Snow, Water and Ice: Understanding and Solving Water Backup and Ice Accumulation

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Key Words

Snowguards, ice damming, snow fences, snow slide, ice and water protection membrane, ice cornices, underlayment, snow creep, ice dam walls, icicles, heat trace

Abstract

As the winter of 2000–01 in the northern United States showed, there is a great deal of misunderstanding among architects and contractors with regard to ice damming and its resultant water backup, eave ice accumulations, snow accumulations, and the potential for personal injury and building damage. This paper proposes to take a practical approach to reviewing these issues across a number of steep-slope roof systems: asphalt shingle, slate, clay tile, wood and metal. Recommendations, suggested details, and examples of successful ways to prevent water intrusion into the roof system and to deal with snow and ice accumulation will be presented.

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Introduction

More than 40 inches (1 meter) of snow accumulated during the month of December 2000 in Chicago as a result of numerous snowfalls. Snow accumulations of 2 feet (.65 m) or more on steep-slope roofs was not uncommon. The following months of January and February brought little additional snow, but periods of clear skies with mild daily temperatures (30° F – 40° F) (0° C – 3° C) had catastrophic results on residential and commercial properties.

Physical damage to buildings caused by moisture intrusion as a result of ice damming and falling and sliding snow and ice was severe. The cost of repairs was astronomical. One insurance company located in the Chicagoland area reports that insurance checks for damages incurred as a direct result of ice damming, falling and sliding snow and ice were in excess of US $100 million. Payments of this magnitude affect everyone with regard to future premiums. The startling fact is that the authors believe that upwards of 75 percent of the conditions that resulted in insurance claims could have been prevented with proper roof system design and installation. Imagine, US $75 million dollars in savings, not to mention the business and family disruptions, loss of revenue and materials, as well as irreplaceable items such as photos and family heirlooms. You would be led to believe insurance underwriters would welcome all attempts to minimize claims. Sadly, there is little current movement toward realizing the benefit of providing incentives for properly designed and installed roof systems. This paper will attempt to define those concerns and provide design guidelines for success.

What Happens When There's Snow on a Roof?

The accumulation of snow on a roof is the initial condition required to produce ice and water concerns and the manifestations of interior—and in some cases exterior—damages. What happens to the snow once it is in position on a roof is key to the type of concern it produces and design steps required to minimize the concerns. The type and moisture content of snow will affect its ability to be modified. Following are some of the changes to snow after it initially accumulates on a roof.

1. Blow off: The best-case scenario occurs when either during a snowfall or afterward, high winds remove snow from a roof. Snow during cold temperatures, defined here as 10° F (-12.2° C), produces the greatest possibility for this type of removal because of its lightness. Roofs of smooth texture, such as slate and metal panel, also facilitate this removal mode. Roofs with steeper pitches, such as 55 degrees (16-in-12), accumulate less snow.

2. Redistribution: In addition to snow removal, high winds may also redistribute the snow in the form of snowdrifts across roofs. Building geometry plays a large part with regard to the location of snowdrift accumulation. The sides of differing roof

heights and roof section offsets are particularly susceptible to large snow accumulations. Snow cornices develop on the lee side of ridges. Snow accumulates in other protected areas, such as the base of valleys and leeward side of walls. Drifts of 6.5 feet to 10 feet (2 m to 3 m) are not uncommon.

3. Sublimation: Following periods of snow when low temperatures and clear, sunny skies prevail, the accumulation of snow can be reduced through the effects of sublimation. Winds, low relative humidity and altitude will affect the rate of evaporation.

4. Melting and refreezing into ice: The melting of accumulated snows or ice because of either solar radiation, building heat loss, or air vapor transmission and latent refreezing is the most common and recognizable characteristic of accumulated rooftop snows. It is the main condition that leads to the creation of ice dams.

5. Slide off: Built-up snow falling from roofs as a result of sliding can be dynamic, spontaneous and dangerous. Slides usually occur on roofs of steep slope and smooth surfaces such as slate, tile and metal. Slides generally occur when gravitational forces exceed the frictional restraining force of a roof covering. This generally occurs when a roof covering surface warms and a condition of zero frictional force is present. Cohesive failure of the snow pack can occur in conditions of heavy snow and steep slope. Both sliding snow and shearing of accumulated snows pose considerable concern with regard to life safety and the potential for building and property damage.

6. Creep: When conditions for snow slides are not met, accumulated snow will often slowly and methodically move towards a roof's eave edge and over the eave as a result of downward force and gravitational pull. The snow/ice mass has a tendency to curl over the edge toward the building.

