AN APPROACH TO SNOW LOAD EVALUATION

By

John Webster Brown 1/

Introduction

During recent years there has been a tremendous increase in construction in areas receiving heavy snow loads. This is due in part to the interest in winter sports, but is probably more largely due to the affluence of our society coupled with more leisure time and a technical ability to provide convenient year round access to such locations. The economic value of the construction investments in snow country dictates a need for rational guidance in snow load values for the public welfare.

In 1963 Washoe County, Nevada, requested the Author to conduct a study and prepare recommendations for an interim snow load code for the Lake Tahoe and mountainous parts of the County. The recommendations were presented in March of 1964 and an ordinance containing them in a snow load code was subsequently adopted.

Background

It is recognized that there are many variables to be evaluated in the development of the loads that should be used as a representation of the snow on the roof of buildings and structures. These can perhaps be evaluated through a long term research program and at sometime in the future it may be possible to determine which of these are of the most significance. At the present time there is insufficient information available as to the correlation of the snow loading on the ground versus the snow loading on adjacent roofs. Also, there is not enough data developed to correlate the snow loadings occurring on roofs with various pitches and with roofs of different surfacing materials. It is obvious that large differences in loadings occur by virtue of different exposures to sun and wind.

An inspection of the existing snow survey courses, which have been developed primarily for the prediction of runoff, shows that they are not generally located in places that will yield the greatest advantage in analyzing snow loads on buildings and structures. It is particularly significant that there was a definite lack of sufficient snow survey courses at the lower elevations in the Lake Tahoe Basin.

1964 Washoe County Snow Load Code

Due to the lack of finite information, it was decided to establish the interim loadings as a function of the anticipated maximum snow loading on the ground. In order to approximate the maximum snow loadings on the ground at various locations and at different elevations, two approaches were made. The first of these is based on projections of the snow loading on the ground derived from the existing snow survey courses which are read on February 1, March 1 and April 1 of each year. The second method used was to determine the approximate snow loadings on the ground as a function of the annual average precipitation. The correlation between these two methods is not too divergent considering the base information available.

A graph of snow loading versus elevation above sea level was plotted for all snow survey courses in the Lake Tahoe Basin, the Truckee Basin, a few stations in the Carson River Basin, and a few stations that are tributary to the California water sheds on the west slope of the Sierras. This graph shows extreme scattering and very little correlation is possible. Three additional graphs were plotted for individual areas. One is for the east mountain areas which occur on the eastern slopes of the range east of the Tahoe Basin. The second of these is for the Tahoe Basin itself, and the third of these is for the west mountain area which would be the eastern slope of the range west of the Tahoe Basin. (Refer Plate 1) These three independent graphs of snow load versus elevation do show a fairly good correlation and it is believed that a rational evaluation can be made with them. For the purpose of arriving at the snow loadings for various elevations a

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straight line fitting curve was used. This straight line fitting curve gives satisfactory results in the lower elevations; however, it may give slightly higher results than occur at the higher elevations. Perhaps it would have been better to use a curve which flattens out somewhat above 8,000 feet; however, it is not believed that such a refinement is justified at this time.

The U. S. Army Corps of Engineers derived a map showing contours of normal annual precipitation for the Sierra areas under consideration in this report as a part of their studies in connection with the Washoe project. This map is shown as Chart No. 4 in the Appendixes of "Interim Survey Report for Flood Control Reno Area Truckee River and Tributaries", dated 1 March 1960. (Refer Plate 2) With the aid of this map, cross sections were drawn in various locations across the Sierras in the regions of Washoe County which relate normal annual precipitation to elevation. Since the normal annual precipitation is for the entire year, it was necessary to approximate the amount of this annual precipitation that would be cumulative in a snow pack. The above mentioned Appendixes indicate that approximately 86% of the annual precipitation occurs in the November to April period of time. Therefore, the 1964 Washoe County study has assumed that 86% of the normal annual precipitation will be in the snow pack and will be a measure of the snow loading. In the normal and light snow years this 86% of annual will be too high for an indication of the snow pack; however, in the maximum snow years it is believed that this 86% is not out of line. In order to relate the maximum years of snow fall to the normal annual precipitation, the ratio of long term normal [1] water equivalent to the maximum water equivalent as shown by the existing snow survey courses was used. In the elevations below 8,000 feet the maximum snow loadings from the snow survey courses are approximately 200% of the long term normals. Above 8,000 feet the maximum snow loadings are approximately 161% of the long term normals. Using the above set forth correlations, curves were drawn with snow load versus elevation to plot the loadings derived from normal annual precipitation. These curves show a reasonable consistency and compare favorably with the loads derived from the existing snow survey course data.

