AUTOMATED DATA ACQUISITION FOR STRUCTURAL SNOW LOADS

Ronald L. Sack, George G. Burke and Kent J. Penningroth

Department of Civil Engineering
University of Idaho
Moscow, Idaho 83843

ABSTRACT

Snow loads on flat roofs are affected by local conditions, as well as the roof geometry, wind exposure and building thermal properties. Snow loads for sloped roofs are influenced by roof slope and surface. The ground-to-roof conversion factors C_t (thermal) and C_s (slope) proposed by American National Standards Institute (ANSI) are examined. Heat flux and temperature data for a structure with four distinct thermal environments were combined with National Weather Service data and snow core samples from the roof and ground to obtain C_t. Strain gage readings, temperatures and snow cores were obtained for a cluster of six small roofs to obtain C_s. All transducers were continuously monitored using two data acquisition systems, and each site computer transmitted its data daily to a central computer. Results from the study indicate that ANSI recommends unrealistic low values for C_t and higher than actual values for C_s.

INTRODUCTION

Snow loading is the governing criterion for roof design in many regions of the United States. This is of concern to engineers charged with the public welfare and performance of buildings. The problem is complicated by the paucity of data that exists for calculating roof snow loads for a specific structure, given the ground snow load. Snow melt from buildings due to heat loss and shedding of snow from slippery sloped roofs are two significant influences that require additional field data for better predictive capabilities. Examination of any single factor affecting roof snow loads requires that only the one parameter being examined should be varied and its effect measure directly. This is now possible with reliable transducers, sophisticated data acquisition systems and the development of hardware/software for data transmission from remote sites.

FACTORS AFFECTING ROOF SNOW LOADS

The snow load on a building is influenced by the basic ground snow load for the site, plus the depth and density of snow on the roof. The snow mass on the roof is dependent upon the building geometry and roofing material, in addition to factors influencing snow melt such as long wave radiation, absorbed solar radiation, convective melt from the air, condensation and/or sublimation, heat flux of the building, and the heat content of rainfall.

One method for calculating structural snow loads consists of multiplying the ground snow load by a coefficient that reflects both the building shape and other effects such as wind exposure. This approach was initially suggested by the National Research Council of Canada, and these ground-to-roof conversion factors were obtained from an extensive investigation involving field observations, practical experience and engineering judgement. The results of this study are contained in the present National Building Code of Canada. The American National Standards Institute used these same conversion factors in their 1972 standard (ANSI.1-1972). In the snow load criteria for Alaska, it is suggested that snow loads on roofs are affected by local winds and temperatures, the exposure of the roof to wind, as well as the roof's thermal characteristics and geometry (Tobiasson and Redfield, 1973). The authors proposed that the basic roof snow load be obtained by multiplying the ground snow load by three dimensionless coefficients; one each for regional, building thermal, and exposure effects.

Proceedings, Eastern Snow Conference, V. 29, 41st Annual Meeting, Washington, D.C., June 7-8, 1984

In 1975 the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) initiated a study of roof snow loads at eight locations across the country. Data for 199 structures were accumulated for three winters beginning with 1975-76 in the states of Colorado, Idaho, Michigan, New York, Oregon and South Dakota. Analysis of the data (O'Rourke and Redfield, 1980) indicated that the range of values for the exposure coefficient in the Alaska study was reasonable; however, it failed to provide concise information about the effects of building thermal characteristics and slope. Seventy five percent of the roofs were in only one of the four thermal categories; furthermore, only 20 percent of the structures had slopes greater than 30 percent which is the geometry where slope effects can become significant.

SNOW LOADS USING ANSI A58.1-1982

In 1978 ANSI established a snow load subcommittee with membership from the industrial, governmental and academic communities to study and formulate recommendations for a revised standard (ANSI A58.1-1982). This subcommittee used the Alaska study and the CRREL information as a data base and recommended that the roof snow load on an unobstructed flat roof for the contiguous United States to be

$$p_f = 0.7C_eC_tIp_g \qquad (1a)$$

and for Alaska

$$p_f = 0.6C_eC_tIp_g \qquad (1b)$$

where p_f is the flat-roof design snow load and p_g the site-specific ground snow load. The values for the dimensionless factors C_e (exposure) and C_t (thermal) are presented in Tables 1 and 2, respectively.

Table 1

Exposure Factor, C_e From ANSI A58.1-1982

Site Description	C_e
Windy with roof exposed on all sides and no shelter afforded by terrain, etc.	0.8
Windy with little shelter	0.9
Discontinuous snow removal by wind because of terrain, etc.	1.0
Little wind with terrain, etc. to shelter roof	1.1
Densely forested with little wind, and roof located in among conifers	1.2

Table 2

Thermal Factor, C_t From ANSI A58.1-1982

Thermal Condition of Structure	C_t
Heated	1.0
Heated just above freezing	1.1
Unheated	1.2

The building importance factor, I, is included as a multiplier of p_g so that different mean recurrence intervals (mri) can be used. Thus, agriculture buildings are designed for a mri of 25 years (I = 0.8), essential facilities for a mri of 100 years (I = 1.2), buildings with more than 300 people in one area use I = 1.1, and all other structures are to be based on a mri of 50 years (I = 1.0). The fact that snow is not totally retained on a sloped roof is accounted for by computing the sloped roof snow load, p_s, as follows:

$$p_s = C_s p_f \tag{2}$$

where the roof slope factors C_s, are shown in Table 3. In addition, values of C_s for various roof configurations, e.g., curved and vaulted, are also prescribed. Procedures are also described for calculating the effects of unloaded roof portions, unbalanced snow load, drifting snow, sliding snow, and the additional load from rain on snow.