7. Snow/ice cornices: The drifting of snow and continual buildup of snow and/or ice at a roof's eave edge may form large vertical or just slightly off-vertical faces. Although often a result of melting and refreezing, the snow/ice cornice could also be the result of the break off of creeping snow and ice. These cornices tend to be heavy and potentially dangerous.

8. Falls off: As snow and/or ice accumulate at an eave edge, the potential exists for it to fall. The potential for sections of ice/snow to break off and fall are exacerbated by warm temperatures; additional snow sliding from above; dynamic loading, such as being hit by falling snow/ice from above; and removal of associated icicles. Great caution and care should be taken around snow/ice cornices, creeping movement and areas of sliding snow because as the potential for life-threatening conditions exists, as does the potential for building and property damage.

POTENTIAL PROBLEMS

Snow or ice accumulation on a roof surface may not be problematic. Many buildings and roof systems have been properly designed for the conditions indicated previously. The best defense against dangerous snow and ice conditions is to design a building to avoid them. Sometimes, it is not possible; often, it is not given consideration or the building designer is just not cognizant of the potential concerns. Because most buildings are not designed to avoid snow and ice problems, problematic conditions should be defined before solutions are considered. Following are conditions the authors feel would be unacceptable to building users.

1. Leakage: Interior and exterior moisture infiltration caused by snow and ice accumulation is considered to be unacceptable, presenting a basic goal of roof system design. Not all leakage caused by snow and ice manifests as ice-dam conditions at eaves. Building geometry often causes shadows across lower roof areas, creating *cold spots* on a roof where refreezing of melted ice can occur. The result can be ice damming in the field of a roof. Roof system designers are encouraged to consider a building's form and how this might affect the roof during periods of snow and ice and freeze and thaw. Ice formation on walls and around roof drainage systems cause damage.

2. Icicles and ice cornices over public areas: Icicle formation at eave and gutter eave locations is typically considered a normal manifestation of snow melting and refreezing. Icicle formation over areas where there is no anticipated foot or vehicular traffic would most often be considered acceptable because falling ice would not result in injury or damage. Eave conditions that allow icicle formation over sidewalks, entries, parking lots and vehicular paths should all be considered unacceptable. Icicles with a potential to cause damage to roofs below or gutter deformation are unacceptable. The potential, over the long term for injury, death or damage is too great not to be considered a condition requiring specific and special design consideration.

3. Snow slides: The spontaneous and dynamic release of a snow mass across a roof system carries with it the potential for major building damage, property damage and personal injury. Rooftop damage, such as sheared-off plumbing vents, repositioned and damaged roof curbs and rooftop equipment and damage to the roof system itself, are possible in slow-slide conditions. Damaged or destroyed landscaping, cars, building components and equipment, as well as increased maintenance of walkway and driveways are a problem. Snow slides carry the risks of personal injury or perception of personal danger.

4. Loading (structural concerns): Solid ice dams, icicles, or cornices of considerable thickness and size are not out of the ordinary. A solid square foot of ice weighs about 62 pounds (28 kg). When masses of ice reach 2 feet to 3 feet (.67 m to 1 m) and are increasing in thickness, potential structural loading concerns exist.

Concerns with the Potential Manifestations of Problems

1. Moisture intrusion: The interior and exterior presence of moisture caused by any of these conditions has the potential to destroy finishes, materials, furniture, equipment or products; damage walls and windows; create long-term structural concerns; and, in the worst case, support mold and fungi growth. This last concern problem has raised air-quality and health concerns. In the United States mold growth caused by roof and wall leaks is of tremendous concern. With no medical or environmental guidelines to moderate concern and even hysteria, judicial awards can be significant.

2. Building and property damage: For the purposes of this paper, building and property damage is defined as the complete or partial destruction of equipment, landscape and physical building components beyond that which can occur through moisture intrusion. Falling icicles, sliding snow and dropping ice cornices can result in considerable damage. Landscaping elements can be crushed. Lower roof systems and even roof decks can be penetrated or damaged. Penetrations, such as plumbing vents, exhaust fans, chimney flues, gutters and ice-guard fences, have all been known to be sheared off. Gutters and drain systems are often damaged. Cars, mechanical equipment and property on the ground have also been destroyed because of ice movement. A key concern to preventing this damage is to prevent the snow/ice from moving or prevent it from forming in areas outside a controlled area. Once a zero-frictional plane develops and snow and ice slide, attaining momentum force, there is little that can be done to prevent the mass from leaving the roof, resulting in damages.