In order to arrive at the recommended design snow loading on roofs, it was felt that 70% of the maximum snow loadings occurring would be satisfactory for safe construction. Of the normal building construction materials used, structural steel has the least factor of safety. This factor of safety is normally considered to be 1.65. By using 70% of the maximum snow loadings it would indicate that the stresses in structural steel would be approximately 1.43 times the normal allowable stresses. This would leave about a 22% margin to failure.

In order to illustrate the frequency of occurrence of the design snow loads, a graph showing maximum snow load for the year versus the year of occurrence was plotted for several snow courses. (Refer Plate 3 for example) Also plotted on this graph were horizontal lines showing the value of long term normal snow loads together with the value of 70% of the maximum snow load (approximate proposed code value) of record. These graphs indicate that the occurrence of the 70% value is quite frequent even though the maximum recorded value is approached fairly infrequently.

As was previously stated, during the preparation of this report the lack of low level snow survey courses in the Tahoe Basin became evident. On March 13, 1964, the Author and Mr. Manes Barton, Snow Survey Supervisor of the Soil Conservation Service in Reno, Nevada, set six new snow survey courses in the Tahoe Basin. Since 1964 these six new snow courses have been surveyed each year. To date the correlation of the measurements with the established code values has been satisfactory.

The snow loadings recommended by the Washoe County Code have been tabulated (Refer Appendix) with loading versus elevations above sea level with a column for the Lake Tahoe Basin and a column for the remainder of Washoe County (exclusive of the Tahoe Basin). In addition to the table, there is set forth a list of items that should be given consideration in the design of buildings and structures that are above 5,000 feet in elevation. Some credit is given to roof pitches by allowing the use of 80% of tabulated values for roofs having a pitch of between 6 in 12 and 12 in 12. Also 60% of tabulated values may be used with roofs having a pitch in excess of 12 in 12. Traditionally the literature has given credit for steeper roof pitches on the assumption that sliding can occur from them. In general it is the Author's opinion that there is no assurance that sliding will occur in the Sierra Nevada Range until sometime later in the season than the time of anticipated maximum snow load. Credit for the steeper roof pitches is given in the Washoe County Code