Table 3

Roof Slope Factors (C_s)

Surface	Warm Roofs (C_t = 1.0) Slope (θ)	 C_s	Cold Roofs (C_t > 1.0) Slope (θ)	 C_s
	0°-15°	1.0	0°-30°	1.0
Slippery	15°-70°	1.0-(θ-15°)/55°	30°-70°	1.0-(θ-30°)/40°
	> 70°	0	> 70°	0
All	0°-30°	1.0	0°-45°	1.0
Others	30°-70°	1.0-(θ-30°)/40°	45°-70°	1.0-(θ-45°)/35°
	> 70°	0	> 70°	0

FIELD INVESTIGATION OF BUILDING THERMAL EFFECTS

A study was carried out by the University of Idaho during the winters of 1982-83 and 1983-84 to examine the thermal factor C_t (see Eq. 1). A test structure was identified in deep-snow country that had multiple thermal environments so that building thermal effects could be measured independently of other factors such as wind and roof slope. The single-story building is approximately 18 by 53 m, with a roof 4 by 18 m protruding over an open loading dock (see Fig. 1). The test structure is situated in a relatively sheltered location surrounded by coniferous trees and other buildings so that the roof and ground snow experience the same wind and convection environments. That is C_e = 1.0 from Eq. (1).

Building - The structure is a warehouse which has a nominally flat roof sloping downward 0.01 from west to east. The north 20 m are used as an office and staging area with the temperature maintained higher than in the south 33 m, where equipment is stored. In one bay of the heated area, 230 mm of fiberglass insulation was installed. Thus, in one building we have four thermal roof environments: (1) the heated and newly insulated area (bay 1); (2) the heated office area (bay 2); (3) the warehouse area with low heat (bay 3); and (4) the outside dock roof which is unheated (overhang). Between the two winter seasons investigated, the entire warehouse was fitted with a suspended ceiling and a uniform layer of 250 mm of fiberglass insulation. This new configuration still has four distinct thermal environments as before; however, with the exception of the overhang, they have thermal properties that are different from those for the winter of 1982-83. The characteristics of the building for the two winter seasons are summarized in Table 4.

Climatology - The test structure is located in McCall, Idaho (Sec. 8 and 9; T18N; R3E; elev. 1532 m), which is situated at the south end of Payette Lake and is flanked by the north-south-trending mountains of the Payette-Salmon Divide (elev. 1525 m to 2745 m). The area receives 3.36 m of snow annually with an average water content of 340 mm (Rice, 1970), and the average maximum ground snow depth is 1.10 m. The maximum expected ground snow depth with a 50 year recurrence interval for the area is 1.90 m with a water content of 733 mm (Sack, Sheikh-Taheri, 1984), and the regional wind speed with a 50 year recurrence interval is 44 km/h (Smith, 1980). The climatological statistics for the two test winters are shown in Table 5.

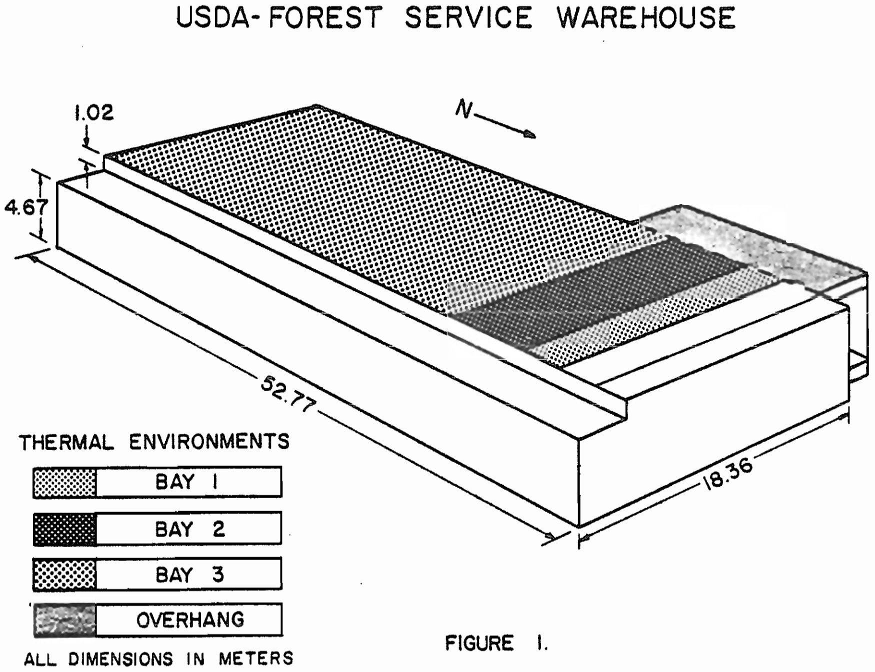


FIGURE 1.

