed ~ 32 psf
- Increase due to **long** tail



Ground Snow Load

Clarification in ASCE 7-22

The LRFD load combination wherein Snow is the **principal load** is

1.2D +(1.6Lr or 1.0S or 1.6R) + (L or 0.5W)

If 1.6 Lr > 1.0S and no drift/unbalance , then the snow load provisions may be neglected

If A_T > 600 ft^2 or Roof slope > 12 on 12 then L_r = 12 psf and 1.6 L_r = 19.2 psf

Ground Snow Load

In the new P_g map , we now have places where the 7-16 $P_g = 0$ psf , but the 7-22 $P_g > 0$ psf – Tallahassee Fla. is an example

To avoid designing for snow loads in places where snow had been neglected (without insured losses) in 7-16 , we now have

Neglect snow OK if

$P_g < 5$ psf & $l_u < 100$ ft.

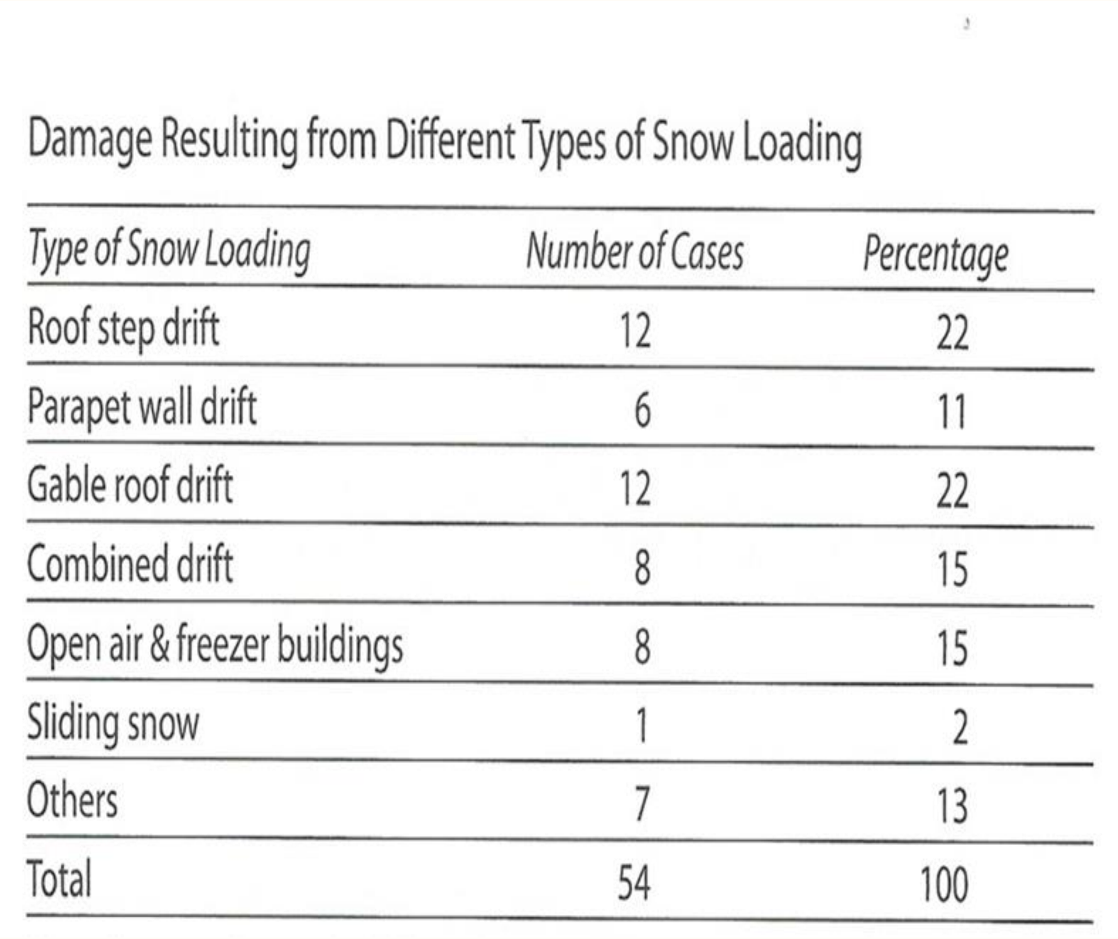
$P_g < 10$ psf & $l_u < 300$ ft.

Outline

- Ground Snow Loads
- **Winter Wind Parameter**
- Windward Drifts
- Roof Thermal Factor
- Snow Capture Walls

Winter Wind Parameter

- Drift loads are arguably the most important roof snow load since they account for roughly 75% of snow related structural performance problems
- Drift surcharge over limited portions of a roof more likely to cause damage than uniform snow loads over the whole roof



Damage Resulting from Different Types of Snow Loading

Type of Snow Loading	*Number of Cases*	*Percentage*
Roof step drift	12	22
Parapet wall drift	6	11
Gable roof drift	12	22
Combined drift	8	15
Open air & freezer buildings	8	15
Sliding snow	1	2
Others	7	13
Total	54	100

Winter Wind Parameter

- In ASCE 7-16 , drift height a function of the snow source as characterized by the upwind fetch l_u and the ground snow load p_g

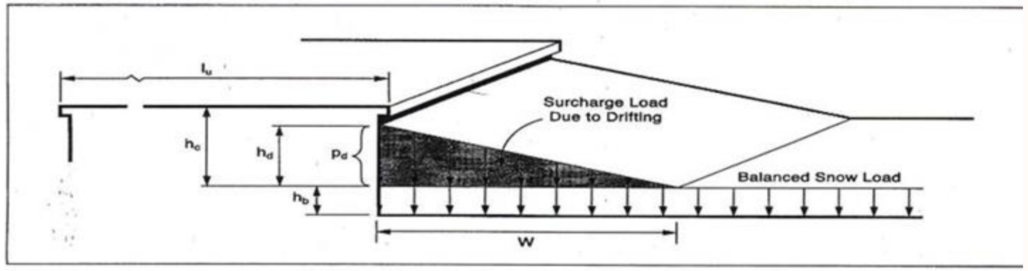
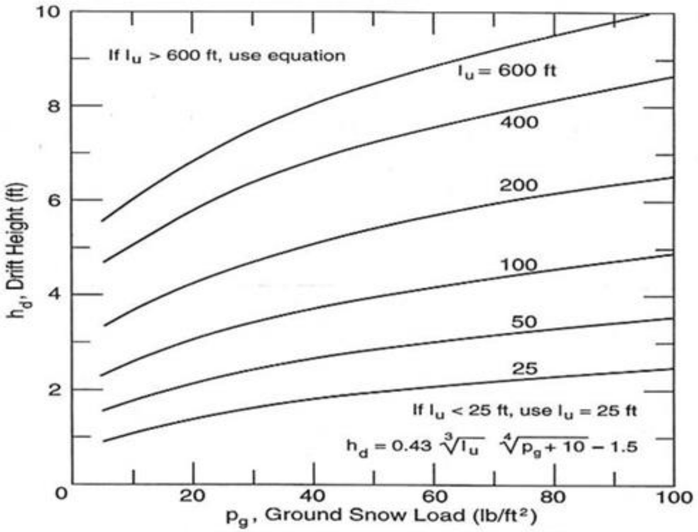


FIGURE 7-8
CONFIGURATION OF SNOW DRIFTS ON LOWER ROOFS

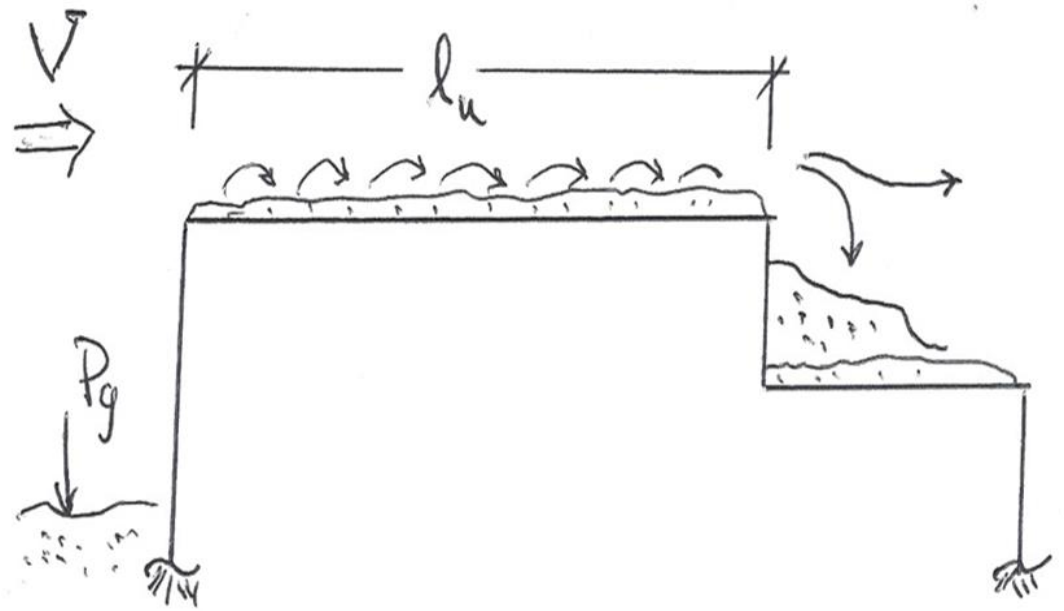


To convert lb/ft^2 to kN/m^2, multiply by 0.0479.
To convert feet to meters, multiply by 0.3048.