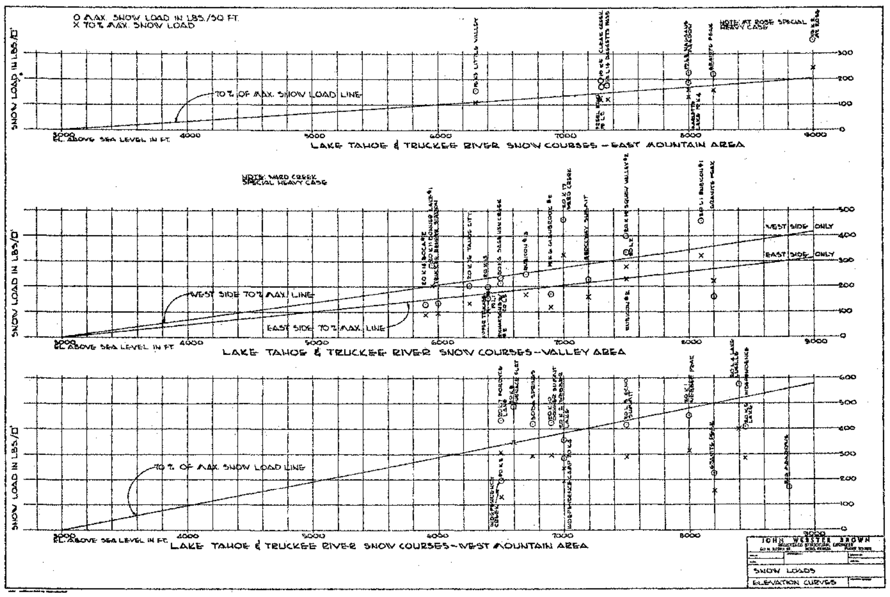

PLATE 1

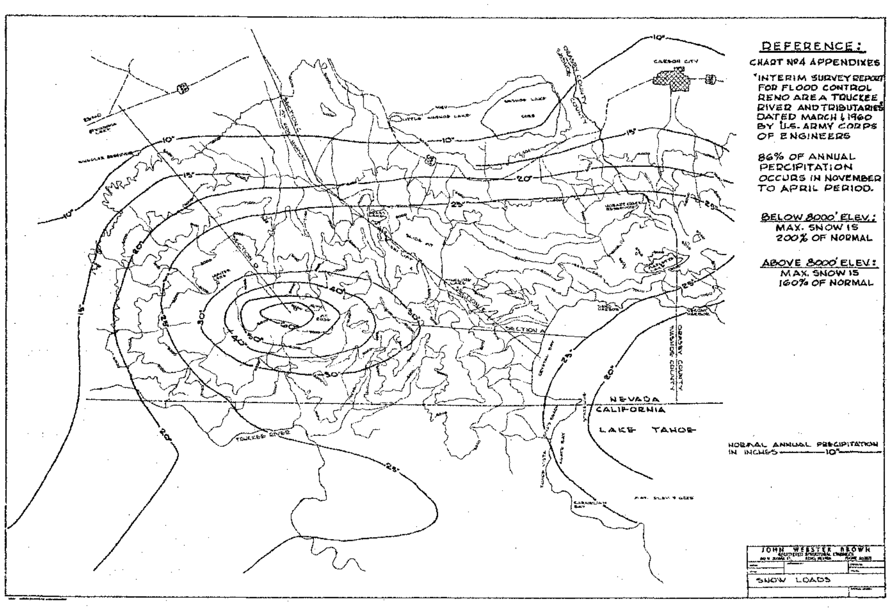

PLATE 2

based on the resulting increase in roof height above general snow level and increased exposure to the wind. In order to allow for special conditions of exposure and construction, it was recommended that deviations from the tabulated snow loadings may be permitted by the building official provided the snow load and conditions in each individual case are derived, and certified to by a registered structural engineer who can show proper experience in snow load evaluation.

Present State of Technology

It should be noted that the Washoe County snow load code was developed prior to the publication of the 1965 National Building Code of Canada [2] and prior to the writer's knowledge of the Canadian studies on the subject.

The Canadian Code uses 80% of the ground snow as a base value, with a reduction of this loading to 60% of the ground snow for roofs exposed to the wind. It appears that the Washoe County Code using 70% of ground snow compares favorably with the Canadian concept.

Shape factors for snow load distribution on various configurations of roofs are published for the first time in the Canadian Code of 1965. These factors represent a realistic representation of distributions that have been observed in many parts of the world.

The Writer has continued his studies of snow loads since 1964 and has developed another approach to the determination of base snow loads to be used in a given locality. This approach is based on the recurrence interval of snow loads of different magnitudes at the site under consideration. For years Civil Engineers have been setting the level of flood protection for various facilities on the basis of return frequencies of floods of different magnitudes. It seems reasonable that this analogy could be extended to the levels of protection against snow loads. A simple representation of return frequencies has been in common use and is shown by the formula as follows:

$$R = \frac{N + 1}{m}$$

where R is return frequency in years.
N is the number of years of record.
m is the order of magnitude of the value in the series.
(as an example: m = 3 for the value of snow load for the third heaviest year of record.)

Many more methods are available for the determination of return frequencies, but most of them are merely refinements that modify extreme values and deviations from the mean. The proposed formula gives results consistent with the reliability of the raw data if there are five or more years of record.

If the values calculated from the formula are plotted with snow load versus recurrence interval in years on a semilog sheet, a straight line fitting curve can be approximated. (Refer to Plate 4 for example) Then the snow load for any return frequency may be read from the curve. Plots of recurrence intervals for 11 long term snow survey courses in the vicinity of the Tahoe basin were made. From these curves it was found that the average recurrence interval of the maximum snow load of record at these 11 courses was 38 years and the average recurrence interval for 70% of maximum was 8 years. (refer appendix.) This indicates that while the maximum snow load of record may only occur once or twice during the life of a structure, 70% of maximum will occur many times.

Recommendations

The basic problem in either the Washoe Code or the Canadian Code approach is to determine the weight of the ground snow at the site. It is suggested that County and/or local agencies begin immediately to sample snow in urban areas and in areas in which development is expected. These new short term courses can be correlated to other similar courses in the region with longer periods of record by straight proportion with reasonable accuracy. If a similar long term course shows 40% of its maximum of record on the date of sampling, then the new course should show about 40% of its maximum load on the same date.