Table 4

Summary of Building Thermal Environments

Property	Year	Bay 1	Bay 2	Bay 3	Overhang
R	82-83	6.15	0.87	0.87	0.87
(°C•m^2/W)§	83-84	12.37	7.08	7.08	0.87
Inside					
Temp	82-83	18	18	14	*
(°C)†	83-84	19	18	16	*
Heat					
Flux	82-83	4.728	14.848	8.985	0
(W/m^2)‡	83-84	3.105	3.174	1.711	0

*Outside air temperature

§ 1°F•hr•ft^2/BTU = 0.1761°C•m^2/w

† °F = (9/5)°C + 32

‡ 1 BTU/ft^2•hr = 3.5125 W/m^2

Note: Mean values given for
12/29/82 - 3/11/83 (82-83)
1/21/84 - 3/11/84 (82-83)

Table 5

Weather Statistics for McCall, Idaho

Period	Total Snow Depth (m)	Total Snow Water Equiv.(mm)	Max. Ground (m) Snow Depth	Temperature (°C) Min.	Temperature (°C) Max.	Temperature (°C) Mean	Mean Wind Speed (km/h)
11/82-3/11/83	3.09	440	1.14	-23	+13	-1	2.82
12/1/83-3/11/84	2.97	289	1.19	-35	+9	-6	3.07

Instrumentation - A bay in thermal environments 1, 2, and 3 were instrumented as follows: three copper-constantan thermocouples placed at the top, middle and bottom of the 1-m deep beams for air temperature; square (114 mm) heat flux transducers (Thermonetrics Corp., Model H11-18-1-SHF, series S418) placed on the ceiling near the center of each monitored bay. An additional copper-constantan thermocouple was placed outside the building on a beam underneath the overhang for outside temperature. Copper-constantan thermocouples were also placed on the roof in bays 1, 2 and 3 to monitor roof-snow interface temperatures. Wind speed and direction were monitored using a Weathertronics Model 2112 Stratavane wind sensor mounted on a 4.57-m tower attached to the roof. All transducers were continuously monitored by a Hewlett Packard Model HP3497/HP85 data acquisition system located inside the building. All the instruments were read every five minutes, and these point readings were averaged over a six-hour period. The mean and standard deviation were computed for each transducer for each six-hour period.

During the first winter the six-hour averages were recorded on magnetic tape by the HP 85F computer Since the test site is approximately 300 km from the university campus in Moscow, we decided to eliminate unnecessary travel and optimize data acquisition by installing a data link. This was used to transmit data from the test site to campus and allow prompt detection of malfunctioning transducers. The HP 85F computer was fitted with an HP82939A serial interface which was connected to a Hayes 1200 Smartmodem. A Hayes 1200B Smartmodem which plugged directly into the IBM PC, was used for the campus-end of the link. This is functionally equivalent to the Hayes 1200 Smartmodem connected to an IBM asynchronous communications adapter. These modems operate automatically and switch to match the transfer rate of the incoming signal. Thus, it was the HP serial interface, set at 1200 baud which actually established the basic transfer rate for the system. The modem in McCall was totally controlled by the computer program which provided setup parameters, dial commands and telephone numbers. Because of telephone company requirements, pulse dialing was used.

Typically, the normal data-gathering task of the system was interrupted once a day when the computer would initiate a call to Moscow. In succession, the HP 85F computer would: (1) halt data acquisition; (2) rewind the data tape; (3) reset the modem; (4) issue a dial command with the phone number to the modem; (5) wait for a period of time sufficient to allow the telephone switching equipment to complete the connecting and (6) transmit all the data from the tape to campus. At the end of the data transmission the computer would issue a command to the modem to hang up and then continue with the task of gathering data.

The Hayes 1200B used in Moscow comes with the Smartcom software package which is designed to give the user access to various information services (e.g., Telenet and Dow Jones) and provide for transmission and reception of files once the link has been established. The features of Smartcom were designed assuming an operator is present at the keyboard during the session; however, it would have suited our purposes better if unattended operation were possible and the software for communications made more general. We intend to write custom software for the Smartmodem 1200B that will permit unattended operation before the next snow season, and this new software will also provide for initiation of calls from the Moscow end so that the remote site computer status can be conveniently queried.

An additional problem we encountered with the data link was the propensity of the free-standing Hayes modem at the remote site to periodically "lockup" and become incapable of following the instructions from the controller. The modem is enclosed in an aluminum box with no ventilation which sometimes caused the unit to overheat. Since this installation is unattended the problem was solved by adding a timer to the power line feeding the modem, and keeping the power off until just before it is time for the computer to start the transmission sequence.

