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MINIMIZING THE ADVERSE EFFECTS OF SNOW AND ICE ON ROOFS

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ABSTRACT
Snow load design criteria in the United States are established in ASCE Standard 7, "Minimum Design Loads for Buildings and Other Structures." The information in that standard documents how dramatically the geometry of a building can influence snow loads on its roof. Problems can be avoided and more functional designs developed when the design team considers snow and ice issues early in the design process as the shape of the building evolves. Examples are presented to document how the adverse effects of snow drifting, sliding snow, ice damming, and snow ingestion can be minimized.

1. INTRODUCTION

Building configuration and its thermal design can dramatically influence the distribution of snow and ice on its roof. The snow load provisions of ASCE Standard 7 [1] document how the geometry and thermal characteristics of a building affect snow loads on its roof. Problems can be avoided and more functional designs developed when snow and ice issues are considered as the design of the building evolves.

2. DRAINAGE

Most steep roofs drain over their eaves. Some low-slope roofs also drain to cold eaves, but others drain internally. Over-the-eaves drainage in cold climates can result in the problems shown in Figure 1 and the following:

- Creeping, sliding, and falling snow and ice should be anticipated from roofs that drain to cold eaves. Property has been damaged and people have been injured and killed by snow and ice falling from roofs that slope to cold eaves. Steep slopes, warm roofs, and slippery surfaces increase these risks.
- Falling ice and snow can damage lower roofs.
- Meltwater can cause problems associated with excess ground water and below-grade dampness beneath the eaves.
- Problematic icicles and ice dams can develop on warm roofs that drain to cold eaves (Fig. 2). Meltwater that backs up behind such icings may leak into buildings, causing serious interior damage and possible loss of occupancy.
- Roofing system deterioration can result from leaks due to severe winter icings.
- Snow and ice removal operations in response to winter roof leaks at cold eaves usually damage the roofing and create more leaks.
- Icicles and ice dams can create heavy concentrated loads along eaves.
- Narrow eaves or inadequate drip edges can cause icing of walls, which then deteriorate rapidly. A 12-inch overhang is a good minimum in cold climates. Wider overhangs may produce bigger icings.
- Ice dams or ice-blocked scuppers and leaders can cause extensive ponding on low-sloped roofs. This increases the potential for leaks and progressive collapse.

In cold climates, internally drained low-slope roofing systems have an important advantage over systems that drain to cold eaves, since they avoid <u>all</u> of the above problems. Unfortunately, it is impractical to drain low-slope metal roofs internally.

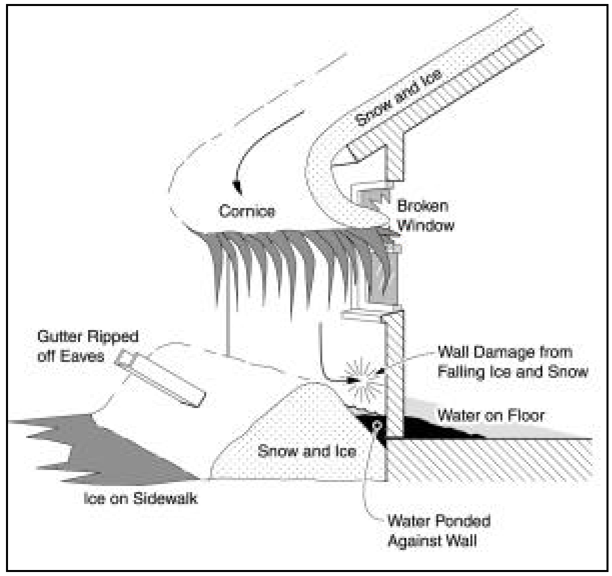

Figure 1. Over-the-eaves drainage problems.

Figure 2. This large ice dam caused this metal roof to leak at its eaves.

Because of waterproofing issues, a dead flat roof is a design mistake. Membrane roofing systems with a slope of ¼ inch/foot to internal drains are appropriate. It is not necessary to increase the slope of such roofs to ½ inch/foot in snow country. Switching from internal drains to over-the-eaves drainage or scuppers along a raised edge can lead to problematic, dangerous icings, ponding of water over large areas of the membrane, and inevitable leaks.