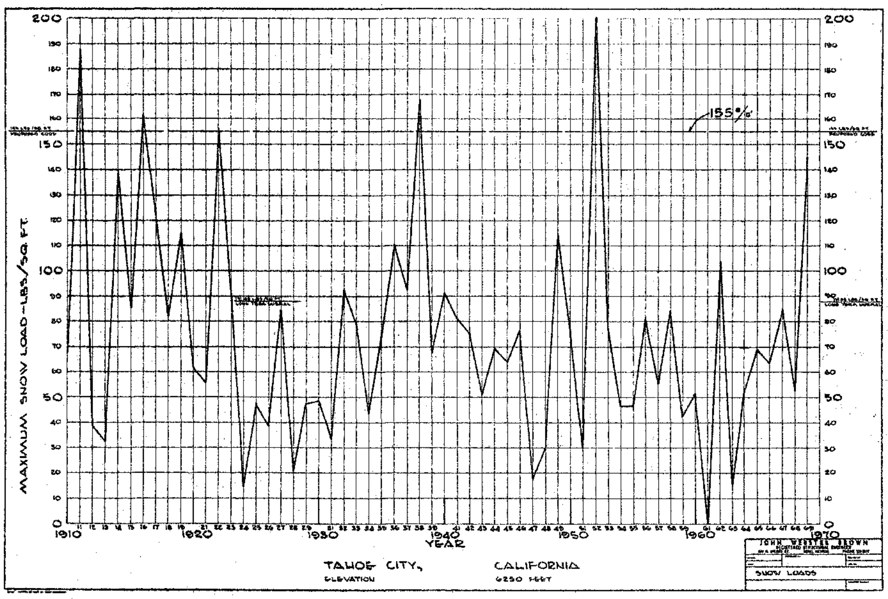

PLATE 3

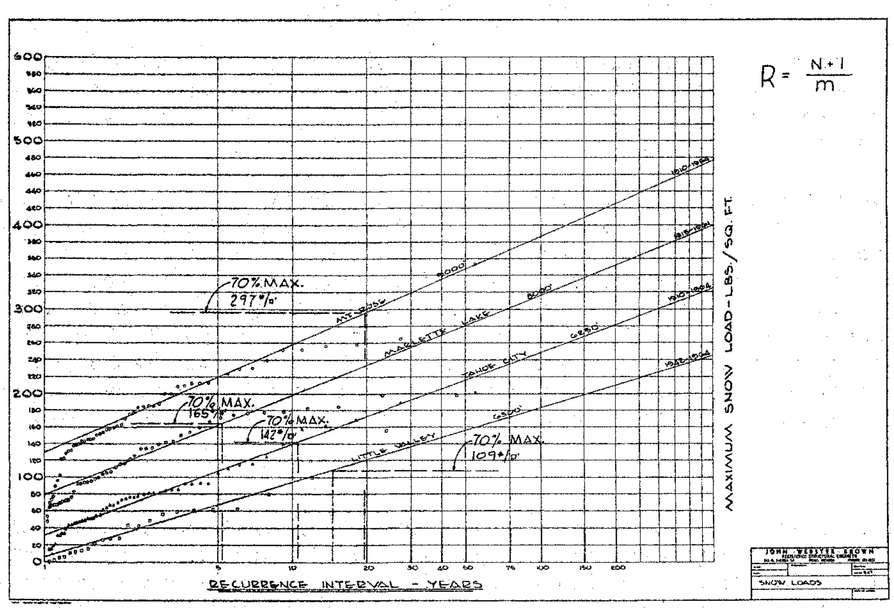

PLATE 4

Summary

Both the 1964 Washoe County, Nevada, snow load code and the 1965 National Building Code of Canada base the design snow loads on a percentage of the ground snow load at the site. The base percentage of the ground snow to be applied varies from 60% to 80%, and a value of approximately 70% is justified economically by the recurrence interval of snow loadings of such a magnitude in the Sierra Nevada Mountain Range.

The Canadian Code presents snow distribution factors on various types of roofs which can be applied universally with reliability and need only be tempered in detail with local experience.

A need for additional snow survey courses in developed and developing areas is apparent, and such courses can be correlated with others having longer records.

Further research on the subject of snow loads is warranted, and such investigations should include the concepts of basic meteorology.

The determination of snow load code values by rational methods for areas experiencing urbanization is necessary and in the public interest.

BIBLIOGRAPHY

1. "Snow Surveys for Forecasting Stream Flow in Western Nevada"; by Horace P. Boardman, C.E., the University of Nevada Agricultural Experiment Station, Reno, Nevada - Bulletin No. 184, Sept. 1949.

2. "Structural Information for Building Design in Canada 1965", Supplement No. 3 to the National Building Code of Canada, by the Associate Committee on the National Building Code, National Research Council, Ottawa, Canada - NRC No. 8331.

