

## GROUND SNOW LOADS FOR IDAHO

Ronald L. Sack and Azim Sheikh-Taheri

Department of Civil Engineering  
University of Idaho  
Moscow, Idaho 83843

### INTRODUCTION

A country-wide map with snow load zones based upon a 50-year mean recurrence interval has been published for the United States by the American National Standards Institute (ANSI A58.1-1982). The map is not applicable for the entire country since in some areas the snow loads shown are not appropriate for geographical locations such as high country, and for other locations, an entire area may have extreme local variations in snow loads. Thus, localized studies based upon meteorological and topographic conditions are necessary in these areas with local exceptions. Most of the State of Idaho lies within one of these areas with difficult local snow conditions.

Previously, a snow load study was done of the State of Idaho (Sack, et al, 1976), and it has been used continuously as the design guide for the state. The data base for that study was approximately 270 snow course stations of the Soil Conservation Service (SCS). Most of those stations were within the state boundaries; however, that total included 28 stations in Montana and 7 in Wyoming. The data from 129 National Weather Service (NWS) stations were also examined, but these were only used as a secondary data source if the SCS data were sparse in a given area. In those cases, an average specific gravity of 0.385, obtained from the SCS data, was used with the NWS snow depths to obtain snow loads. In general the predicted snow loads were quite accurate for most high elevations, but they appear to be conservative for some low-elevation locations. The objective of the current study is to refine the snow loads throughout the state; specifically near populated locations since this is where most of the construction occurs.

The contour lines for the 1976 Idaho study were based upon normalized snow loads. For this technique, which was introduced by Davis for the State of Washington (SEAW, 1975), the snow load data (in units of force per area) at a given site is divided by the elevation of the station to give a quasi-normalized quantity in units of force divided by length cubed. These quantities seem to have no obvious physical significance; however, the effect is to reduce the entire area to a common base elevation, since all loads have been normalized with respect to the elevation. This procedure appears to mask out the effects of the environment on the snow-making mechanism. In the absence of any definitive quantitative information on the mechanism by which snow is produced, this seems to be a reasonable and logical method for handling the data.

### DATA BASE

A total of 514 stations from both SCS and NWS were used for this second study of snow loads in Idaho. The total of 375 SCS stations were composed of 234 from Idaho, 93 from Montana, 30 from Oregon and 18 from Washington. All snow courses included in the study had a minimum of ten years of data. The maximum recorded weights of snow on the ground were selected from records taken during the following snow seasons: Idaho (1927-1983); Montana (1922-1974); Oregon (1928-1972); and Washington (1915-1969). Most of the maxima for these stations occurred in the month of April with a few exceptions. The annual maximum values of snow water equivalent for each station were analyzed for various mean return intervals (mri) using a Log Pearson Type III frequency analysis. Snow depth data was available from 139 NWS stations in Idaho (1927-1981). These depths were also analyzed for various mri using the Log Pearson Type III frequency analysis. The maximum values for the NWS data generally occurred during the months of January and February which reflects the usual situation for the relatively flat areas where these stations are located.

For this follow-up study, we decided that all the NWS snow data should be utilized to construct contour lines; therefore, an appropriate specific gravity had to be chosen. The Proceedings, Eastern Snow Conference, V. 29, 41st Annual Meeting, Washington, D.C., June 7-8, 1984

specific gravity of these stations was treated as a free parameter that could be varied in a uniform and consistent manner and the effect studied. The specific gravities chosen were 0.192, 0.385 and that associated with the so-called Rocky Mountain Conversion Density (RMCD). The value of 0.192 is used by Canada and the State of Washington and is indicative of specific gravities in valley and flat locations where the snow is usually not on the ground a sufficient amount of time to form a densified snow pack. The value of 0.385 was obtained from the 1976 Idaho study and it represents the mean specific gravity for 230 SCS stations in Idaho for the 30-year mri. This high value reflects the usual situation in the mountains wherein the snow accumulates, settles and compacts during the entire winter, giving a maximum ground snow load typically in April. The RMCD was obtained by fitting a bilinear distribution to data from 3000 western SCS stations with over five years of record. The philosophy behind this approach was to attempt to identify a depth-snow load relationship and thus reflect the true natural phenomena. The relationships for this approach are:

$$\begin{aligned} \text{and } p_g &= 0.90h && (\text{for } h \leq 22 \text{ in.}) && (1a) \\ p_g &= 2.36h - 31.9 && (\text{for } h \geq 22 \text{ in.}) && (1b) \end{aligned}$$

where  $p_g$  is the ground snow load in  $\text{lb/ft}^2$  and  $h$  is the snow depth in inches (note that  $1 \text{ lb/ft}^2 \cong 47.88 \text{ Pa}$  and  $1 \text{ in.} = 25.4 \text{ mm}$ ). For depths less than 22 in. (560 mm) this gives a specific gravity of 0.175 and for depths greater than 22 in. (560 mm) the specific gravity is variable, but if the line started from the origin it would give a specific gravity of 0.444.