3. SNOW DRIFTING

Snow will drift into areas of “aerodynamic shade.” Figure 3 illustrates such places and the

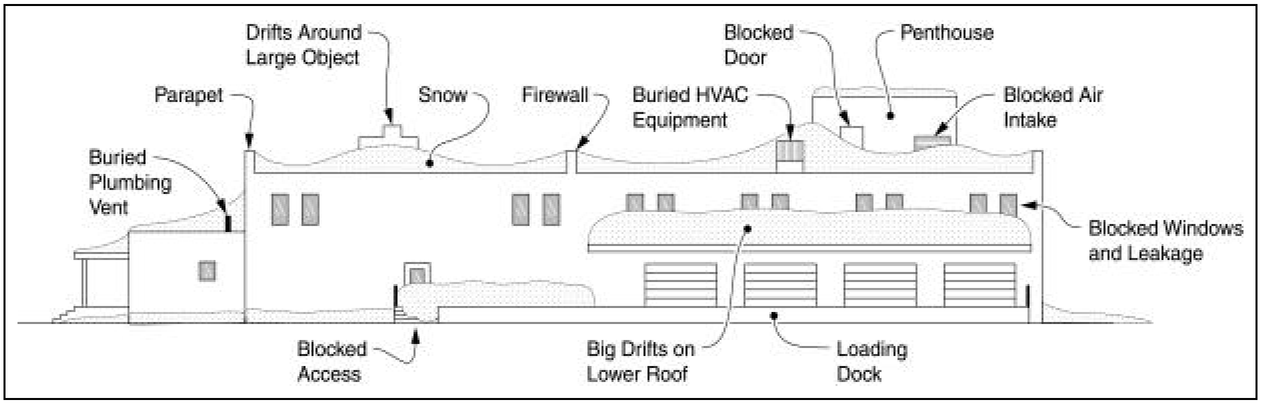

Figure 3. Snow drifts and their consequences.

kinds of problems that are encountered. Drifted snow can then affect the operation of plumbing and HVAC equipment or restrict access to the facility. Solutions to these problems are generally self-evident (e.g., place air intakes high up on the wall, keep windows at roof steps as high above the lower roof as possible, locate plumbing vents and HVAC equipment away from places where drifts are to be expected).

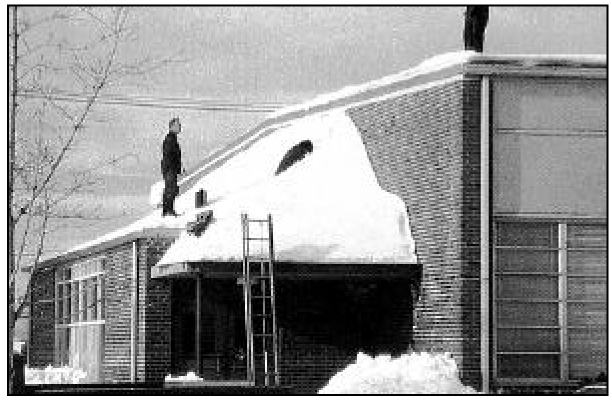

Figure 4. The peak snow load of this drift was 130 psf. The ground snow load at the time was 20 psf, and the snow load on the upper roof was 15 psf.

Big drifts often form on lower roofs. Figure 4 shows a large snow load due to drifting on a flat lower roof. The peak snow load on the lower roof is about nine times the load on the upper roof.

ASCE Standard 7 requires designers to assume that the high winds that cause snow to drift could come from any direction. Nonetheless, information should be sought from “locals” on drift orientation. Where such information indicates strong preferential orientation of snow drifting, give thought to placing drift-prone features (e.g., loading dock roofs) either upwind or alongside the building rather than at its downwind end. Design loads will not change, but the amount of drifting may be reduced significantly (Fig. 5). Raising or

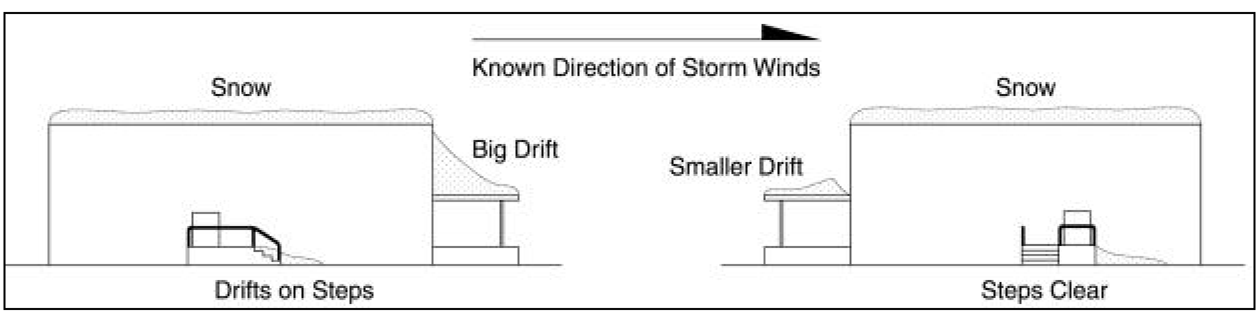

Figure 5. Orienting buildings with respect to the known direction of winter storm winds can reduce actual drifting, even though design loads do not change.

sloping roofs over the loading docks can also reduce drift loads. However, sloping may introduce drainage, ice damming, and sliding snow problems.

