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Developing ground snow loads for New Hampshire

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ABSTRACT: Because of New Hampshire's hilly landscape, mapped values of ground snow load are not available for much of its area. We conducted snow load case studies to establish ground snow loads for a specific elevation in each of the 140 towns where no values are currently available. That work was done by three researchers and three structural engineers practicing in New Hampshire. While our methods of analysis varied somewhat, our results were comparable and the feedback we received from each other was quite valuable. We then established an elevation correction factor to transfer our snow load answers to other elevations in each town. We did not do case studies for the 102 towns in New Hampshire where mapped values are available. We are now planning to do that, as we believe that case studies improve snow load design criteria. We suggest that similar studies be conducted for other places in the United States.

1 INTRODUCTION

The primary resource document for the design of structures in the United States is American Society of Civil Engineers (ASCE) Standard 7, "Minimum design loads for buildings and other structures" (ASCE 1996). It is commonly referred to as ASCE 7-95. The first step in determining design snow loads is to determine the ground snow load at the place of interest. ASCE 7-95 contains a map of the United States overlaid with that information. That map was made by Tobiasson and Greatorex of CRREL using data from 226 "first order" National Weather Service (NWS) stations, where snow depths and snow loads are measured frequently, and data from about 11,000 other NWS "co-op" stations, where only the depth of snow on the ground is measured frequently. In some areas, extreme local variations in ground snow loads preclude mapping at a national scale. In those areas the national map contains the designation "CS" instead of a value. CS indicates that case studies are required to establish ground snow loads in these areas. Figure 1 presents the information from the ASCE 7-95 map on a larger map of New Hampshire, showing county and town boundaries. The zoned values in Figure 1 are ground snow loads with a 2% annual probability of being exceeded (i.e., the 50-year mean recurrence interval value). As can be seen in Figure 1, all of New Hampshire is either in a "CS" area or the zoned values have elevation limits (the numbers in parentheses) above which case studies are needed. Thus, case studies are needed to determine ground snow loads for many buildings in New Hampshire. ASCE 7-95 requires that, in these situations, ground snow loads "shall be based on an extreme value statistical analysis of data available in the vicinity of the site using the value with a 2% annual probability of being exceeded (50-year mean recurrence interval)".

At CRREL a methodology has been developed to conduct snow load case studies. It and the data used are described in the paper, "Database and methodology for conducting site specific snow load case studies for the United States," which was presented at the Third International Conference on Snow Engineering (Tobiasson & Greatorex 1997). That database also contains information from an additional 3300 locations across the United States where ground snow loads are measured a few times each winter by other agencies and companies.

Figure 2 shows New Hampshire overlaid with town boundaries and the location of each station in the database. There is 1 NWS "first order" station, and 89 NWS "co-op" and 91 "non-NWS" stations in New Hampshire. First order stations in adjacent states within 50 miles (80 km) of the border and other stations within 25 miles (40 km) of the border were also used in our analysis. They are also shown in Figure 2. Shading in that figure and its legend indicate towns we studied and others we did not.

Structural Engineers of New Hampshire, Inc. (SENH), is a non-profit professional association of structural engineers. Their members expressed interest in using the CRREL database and methodology to develop ground snow loads for each town in New Hampshire. Several volunteered their time to conduct case studies. All prior case studies had been done by

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14. ABSTRACT

Because of New HampshireÕs hilly landscape, mapped values of ground snow load are not available for much of its area. We conducted snow load case studies to establish ground snow loads for a specific elevation in each of the 140 towns where no values are currently available. That work was done by three researchers and three structural engineers practicing in New Hampshire. While our methods of analysis varied somewhat, our results were comparable and the feedback we received from each other was quite valuable. We then established an elevation correction factor to transfer our snow load answers to other elevations in each town. We did not do case studies for the 102 towns in New Hampshire where mapped values are available. We are now planning to do that, as we believe that case studies improve snow load design criteria. We suggest that similar studies be conducted for other places in the United States.

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two or three CRREL personnel familiar with the database and methodology. To see how well the methodology could be used by others to determine ground snow loads, CRREL trained five practicing licensed SENH engineers in the case study methodology and 20 case studies were done by both groups. This pilot study showed that comparable results could be achieved when the groups shared ideas. CRREL and SENH then entered into a Cooperative Research and Development Agreement (CRDA) to determine ground snow loads for the 140 New Hampshire towns in the "CS" zone; 17 other towns in that zone in portions of the White Mountain National Forest where little or no construction is to be expected were not studied. We did not do case studies for the remaining 102 towns where, as shown in Figure 1, ground snow load values up to a limiting elevation are available on the map in ASCE 7-95. We reasoned that we did not wish to develop values that might contradict mapped values in ASCE 7-95. We have subsequently changed our minds on this point, as will be discussed.