FIGURE 7-9
GRAPH AND EQUATION FOR DETERMINING DRIFT HEIGHT, h_d

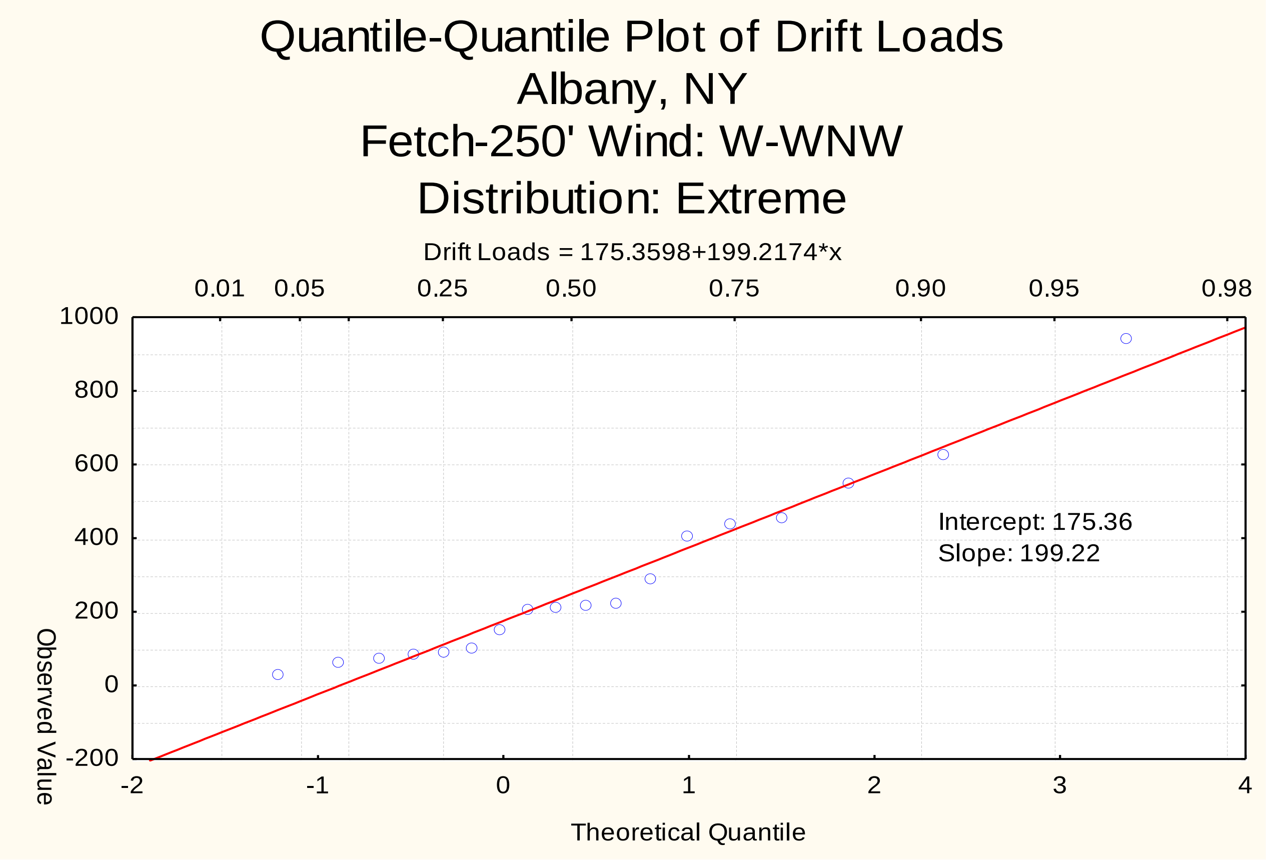
Winter Wind Parameter

- Simulated roof snow drifts show importance of **wind speed**
- Transport rate (lbs/hr/foot width) for simulations based upon Tabler & Takeuchi $T_r(V) = .00048\ V^{3.8}$
- Trapping efficiency (TE) (% snow remaining at step) taken as 50% based upon water flume tests @ Rensselaer



Winter Wind Parameter

- Max annual drifts for 19 winters used to determine 50 year drifts for 46 sites across the US
- Drift characterized by drift ratio DR DR = drift load/snow source



Winter Wind Parameter

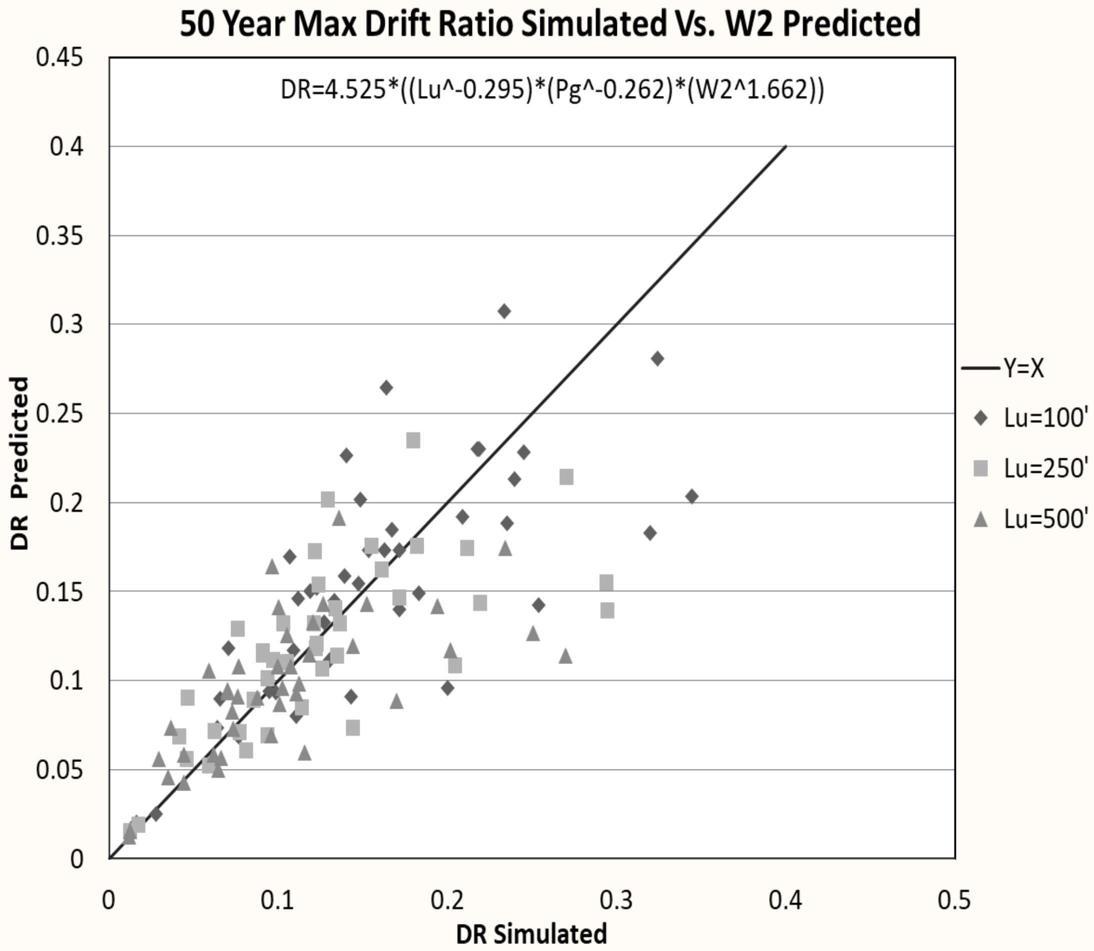
- Using ASCE 7-16 , DR for Buffalo Boston & Yakima between 0.13 and 0.14 for l_u = 250 ‘
- From the simulations, the DR for Buf. Bos. & Yak. were 0.29 , 0.13 & 0.01 respectively, again for l_u = 250’
- Simulations show that winter wind is an **important** variable

Winter Wind Parameter

- Four "mapable" wind parameters considered
  W_1 – mean Oct-Apr wind speed
  W_2 - % time V > 10 mph Oct-Apr
  W_3 – mean $V^{3.8}$ for V > 10 mph O-A
  W_4 – Largest W_2 in N, NNE, ENE…

- Two functional forms considered
  $DR = a^* P_g + b^* l_u + c^* W$ (additive)
  $DR = (aP_g)^*(bl_u)^*(cW)$ (multiplicative)

- Multiplicative with W_2 chosen based on simplicity and multiple regression analysis



Winter Wind Parameter

- W_2 winter wind parameter determined for 272 weather stations across the US
- W_2 ranged from 0.041 (Liggett CA) to 0.83 (Ping Springs TX) with a mean of 0.42 and a standard deviation of 0.14

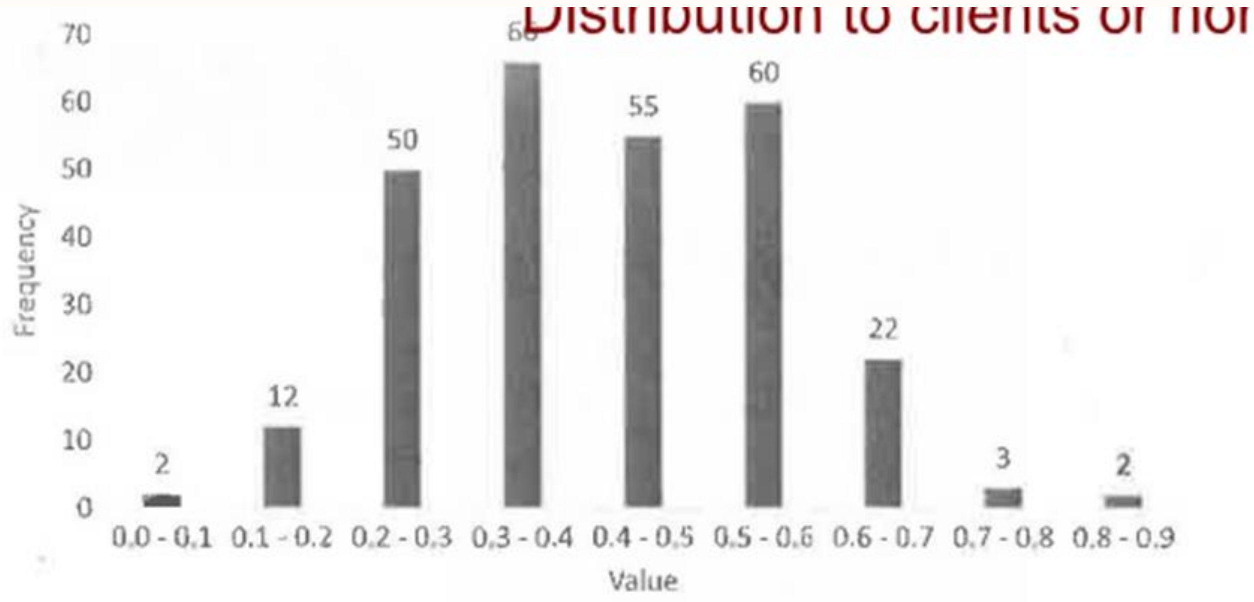
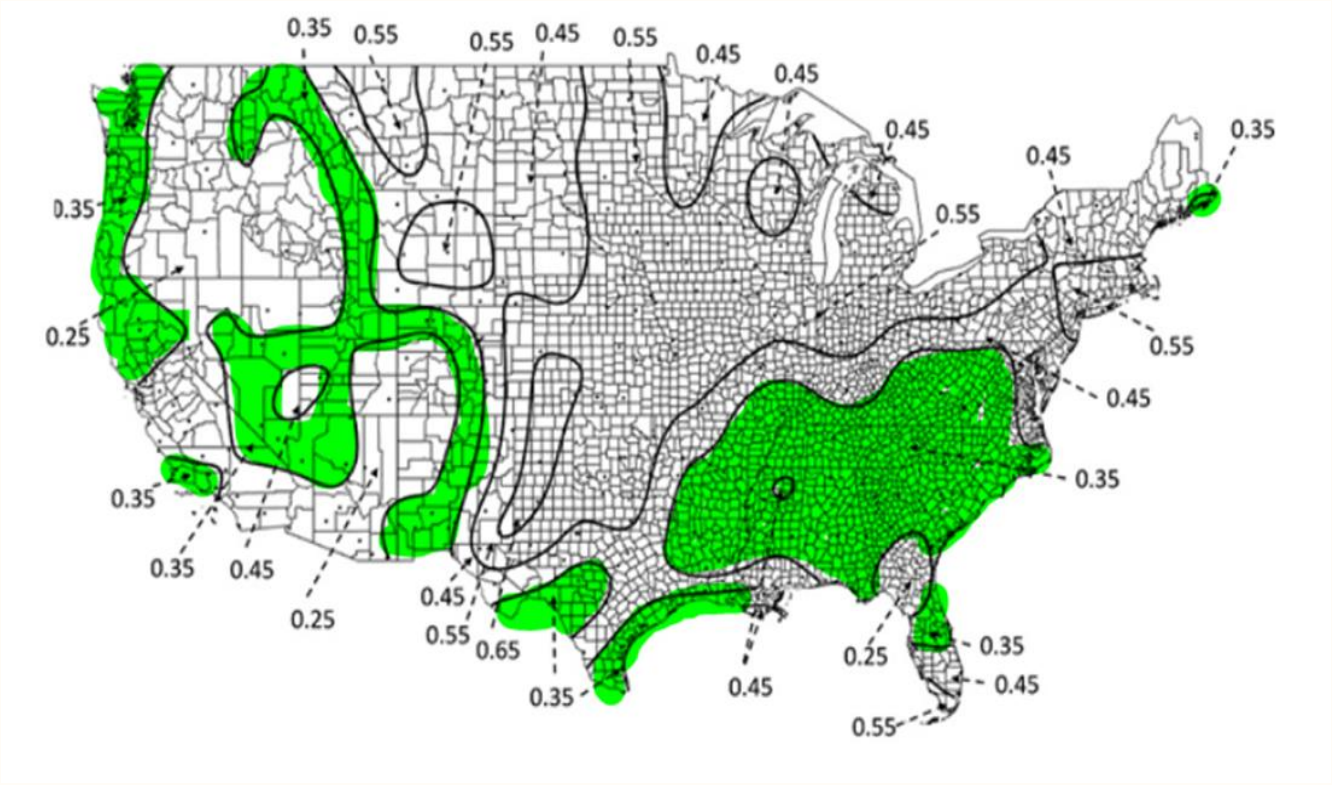


Fig. 1. Histogram of wind parameter W_2 based upon 272 stations' samples.