Since both SCS and NWS data were used to draw the maps we can note that there is a temporal disparity. For the SCS data only monthly readings are taken, and virtually all maxima of snow depths and snow water equivalents occur in April. Thus, the same month, with few exceptions, was used for each year of record for the SCS data base. In contrast to this, for the NWS stations, daily snow depth accumulations are recorded, and the largest of these were selected for each year without regard for the month in which the greatest reading occurred. The majority of the NWS maxima were in the months of January and February. In the absence of additional data it is impossible to resolve this incongruity, but this fact should be noted when using the results of this study.

Since the ANSI snow load map uses a 50-year mri, the same return interval was chosen for this Idaho study. Ground snow loads for the three data sets were obtained at all 514 stations. That is, the single values for the 375 SCS stations were combined with each of the three values from the 139 NWS stations using the distinct specific gravities discussed previously.

We elected to use the normalized ground snow loads following the approach established for the state in the 1976 study since this was the only procedure that proved tractible for the entire state-wide region. Hence, each ground snow load was divided by the respective station elevation giving normalized ground snow loads in  $\text{lb/ft}^2/\text{ft}$ . The three data sets of normalized load values for a 50-year mri were used to construct three distinct contour maps.

#### AUTO PLOT OF CONTOUR MAPS

The computer plotting program SURFACE II (Sampson, 1978) was used to generate contour maps of normalized ground snow loads. This program utilizes the station locations in  $x$  and  $y$  coordinates and the normalized ground snow loads as the  $z$  values to obtain a surface described by the changes of  $z$ . The surface is approximated by superimposing a regular rectangular grid of values over the entire region and interpolating between these regularly-spaced points. As the contours are being generated by the program, the contour line is guided by the mesh point values and not by the individual point (station) values. As a particular contour line enters a grid rectangle, the line is guided through the rectangle by the mesh point values and exits by being the properly interpolated distance from each mesh point.

Mesh point values are typically determined by one of several methods that can be selected by the user. A two-part procedure is employed for the standard method. First,

the slope of the surface is estimated at every data point. This is accomplished by locating the nearest neighbors to the data point considered and fitting a weighted trend surface to these points. Weights inversely proportional to the distance from the data point considered are assigned to the other point values. The plane is made to pass exactly through the data point by adjusting the constant of the fitted regression equation. Second, the value of the surface at the grid nodes is estimated. The nearest neighboring data points are located and each local surface is projected to the location of the node of interest. A weighted average of these estimates is calculated. Typically, the user can select from a number of different weighting functions which include  $1/D$ ,  $1/D^2$ ,  $1/D^4$ ,  $1/D^6$  and a complex function which is widely used in some commercial contouring systems and drops off at a rate of approximately  $1/D^2$  (i.e.,  $D$  is the distance between grid points in the mesh). For this study we used a weighting function of  $1/D^2$ , but several others were tried and examined to determine their effect on the contour maps.

The grid size must be selected by the user, and this can have an effect on the contour maps. The map of Idaho has a range of  $x$  values from -400,000 to +1,800,000 ft and  $y$  values between 100,000 and 2,700,000 ft (1 ft = 0.3048 m). The grid size judged most desirable was 100,000 ft, but values of 50,000 ft and 75,000 were also tried and the results examined.

#### DISCUSSION AND RESULTS

The autoplot procedure with a grid size of 100,000 ft and a weighting function of  $1/D^2$  was used to generate three distinct maps from the data files containing both SCS and NWS information. For example, the maps using specific gravities of 0.385 and 0.192 for the NWS stations are shown in Figs. 1 and 2, respectively. These maps were compared to determine the effect of varying the specific gravity of the NWS data. It was established that the three maps were significantly different since the contour lines could be shifted appreciably depending upon the specific gravity used.

Because of the significant effect of specific gravity and the temporal difference between the SCS and NWS data, we decided to study each NWS site and select a specific gravity that had a high probability of occurring at that location. For each site we considered factors of topography, wind speed and exposure, and the duration of ground snow. Using this information, in conjunction with personal knowledge of the sites, we selected a specific gravity for each NWS station. Generally, the assumption was made that snow will reach a greater density when exposed to a windy environment, when it occurs in the mountains, and/or it remains within a snow pack for a long period. Conversely, the snow should have a lower specific gravity in locations where wind is relatively mild and/or the snow remains on the ground only a short time. Thus, a specific gravity of 0.192 was typically selected for valley locations, mountainous terrain was given 0.385, and in some instances a compromise value of 0.288 was used at sites such as those where the snow is on the ground for a considerable period of time but the station is in a valley location. This information was used to create a fourth data file consisting of the SCS data and a composite specific gravity applied to the NWS data. Utilizing SURFACE II, along with the same grid size and weighting function used previously, we generated the final ground snow load map with normalized contour lines for Idaho.

#### REFERENCES

- 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.
- Sack, R. L., A. Rusten and M. P. Molnau, 1976, Snow Loads for Structures in Idaho, The University Press of Idaho, Moscow, Idaho.
- Sampson, R. J., 1978, SURFACE II Graphics System, Series on Spatial Analysis, Kansas Geological Survey, Lawrence, Kansas.
- Structural Engineers Association of Washington, 1975, Snow Load Analysis for Washington, Seattle, Washington.



PLOT NO. 1

IDAHO SNOW LOAD CONTOUR (SP.GR.=0.385)

DATE 6/02/84

TIME 12:55:13