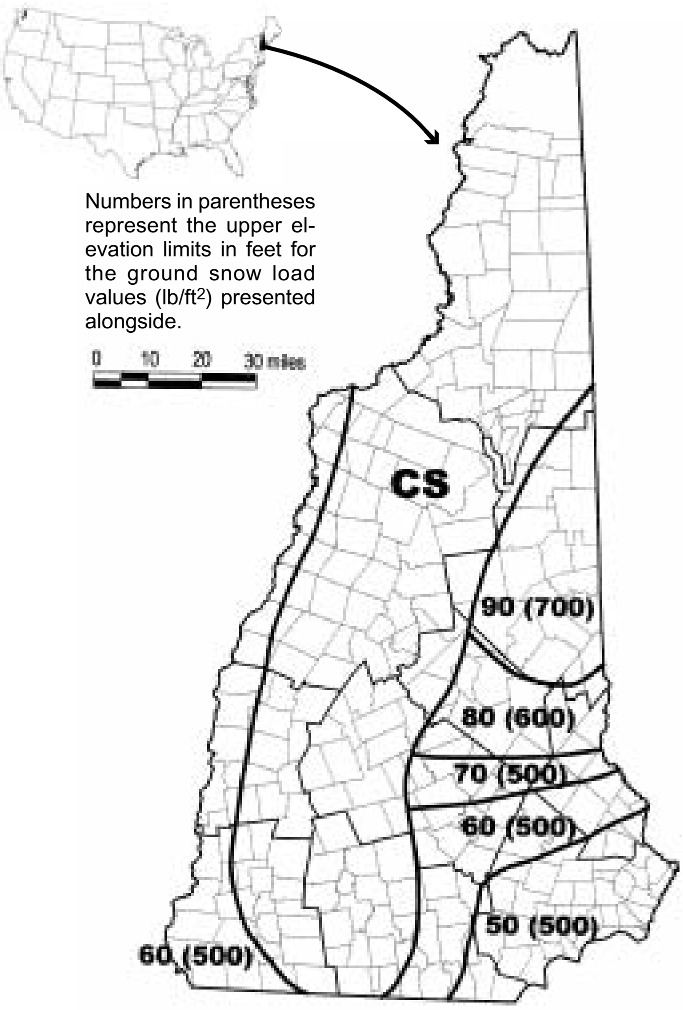


Figure 1. State of New Hampshire showing town and county boundaries overlaid with the ground snow load information in ASCE 7-95. (To convert lb/ft^2 to kN/m^2, mulitply by 0.0479, for miles to km, multiply by 1.609, and for ft to m, multiply by 0.3048.)

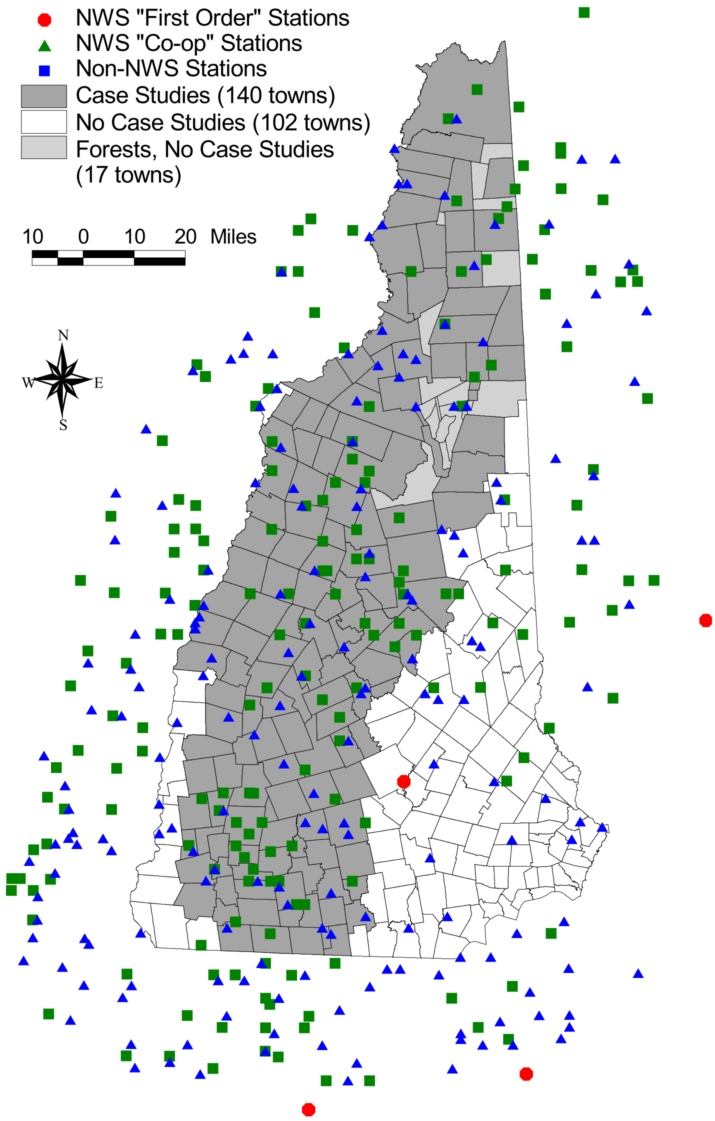


Figure 2. State of New Hampshire showing stations where ground snow load information is available and where our case studies were and were not done. (To convert miles to km, multiply by 1.609.)

2 ESTABLISHING CASE STUDY LOCATIONS

United States Geological Survey (USGS) 1:24000 scale topographic maps of the state were used to determine the coordinates of the geographical center, not the population center, of each town to the nearest minute of latitude and longitude. Those maps show town boundaries as well as roads and buildings. We did not use the elevation of the geographical center as the case study elevation but, instead, determined six elevations for each town: (1) lowest land; (2) lowest building; (3) lower limit of most buildings; (4) upper limit of most buildings; (5) highest building; and (6) highest land. Significant elevation differences exist within most towns. Thus, each ground snow load answer would not be a single value for all places in a town but a value at the case study elevation and an elevation factor for correcting that value to other elevations in that town.