4. SLIDING SNOW

The ability of slippery unobstructed roofs to shed snow loads by sliding can be an advantage and a disadvantage [2, 3, 4]. Loads on a roof are reduced when snow slides off, but loads will increase on any lower roofs onto which that snow slides. If snow or ice drops some distance, dynamic loads may be imposed on a lower roof or on an object located below (Fig. 6). Several sliding snow issues are illustrated in Figure 7.

Figure 6. Vehicle damaged by snow and ice that fell from a roof.

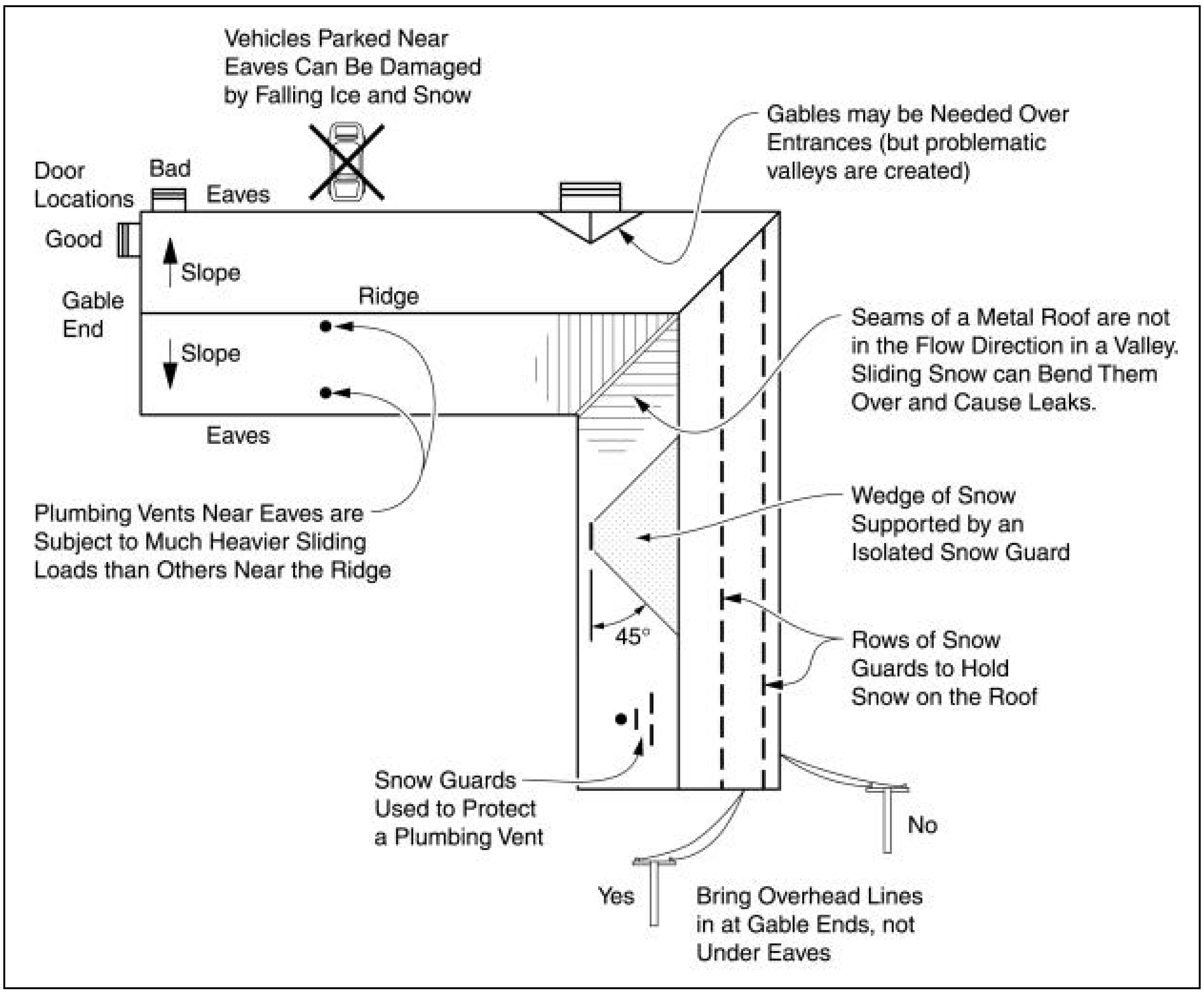

Figure 7. Plan view of a gabled-roof building showing some sliding snow issues.