Data Base for Thermal Study - Daily records of depth and water content of the newly fallen snow, depth of snow on the ground, cloud cover at the time of the precipitation readings and a continuous record of relative humidity were obtained from the McCall National Weather Service (NWS) station No. 10 5708-4. The site where these data were obtained is approximately 30 m from the test structure. Daily water content for the precipitation was distributed over the four six-hour periods according to the times reported by NWS. Using the procedures outlined by Linsley et al (1975), the atmospheric vapor pressure and dew point were estimated by combining the average six-hour readings for relative humidity with the average outside air temperature at the building test site. The cloud cover for the entire day was assumed to be the same as that reported at the time of the precipitation readings (1800 mst).

Snow core samples were taken from the ground and the roof at each of the four thermal

Figure 2 ; WATER CONTENT : BAY 1 - GROUND

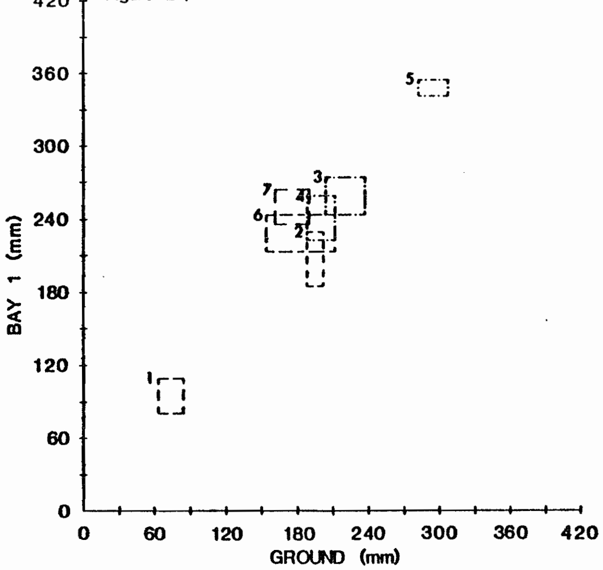


Figure 3 ; WATER CONTENT : BAY 2 - GROUND

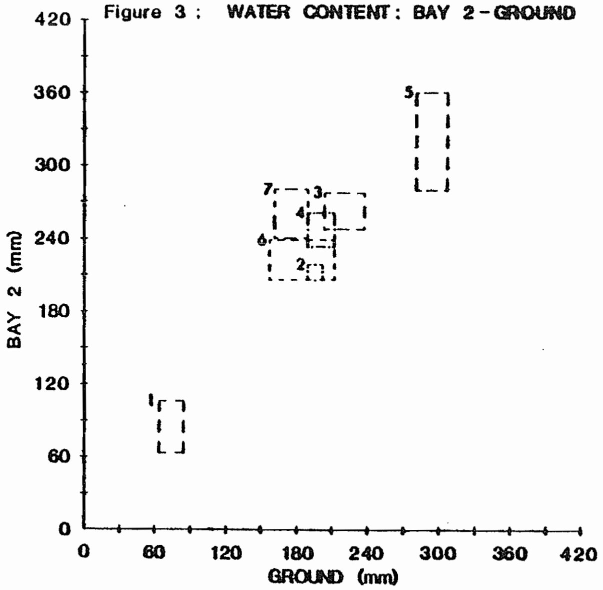


Figure 4 ; WATER CONTENT: BAY 3 - GROUND

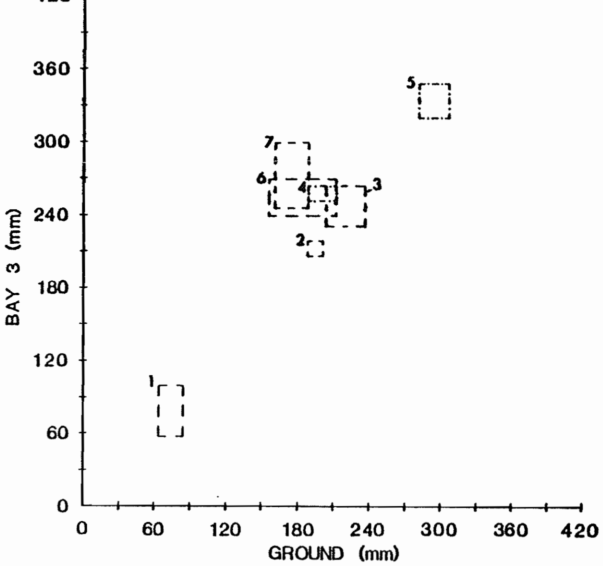
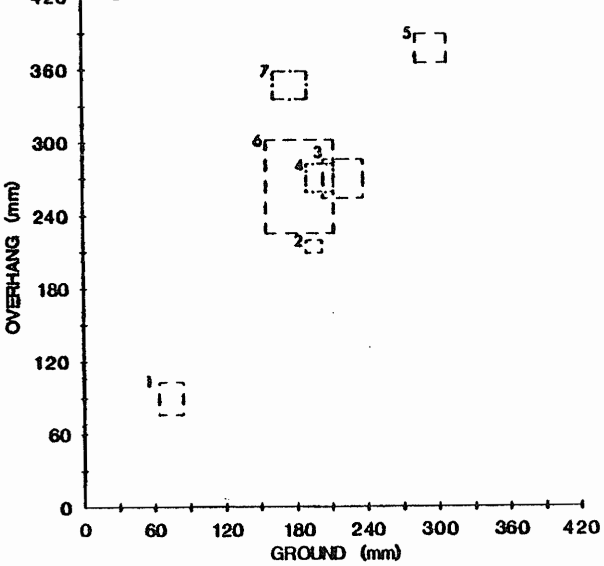