We chose an elevation near the upper limit of most buildings as our case study elevation. Had we done these case studies at lower elevations, failure to apply the elevation correction factor would have resulted in inappropriately low design loads for some of the buildings in each town.

3 CASE STUDY FORMS AND GUIDELINES

Case study forms were computer-generated for each town. Figures 3 and 4 present such forms for the town of Salisbury. The first page (Fig. 3) contains the data available in the vicinity. For many towns, that tabulation contains data from neighboring states. For Salisbury, periods of record range from 4 to 44 years; about half the stations are NWS and half non-NWS, and ground snow loads are available in the vicinity at elevations from 350 ft (107 m) to 1500 ft (457 m), bracketing the 900 ft (274 m) elevation chosen for Salisbury.

The final page (Fig. 4) of each case study contains two plots of ground snow load vs. elevation. The upper plot contains just the data from the nearest six to eight stations, while the lower plot contains all the data available within a 25-mile (40-km) radius, plus any NWS first order data within 50 miles (80 km). As shown in Figure 4, the elevation of interest is highlighted on the plots, as is a straight line of best fit using least squares and the best fit value of the ground snow load at the elevation of interest. For some towns the ground snow load "answer" is similar on the upper and lower plots but for other towns it is quite different.

Ground snow loads generally increase at higher elevations up to the tree line. Above the tree line, they may decrease because of wind action. The upper plot in Figure 4 has a negative "slope" (i.e., elevation correction factor) of –1.67 lb/ft^2 per 100 ft (–0.26 kN/m^2 per 100 m). The few data points on the "nearest 6" plot result in an unrealistic slope and thus the ground snow load answer of 68 lb/ft^2 (3.3 kN/m^2) is not to be trusted. The lower "all values" plot in Figure 4 contains enough data points to generate a physically more realistic slope of 2.5 lb/ft^2 per 100 ft (0.39 kN/m^2 per 100 m) and, thus, a believable ground snow load of 80 lb/ft^2 (3.8 kN/m^2).

Data from near the 6288-ft (1917-m) summit of Mt. Washington created problems. The tabulated ground snow load there is only 56 lb/ft^2 (2.7 kN/m^2), which is far below the ground snow load at many other places at elevations well below 1000 ft (305 m). The high winds on that treeless summit result in ground snow load measurements that are much too low to be used for our purposes. Several plots containing the Mt. Washington value have a negative slope and the ground snow load answer suffers as a result. While Mt. Washington and a few other stations frustrated us, their implications were worth considering. Mt. Washington's redeeming value was to remind us that we should not apply our elevation correction factor above the tree line.

Each of the three CRREL researchers and the three SENH structural engineers involved was provided with a copy of the "data and methodology" report mentioned previously (Tobiasson & Greatorex 1997), several representative case studies done by CRREL previously, and written suggestions by Tobiasson and Greatorex for conducting case studies, a copy of which can be obtained from CRREL.

We began by working on 40 towns, about half of which were in the rugged northern portion of the state and the rest in the rolling hills of southwestern New Hampshire. We each conducted our analysis in our own way and forwarded our "preliminary" ground snow load answers to a third party at CRREL, who tallied them without divulging the author of each value, and then sent the tally to us. We then reassessed our answers in light of those of the five others, and then sent in our "semi-final" answers, which were tallied in a similar fashion, then returned to us. We met shortly thereafter to discuss our various methods of analysis and our answers and to arrive at a final answer for each of the 40 towns. As a result of our first meeting, we each made some changes to our method of analysis. We then repeated the process for the remaining 100 towns being studied.

4 DIFFERING WAYS OF ARRIVING AT ANSWERS

The three individuals representing CRREL had done many case studies and were comfortable with the case study forms and the guidelines for analysis. They closely followed the instructions, giving more weight to closer stations and stations with longer periods of record. They gave little weight to stations with less than about 15 years of record and they gave little weight to stations where the ratio of the 50-year ground snow load (i.e., P_g on the case study tabulation) to the largest ground snow load ever measured there (i.e., the Record Max value, P_{max}, on the case study tabulation) was greater than 1.6. They flagged such stations on the upper plot and added a few stations somewhat further away, but with longer periods of record, to replace them. Often, more stations were added than were eliminated. Then they either "eyeballed" or calculated a new line of best fit in their quest for that case study's answer. When "eyeballing" in a line of best fit, they gave it a slope of between 2 and 2.5 lb/ft^2 per 100 ft (0.31 to 0.39 kN/m^2 per 100 m), based on the written suggestions mentioned above. Two of them found it valuable to bound the good data by upper and lower lines at one of these slopes. Their answer was usually somewhat above the midpoint of the upper and lower bounds at the case study elevation. The third individual devoted additional attention to the geographical position of stations used in his analysis. He plotted this for some case studies.