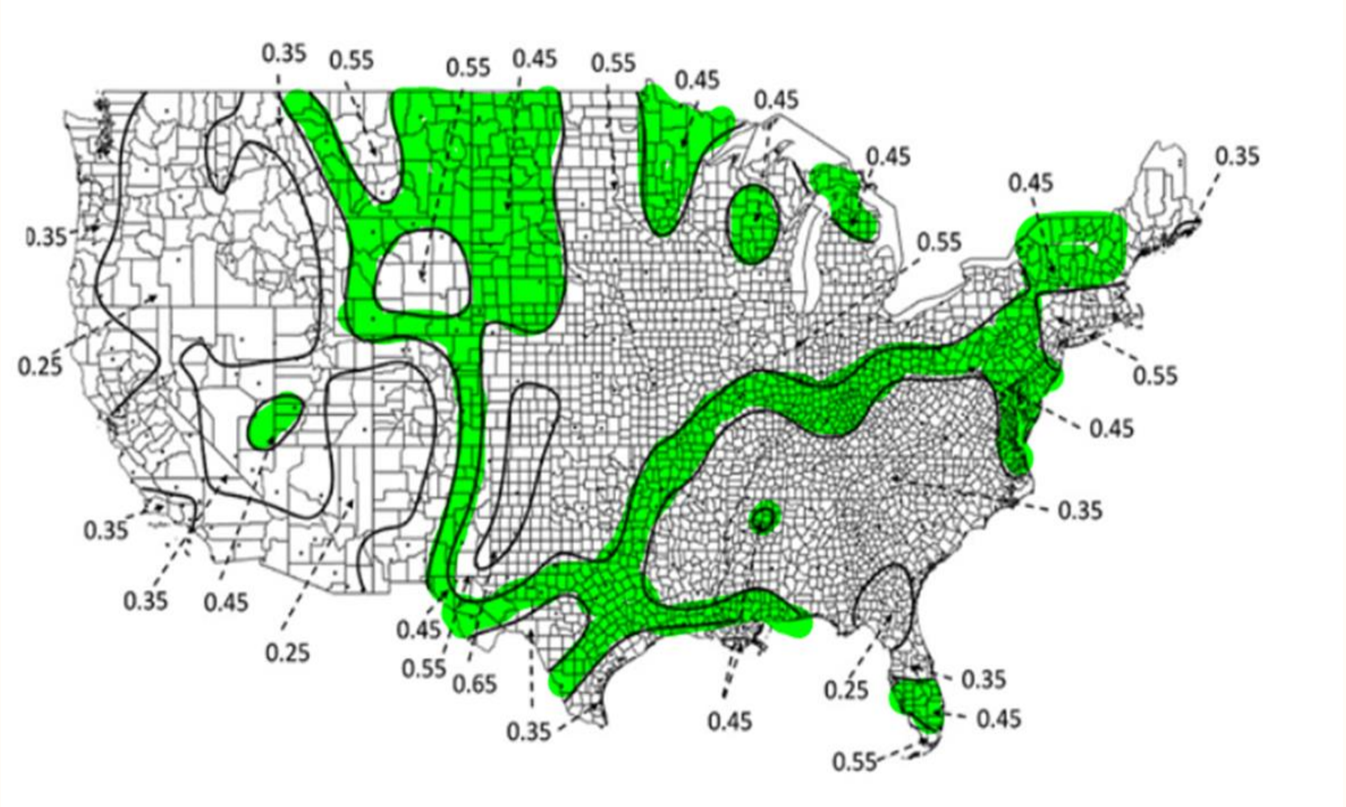
Winter Wind Parameter $W_2 = 0.35$

- For p_g between 20 and 60 psf and l_u between 25 and 1000 ft , h_d was typically 60% to 90% of the ASCE 7-16 values
- On average about a **25% reduction** in h_d



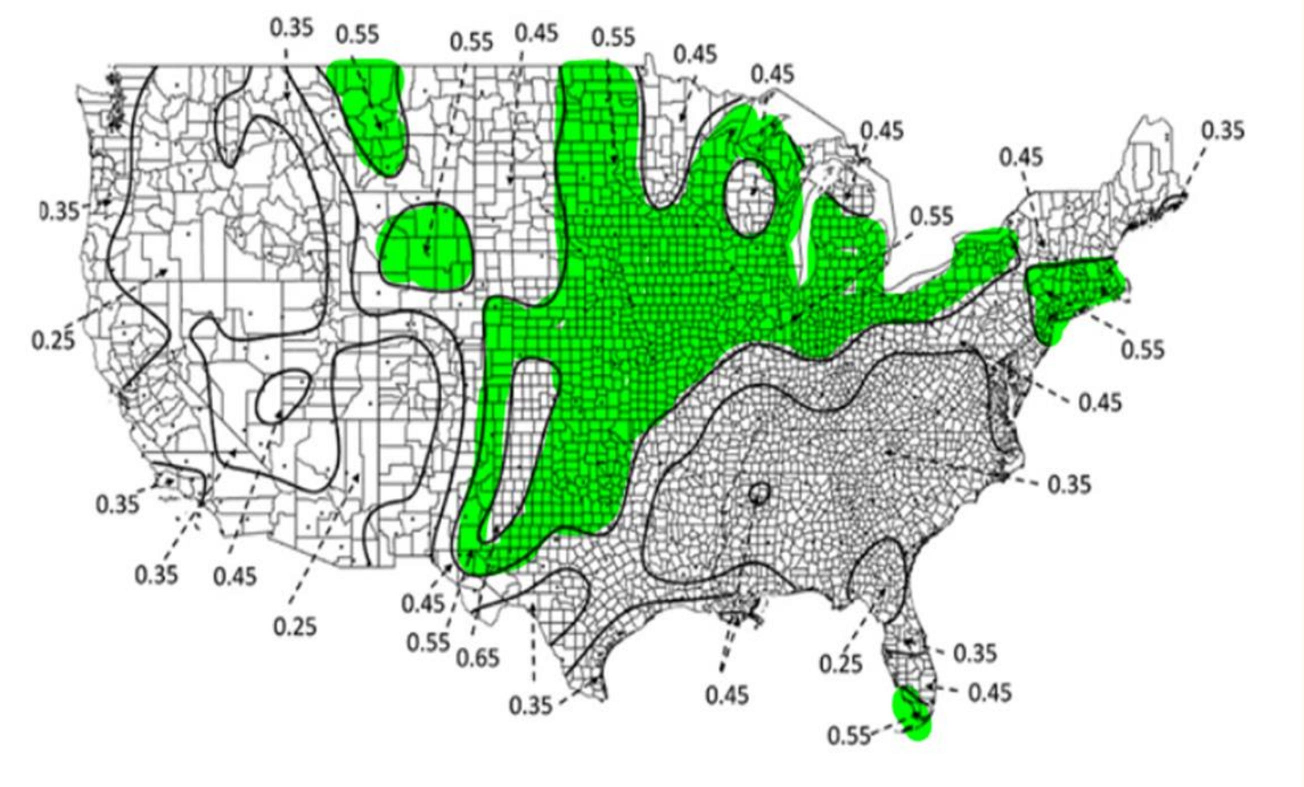
Winter Wind Parameter $W_2 = 0.45$

- For p_g between 20 and 60 psf and l_u between 25 and 1000 ft , h_d was typically 75% to 110% of the ASCE 7-16 values
- On average about a **10% reduction** in h_d



Winter Wind Parameter $W_2 = 0.55$

- For p_g between 20 and 60 psf and l_u between 25 and 1000 ft , h_d was typically 90% to 130 % of the ASCE 7-16 values
- On average about a **10% increase** in h_d

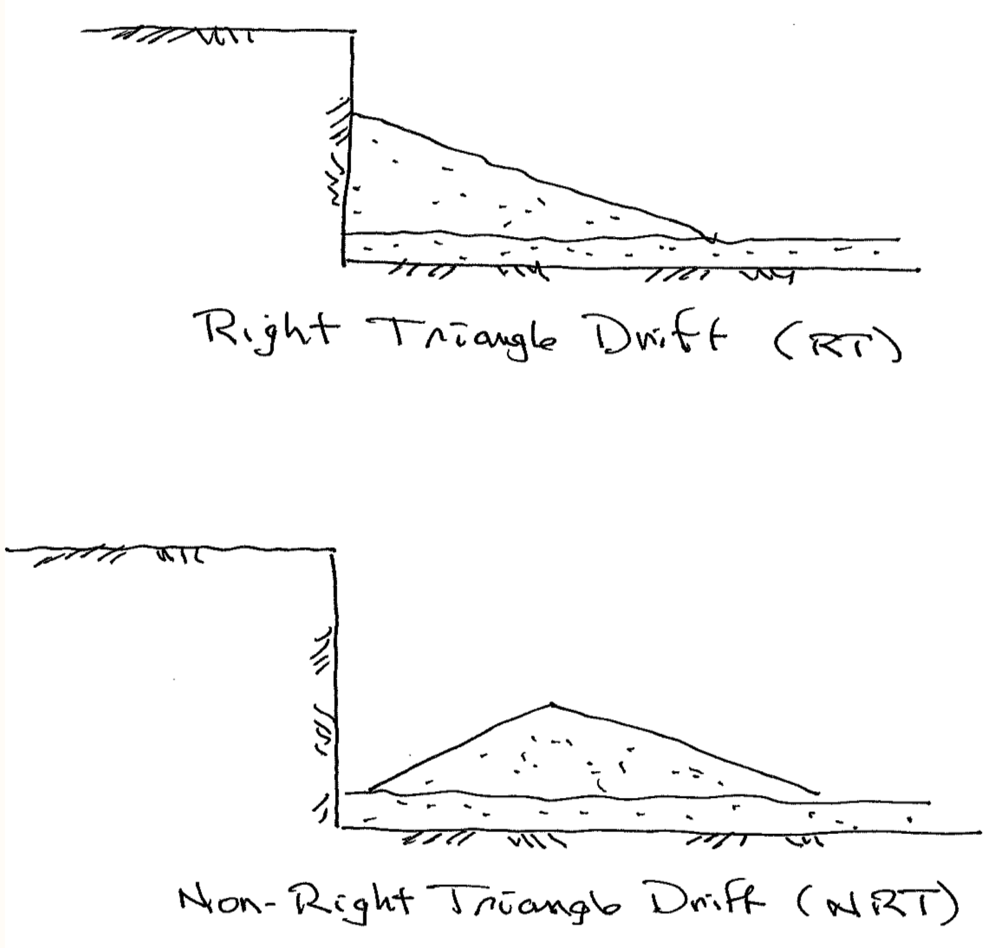


Outline

- Ground Snow Loads
- Winter Wind Parameter
- **Windward Drifts**
- Roof Thermal Factor
- Snow Capture Walls

