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Baker, M. C.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000883
Canadian Building Digest, 1967-05

Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 89

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Originally published May 1967.

M.C. Baker

Please note

In most parts of Canada ice has a tendency to form on roofs during the winter months, particularly when there has been heavy snowfall. On poorly-drained flat roofs the ice may seldom be seen, but the occupants of the building are often made aware of its presence by loud cracking noises on cold nights. On sloping roofs, ice is usually visible as a build-up at the eaves, often with icicles hanging down to form a pleasant winter scene. The occupants of the building may sometimes be very much aware of its presence because of leakage of water into the building.

Flat Roofs

Roofs referred to as flat usually have shallow depressions due to structural deflections, and these tend to pond water from melting snow. When the temperature drops below 32°F, the water may freeze completely to form a thin plate of ice, and repeated thawing and freezing may take place with changing temperature conditions. The strains induced in the ice by contraction of the thin plate are relatively small, and because the ice is weak in tension it soon cracks and relieves them. The strains induced in the roofing membrane will probably be even less than those in the ice, and are considered to be very much below the strains that roofing membranes are capable of resisting. Such ice formations will probably not damage roofing, but if water can penetrate cracks, wrinkles, holes or other defects and then freeze, the expansive force of the freezing water may tear the membrane apart. This danger of damage to the membranes of nearly flat roofs can be greatly reduced by designing them with adequate slopes to interior drains.

Sloping Roofs

Roofs that slope downwards to the outside walls of a building are cause for much greater concern. Quite large quantities of ice can form at the eaves, even on small buildings such as residences. The weight of ice can cause structural damage at the eaves, and falling icicles can constitute a significant hazard to persons and property.

Water from melting snow may be prevented from running off the roof by ice formations at the eaves. On buildings with overlapping water-shedding units such as shingles, tiles or corrugated sheet roofings, the backed-up water may leak into the building or into the roof and wall construction to cause considerable damage. Home owners may be familiar with effects such as wet insulation in roofs and walls, wet wood causing decay and paint failure, efflorescence on masonry walls and, in severe cases, damage to interior ceiling and wall finishes and to furnishings. This Digest will, therefore, be chiefly concerned with ice dams on the eaves of sloping roofs.

Conditions for Ice Dams

Ice damming results from a combination of snow on a sloping roof, outside air temperatures below freezing, heat loss or radiation to cause snow melting, and an open end of snow where ice can form. A continuous, almost uniform, coating of ice can form on a roof surface during a sleet storm and under patches of snow, but ice dams at the eaves form only when there is a full or partial blanket of snow on the roof that extends to the eaves.

The outside temperature at which snow melting will take place on a roof surface depends on the depth of snow, the wind conditions, the roof construction, and the inside temperature conditions. On some buildings melting may take place at very low outside temperatures, but for insulated buildings it will probably occur at temperatures above 15°F.

Ice dams form when water from the melting snow drains (under the snow) down the slope to the eaves, where some of it is held by the snow at its open end and freezes. Water that cannot be held drips off to form icicles. Progressive accumulation causes a build-up of the dam in roughly horizontal layers, and spilling and dripping over the dam causes enlargement of the icicles hanging from the dam. When the outside temperature rises above freezing, the ice rapidly melts at its contact with the roof and eaves. Under such conditions the ice weight soon causes it to slip away from the roof to create the falling ice hazard.

An area of bare roof surface is exposed below the open end of snow when the snow on a roof does not extend to the eaves. It has been observed that ice dams do not usually form in such cases; and that water is not held by the snow, but flows out onto the bare roof surface to evaporate or form only a thin layer of ice.

The rate at which an ice dam forms depends on the amount of melting and, to some extent, on the shape of the roof. Valleys formed at the intersection of two sloping roofs, for instance, act as collectors and concentrate all the water from the melting snow of both slopes in the lower end of the valley. This, combined with drifting of snow into the valleys to provide a large supply for melting, can produce very large ice dams at the ends of valleys. On wide overhangs and extensions of roofs over unheated spaces such as car ports, ice will still form at the eaves of the overhang, as already described, and there may also be a thin layer of ice on the roof back to the building wall.

Snow Melting

The main mechanism for snow melting is heat loss from the building through the roof, but sun heat by radiation may also be a factor in melting the snow or in heating attic spaces to cause melting. Heat loss through the roof will depend on the inside temperature conditions, the amount of insulation in the roofing system, and the ventilation of spaces, if any, between the insulation and the roofing. These factors can be allowed for in design of buildings, and often can be adjusted on existing buildings to reduce the heat loss to a point where melting will be minimal from this source.

