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Snow Loads on Roofs

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Please note

Snow, the principal ingredient of Canadian winters, must figure in the plans of many as a source of delight to skiers and as a burden to shovellers. Whatever personal reactions there may be, snow cannot be ignored and remains a major factor in many aspects of Canadian life. Structural designers are well aware of the influence of snow loads on the design of buildings as in many cases they constitute the largest design load for the roof system. A careful assessment of the snow load is required, therefore, to avoid both unnecessary construction costs and undue risk of failure.

Snow loads on roofs vary widely according to geographical location (climate), site exposure, and shape of the roof. In considering snow loads on roofs, Canada can be divided into four major regions. The coastal regions (both Atlantic and Pacific), because of frequent melt periods during the winter, are usually characterized by snow loads of short duration, often caused by a single storm. The mountainous regions of British Columbia and Alberta experience the heaviest snow loads in the country, lasting the entire winter and varying considerably with elevation. Prairie and northern regions have very cold winters, with small annual snowfalls; owing to frequent strong winds there is considerable drifting of snow both on roofs and on the ground. Finally, the central region, including Ontario and Quebec, is marked by varying winds and snowfalls, and sufficiently low temperatures in many places to allow snow accumulation all winter. In this area high uniform loads as well as high drift loads occur.

Figure 1, taken from the National Building Code 1960, shows the variations across Canada of snow loads on the ground.

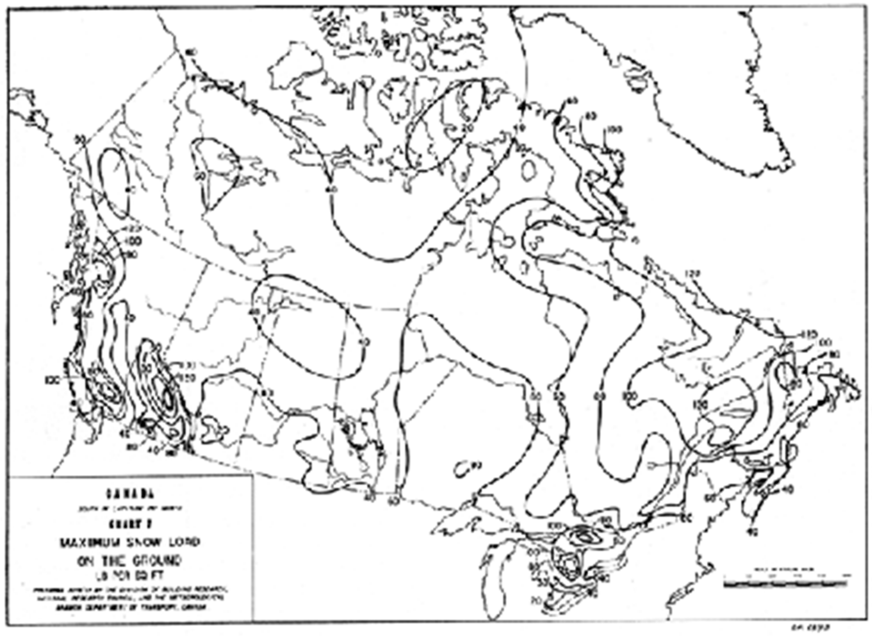

Figure 1. Chart of the National Building Code of Canada 1960 showing snow load on the ground.

Some Properties of Snow

Snowflakes of falling snow consist of ice crystals with their well-known complex pattern. Owing to their large surface area to weight ratio they fall to the ground relatively slowly and are easily blown by the wind.

Freshly fallen snow is very loose and fluffy, with a specific gravity of about 0.05 to 0.1 (1/20th to 1/10th of water). Immediately after landing, however, the snow crystals start to change: the thin, needle-like projections begin to sublime and the crystals gradually become more like small irregularly shaped grains. This results in settlement of the snow and after a few days the specific gravity will usually have increased to about 0.2. This compaction further increases and specific gravities of about 0.3 will often have been attained after about a month, even at below-freezing temperatures. Longer periods of warm weather as well as rain falling into the snow (a possibility that must be included in proper design loads) may increase this density even further.