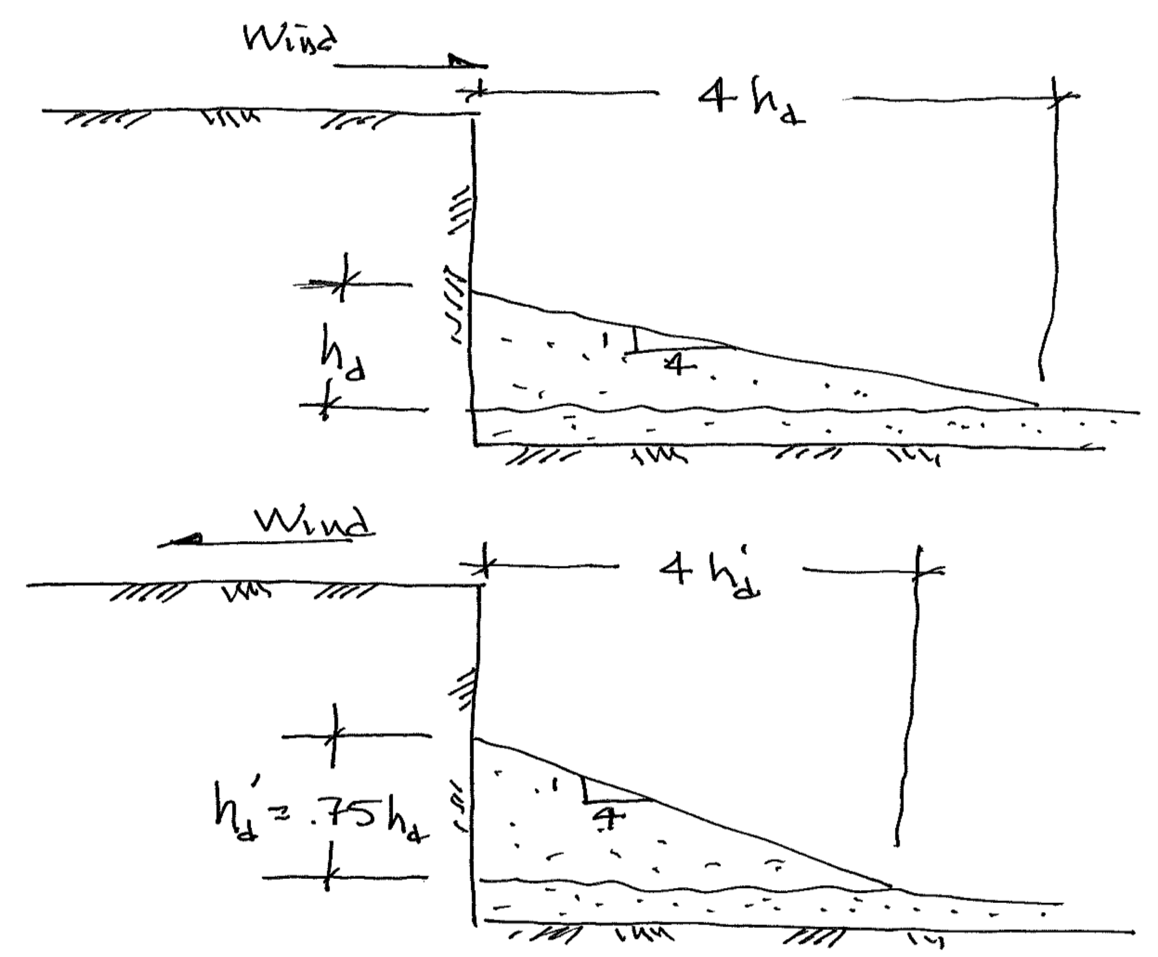
Windward Drifts – Original Database

- Original database of drifts consisted of many large right triangular (RT) drifts and fewer generally smaller non-right triangular (NRT) drifts
- All RT drifts were **assumed** to be leeward , turns out **not correct**
- All NRT drifts were **assumed** to be windward, this **assumption correct**



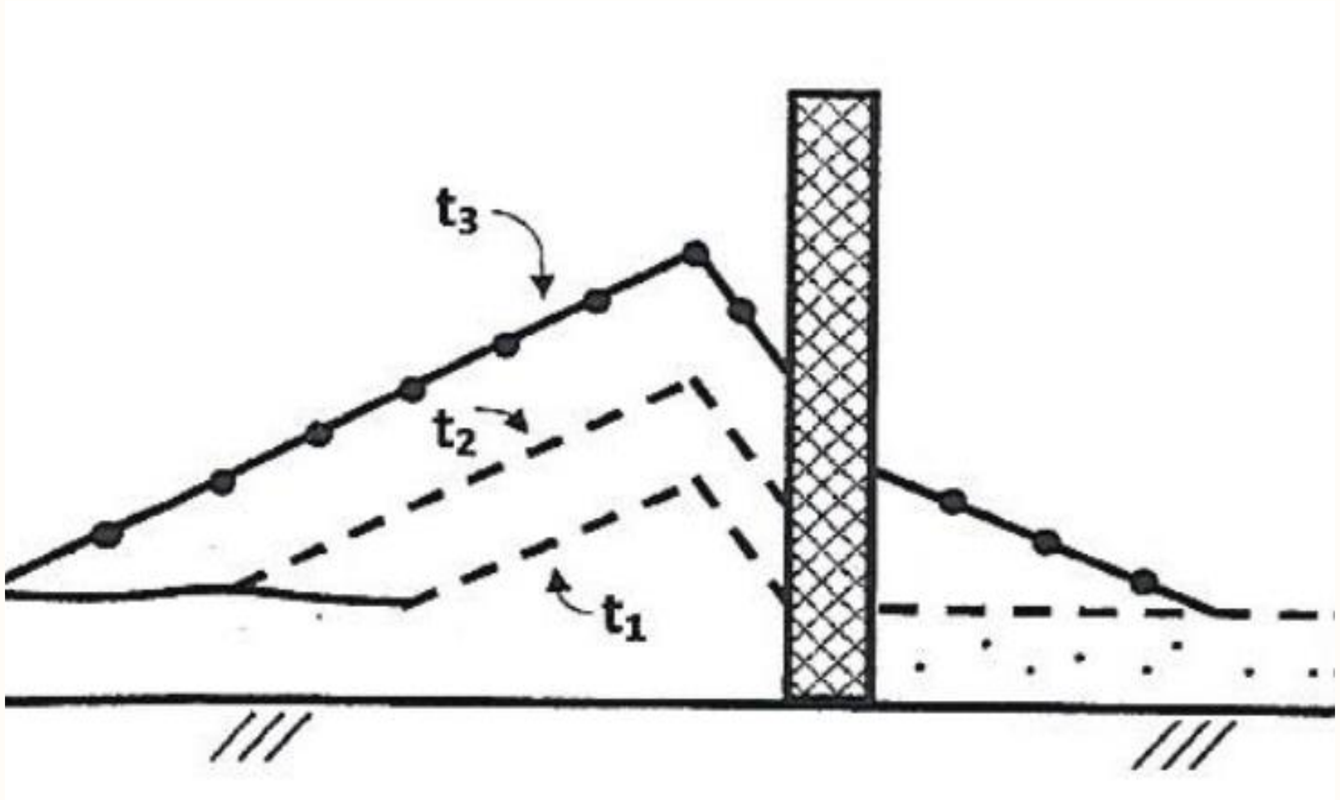
Windward Drifts – Leeward &Windward

- Current ASCE 7-16 drifts
- Leeward Drift – RT shape , surcharge height = h_d , surcharge length = 4 h_d
- Windward Drift – RT shape , surcharge height $h'_d = 0.75\ h_d$, surcharge length = $4h'_d$, cross-sectional area 56% of Leeward



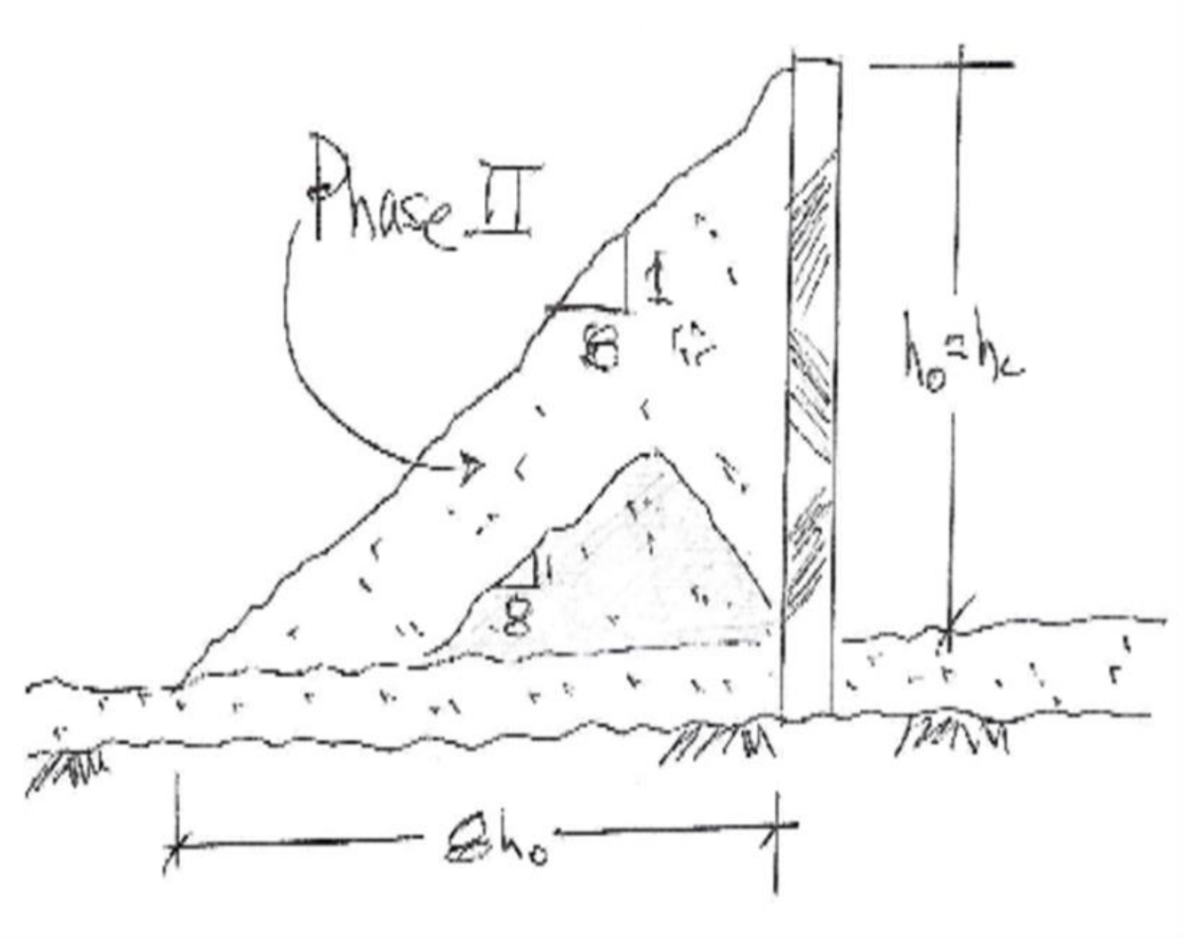
Windward – Recent Norwegian Tests

- Multiple observations over time
- Wind from left to right
- Initial trapping efficiency 100% at times t_1 & t_2 (NRT)
- Later trapping efficiency ~ 20 % at time > t_3 (eventually RT)
- For comparison , leeward drifts trapping efficiency ~ 50 %



