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Estimating Snow Loads on Roofs

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Please note

Snow can affect buildings, particularly roofs, in many ways. It can cause the collapse of roofs due to heavy snow accumulation; ice and ice dams that result in water leakage under shingles and over flashings; snow slides from sloped roofs and skylights, endangering pedestrians; drifting round buildings, hindering access by people and vehicles; and wetting inside buildings from infiltration of wind-blown snow.

Although all snow problems deserve attention, this Digest will discuss snow loads on roofs, probably the most important problem in terms of economics and human safety. It is an updated version of **CBD 37** and intended as an introduction to the estimation of roof snow, based on information given in the National Building Code of Canada and its supplements.[1-3]

Factors Affecting Roof Loads

Snow loads on roofs depend on climatic variables such as the amount and type of snowfall, wind, air temperature, amount of sunshine, and on roof variables such as shape, thermal properties, exposure and surrounding environment. A knowledge of how they influence snow loads is of value not only for determining design snow loads but also for obtaining an appreciation of the reliability of calculated snow loads for a particular roof at a specific site.

Climactic Variations

The large climatic variations that exist in Canada produce a wide range of snow types and accumulation patterns. The Atlantic and Pacific coastal regions and other temperate areas with frequent thaws during the winter are characterized by snow accumulations of relatively short duration, often produced by one or two snow storms only. The mountain regions (Western Canada) experience the deepest snow accumulations which usually last the entire winter and increase considerably with elevation. The northern and some Prairie regions have very cold winters with relatively small annual snowfall, where frequent strong winds result in much drifting. The central regions, including many parts of Ontario and Quebec, are marked by varying winds and snowfalls, and sufficiently cold winters in many places to allow snow accumulation for extended periods. In these regions significant uniform loads as well as high drift loads may occur.

The amount of snowfall and other climatic conditions can vary tremendously within each region, making it difficult to generalize about snow loads on a regional basis. Furthermore, there may be large variations in the properties of falling snow, ranging from dry and granular to wet and sticky, intermixed with precipitation such as rain and sleet.

Drifting

Of all the variables that influence snow loads on roofs the effect of wind is probably the most important. Snowcovers on roofs are particularly susceptible to drift action because of their exposed location and because wind speeds are higher there than at ground level. As the wind speed increases during a snow storm, more and more of the falling snowflakes are carried horizontally past exposed roof areas to those of lower wind speed where the snowflakes can be deposited and accumulate in drifts. At wind speeds greater than about 20 km/h (12.5 mph), particles are also picked up from the existing snowcover and carried along the flow. This scouring action leads to removal of snow from some areas and an accumulation in others such as the lower levels of multilevel roofs (Figure 1 and Figure 2), valleys, and the downwind side of peaked and arched roofs. In the redistribution process some snow is blown off the roof and falls to the ground, but sometimes snowcovers are affected by freezing rain or by freeze-thaw conditions that create a hard crust on the existing surface, making it essentially invulnerable to scouring or drifting.

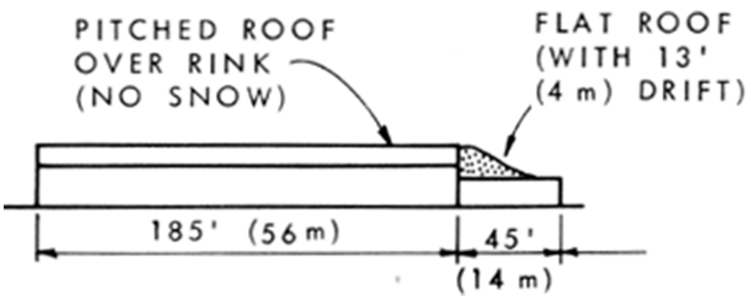


Figure 1. Example of drift load in Ottawa, NBC ground load 60 psf (2.9kN/m²). Maximum drift load observed -- 240 psf (11.5 kN/m²) in 1975; 125 psf (6.0 kN/m²) in 1976.

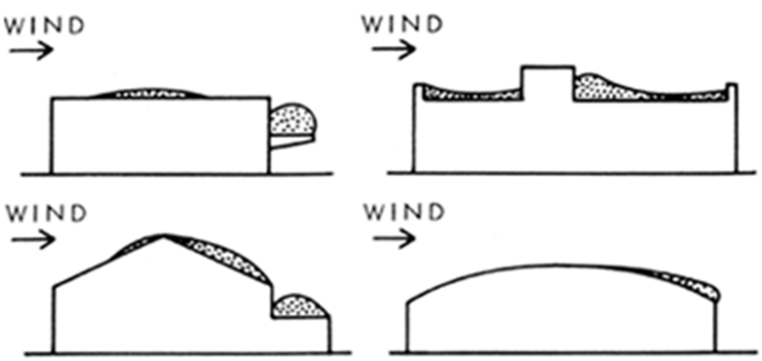


Figure 2. Typical snow accumulation on common roof shapes.