Figure 5 ; WATER CONTENT: OVERHANG - GROUND



environments to determine the snow depth, water content and density. This was done five times during the 1982-83 winter and seven times for the 1983-84 test period. At each sampling location, six vertical core samples were taken from a 0.30-m square using a Mt. Rose snow sampler. Standard data reduction procedures were used. The mean, standard deviation, standard error of the mean, and the 95 percent confidence interval for the standard error of the mean were calculated for each parameter for the aggregate of the six samples at each location.

Analysis of Thermal Data - The water content data for the four thermal environments are plotted against the ground water content to determine the ground-to-roof snow load ratio (e.g., Figs. 2 through 5). For the 1982-83 study a snow-melt model was used to predict roof water content using a combination of measured and calculated quantities (Sack and Inverso, 1983). With this approach it is possible to follow snow accumulation and depletion and note the ground-to-roof snow load ratio. For purposes of design, however, the ratio of maximum roof load to maximum ground snow load is a better indicator of critical loading. Therefore, this is the approach taken herein, and the results from both the 82-83 and 83-84 studies are shown in Table 6.

FIELD INVESTIGATION OF ROOF SLOPE EFFECTS

During the winter of 1983-84 a field investigation was initiated to study the effects of sliding on roof snow loads. This was motivated by the paucity of data on the subject and the structural economies that could conceivably be realized if roofs shed more snow than is predicted by the roof slope factors suggested by ANSI A58.1-1982 (see Table 3). The objective of this study was to examine the conditions under which cold roofs with a slippery surface predictably shed snow. The roof slope effect was to be measured independently of all other factors that affect roof snow loads. Six test structures were erected on a flat area, approximately 100 m square and protected from the wind by the surrounding coniferous trees. Thus, uniform snow deposition was assured and since this test site is about 400 m to the south of the thermal study, the meteorological data from the ware house can be used as an indication of conditions at the roof slope site.

Table 6

Summary of Critical Parameters - Thermal Study

Property	Year	Bay 1	Bay 2	Bay 3	Overhang
Heat Flux (W/m^2)	82-83	4.728	14.848	8.985	0
	83-84	3.073	3.134	1.744	0
C_{rgl}†	82-83	0.94	0.29	0.54	1.21
	83-84	1.18	1.09	1.14	1.28
C_t‡	82-83	1.34	0.41	0.77	1.73
	83-84	1.69	1.56	1.63	1.82

† $C_{rgl} = (\text{roof})_{max}/(\text{ground})_{max}$

‡ $C_t = C_{rgl}/0.70$ for contiguous United States (see Eq. 1)

Description of Roofs - A cluster of six small roofs were grouped together at the site to insure similar deposition and exposure conditions. Roof slopes of 10°, 30° and 45° were selected. Two roofs of each slope were constructed, and these were located with one roof facing north and its equal-slope companion facing south. Thus, the effects of solar radiation on sliding could be isolated. The dimensions of the roofs were those suggested by Taylor (1980) to mitigate any snow deposition edge effects. The structures were built sufficiently high so that sliding would not be impaired by the ground snow, and the underside of the roofs were covered with plywood and painted white to minimize any effects of solar heating. Details of the design are shown in Fig. 6. The basic study of Hoehner (1983) on surface roughness of various metal roofs suggested that "high rib Steelco roof" with a brown polyceram 3100 Whittaker coating is optimal for shedding the snow; this material was fastened to all roof surfaces with standard metal roof screws.

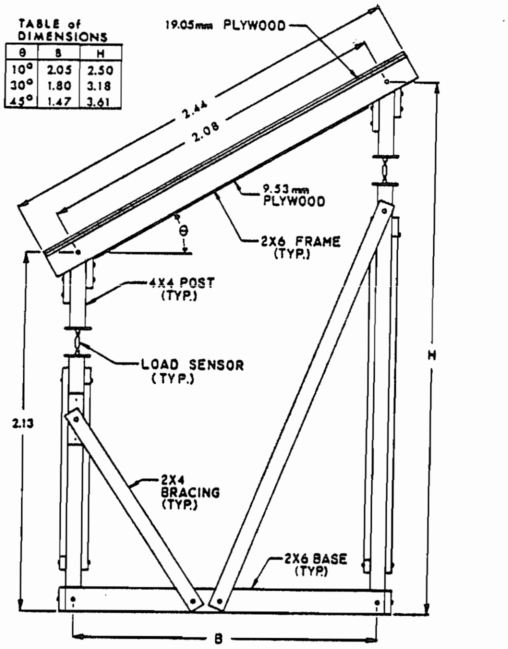


TABLE of DIMENSIONS

θ	B	H
10°	2.05	2.50
30°	1.80	3.18
45°	1.47	3.61

(EXCEPT WHERE INDICATED. DIMENSIONS ARE IN METERS)