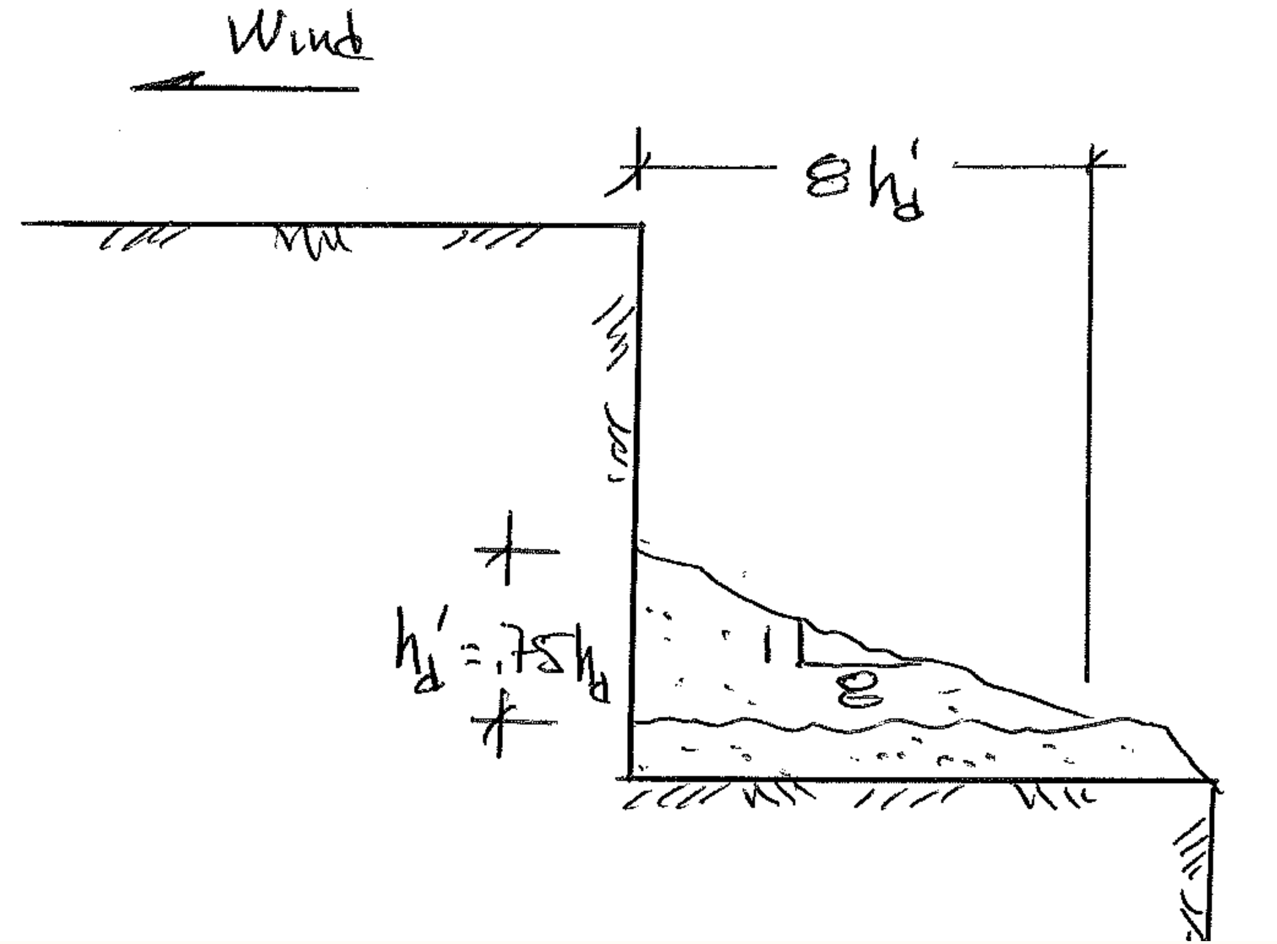
Windward Drifts – Options

- Knowing TEs , **could** determine effective cross-sectional area for given p_g , l_u , and W_2
- **Could** have shape morph from NRT to RT as X-sectional area increases



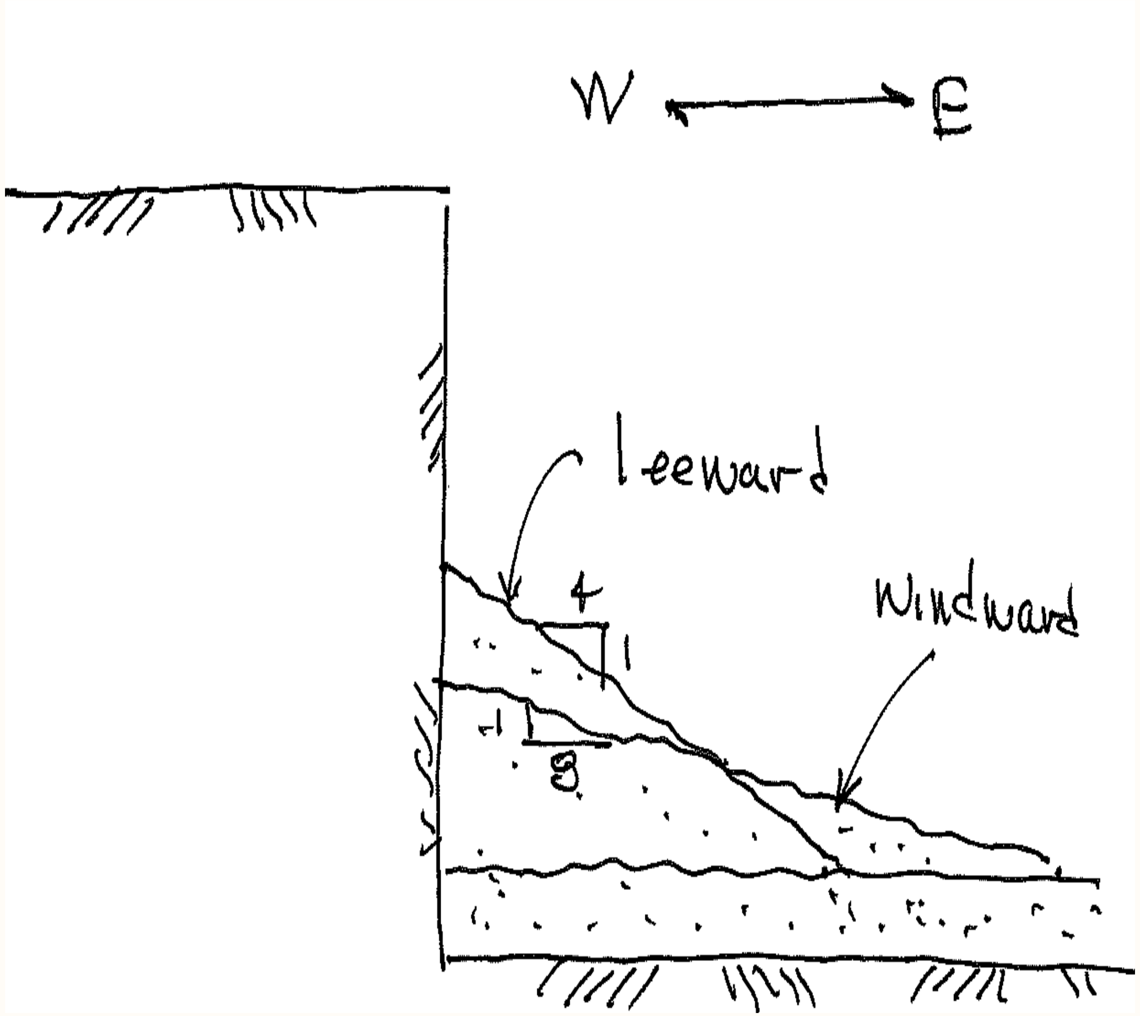
Windward Drift – Compromise

- All windward drifts to have **same RT shape** as leeward drifts
- All windward drifts keep the **same drift height** as before $h'_d = 0.75\ h_d$
- Length of windward **now 8 h'_d**



Windward Drift

- Good news - windward drifts now **more realistic**
- Bad news - determination of controlling drift at roof step is **more complicated**
- For beam spanning E-W , center of gravity of leeward and windward loads different
- For beams spanning N-S , leeward could control close to step , windward could control away from step



Outline

- Ground Snow Loads
- Winter Wind Parameter
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- **Roof Thermal Factor**
- Snow Capture Walls

Roof Thermal Factor

- In ASCE 7-16 for **unvented** roofs, C_t not directly related to roof insulation R_{roof}
- Reroofing of **unvented** roofs results in higher insulation , but C_t still the same ??

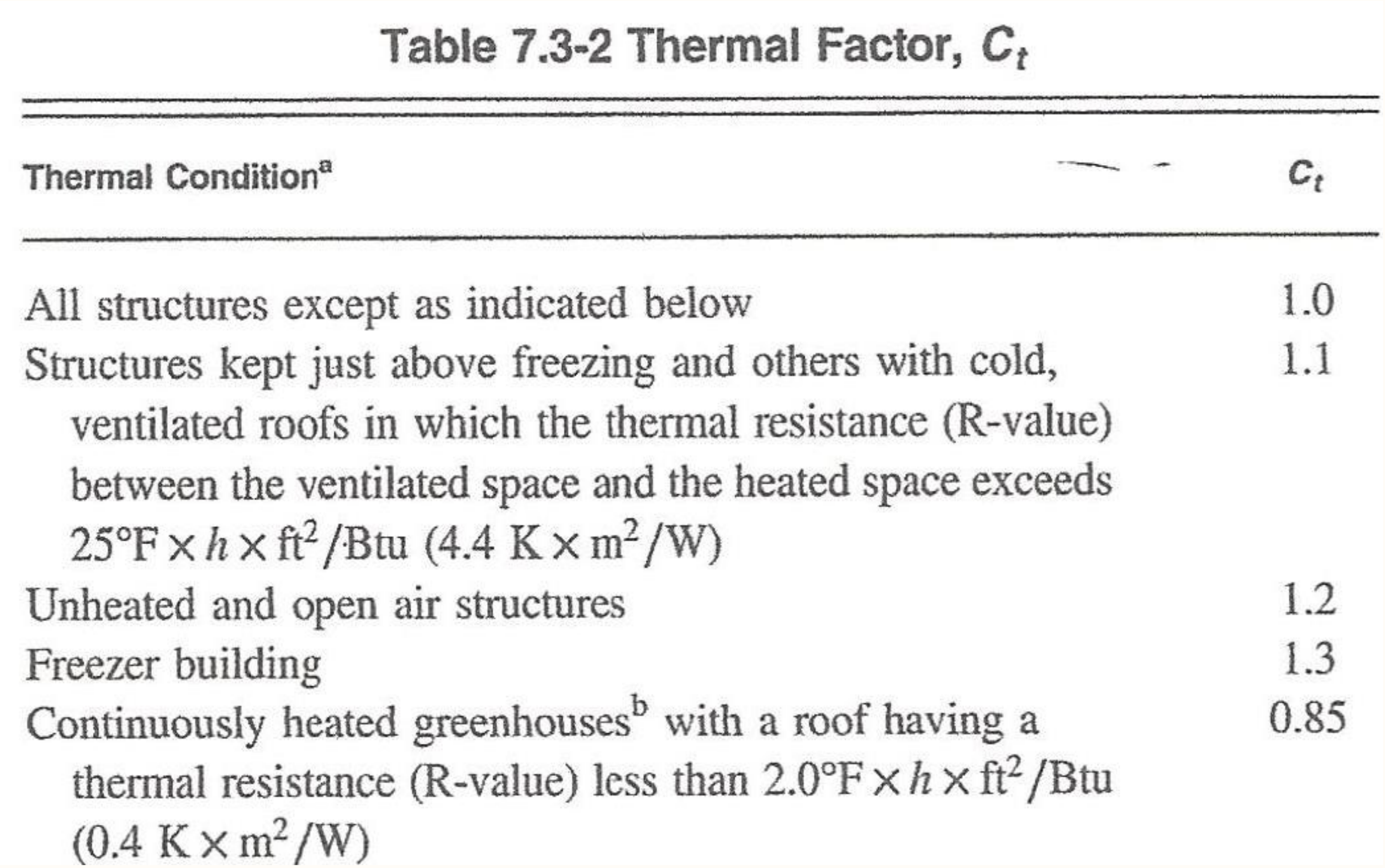

Table 7.3-2 Thermal Factor, C_t

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 $25^\circ\text{F} \times h \times \text{ft}^2/\text{Btu}$ ($4.4\ \text{K} \times \text{m}^2/\text{W}$)	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 $2.0^\circ\text{F} \times h \times \text{ft}^2/\text{Btu}$ ($0.4\ \text{K} \times \text{m}^2/\text{W}$)	0.85