Although there are predominant wind directions in most regions, wind and snow should usually be assumed to blow from any direction because it would be too unreliable to limit the directions from which drifting might occur. Surrounding buildings or trees may also change during the life of a structure, affecting drifting patterns. Fairly conservative assumptions with regard to wind direction and possible drifting are thus usually desirable.

Though difficult, predicting probable drift shapes on buildings is feasible to a degree. For relatively simple building shapes they can be estimated using the recommendations of Commentary H, Supplement No. 4 to the National Building Code,[3] can be augmented by aerodynamic considerations and experience. For more complicated shapes and unusual terrain conditions it may be advisable, and economically justifiable, to use experimental studies such as water flume or wind tunnel tests to get a better feel for probable drift distributions.

Other Factors Affecting Roof Loads

Various factors other than wind may modify the amount and distribution of snow that will accumulate on roofs. In regions with mild winters or in late winter in colder regions solar radiation can effectively reduce snow loads by melting, particularly if part of a roof is bare and the surface is dark in colour. It would be wrong, however, to rely on a reduction in load as a result of solar radiation when determining design load because in the colder months of the winter the effect might be insignificant.

Heat loss through the roof may also cause a significant reduction in the load, especially where the maximum load results from snow accumulations over a relatively long period. Many older roofs have been saved from collapse as a result of reduction of load due to melting (actually sliding of snow on a sloped surface induced by melting at the snow/roof interface). Again it is not recommended to count on such reductions when determining the design load (except for greenhouses), particularly in view of the present trend towards better insulated and ventilated roofs.

Generally, snow load decreases as roof slope increases, mainly because the steeper the roof the greater the chance that some of the snow will slide off or blow away. The surface material has a considerable effect on the point at which friction is overcome and sliding occurs. Smooth surfaces such as sheet metal or glass have lower coefficients of friction than asphalt or wood shingles. In addition, heat loss through the roof may produce melting at the roof surface and thus, by reducing friction, initiate sliding. The National Building Code suggests a linear reduction from the applicable basic snow roof load, with full load at 30 degrees reducing to "zero" load at 70-degree slope. Even though sloped roofs benefit from reduced snow loads, snow sliding from such roofs onto a lower roof may greatly increase the load on the lower roof. The dangers of snow slides hitting pedestrians on sidewalks and at entrances should also be considered.

A redistribution of load may occur as a result of melting and subsequent re-freezing. Even at air temperatures below freezing, melting due to heat loss through the roof or heat coming from exhaust fans, etc., can lead to additional loads in areas where melt water refreezes. On flat roofs, for example, melt water may collect in areas of greatest deflection such as at mid-span of roof beams, causing "ponding." On sloping roofs, melt water often refreezes along the eaves, causing problems of ice dams or icicles. Where a roof serves as a parking deck, the extra snow accumulations that may result from snow clearing operations should be considered in the design.

Estimating Design Roof Snow Loads

Ground Snow Load

Ground loads are the basis for the estimation of roof loads. The ground loads for the National Building Code are based on measurements of snow depth over many years at over 200 meteorological stations. Assuming a snow density of about 0.2 gm/cm^3 (12 lb/ft^3), with some load added to represent the rainwater that the snow might retain, specified ground snow loads for code use were calculated. The snow depth used is calculated as that which will be equalled or exceeded once in 30 years on the average. It has a probability of 1 in 30 of being exceeded in any one year.[4] The ground snow loads for many locations for which calculations were made are listed in Supplement No. 1 to the National Building Code.[2]

Roof Snow Load

Roof loads are equal to ground snow loads only if the roof is completely protected from wind action and if there is no melting. Under calm conditions, falling snow will cover the roof and ground with the same uniform layer, which will grow in depth with each successive fall provided the temperature of the air and the roof surface remain below the freezing point. The prediction of roof load is then a relatively simple matter because it is basically the same as the ground load. But such calm conditions are rare. They occur only in sheltered mountain valleys or other very sheltered locations, for example. on a house surrounded on all sides by a forest and, very occasionally, in other locations when a snowfall occurs without wind or drifting.

Under more ordinary, windy conditions, as shown by roof load surveys of the Division of Building Research, average roof snow loads are lower than ground snow loads. The National Building Code recommends a "basic" roof snow load of 0.8 of the ground load, and 0.6 for roofs that are completely exposed to wind provided the designer can demonstrate to the satisfaction of the authority having jurisdiction that the roof will remain exposed.