FIGURE 6
SNOW LOAD
TEST UNIT
(SIDE VIEW)

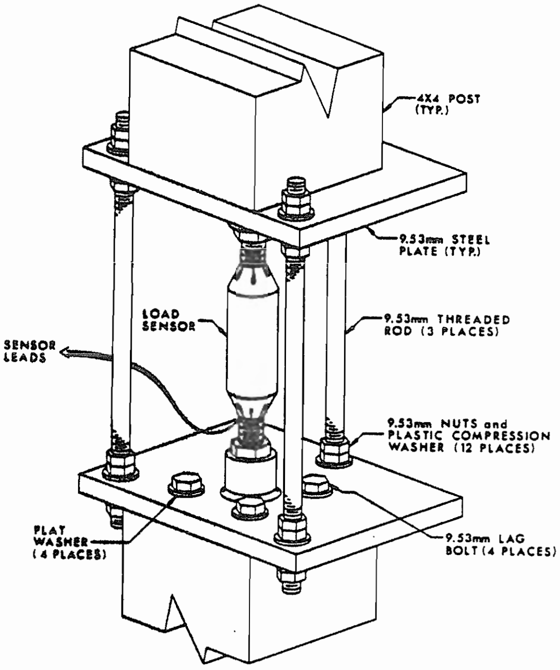


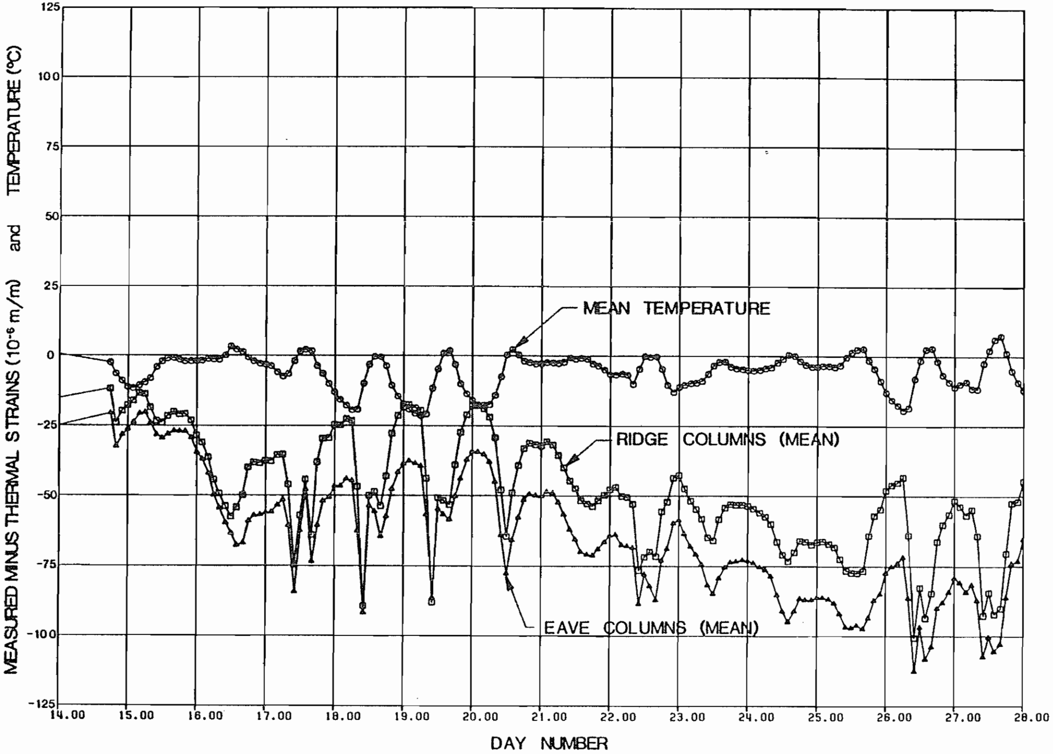
FIGURE 7
LOAD SENSOR
PICTORIAL

Instrumentation - A load sensor (Fig. 7) was fitted to each post of the roofs as shown in Fig. 6. The strain sustained by the sensor is measured by two Micro-Measurements type CEA-13-250UW-350 strain gages, affixed to a 2024-T4 aluminum rod with a diameter of 127 mm. These gages were located on diametrically opposite sides of the rod and wired into opposite legs of the Wheatstone bridge in order to cancel bending and give double the axial strain in the rod. Unfortunately, this arrangement also gives a sensor that is doubly sensitive to thermal strains. Two stress-free load sensors, identical to the other 24 active load sensors were positioned on the undersides of two of the roofs to allow a correction for thermal strains. In addition, a copper-constantan thermocouple was installed near the peak of both 10° roofs and another on the south 30° roof.