The amount of melting that can take place from sun heat is highly variable and depends on factors such as snow properties, depth of snow, wind conditions, slope of the roof, and building orientation. Transmission of radiation into deep snow can cause some melting, but transmission through shallow depths for absorption at the roof surface is usually the more significant factor. At Ottawa enough sunlight can be transmitted through a 6-inch snow cover on a clear winter day to cause melting at the roof surface, even when the outside temperature is as low as 10°F, with an attic temperature of only 25°F.

A roof slope facing south will become bare of snow much more quickly than one facing north, because of melting from heat loss and sun radiation combined. This sometimes can add to the problem of ice formation on north slopes. The heating of the attic space from absorption of heat energy from the sun on the bare south slope can cause melting of snow at the roof surface on the north slope. This effect will be most noticeable on buildings with a limited amount of attic ventilation and roofs of steeper slope.

Conditions for Leakage

For leakage to occur there must be water at the roof surface, openings to permit entry, and forces acting to move it inward. If any one of these conditions is eliminated, water penetration will not occur (CBD 67, **CBD 73**). When there is snow on the roof of a heated building, there will almost surely be water at the roof surface, either from melting by heat loss from the building or by sun heat. Leakage will not occur when roof coverings are impervious, and will seldom be a problem on roof coverings of sloping, overlapping units unless some obstruction interrupts the gravity flow down their surface.

Ice formations starting at the eaves and progressing up along the roof slope can, however, produce such an obstruction. When the ice reaches a level on the roof near the extension of the wall line, the water may not freeze at the roof surface because of heat loss through the roof. The ice formation may continue to build, with water backing up behind it (Figure 1) and draining by gravity through any openings it contacts such as those at the overlaps of roofing units. It will continue to drain while the supply of water lasts, unless some easier path of drainage occurs, such as can be produced by making drainage channels through the ice dam.

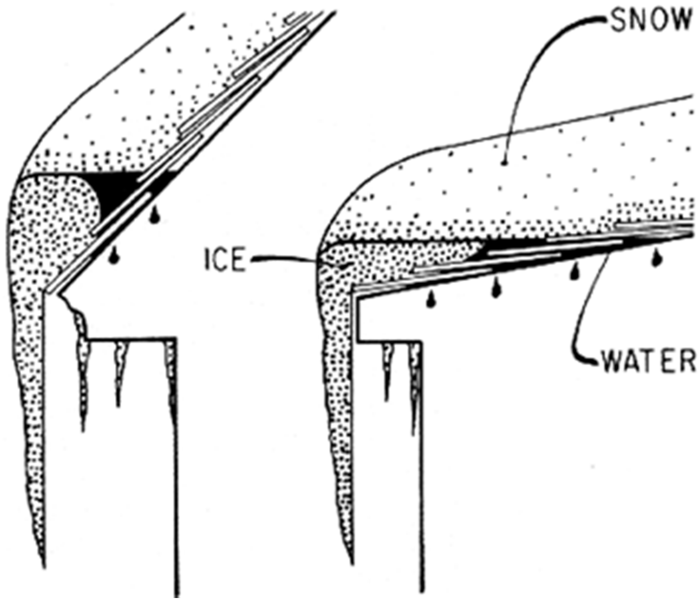

Figure 1. Formation of ice dam.

Slope of the roof is important in relation to the snow that can accumulate and in relation to ventilation by chimney effect where attic spaces are involved. Together with the amount of unit overlap, it also determines the height of rise at which water will penetrate the overlaps of the units. This height of rise for the same amount of overlap will be much smaller on a low-sloped roof and the likelihood of water penetration greater.

The distance the eaves extend beyond the wall is of considerable importance in determining whether leakage will occur. On wide overhangs and extensions of roofs over unheated spaces, leakage will probably not occur because there will usually be no melting from below to cause a water back-up. If leakage does occasionally occur in these cases, it is seldom of consequence.

The type of eaves construction and the presence of gutters or snow guards will affect ice formation. Construction that makes it difficult to achieve continuity between the wall and ceiling insulation may be troublesome, and lack of insulation or gaps in it at this junction can permit excessive heat loss to cause melting behind an ice dam. It is important, too, that the construction is such that ventilation through the eaves to attic space is not restricted.

Snow guards at the eaves will usually prevent snow slides, but may cause an increase in ice formation. Gutters also may increase the ice formation, although initially icicles may be prevented from forming. As soon as the ice fills the gutter, however, icicles will then form at the edge of the gutter as the ice builds up above it.