APPENDIX

April 1, 1969

SNOW LOADS

TYPICAL RECURRENCE INTERVALS

Snow Course	Elevation of Snow Course	Max. Snow Load #/sq.ft. & Date	70% Max.	Return Frequency Max. Snow	Return Frequency 70% Max.
Rubicon # 1	8100	4-6-52 464	325	32	6
Rubicon # 2	7500	3-30-52 334	234	39	8
Rubicon # 3	6700	3-30-52 250	175	46	10
Richardsons # 2	6500	3-30-52 218	153	48	10
Little Valley	6300	4-5-52 155	109	50	15
Tahoe City	6250	3-28-52 202	142	37	11
Soda Springs	6750	3-27-52 420	294	51	8
Donner Summit	6900	3-28-52 426	298		
Squaw Valley # 2	7500	3-30-69 437	306	18	5
Fordyce Lake	6500	4-22-52 438	307	46	8
Ward Creek	7000	3-29-52 465	326	37	7
Marlette Lake	8000	3-26-69 236	165	20	5
		Average of 11 Courses	-	38 yrs.	8 yrs.

CHAPTER 23 - Live and Dead Loads

Section 2305 - Delete Sec. 2305 and Delete Table 23-B.

Add the following:

Roofs shall sustain, within the stress limitations of this Code, all "dead loads" plus unit "live loads" as set forth in Tables No. 23-B1 and 23-B2. The live loads shall be assumed to act vertically upon the area projected upon a horizontal plane.

Trusses and arches shall be designed to resist the stresses caused by unit live loads on one-half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load upon the entire span. For roofs whose structure is composed of a stressed shell, framed or solid, wherein stresses caused by any point loading are distributed throughout the area of the shell, the requirements for unbalanced unit live load design may be reduced 50 per cent.

Snow load, full or unbalanced, or wind load shall be considered in place of loads as set forth in Table No. 23-B1, where such loading will result in larger members or connections.

TABLE 23-B1 Roof Live Loads - Pounds Per Square Foot

ELEVATIONS BELOW 5000 ft. Above Sea Level	
ROOF SLOPE	LIVE LOAD
Flat or rise less than 4 inches per foot. Arch or dome with rise less than 1/8 of span.	20 lbs./sq. ft.
Rise 4 inches per foot to less than 12 inches per foot. Arch or dome with rise 1/8 of span to less than 3/8 of span.	16 lbs./sq. ft.
Rise 12 inches per foot and greater. Arch or dome with rise 3/8 of span or greater.	16 lbs./sq. ft.

TABLE 23-B2 Roof Live Loads - Pounds Per Square Foot[4]

ELEVATIONS AT or ABOVE 5000 ft. Above Sea Level[3]

ELEVATION[1] Above Sea Level in Feet	SNOW LOAD IN lbs./Sq. ft.[2]	
	LAKE TAHOE BASIN	ALL WASHOE CO. except Lake Tahoe Basin
5,000	---	40
5,500	---	80
6,000	155	100
6,500	165	120
7,000	175	140
7,500	185	150
8,000	200	160
8,500	225	170
9,000	250	190
9,500	275	210
10,000	300	250

1. Intermediate Values may be interpolated by proportion.

2. Deviations from the above set forth snow loadings above 5000 ft. elevation may be permitted by the Building Official provided the snow load and conditions in each individual case are derived, and certified to, by a Registered Structural Engineer who can show proper experience in snow load evaluation.

3. In the design of buildings and structures above the 5000 ft. Elevation, consideration shall be given to the following:

   a. Unbalanced loading on roofs.

   b. Drifting due to adjacent obstructions.

   c. Accumulation in valleys and adjacent to Parapet Walls and Chimneys.

   d. Ice Loadings on Cornices.

(NOTE: Lake Tahoe Basin Minimum Elevation is approximately 6,225 feet above sea level.)

   e. Possible impact loadings from snow falling on structure from higher roofs.

   f. Effect on structure from dynamic loading caused by snow sliding off roof.

   g. Snow sliding off roof and dynamically loading side walls by being forced against same due to the snow embankment adjacent to the structure.

   h. Permanent automatic roof heating systems.

   i. Protection of entrances and exits from danger of falling icicles and snow sliding off pitched roofs.

4. 80% of the tabulated values in Table 23-B2 may be used with Roofs having a Pitch of between 6 in 12 and 12 in 12. 60% of the tabulated values in Table 23-B2 may be used with Roofs having a Pitch in excess of 12 in 12.