All transducers were continuously monitored by a Hewlett Packard Model HP3497/HP85 data acquisition system located in a heated building approximately 30 m to the east of the roofs. All strain gages were connected to shielded cable which was buried underground in a 49 mm PVC pipe. All gages and outside connections were thoroughly waterproofed and protected from the elements. All the instruments were read every five minutes, and these point readings were averaged over a two-hour period. The mean and standard deviation were computed for the instruments for each two-hour period. This data acquisition system was linked to campus by a data transmission system identical to that at the warehouse, and once each day the system would transmit its data to the IBM PC computer at the University of Idaho.

Analysis of Roof Slope Data - The strain for one of the stress-free load sensors was plotted against temperature. Ideally, the slope of this straight line should be identical to that obtained if each of the active load sensors are plotted against temperature during those times when the roofs are free from snow. This was not the case; therefore, the slope of the line for the stress-free gage was divided by the slope of the line for each sensor when the roof is without snow. This gave a thermal correction factor for each of the active load sensors (near, but different from 1.0) to be used to obtain the thermal strain for each sensor. The corrected thermal strains for each sensor were subtracted from the recorded strains to give the strains experienced by the sensors. The average of the two ridge posts and the average for the two eave posts for the south 10° roof, along with the air temperature, are shown in Fig. 8. One would expect that any change in the slope of these sensor curves would represent loading or unloading of the roof; however, visual observations do not verify that there was as much activity as this plot implies. There are only three thermocouples for the entire cluster of 16 load sensors; therefore, if all gages are not at the same temperature, this could give erroneous results. It can be shown that a 1°C change in temperature corresponds to a change in load of 64 N on the entire roof, which is approximately 40 mm of snow distributed uniformly over the roof. This explains why there are significant peaks in Fig. 8 near the times of 1000, 1200 and 1400 on sunny days. For this reason, it was decided to use only night values where all temperatures are equalized in the sensors.

FIGURE 8 **RESPONSE of SENSORS (10° SOUTH ROOF)**



The loads on the roofs were calculated by first inspecting the corrected strains (e.g., Fig. 8) during the night hours and locating reference readings during those nights when we know from visual observations that the roofs have no snow on them. These reference readings were subtracted from the strains on other nights with approximately the same temperature to give loads on the roof. The results of this type of inspection for the south 10° roof are shown in Fig.9, along with ground snow depths and daily maximum temperatures. From plots such as this we can follow the increase and decrease of loads on the roofs. Note that it must be relatively warm for it to snow; thus, an increase in temperature may not result in sliding, but may give an increased snow load on the roof. Using a plot of composite results (e.g., Fig. 9) for each of the roofs, the maximum roof snow load was obtained and the ratio of maximum roof snow to maximum ground snow calculated. These results are presented in Table 7.

DISCUSSION

The results of the thermal investigation clearly indicate that the snow load on a building is dependent upon the amount of heat loss through the roof of the structure. Data were collected during the first winter when the building was relatively uninsulated and compared to data for a second winter after the building was uniformly insulated. ANSI

A58.1-1982 predicts (Table 2) a value of $C_t = 1.0$ for bays 1, 2 and 3 and $C_t = 1.2$ for the overhang. These values apply equally for either the insulated or uninsulated configuration of the building. From Table 6 we observe that in all cases the measured values of C_t are much greater than the suggested design values, and C_t is dependent upon heat flux. In light of these results it appears that a heated structure should be designed using C_t