Except for the simplest buildings and for houses (which are exempted from the provisions for drift loads, etc., if they come under Part 9 of the National Building Code), three loading cases should be considered in a design:

Case I. a uniformly distributed "basic roof load" depending on exposure conditions;

Case II. drift loads and other modified loads up to two or three times the ground load in selected wake areas, assuming that wind may blow from any direction, plus the basic roof load in other areas;

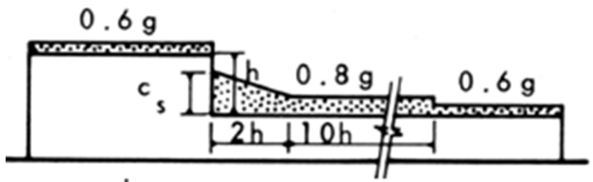
Case III. a certain degree of unevenness in the deposition of the Case I load (represented in the National Building Code by full load on any one portion of a roof and half load on the rest).

Some of the modifications mentioned in Case II to the basis snow load coefficients are those recommended in Commentary H [3] to account for effects of wind, slope, etc. Because of space limitations, only a few points can be discussed here.

On gable roofs, for example, windward slopes are sometimes blown clear whereas leeward slopes are subjected to increased loads from snow blown over the top. For gable and hip roofs, therefore, it is recommended that (in addition to uniform load on the whole roof) they be designed for zero load on one side and full ground load on the other side. Similar considerations apply to arched and curved roofs, except that distribution on the leeward side is more complicated.

In valley areas of roofs snow may accumulate in two ways: first, snow transported by the wind from another side may be deposited in the valley; second, snow creeping down from the sloping surfaces into the valley may accumulate.

Multilevel roofs, which are very common on industrial and commercial buildings, often have triangular drifts on the lower roofs. These can become quite deep, especially if the upper roof is large and serves as a "reservoir" of snow for the wind to draw from and dump over the downwind edge. The National Building Code suggests triangular drift loads of up to three times the specified ground load ($C_s = 3$, see Figure 3). Three times the ground load may seem very high at first sight (e.g. 180 psf (8.6 kN/m²) in a 60 psf (2.9 kN/m²) ground load area such as Ottawa), but maximum drift loads exceeding this value have been measured (240 psf (11.5 kN/m²) for the building shown in Figure 1). Perhaps one day it will be possible to make maximum drift load a function of the size and orientation of the upper roof, but this will obviously require very careful judgement and perhaps involve water flume or wind tunnel tests.



$c_s = \gamma \frac{h}{g}$ $\gamma = 15$ lb/cu ft

WHEN $15\frac{h}{g} < 0.8$ USE $c_s = 0.8$

WHEN $15\frac{h}{g} > 3$ USE $c_s = 3$

h = DIFFERENCE IN ROOF HEIGHTS IN ft

g = GROUND SNOW LOAD IN psf

Figure 3. Simplified drift load sketch for multilevel roofs (for full details see Commentary H of Supplement No. 4 to the NBC).

With sloping, multilevel roofs, snow sliding off an upper level may add a considerable load to the existing triangular drift on the lower roof. Half of the total design load on the upper roof is suggested in Commentary H.[3]

Drifts also accumulate behind roof obstructions such as penthouses or air-conditioning equipment, but usually not to the degree found in true multilevel roofs, and therefore reduced C_s values (up to $C_s = 2$) are suggested.

Conclusion

Estimating snow loads on roofs, with so many variables involved, often requires considerable judgement and investigation. The National Building Code and its Commentary H both contain information for common roof slopes, but additional sources of information, personal judgement by the designer, wind tunnel or water flume tests by qualified experts, and local experience may be desirable in providing the best estimate of the expected snow loads for a given building.

References

1. National Building Code of Canada, National Research Council of Canada, Assoc. Comm. on the National Building Code, NRCC 13982, 1975.
2. Climatic Information for Building Design in Canada. Supplement No. 1 to the National Building Code, National Research Council of Canada, Assoc. Comm. on the National Building Code, NRCC 13986, 1975.
3. Commentary H on Snow Loads of Supplement No. 4 to the National Building Code, National Research Council of Canada, Assoc. Comm. on the National Building Code, NRCC 13989, 1975.
4. Boyd, D. W. Maximum Snow Depth and Snow Loads on Roofs -- Canada. Proceedings, 29th Annual Meeting, Western Snow Conference, Spokane, Washington, April, 1961, (NRC 6312).