Roof Thermal Factor

- C_t database characterized buildings as heated or unheated
- Roughly a 20 % increase in roof snow load for unheated structures
- Very little heat flow thru the roof layer for **modern** ventilated roofs , act as unheated with $C_t = 1.2$

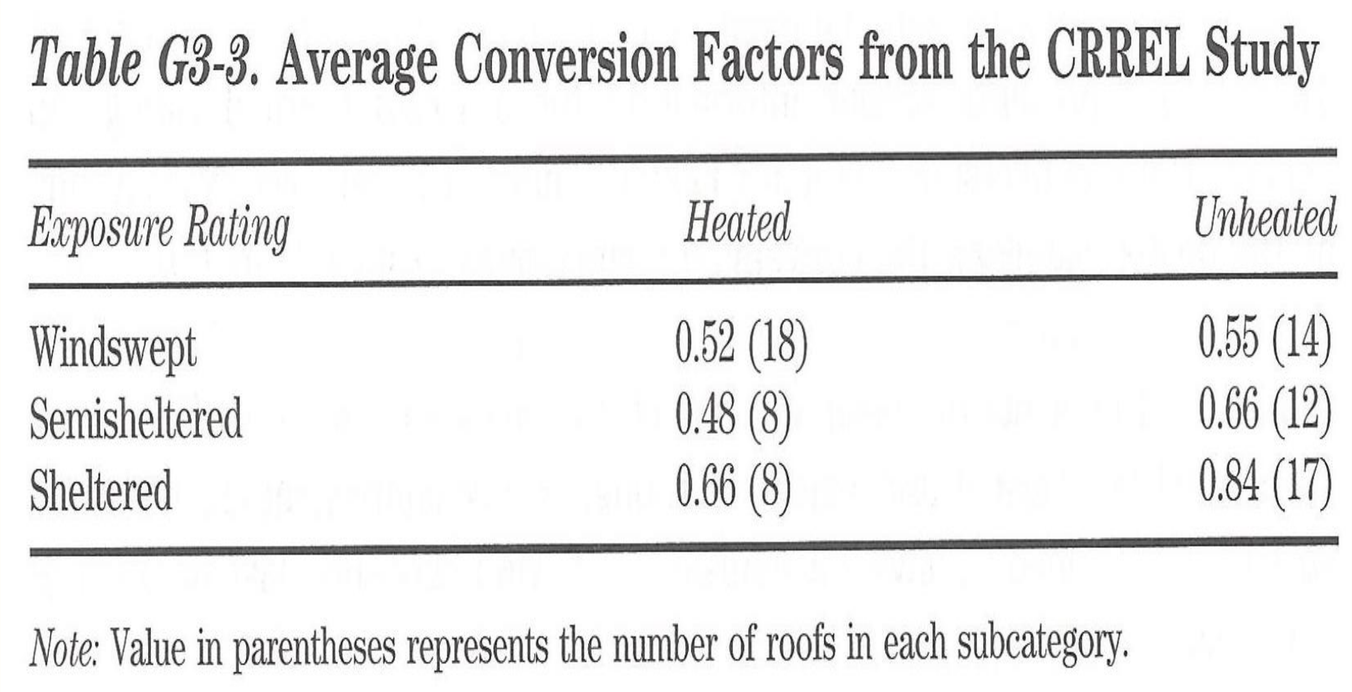

Table G3-3. **Average Conversion Factors from the CRREL Study**

Exposure Rating	*Heated*	*Unheated*
Windswept	0.52 (18)	0.55 (14)
Semisheltered	0.48 (8)	0.66 (12)
Sheltered	0.66 (8)	0.84 (17)

Note: Value in parentheses represents the number of roofs in each subcategory.

Roof Thermal Factor

- In ASCE 7-22, C_t for **unvented** roofs based upon thermal model for estimation of eave ice dams
- With high R_{roof} and small roof snow load, 32° F point is within the insulation layer – no roof snow melt due to heat flow thru roof – acts like unheated $C_t = 1.2$

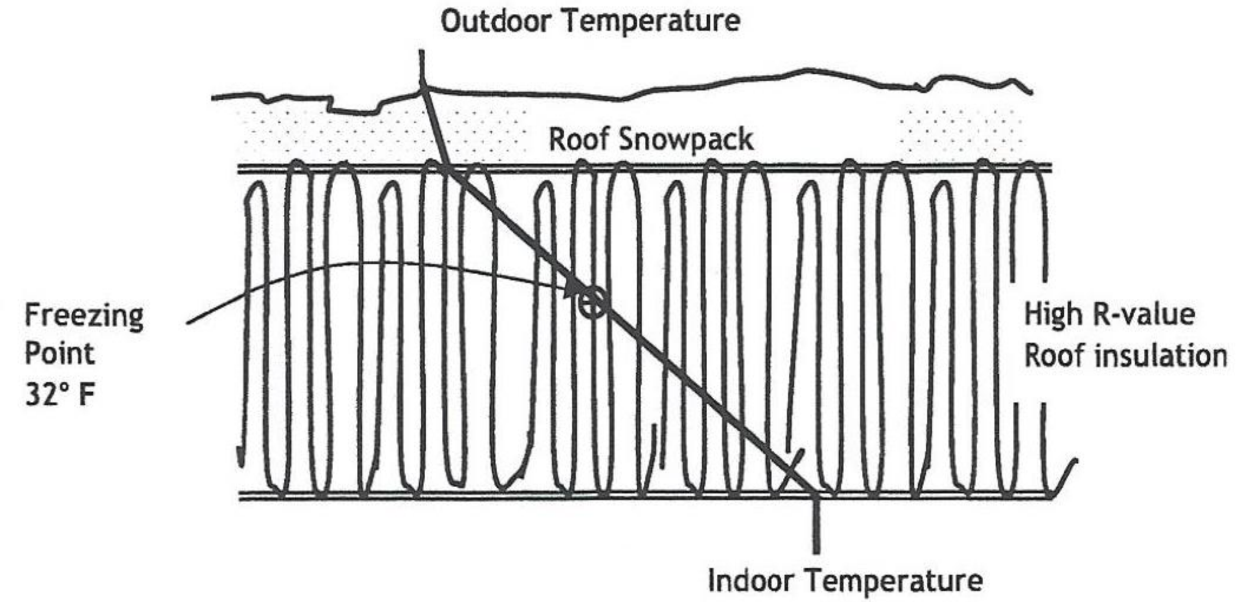

Fig. 1. Variation of temperature for outdoor temperature below freezing, well insulated roof, and thin snow layer (32°F=0°C)

Roof Thermal Factor

- With large roof snow load and poor roof insulation , 32 º F point at bottom of snowpack – melting of roof snow , reduction in roof snow load

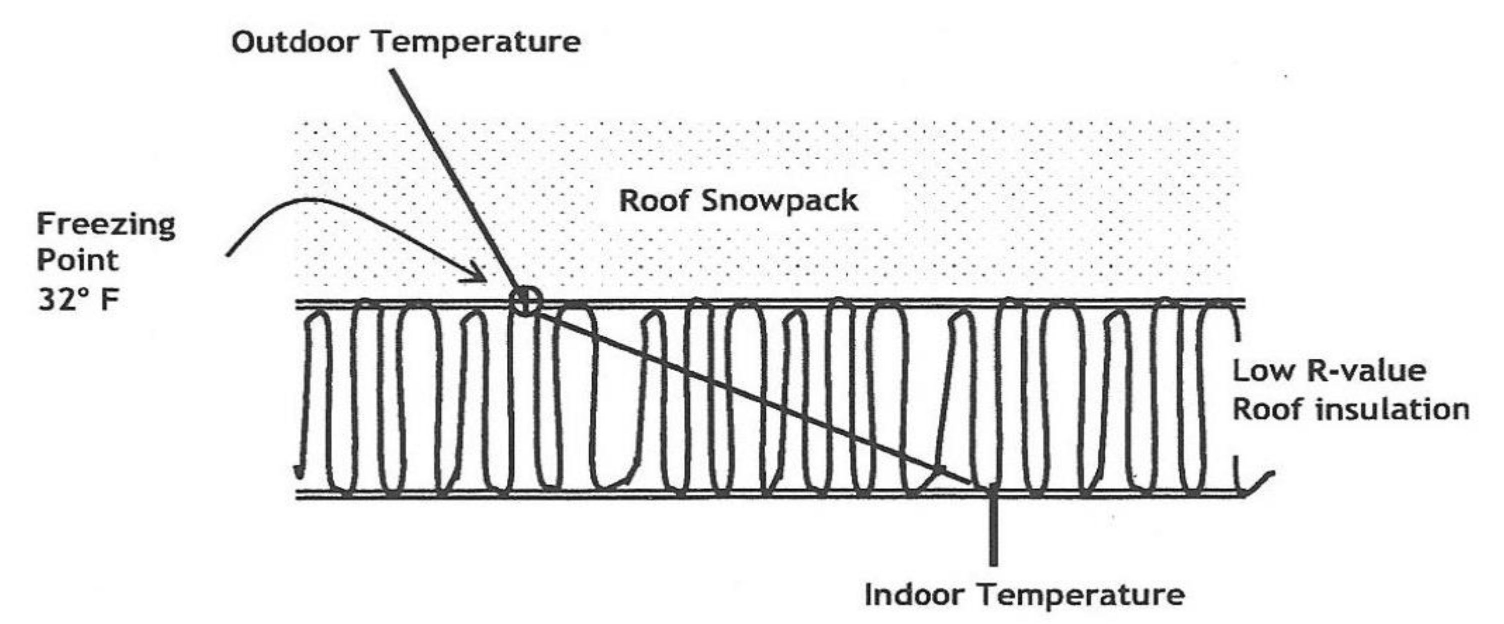

Fig. 2. Variation of temperature for outdoor temperature below freezing, poorly insulated roof, and thick snow layer (32°F=0°C)

Roof Thermal Factor

- Accounting for residual saturation at bottom of roof snow pack, able to calculate loss of roof snow due to melting (water flow off roof) and back-calculate C_t – see June Structures mag for math.