Snow and ice sliding off sloped slippery roofs can damage property and injure people as far as 30 feet away from two-story facilities. Snow sliding off roofs can block pedestrian and vehicle access. Providing access at the gabled ends of a facility is one way to avoid such hazards (Fig. 7). Entrances located under eaves should be covered.

Snow can creep and glide slowly down slippery surfaces, even those with very shallow slopes. Moving snow can drag plumbing vents (Fig. 8) and other roof penetrations with it, damaging them and creating holes in the roof (Fig. 9) and leaks. By minimizing the number of roof penetrations on slippery roofs and placing them near the ridge, such problems can be reduced. Penetrations that must be placed farther down a slippery roof should be strengthened or protected by snow guards (Fig. 7). If snow slides from roofs having gutters, they will probably be ripped off. Parapets and fascias can also be damaged. Flow of snow down valleys can bend the standing seams of metal roofing, reducing their strength and violating their waterproofing integrity (Fig. 7).

Electrical service entrance cables and other overhead lines located below eaves can be ripped loose by falling snow or damaged by the weight of ice that collects on them from roof meltwater (Fig. 7 and 10).

Large curling snow cornices can be created at eaves (Fig. 1). Such cornices can be quite heavy, and they may curl around enough to damage walls and windows. When they break off, piles of snow and ice are created on the ground. These piles may deflect falling snow sideways towards walls, damaging them. Meltwater that drips onto these piles can enter the building at the base of the wall if that base is not far above the finished grade outside.

Consideration must be given to the fate of meltwater draining onto lower roofs. That meltwater will exacerbate the problems of icings at lower eaves. In addition, lower roofs may need protection from damage due to snow and ice falling from higher roofs. Snow guards may be needed to hold snow in place on slippery roofs.

Figure 8. Plumbing vent displaced by snow creeping down a slippery metal roof.

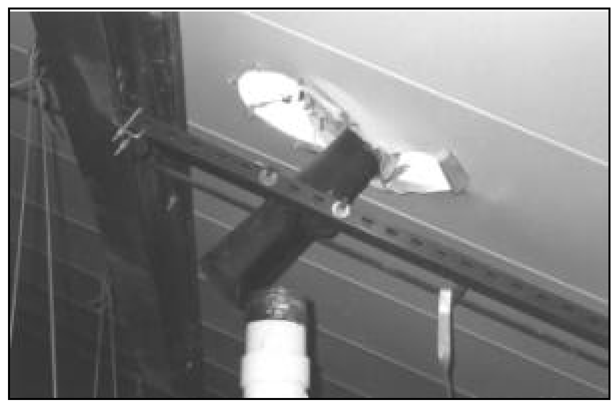

Figure 9. Tear in metal roof caused by plumbing vent displacement shown in Fig. 8.

Figure 10. Electrical service entrance cables should not be located below cold eaves.

5. SNOW GUARDS

Snow guards are objects used to hold snow on slippery roofs. Many slate and metal roofs require snow guards to protect people and property. Snow guards may also be needed on barrel vaults and other such roofs with smooth membranes. Some snow guards are attached mechanically, while others are adhered to the roof surface. Design loads on snow guards should be based on the assumption that friction between the snow and the roof is zero. Multiple rows of snow guards spaced well apart up the roof are better at holding snow in place (i.e., avoiding the dynamic loads created by sliding snow) than one row of last-resort snow guards placed near the eaves. A short snow guard on a long roof without other snow guards must be able to resist all the snow located within outward 45° angles upslope of its location (Fig. 7). The loads at the ends of such a snow guard are about twice the average load on it. The design load on a snow guard should be less than half of any failure load reported by its manufacturer. In high-risk situations (e.g., entrances and emergency exits of schools), allowable loads on snow guards should be even lower. Design guidance, test data, and performance standards on snow guards are limited, so they should be used with caution. Some guidelines are available in the paper "Snow Guards for Metal Roofs" [5].

6. ICICLES AND ICE DAMS

Large icicles and ice dams can form along the eaves of inadequately insulated and ventilated roofs of heated buildings that drain to cold eaves (Fig. 11). Meltwater that backs up behind such icings may leak into buildings, causing serious interior damage and possible loss of occupancy. Icings at eaves prevent snow load reductions by sliding until that ice warms up and either melts or breaks free. Falling ice is a hazard (Fig. 6).