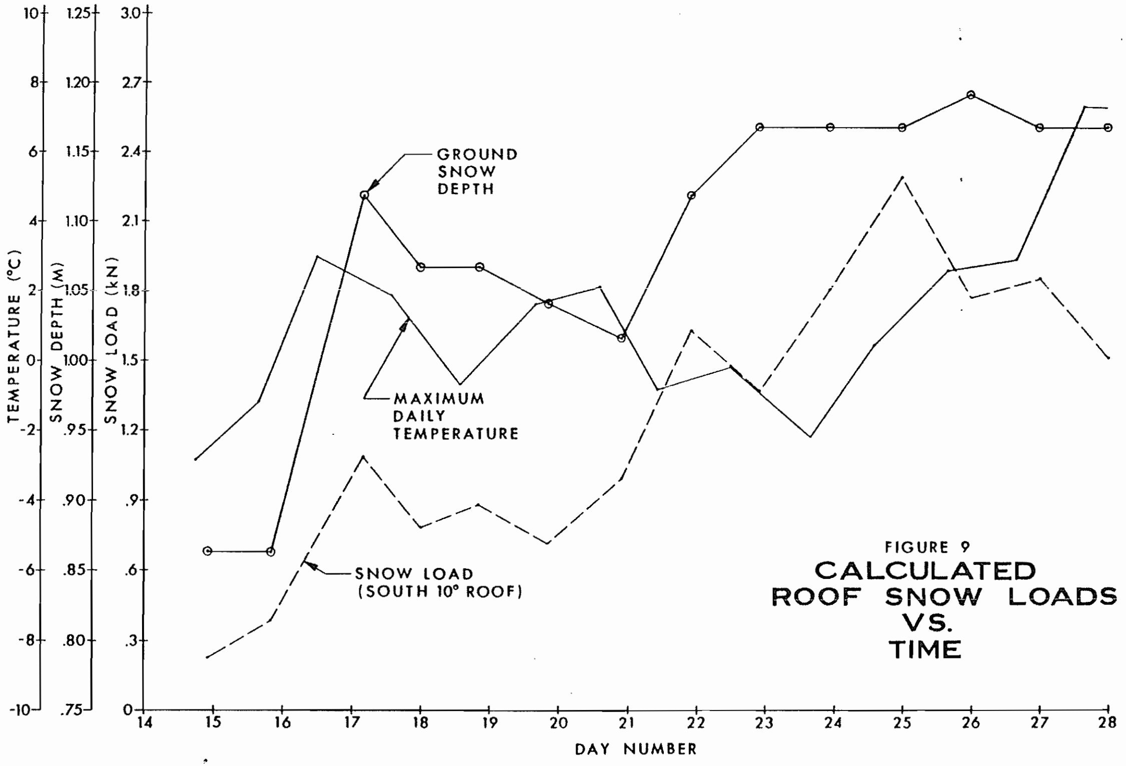


FIGURE 9
CALCULATED ROOF SNOW LOADS VS. TIME

Table 7

Summary of Critical Parameters - Roof Slope Study

Roof	10°		30°		45°	
Parameter	North	South	North	South	North	South
C_{rg2}†	0.183	0.125	0.258	0.083	0.102	0.086
C_s‡	0.22	0.15	0.31	0.10	0.12	0.10

†$C_{rg2} = (\text{roof})_{\max}/(\text{ground})_{\max}$

‡$C_s = C_{rg2}/0.84$ for contiguous United States (see Eqs. 1 and 2)

greater than 1.0, depending upon building thermal conditions. Furthermore, values of C_t for a heated, but well insulated structure, approach those for an unheated building and can be significantly greater than the value of 1.2 given by the standard.

From the roof slope study we can conclude that considerable savings can be obtained by recognizing that snow will slide from cold roofs with slippery surfaces with slopes as low as 10°. The suggestions from ANSI A58.1-1982 in Table 3 give values of C_s equal to 1.0, 1.0 and 0.625 for the 10°, 30° and 45° roofs, respectively. The measured values in Table 7 show that the design values greatly overpredict the amount of snow that actually accumulates on these roofs.

Ground-to-roof conversion factors predicted by this study were obtained for a region with large amounts of snow accumulated over a period of five to six months. In regions such as this where a permanent winter snowpack exists, a substantial amount of the roof snow may melt or slide between snow storms. Roof and ground snow depositions can be influenced by various regional climatic factors not included in this study, (e.g., ground snow pack may be affected by soil characteristics that influence infiltration and runoff). Therefore, in the absence of additional data it could be tenuous to extend the findings of this research to general situations.

ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Grants No. CEE-8109747 and CEE-8300465. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors extend their thanks to U.S.D.A.-Forest Service, Payette National Forest, McCall, Idaho for their cooperation in this study.

REFERENCES

American National Standards Institute, Inc., 1972, American National Standard Building Code Requirements for Minimum Design Loads for Buildings and Other Structures, ANSI A58.1-1972, New York.

American National Standards Institute, Inc., 1982, American National Standard Building Code Requirements for Minimum Design Loads for Buildings and Other Structures, ANSI A58.1-1982, New York.

Hoehner, M. G., 1983, "Influence of Metal Cladding on Snow Sliding," Master of Science Thesis, Dept. of Civil Engineering, Univ. of Idaho, Moscow, Idaho.

Linsley, R. K., M. A. Kohlev and J. L. H. Paulhus, 1975, Hydrology for Engineers, 2nd edition, McGraw-Hill, New York.

McGuinness, W. J., B. Stein and J. S. Reynolds, 1980, Mechanical and Electrical Equipment for Buildings, 6th edition, Wiley.

O'Rourke, M. J., and R. Redfield, 1980, Analysis of Roof Snow Load Case Studies: Uniform Loads, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

Rice, K., 1970, "Narrative Description of Climatology of McCall, Idaho," NOAA unpublished report, National Weather Service, Boise, Idaho.

Sack, R. L. and G. Inverso, 1983, "Structural Snow Loads," Proceedings of the Western Snow Conference, paper #735-83, pp. 120-129, Vancouver, Washington.

Sack, R. L. and A. Sheikh-Taheri, 1984, "Ground Snow Loads for Idaho," Eastern Snow Conference, Wash., D.C.

Smith, W. B., 1980, "The Idaho Wind Environment and Structural Design Considerations," Master of Science Thesis, Dept. of Civil Engineering, Univ. of Idaho, Moscow, Idaho.

Taylor, D. A., 1980, "Roof Snow Loads in Canada," Canadian Journal of Civil Engineering, Vol. 7, No.1, pp. 1-18.

Tobiasson, W. and R. Redfield, 1973, "Alaska Snow Loads," 24th Alaskan Science Conference, Fairbanks, Alaska.