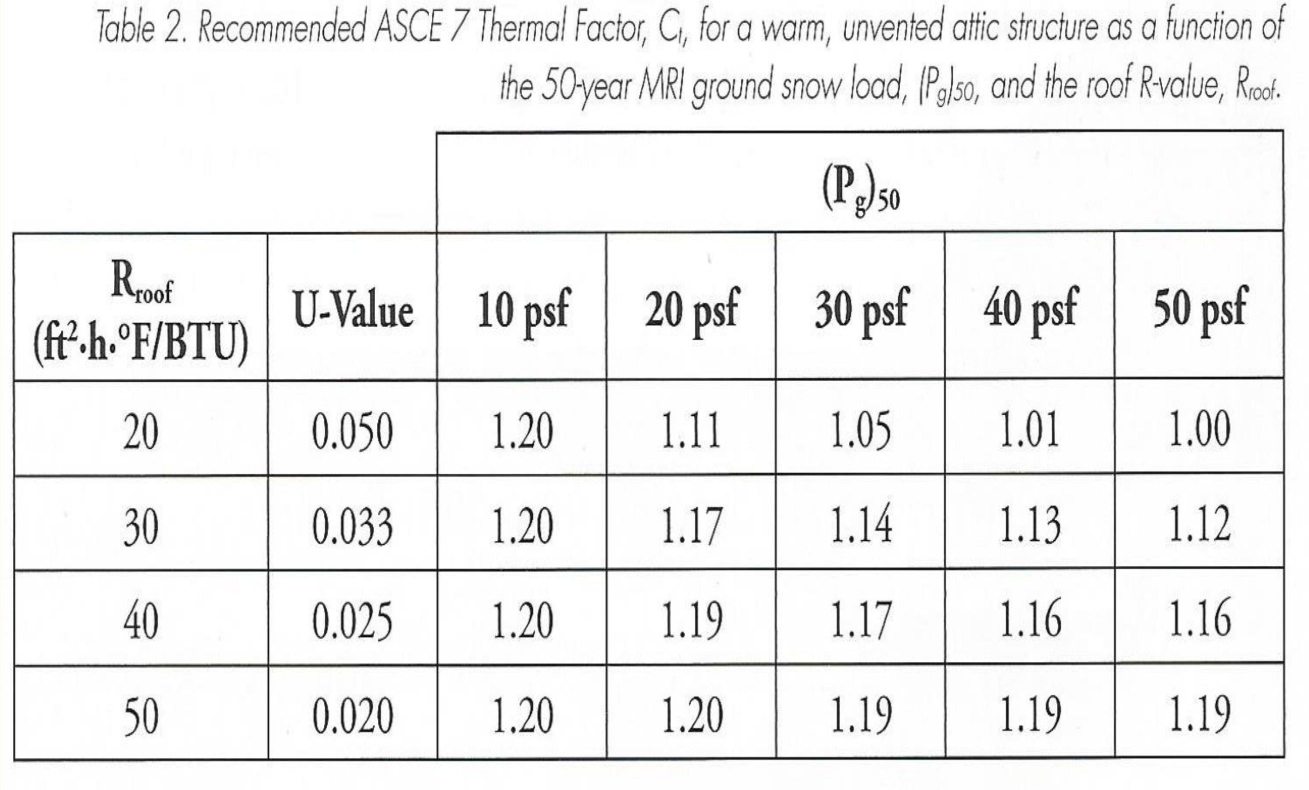

Table 2. Recommended ASCE 7 Thermal Factor, C_t, for a warm, unvented attic structure as a function of the 50-year MRI ground snow load, $(P_g)_{50}$, and the roof R-value, R_{roof}.

		$(P_g)_{50}$				
R_{roof} (ft²·h·°F/BTU)	**U-Value**	**10 psf**	**20 psf**	**30 psf**	**40 psf**	**50 psf**
20	0.050	1.20	1.11	1.05	1.01	1.00
30	0.033	1.20	1.17	1.14	1.13	1.12
40	0.025	1.20	1.19	1.17	1.16	1.16
50	0.020	1.20	1.20	1.19	1.19	1.19

Roof Thermal Factor

- Increase in R_{roof} results in increase in C_t
- Increase in P_g results in a decrease in C_t
- For $R_{roof} = 50$, freezing point in roof insulation – no melting - acts as unheated
- For $P_g = 10$ psf , freezing point again in roof insulation – no melting – acts as unheated

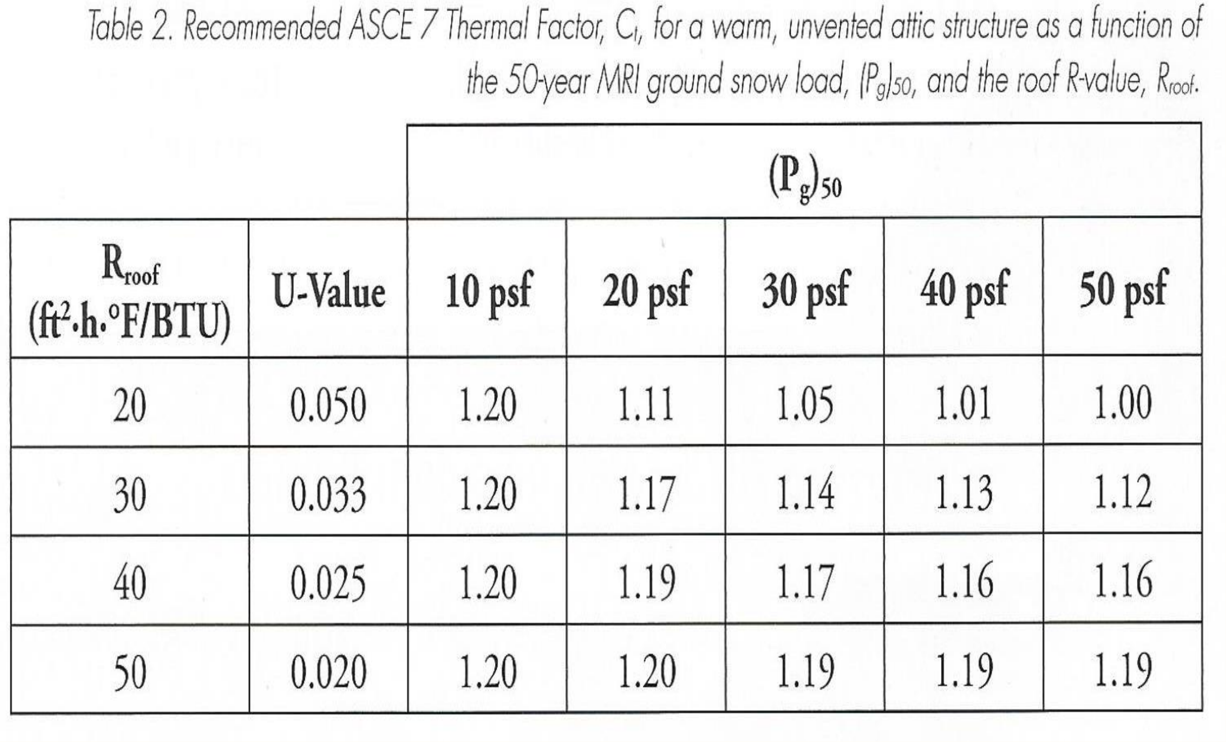

Table 2. Recommended ASCE 7 Thermal Factor, C_t, for a warm, unvented attic structure as a function of the 50-year MRI ground snow load, $(P_g)_{50}$, and the roof R-value, R_{roof}.

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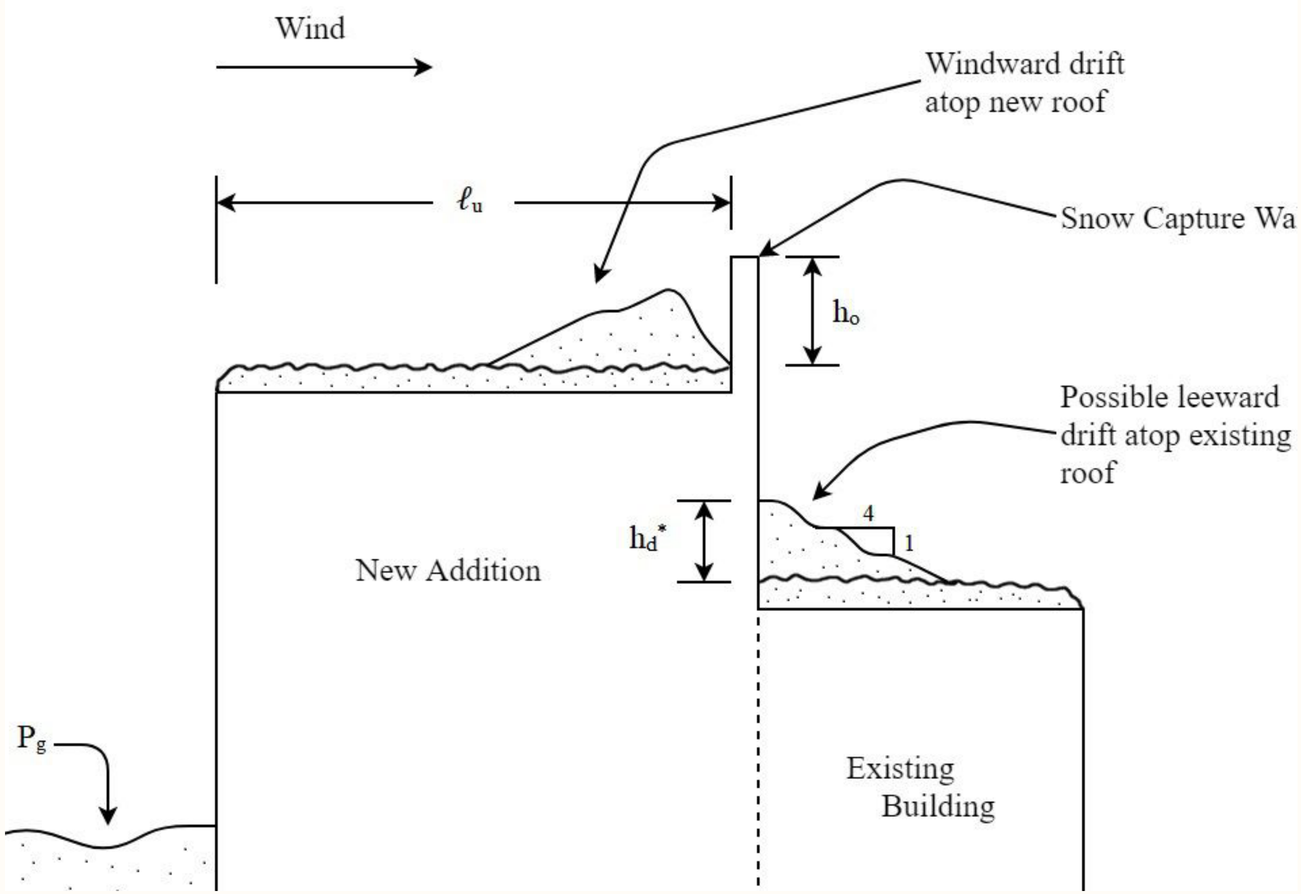
Outline

- Ground Snow Load
- Winter Wind Parameter
- Windward Drifts
- Roof Thermal Factor
- **Snow Capture Walls**