The three SENH practicing structural engineers had participated in the pilot study. Each had developed a slightly different way of doing case studies. They chose not to work on the case study plots, believing them to contain too much information of limited value, which hides trends of interest. Instead, they reanalyzed only the better stations in the data tabulation. One of them felt that the NWS co-op information, since it is based on measurements of the depth of snow on the ground, not measurements of the weight of that snow, is inferior to the non-NWS values, which are measurements of the weight. The other five individuals felt that both the NWS and non-NWS data sets were of comparable value, each having its own strengths and weaknesses. The individual who focused on the non-NWS data only included NWS information when few non-NWS data were available. He attempted to have 6 to 8, and occasionally 10, stations with 20 or more years of record in his analysis. He did not use stations where the P_g/P_{max} ratio was greater than 1.5. He re-plotted the P_g values selected vs. elevation and used a straight line, least squares fit to establish a preliminary answer. That answer was modified with consideration given to the slope of his trend line and the scatter of points.

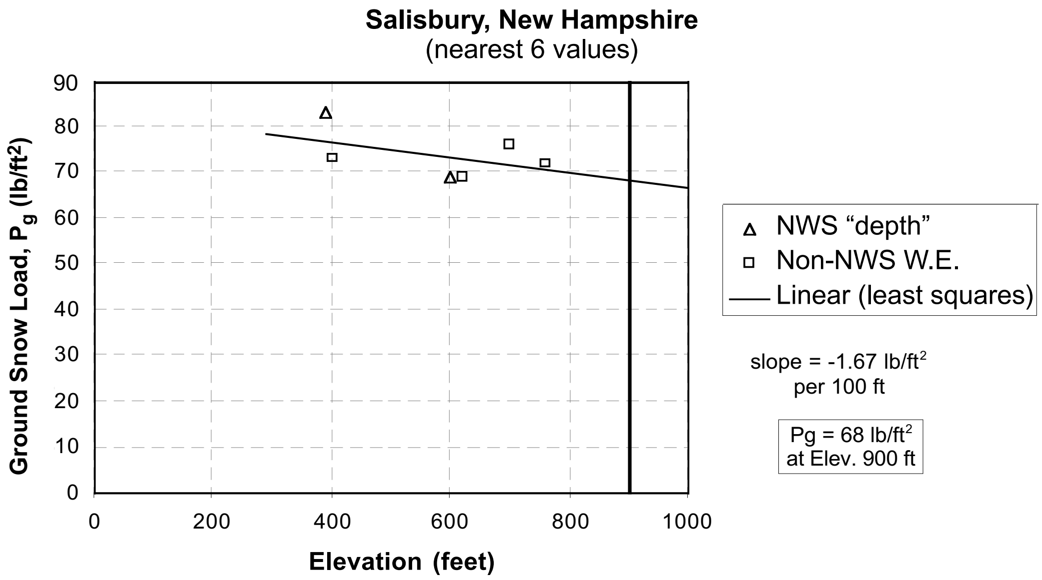
SNOW LOAD CASE STUDY FOR

Salisbury, New Hampshire

Latitude 43° 23' N Longitude 71° 46' W Elevation 900 ft

Station	Radius (mi.)	Azimuth (from site)	Elev. (ft)	P_g (psf)	Record Max. (psf)	Years of Record	
						Total	No Snow
NWS FIRST ORDER							
CONCORD (W.E.)	18	125	350	63	43	40	0
CONCORD WSO AP ("DEPTH")	18	125	350	44	38	44	0
NEW HAMPSHIRE (NWS co-op)							
BLACKWATER DAM	5	143	600	69	59	44	0
FRANKLIN	7	56	390	83	94	13	0
FRANKLIN FALLS DAM	8	54	430	72	67	44	0
SOUTH DANBURY	10	311	930	101	85	22	0
NEW LONDON	11	279	1340		51	9	0
BRADFORD	14	236	970	75	73	39	0
BRISTOL 2	14	9	590		27	8	0
WEST HENNIKER	16	201	500		59	5	0
GRAFTON	16	315	840	101	67	25	2
MOUNT SUNAPEE	16	261	1260	132	78	18	2
GILMANTON	18	79	1030	86	55	16	0
LAKEPORT	19	61	560	69	68	34	0
LAKEPORT 2	19	61	500	67	28	11	2
ALEXANDRIA	19	339	1370		38	5	0
GILMANTON 2 E	20	83	800		23	4	0
WEARE	21	174	720	50	32	20	0
NEWPORT	21	270	790	78	57	39	1
NORTH CHICHESTER	21	109	360		27	8	0
DEERING	22	201	1010	83	41	16	0
EAST DEERING	22	189	790	77	65	26	0
SOUTH WEARE	23	171	700	82	71	18	0
ALTON	25	84	800		28	5	0
NEW HAMPSHIRE (NON-NWS)							
SALISBURY	1	90	760	72	54	40	0
ANDOVER	4	315	700	76	61	32	0
BLACKWATER	5	166	620	69	56	40	0
FRANKLIN FALLS	7	45	400	73	54	39	0
SOUTH DANBURY	10	315	800	74	62	40	0
DAY POND	12	218	780	83	62	29	0
LITTLE SUNAPEE	15	287	1490	93	59	31	0
NEW LONDON	15	287	1170	86	75	26	0
CHASE VILLAGE	16	180	700	81	59	29	0
GRANLIDEN	17	276	1220	89	60	31	0
SADDLE HILL	18	33	1020	73	69	41	0
GILFORD	18	49	1000	90	71	40	0
CARDIGAN MOUNTAIN	19	336	1500	72	64	15	0
NEW HAMPTON	19	24	560	76	62	41	0
GRAFTON CENTER	19	317	900	69	60	24	0
NELSON BROOK	20	78	770	89	55	11	0
EVERETT DAM	22	159	460	78	53	29	0
WASHINGTON	22	236	1500	88	64	22	0
MEREDITH	22	43	880	80	62	40	0
WASHINGTON	22	237	1340	90	61	11	0
WEIRS BEACH	23	54	520	50	38	27	0
HOYT HILL	24	360	950	72	73	41	0
SALMON BROOK	25	223	1300	88	57	22	0