Figure 11. Severe icings developed all along the eaves of this facility.

Figure 12. Electric heaters can create tunnels, which limit ponding behind ice dams on roofs.

An adhered waterproof membrane is needed under steep roofing such as shingles at valleys, around skylights and other large penetrations, and along eaves to avoid leaks when icings back up water in these places.

On existing buildings, electric heaters may be needed to keep small tunnels melted through ice dams (Fig. 12). The tunnels allow meltwater to run off the roof, reducing the potential for ponding, roof leakage, and ice dam growth. Electric heaters are relatively easy to install along the eaves of a roof with asphalt shingles. Installing electric heaters on standing seam metal roofs is more difficult. Guidelines are available in the paper "Electric Heating Systems for Combating Icing Problems on Metal Roofs" [6]. Slippery surfaced roofs with electric heaters need snow guards to prevent heater damage by moving snow. New roofs should be designed so that they do not require electric heaters.

7. ROOF VENTILATION

Problematic icings at eaves can be avoided when roof ventilation systems are able to keep the temperature of the roof from rising above 32°F when the temperature outside is about 22°F. When it is warmer outside, icings usually do not grow, and when it is colder outside, less ventilation is needed.

Equations for sizing attic ventilation systems are presented in the article "Attic Ventilation Guidelines to Minimize Icings at Eaves" [7]. Equations and graphs for sizing ventilation systems for sloped roofs with cathedral ceilings are presented in the article "Ventilating Cathedral Ceilings to Prevent Problematic Icings at Their Eaves" [8]. The extra cost of adequately insulating and ventilating a roof to limit icings is easy to justify since the water that ponds behind ice dams is apt to leak into the building, causing significant problems.

Details often determine the success or failure of ventilation systems. Many "as-built" ventilation systems contain constrictions and blockages, which greatly diminish their performance. Attention must be given to minimizing exfiltration of warm, moist indoor air up into attics and cathedral ceiling airways, since it can significantly reduce the effectiveness of ventilation provisions. Vapor retarders are often necessary in cold climates. Air leakage at gaps in poorly installed vapor retarders is often the reason for moisture problems within roofing systems in cold climates. Vapor retarder continuity is essential.

Complex roof geometry tends to create problems in cold climates [3, 4, 9]. Simple, sloped roofs with cathedral ceilings are relatively easy to ventilate, but roofs with valleys, dormers, and other complications often require provisions such as cross-purlins to interconnect airways and move cold ventilating air into these areas as shown in Figures 13 and 14 [10, 11]. However, some fire codes restrict or prohibit this type of roof ventilation.

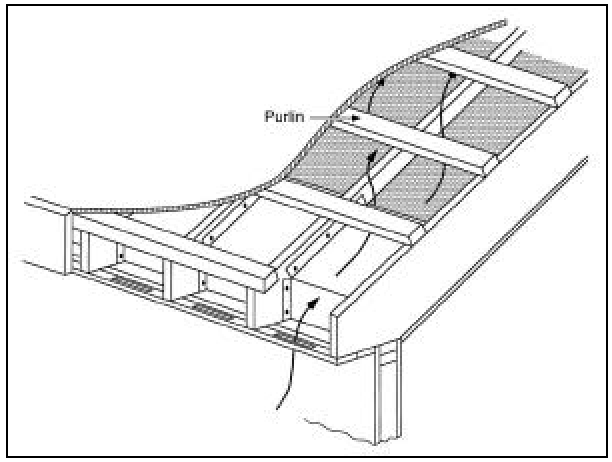

Figure 13. Use of cross-purlins to interconnect the airways of a roof.

Figure 14. Cross-purlins allow ventilation of this valley.

8. SNOW INGESTION

Snow ingestion can become a problem at roof ventilation openings. Wind baffles are effective at directing wind-blown snow up and over ridge vents [11]. On occasion, intakes at eaves may have to be baffled to block infiltrating snow.

9. CONCLUSIONS

Problems can be avoided and more functional designs developed when snow and ice issues are considered as the design of a building evolves. With a little thought during the design phase, the adverse effects of snow drifting on roofs can be minimized.

Low-slope roofs that drain to cold eaves are particularly problematic in cold climates. It is better to drain low-slope roofs internally, since that avoids all of the over-the-eaves drainage problems mentioned in this paper. It is impractical to drain low-slope metal roofs internally.

Roofs that drain to cold eaves can encounter snow and ice related problems in cold climates. Snow guards may be needed on slippery-surfaced roofs to prevent damaging snow movement. Icings at eaves are minimized when roofs are well insulated and ventilated.

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