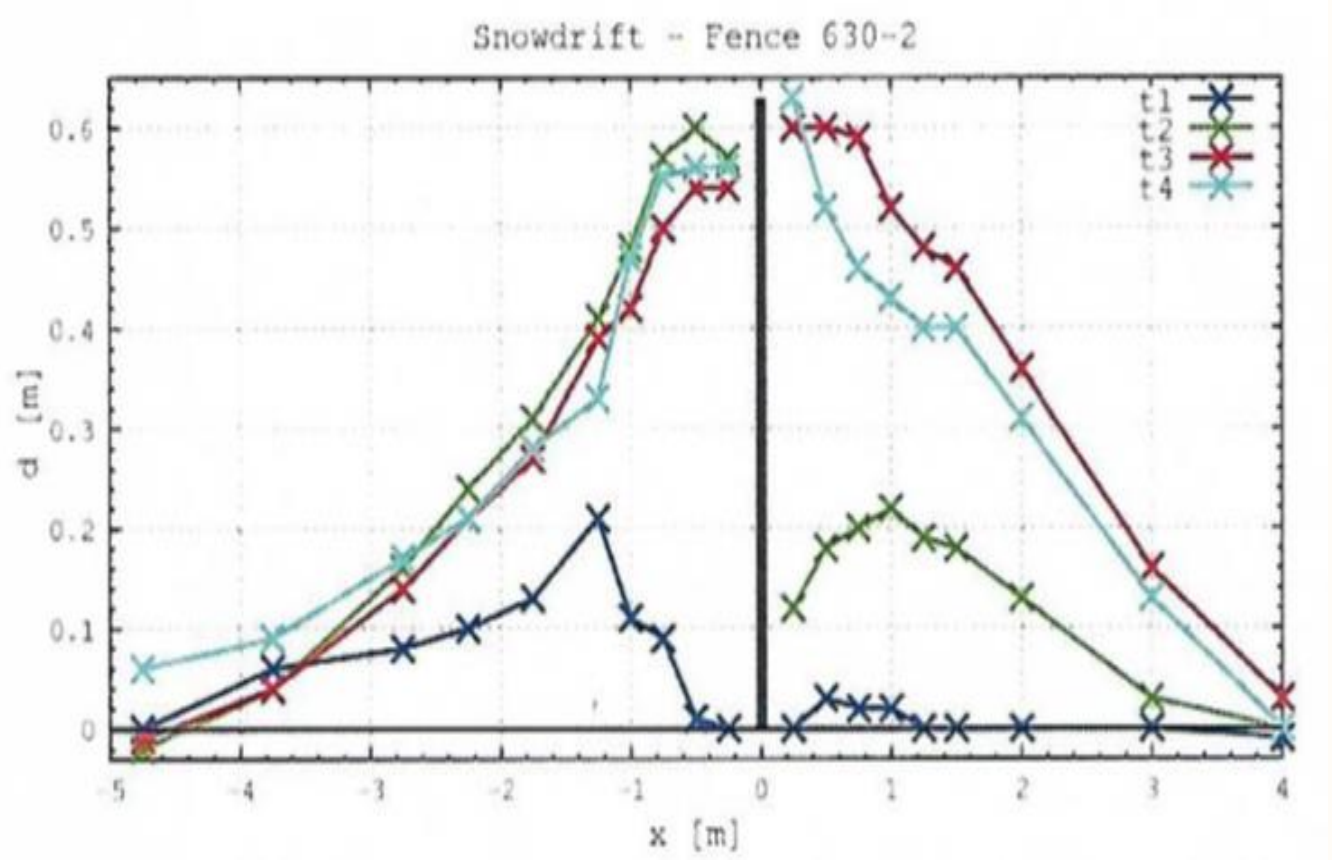
Snow Capture Wall

- This new provision addresses a common problem – **new addition next to lower existing building**
- Existing building originally likely **not designed** for new addition **drifts**
- What about a taller than normal **snow capture wall** at the common column line ?



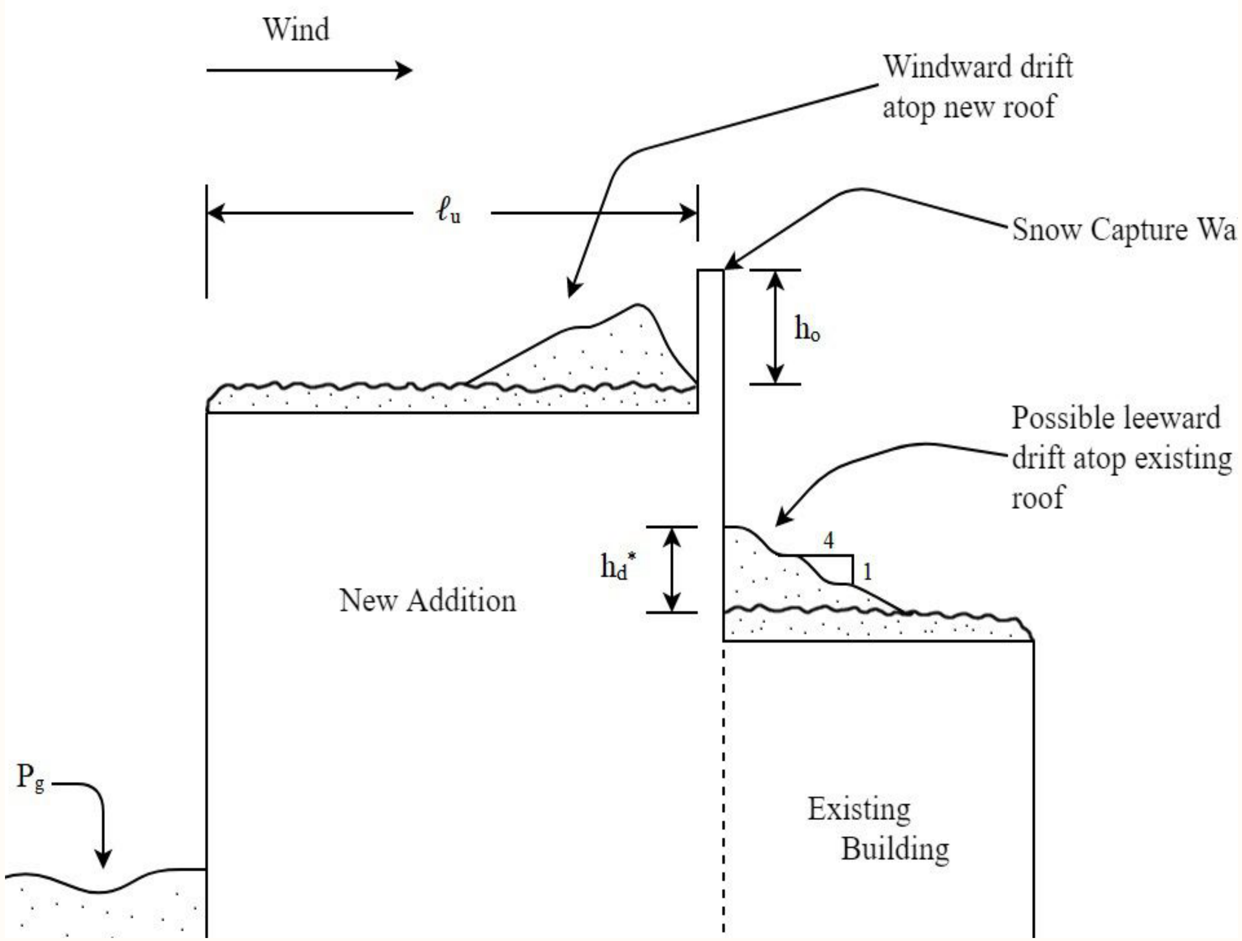
Snow Capture Wall

- Norwegian field tests establish size of 100 % trapping efficiency drift (phase I)
- Windward drift cross-sectional area at transition from phase I to II ranged from 1.15 h_o^2 to 2.74 h_o^2



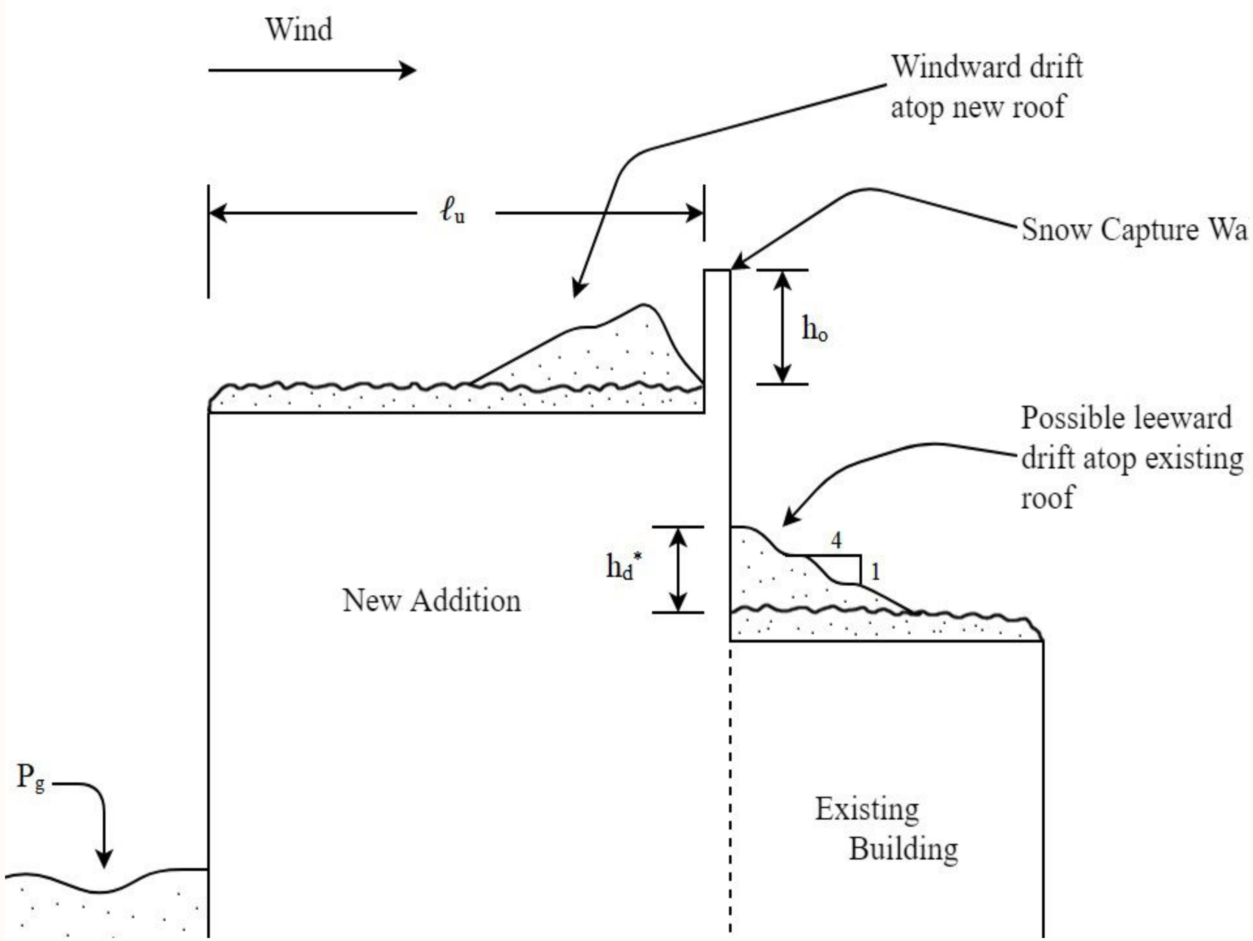
Snow Capture Wall – Full Capture

- Using the lower bound area, no leeward drift (**full capture**) for $h_o > 1.86\ h_d$, where h_d = expected height of leeward drift atop existing roof absent the capture wall
- For $h_o > 1.86\ h_d$, the expected drift atop the existing roof $h_d^* = 0.0$



Snow Capture Wall – Partial Capture

- For $h_o < 1.86\ h_d$, some but not all snow still captured at the wall
- If the wall is moderately tall, $h_o > 0.51\ h_d$, it can be shown that $h_d^* = \mathrm{SQRT}(0.8h_d^2 – 0.23h_o^2)$
- If the wall is small $h_o < 0.51\ h_d$, the addition drift at the capture wall is full and $h_d^* = \mathrm{SQRT}(h_d^2 – h_o^2)$



Questions?

MOR e-mail ….orourm@rpi.edu