Figure 3. Case study data tabulation for the town of Salisbury. (To convert lb/ft^2 to kN/m^2, mulitply by 0.0479, for miles to km, multiply by 1.609, and for ft to m, multiply by 0.3048.)



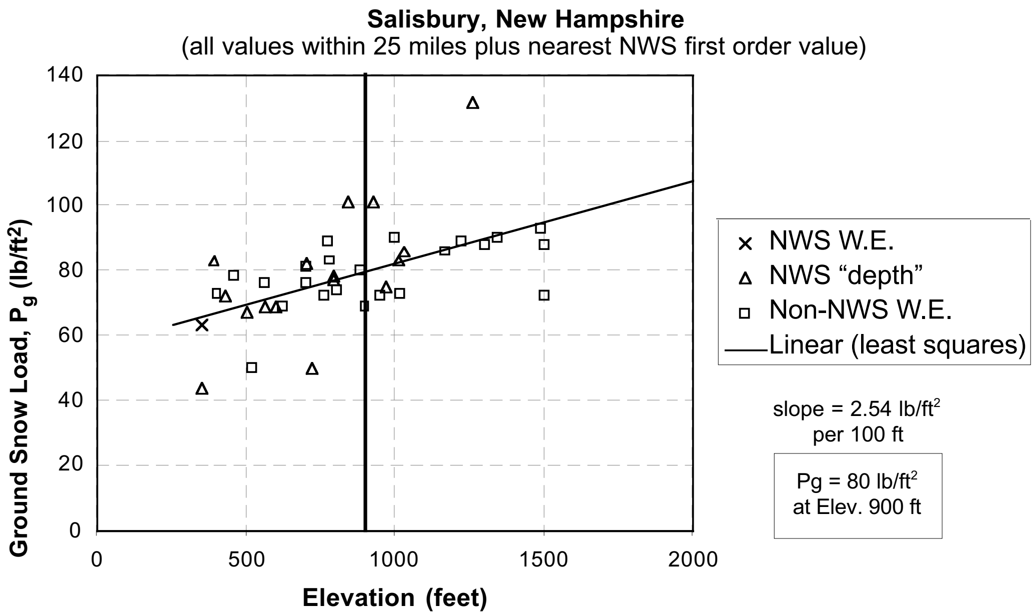


Figure 4. Case study plots for the town of Salisbury. Note that the scales on the two plots differ. (To convert lb/ft^2 to kN/m^2, mulitply by 0.0479, for miles to km, multiply by 1.609, and for lb/ft^2 per 100 ft to kN/m^2 per 100 m, multiply by 0.1572.)

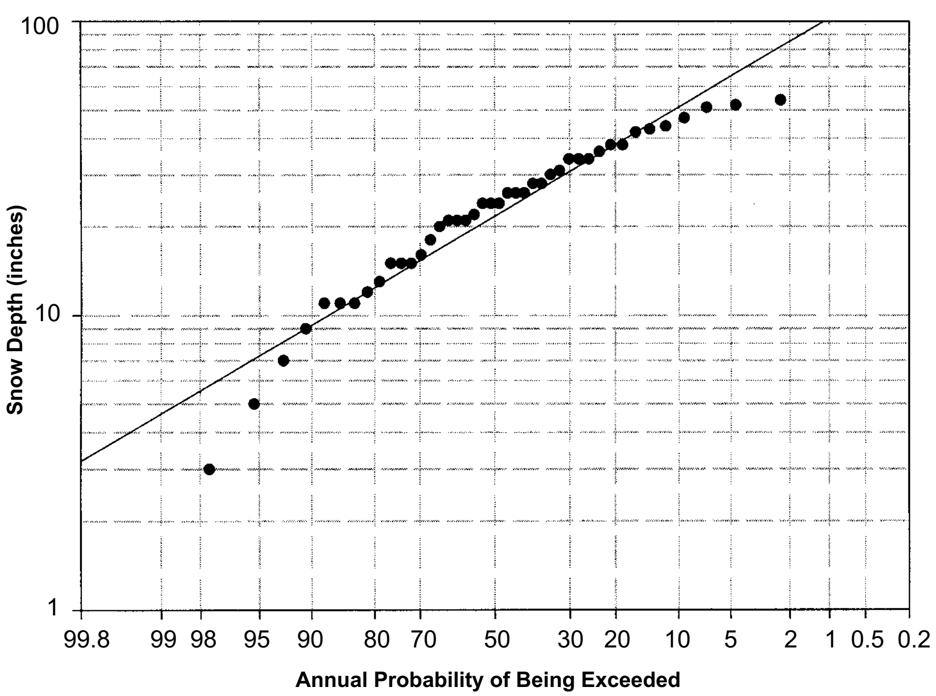


Figure 5. Log-normal probability plot for Milford which has a high P_g/P_{max} ratio of 1.76. (To convert inches to meters multiply by 0.025.)