As a simple rule for estimating loads from snow depths the specific gravity can be considered to, be about 0.2 to 0.3. In other words, each inch of snow represents a load of about 1 to 1½ pounds per square foot.

Accumulation on Roofs

In perfectly calm weather falling snow would cover roofs and the ground with a uniform blanket of snow. If this calm continued, the snow cover would remain undisturbed and the prediction of roof loads would be relatively simple; the design snow load could be considered uniform and equal to a suitable maximum value of the ground snow load.

Truly uniform loading conditions, however, are rare, and have been observed only in certain areas of the British Columbia mountains and occasionally in other areas on roofs that are well sheltered on all sides by high trees (Figure 2). In most regions snowfalls are accompanied or followed by winds, and the snowflakes, having a large surface area for their weight, are easily transported horizontally by the wind. Consequently since many roofs are well exposed to the wind little snow will accumulate on them.

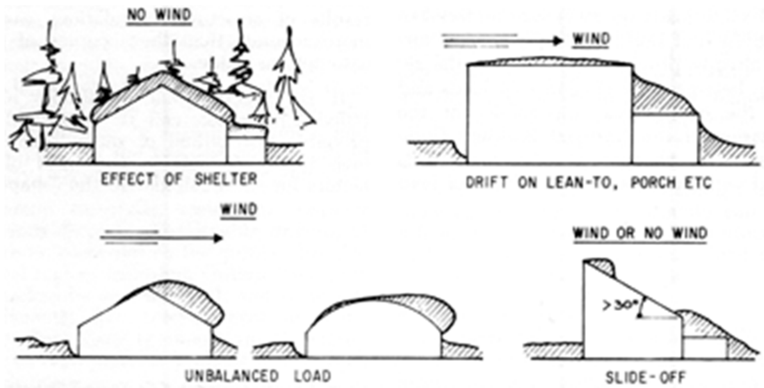

Figure 2. Possible effect of wind and building shape on snow load.

Over certain parts of roofs the wind speed will be slowed down sufficiently to let the snow "drop out" and accumulate in drifts. This can be visualized by reference to the action of snow fences which cause the snow to "settle out." These areas on roofs could be called "areas of aerodynamic shade," and occur mostly behind vertical projections on the roof.

An example of this is the area behind a penthouse on a flat roof where drifts often accumulate. Naturally, since the wind direction is not always the same, drifts on all sides of a penthouse would generally have to be considered.

(a) *Lean-to roofs*, i.e. roofs situated below an adjacent higher roof, are particularly susceptible to heavy drift loads because the upper roof can provide a large supply of snow. Canopies, balconies and porches also fall into this category and the loads that accumulate on these roofs often reach a multiple of the ground load depending mainly on the size of the upper roof. The distribution of load depends on the shape of these drifts which varies from a triangular cross-section (with the greatest depth nearest to the higher roof) to a more or less uniform depth.

(b) *Flat roofs with projections* such as penthouses or parapet walls often experience triangular snow accumulations that reach the top of the projections on the building, but usually the magnitude of the load is less than in category (a).

(c) *Peaked and curved roofs* subjected to winds at approximately right angles to the ridge provide aerodynamic shade over the leeward slope. This sometimes leads to heavy unbalanced loads, since most of the snow is blown from the windward slope to the leeward slope, producing loads that exceed the ground load on occasions. Curved roofs show similar or even more unbalanced distributions (little snow on top and heavy snow near the base of the arch) (Figure 2). On the other hand it is true that many small peaked roofs on residences, in exposed areas, usually (but not always) accumulate little snow compared with that on the ground.