Design Precautions

It may be very difficult to prevent entirely the formation of ice on sloping roofs, but the amount of build-up can be greatly reduced by eliminating some of the conditions that cause it. For buildings with attic spaces or air spaces above the insulation, the two most important considerations are adequate insulation and ventilation of the space above the insulation with outside air. The economic thickness of insulation, based on fuel and insulation costs, will probably be sufficient to minimize snow melting at the roof surface. For houses in Ottawa, the economic thickness is approximately 6 inches, which is probably a good deal more than most houses will have. In general, it would not be practical to use more than the economic thickness merely to control ice damming, but it seems logical to use up to that thickness because there are benefits in summer heat control as well.

Ventilation of spaces above the insulation permits the flow of outside air to remove warmer air from the spaces, providing a so- called cold roof. Such venting is normally installed to control condensation in those spaces during the winter and to limit heat build-up in the summer. It also helps in controlling snow melting at the roof surface. To be effective, the amount and location are important. For housing, the amount is arbitrarily set at a minimum of 1 square foot of unobstructed vent area for every 300 square feet of insulated ceiling. Air movement through the space will be caused by differences in wind pressure and chimney effect. To obtain the advantage from chimney effect, inlet vents must be as low as possible at the eaves and outlet vents as high as possible near the ridge. On low sloping roofs, chimney effect will be small and it may be necessary to increase the size of vents.

For some building occupancies neither ventilation nor insulation may be required or possible. If ice damming is to be prevented in such cases, water from melting snow must be removed before it reaches the eaves and taken away through interior heated drains or in some other manner. On such buildings it is important to give consideration to this at the design stage. Remedial action after construction may be extremely difficult.

In addition to limiting the formation of ice at eaves by insulating and ventilating the roof to reduce heat loss, leakage from water back-up can be prevented by providing impervious roofing or an impervious strip at the eaves and valleys where ice damming can occur. The latter can take the form of impervious flashing underneath overlapping units (although nail holes may still be a problem) or of an impervious strip such as metal at the eaves without overlapping units, if aesthetic considerations will allow this. When a strip of exposed metal is used at the eaves ice damming is generally less of a problem because snow tends to slide off; and even when ice forms it too tends to slide off more quickly during thaws. The hazard from falling snow and icicles, however, is still present.

When no, or only partial, action is possible in relation to the above considerations, the designer may have to consider the use of electric heating cables to maintain drainage channels through ice dams that form at the eaves and to keep gutters and downspouts open. These may be specially designed and fabricated for the job. Ready-to-install units, however, consisting of the heating cable, cold wire leads, and attachment plug are also available, usually as a kit complete with roof attachment clips. Heating cables may be single-wire or two-wire types of varying lengths, usually power rated at from 5 to 7 watts per lineal foot.

Heating cables are considered most effective when fastened along the eaves in a zig-zag fashion extending up the roof with points about 2 feet apart along the eave. The lower points should extend over the eaves to prevent icicles from forming at the end of the drainage channels. The cable is usually carried up the roof so that the upper points of the zig-zag are at least 6 inches past the interior wall line. With wide overhangs, this may not be necessary if the installation is operated to prevent an ice dam from growing. Where there is a gutter, cable should also be laid lengthwise in the gutter and carried down the downspout to keep them free of ice.

As faulty electric installations can create a fire or shock hazard, care must be exercised in the installation, with frequent checking for safe operation. Electrical connections should be moisture-proof and outlets installed in dry locations. The branch circuit supplying the cable must have sufficient capacity to carry the heating load, and all metal gutters and downspouts and all metal siding should be properly grounded. If the cables become twisted and overlap there is a danger that the insulation will melt at the overlap, causing a short circuit.

The usual recommendation for operation is that the power should be turned on whenever it snows, except when temperatures are above 45°F. Ice should never be allowed to form in the channels because the heat from the cables may not be sufficient to clear large ice dams once they have formed.

Summary

The formation of ice dams on the eaves of sloping roofs often causes water leakage through roofing composed of overlapping watershedding units. Snow melting on the roof and freezing at the eaves is the cause of ice damming. Snow melting is due chiefly to heat loss from the building through the roof or from attic spaces, although some melting can occur from sun radiation.

Temporary relief can be obtained from the effects of ice dams by clearing the snow off the roof, particularly at the eaves, and by knocking ice formations from the eaves and valley ends, taking care not to damage the roofing. For a more permanent solution and to limit the formation of dams, consideration must be given to more adequate roof or ceiling insulation, ventilation of air spaces above the insulation, and moderation of inside temperatures.

Leakage can usually be avoided by using wide overhangs, wide impervious flashings or roofing at the eaves, or heating cables to melt drainage channels through the ice.