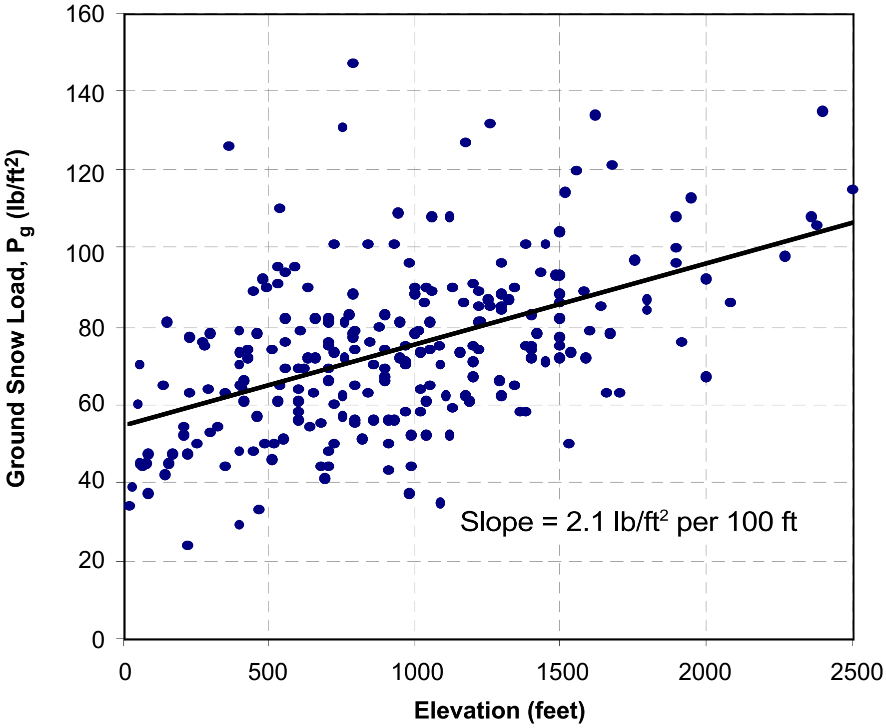


Figure 6. The elevation correction factor for the 236 highest quality stations used in our analyses was 2.1 lb/ft² per 100 ft (0.33 kN/m² per 100 m). (To convert lb/ft² to kN/m², mulitply by 0.0479, and for ft to m, multiply by 0.3048.)

When several points at about the elevation of interest fell above the trend line, he increased his preliminary answer.

The other two SENH structural engineers considered both NWS and non-NWS data, but one of them gave more weight to the non-NWS information because it eliminated the step of having to relate snow depths to snow loads (see equation 1 in Tobiasson & Greatorex 1997). Both of these individuals developed selection criteria that eliminated from consideration a number of the stations on the case study form. The acceptance criteria of one individual were (1) at least 15 years of record, (2) less than 15 (sometimes 20) miles (24, sometimes 32 km) away and (3) P_g/P_{max} ratio no more than 1.75 for non-NWS stations and no more than 1.5 for NWS stations. The other individual's acceptance criteria were (1) at least 20 years of record, (2) less than 15 miles away, and (3) P_g/P_{max} ratio no more than 1.5. Both then adjusted each selected ground snow load to the case study elevation by using an elevation correction factor of from 2.0 to 2.5 lb/ft² per 100 ft of elevation difference (0.31 to 0.39 kN/m² per 100 m). Both then determined the average value of the ground snow load at that elevation for all the stations selected. In the vicinity of Mt. Washington, where a station or two had a value quite different from this average, a second average was often calculated, eliminating the outliers. One individual developed separate averages for all data and for "non-NWS" data and gave more weight to the "non-NWS" average. He always plotted all the data he analyzed and frequently referred back to the case study plots before finalizing his answer.

A review of each individual's final answers indicates that no one's approach caused them to be consistently much lower or much higher than the group's final answer. Thus, quantitatively, it appears that the process we developed to arrive at answers tended to bring each of us to about the same answer. We expect that if any one of us had used our method of analysis alone, without receiving feedback from the others along the way, we may have arrived at significantly different answers for some towns. Thus, we conclude that there is merit in involving several individuals in a way that they periodically receive anonymous feedback from each other. This process allowed the group to determine most answers before our meetings and precluded the need to discuss many of the case studies at those meetings. When we met, we concentrated on the few case studies on which we had remaining concerns or disagreements. This left time for us to explore ways of improving the process, ways of simplifying our findings, and ways of incorporating them into the national standard (i.e., ASCE 7-95) and into practice within New Hampshire. It also allowed us time to discuss our increasing understanding of ground snow loads in New Hampshire.