Solar Radiation and Heat Loss

Various other factors, besides wind, modify snow loads, although some of these factors are effective only under special conditions. It has been found, for example, that solar radiation has little effect in reducing loads in cold weather. Similarly, in cold weather, heat loss from the roof is not very effective in melting the snow with the present trend to better insulated and ventilated roofs. These two factors cannot, therefore, be relied upon to, reduce the snow load significantly during the colder periods when the winter's maximum snow load can be expected. During thaws and toward the end of the winter, however, when the air temperature rises nearer to the freezing point, solar radiation and heat loss do contribute to the melting of the snow.

Redistribution of Load

Redistribution of snow load can occur not only as a result of wind action. On sloped roofs there are two problems connected with the melting of snow at temperatures slightly below freezing. Firstly, melt water can refreeze on caves and cause high ice loads (also water back-up under shingles). This can at least partly be solved by taking steps to, decrease the heat loss from the upper parts of the roof. Secondly, if a roof slopes and drains on to a lower one, melt water sometimes accumulates by refreezing on the lower roof or it is retained in the snow.

Since flat roofs in general do not provide as good drainage as that naturally obtained with sloped roofs, snow and ice will remain on flat roofs longer than on sloped roofs. On large flat roofs of industrial and commercial buildings, heavy loads are observed near projections such as air ducts (which sometimes act like snow fences in retaining snow). When this snow melts it sometimes drains into the lower areas in the centre of bays (i.e. areas of maximum deflection) because usually the drains are located at columns (high points). This redistribution of load causes further deflection and can lead to a very dangerous situation.

Failures due to Snow Load

Unfortunately the number of building failures resulting from snow load is relatively high in Canada. Admittedly many of them occur in older and substandard constructions and should thus be attributed to faults of construction rather than to the snow load. Collapses occur most frequently in older buildings, farm buildings, and cottages as well as in some community buildings such as arenas built with a minimum of funds and professional supervision. Partial failures, however, occur fairly frequently in those parts of roofs that accumulate high loads from drifting, for example, porches canopies and lean-to roofs. These partial failures indicate the need for better design. Although many failures are probably averted each winter by the removal of snow, this fact should never be relied upon and should never be used as a reason for a reduction in the design load.

Design Roof Loads in the National Building Code

In the past, design snow loads were often considered to be equal to the ground snow load with reductions allowed for sloped roofs only. Such design loads were admittedly crude and are known to have resulted in overdesign in some roofs while allowing underdesign in others, particularly in areas subject to high drift load. Information on which to base a more refined assessment of the loads was, however, not available until a country wide survey of actual snow loads on roofs was undertaken by the Division of Building Research. This survey has already provided evidence on the relationship between ground and roof loads and enabled the committees responsible for the 1960 revision of the National Building Code to make some changes in the roof loads compared with the ground load. The roof load was set at 80 per cent of the ground load, the ground load being based on a return period of 30 years and adjusted to allow for the increase in the load caused by rainwater absorbed by the snow.

Certain "shape" influences are also given in the Code. Reductions are allowed on sloped roofs to account for the probability that some of the snow may slide off, but the slope reduction starts at 30° only because steep, but sheltered, roofs often retain their full snow load. Pitched roofs and curved roofs must be designed for unbalanced as well as uniform load. Such roof areas as canopies, porches, the lower of split-level roofs, where snow will probably accumulate in the form of drifts, must be designed for a load increased by 50 per cent compared to the rest of the roof.

Responsibility of Designer

Code requirements for snow loads must necessarily be rather general, and consequently the designer should not apply the loads given in the Code without considering the effects of the shape and exposure of the roof. The loads given in the National Building Code of Canada 1960 are minimum values only, which must be increased where he considers it necessary. The designer should, therefore, consider in each case the building site, size and shape, where drifts are likely to occur on the roof, what the effect of unbalanced loads will be on the structure, whether there will be proper drainage, and so on. He should remember that the final results of structural calculations can be no more accurate than the accuracy of the load assumptions made.

It is expected that eventually more detailed information can be published on the probable distribution of snow loads on common types of roofs in the form of "shape factors for snow" similar to the "shape factors for wind" given in a Supplement to the Code.