5 ADDITIONAL INVESTIGATIONS

For 69 of the 302 stations shown in Figure 2, where a 50-year ground snow load is available, the P_g/P_{max} ratio exceeded 1.5. Often, the 50-year ground snow load at such stations greatly exceeded other ground snow loads in the vicinity. For example, the upper outlier in the lower plot in Figure 4 has a high P_g/P_{max} ratio of 1.7. Responding to this complication proved to be the most controversial aspect of our analysis. To better understand what was happening, we examined probability plots of several of these stations and determined that, for them, the log-normal distribution used to generate the ground snow load values on the case study forms does not fit the actual trend in lower probabilities very well. Figure 5 illustrates this for Milford, where the P_g/P_{max} ratio is 1.76 and the log-normal value at a 2% annual probability of being exceeded (50-year mean recurrence interval) greatly exceeds the data trend there. With this evidence, we gave little weight in our analysis to stations with high P_g/P_{max} ratios.

Once we had all 140 case study answers, we compared them to the answers on the upper and lower plots on the last page of the case study form. The upper "nearest 6" plot answers did not agree with our answers well at all. Only 59 of the upper plot answers were within 5 lb/ft^2 (0.2 kN/m^2) of our 140 case study answers. For 50 stations the upper plot answers were from 10 to 38 lb/ft^2 (0.5 to 1.8 kN/m^2) away from our answers. The lower "all values" plot answers were within 5 lb/ft^2 (0.2 kN/m^2) of our answers for 116 of the 140 case studies (i.e., 83% of the time). However, for eight stations, the "all values" answers were from 10 to 20 lb/ft^2 (0.5 to 1.0 kN/m^2) away from our answers. Thus, while the "all values" answers provide good indications of the "correct" answers most of the time, further study will occasionally result in significantly different, better answers.

The elevation correction factor can also be examined on the upper and lower plots. On the upper plot that factor varied widely between 13.5 lb/ft^2 per 100 ft (2.12 kN/m^2 per 100 m) and minus 9.0 lb/ft^2 per 100 ft (minus 1.41 kN/m^2 per 100 m). The average value of this widely divergent and physically unrealistic set of numbers was 1.8 lb/ft^2 per 100 ft (0.28 kN/m^2 per 100m). We place little value on this average, as it is significantly influenced by some values that are physically unrealistic. Stations like Mt. Washington create these inappropriate values. On the "all values" plot, the slopes make somewhat better physical sense, but Mt. Washington and a few other stations still create problems. Slopes vary from 5.3 lb/ft^2 per 100 ft (0.83 kN/m^2 per 100 m) to minus 3.0 lb/ft^2 per 100 ft (minus 0.47 kN/m^2 per 100 m) and average 2.4 lb/ft^2 per 100 ft (0.38 kN/m^2 per 100 m).

We further examined the elevation correction factor by studying each station in our database. We eliminated stations with less than 15 years of record, others with an elevation above 2500 ft (762 m), and others with P_g/P_{max} ratios less than 0.9 or greater than 1.7. For the remaining, high quality stations, the line of best fit of their elevation to their 50-year ground snow load, P_g, produced a slope of 2.1 lb/ft^2 per 100 ft (0.33 kN/m^2 per 100 m), as shown in Figure 6. While we expect that the elevation correction factor varies from place to place in New Hampshire, we do not have enough data to support such differences. Thus, we have used this elevation correction factor for all New Hampshire towns.

6 FINDINGS

Our answers for the 140 towns are presented in Table 1. Some of the towns listed in Table 1 are only partially in the CS zone. At this time for those towns, we recommend that the ground snow load be determined using the information in Table 1 rather than from the map in ASCE 7-95. The case study process is a more detailed and thus, in all likelihood, a more accurate assessment of the ground snow loads in these towns. This is consistent with the guidance in the commentary attached to ASCE 7-95, which states that "detailed study of a specific site may generate a design value lower than that indicated by the generalized national map. It is appropriate in such a situation to use the lower value established by the detailed study. Occasionally, a detailed study may indicate that a higher design value should be used than the national map indicates. Again, results of the detailed study should be followed"(ASCE 1996).

After discussing the pros and cons of having a portion of New Hampshire defined by the ASCE 7-95 map and the remainder defined by our case studies, we concluded that it would be best to expand our case studies to cover the entire state. We have agreed in principle to do that and will revise the CRDA between CRREL and SENH to increase the scope of work accordingly. We expect that once we have done the entire state and examined all of our answers, some of the values in Table 1 may change a little. Thus, we advise readers to consider those values as interim in nature.

To determine the ground snow load at elevations other than those listed in Table 1 (i.e., at elevations other than those where the case studies were conducted), the values in Table 1 should be increased or decreased by an elevation correction factor of 2.1 lb/ft^2 per 100 ft (0.33 kN/m^2 per 100 m). For example, in Hanover where the Table 1 value is 75 lb/ft^2 at 1300 ft (3.6 kN/m^2 at 396 m), at an elevation of 900 ft (274 m) the answer would be 75 + (2.1/100)(900–1300) = 75 – 8 = 67 lb/ft^2 (in SI units: 3.6 + (0.33/100)(274 – 396) = 3.6 – 0.4 = 3.2 kN/m^2).

We have not fully investigated the upper limit above which our elevation correction factor does not apply. At this time it seems safe to use it up to an elevation of 2500 ft (762 m) in New Hampshire. At higher elevations a larger elevation correction factor may be needed.

7 CONCLUSIONS AND RECOMMENDATIONS

The current case study plots contain some data of limited value that mask rather than define trends. Perhaps stations with fewer than about 14 years of record should be eliminated from the plots on the case study forms and perhaps stations with P_g/P_{max} ratios exceeding about 1.7 should also be eliminated from those plots.

Table 1. Case study findings for the 140 towns studied.

Town	Case study elevation (feet)*	Ground snow load, P_g (lb/ft^2)**
Acworth	1500	90
Albany	1300	95
Alexandria	1100	85
Alstead	1300	80
Andover	900	80
Antrim	1000	80
Ashland	800	75
Bartlett	1200	105
Bath	1000	65
Bennington	1000	80
Benton	1600	90
Berlin	1600	95
Bethlehem	1800	105
Boscawen	700	75
Bradford	1200	85
Bridgewater	1000	80
Bristol	1000	80
Campton	1300	85
Canaan	1200	85
Carroll	1700	95
Center Harbor	900	80
Clarkesville	2000	90
Colebrook	1600	80
Columbia	1600	80
Croydon	1200	90
Dalton	1300	80
Danbury	1000	85
Deering	1200	90
Dixville	1900	90
Dorchester	1400	80
Dublin	1600	90
Dummer	1400	90
Easton	1400	85
Ellsworth	1400	90
Enfield	1300	85
Errol	1600	90
Fitzwilliam	1300	75
Francestown	1100	80
Franconia	1700	95
Franklin	700	75
Gilsum	1200	85
Gorham	1400	105
Goshen	1400	90
Grafton	1400	90
Grantham	1400	90
Greenfield	1100	80
Green's Grant	1700	105
Greenville	1000	75
Groton	1200	80
Hancock	1300	85
Hanover	1300	75
Harrisville	1500	90
Harts Location	1300	100
Haverhill	1200	75
Hebron	900	80
Henniker	1000	80
Hill	1100	85
Hillsboro	1000	80
Holderness	1000	80
Hopkinton	800	80
Jackson	1800	115
Jaffrey	1300	80
Jefferson	1700	100
Keene	900	70
Laconia	900	80
Lancaster	1300	70
Landaff	1300	80
Lebanon	1200	80
Lempster	1600	95
Lincoln	1400	95
Lisbon	1100	75
Littleton	1200	75
Lyman	1200	75
Lyme	1100	70
Lyndeborough	1000	80
Marlborough	1300	80
Marlow	1600	90
Martin's Loc.	1300	100
Mason	1000	75
Meredith	1000	80
Milan	1500	100
Milford	600	70
Millsfield	1700	90
Mont Vernon	900	75
Moultonborough	900	80
Nelson	1500	90
New Boston	800	80
New Hampton	1000	80
New Ipswich	1300	80
New London	1400	95
Newbury	1300	90
Newport	1200	85
Northumberland	1200	75
Odell	1800	90
Orange	1500	90
Orford	1100	70
Peterborough	1000	75
Piermont	1400	75
Pittsburg	1700	80
Plainfield	1300	90
Plymouth	900	75
Randolph	1900	110
Rindge	1300	80
Roxbury	1300	80
Rumney	1300	85
Salisbury	900	80
Sanbornton	1000	80
Sandwich	1100	85
Second College Grant	1500	90
Sharon	1300	80
Shelburne	800	90
Springfield	1500	95
Stark	1200	75
Stewartstown	2000	90
Stoddard	1600	90
Stratford	1100	70
Success	1600	100
Sugar Hill	1600	90
Sullivan	1400	90
Sunapee	1400	90
Surry	1100	80
Sutton	1100	85
Swanzey	800	65
Temple	1300	80
Thornton	1200	85
Tilton	900	80
Troy	1300	75
Unity	1500	90
Warner	800	80
Warren	1300	80
Washington	1700	100
Waterville Valley	1800	105
Weare	900	80
Webster	700	80
Wentworth	1200	80
Whitefield	1400	75
Wilmot	1200	90
Wilton	900	75
Windsor	1200	85
Woodstock	1200	85

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

Most of us think that the NWS and non-NWS databases are of comparable value and both should be used when developing ground snow loads.

The "all values" plot provides a good indication of the "correct" answer in most cases, but in a few cases it is not a very good indication. Thus, simply using the "all values" answer is not recommended.

The three structural engineers involved chose to somewhat modify the analytical procedure developed by CRREL, each in his own way. Nonetheless, when coupled with our anonymous feedback process, it was easy for us to reach a consensus in almost all cases.

Stations with P_g/P_{max} ratios greater than about 1.5 were given little weight and those with ratios above about 1.7 were largely discounted in our analysis. We determined that the log-normal distribution does a poor job of predicting extreme values for such stations. Stations with P_g/P_{max} ratios less than about 0.9 appear to create similar problems.

An elevation correction factor of 2.1 lb/ft^2 per 100 ft (0.33 kN/m^2 per 100 m) works well for New Hampshire to an elevation of about 2500 ft (about 762 m). This factor may increase at higher elevations. It should not be assumed to apply in other parts of the country.

Based on what we learned by conducting the 140 case studies in the CS zone, we think it is important to do case studies for the 102 New Hampshire towns not in that zone. We will begin that work in the near future.

The case study process involves a more detailed examination of an area than was achieved some years ago when the national snow load map was made by two of us. Thus, the case study process, in all likelihood, produces a more accurate ground snow load.

In "CS" areas on the national map, case studies are required. In other areas where mapped values have elevation limits or change rapidly within short distances, case studies are recommended.

8 ACKNOWLEDGEMENTS

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