3. User safety: It is common sense that if sliding, falling, dropping snow and ice can result in building damage and destruction, personal injury or death are great possibilities. Ice and snow buildups on pedestrian and vehicle ways are dangerous and a maintenance problem. Icicles, large columns of ice along walls and downspouts, and ice cornices are all extremely dangerous. Building geometry, design and construction that result in these conditions above personnel traffic areas will create situations of never-ending peril. There is no timing of an icefall event; it just occurs. Hoping that when it does no one is injured is not considered a defendable position in the courts. Building design to prevent potentially dangerous conditions should be the first line of defense against building damage and user injury.

DESIGN CONSIDERATIONS

Most of the building damages and personal injury that result from snow and ice could have been prevented had an architect, engineer or roof consultant taken the necessary steps to design for this concern. Following are parameters that should be considered in the roof system design process.

1. Climatological data: As with all roof system design, a designer should begin with obtaining the pertinent climatological data. It is important for a roof system designer to realize that rainfalls and snowfalls can be localized, and, therefore, data from the closest possible area is imperative. It is not uncommon in areas around the Great Lakes to have snowfall differences of 6.5 feet (2 m) within a 60-mile (100-km) distance. Data that need to be obtained include snowfall data, consisting of average winter snowfall, average snow depth across the winter and the total of all individual snowfalls. The authors believe a roof system should be designed for the worst-case scenario. Consequently, the total expected snowfalls should be used as the design parameter. For example, in Chicago it is expected that eight individual snowfalls will occur totaling 48 inches (1.3 m). If Chicago-area roofs had been designed for that expectation in the early months of 2000, millions of dollars in damages and untold cases of heartbreak could have been prevented. While obtaining and analyzing data is a valuable exercise, the authors acknowledge and agree that the finest designs come from those who work in the climate in question and have the experience that can be complemented by data

   Additional climatological data that needs to be given consideration include the number of days of sun and wind speed and direction. Altitude and solar radiation in mountain areas are important.

2. Slope: Roof slope plays an integral part in the movement characteristics of snow once it is accumulated on a roof. Lower slopes tend to restrict snow's movement once accumulated, resulting in greater loading and ice-damming conditions with its reformed water. Steep slopes tend to shed their loads. It is generally agreed that steep slopes are a more prudent design decision but when all the roof system design parameters, building geometry and design are considered, a low slope may actually be the better choice.

3. Rafter length: The distance from an eave roof edge to a ridge is generally considered the rafter length. In conditions in which a higher roof drains onto a lower roof with its slope in the same direction, the rafter length must also include the length from the lower eave edge to ridge. This rafter length is used to calculate the volume of water that will reach the lowest eave roof edge. Many asphalt shingle manufacturers and producers of ice-dam protection membranes appear to base their recommendations for the application of self-adhering ice-dam protection on traditional residential construction, which has average rafter lengths of 16 feet to 24 feet (4.8 m to 7.3 m). For example, utilizing their recommendations on schools often having rafter lengths in excess of 70 feet (21.3 m) will result in unsatisfactory results.

4. Roof covering: The type of roof covering and its surface texture individually and as a system *in situ* will greatly affect snow/ice potential for sliding. Rough or course surfaces, such as asphalt shingles and some clay tile, assist in preventing snow and ice movement, and the smooth surfaces of glazed clay tile and metal

almost promote the sliding of snow and ice. As suggested previously, though it is generally preferred to retain snow and ice on a roof, knowing how a roof covering texture affects snow movement can be an important design tool. By way of example, one author had to deal with enormous ice cornices and icicles on snow conditions that, though they posed known personal safety concerns because of location, they also posed considerable concern for the fragile landscaping below, as well as loading conditions for the roof deck. The solution was to install a copper Bermuda seam roof 5 feet (1.5 m) upslope from the eave edge and asphalt shingles above. The copper roofing provides a slip plane by which even the heaviest of snows are removed within a few days.

5. Ventilation: Current thought permeating the roofing industry calls for utilizing ventilation as a means for creating a cold plenum below a roof deck, thus preventing built-up heat and air loss from melting the snow and ice above. Although the Cold Regions Research and Engineering Laboratory (CRREL) has researched this considerably in arctic locations, the authors have found in field experiences and observation across the mid-western United States in a more moderate climate that too much emphasis is placed on ventilation. This results in poor design, improper ventilation techniques, and a failure to understand the plain fact that cold air movement into and out of most attic spaces is much too little to obtain temperatures below the freezing point. Although ventilation of an attic space may be prudent, like all the other parameters it needs to be considered as one part of a roof system design. The decision of how much or how little ventilation should be incorporated into a design is based on how a roof is designed to function. Ventilation cannot affect the role of solar radiation on these snow and ice problems as shown by problems on unheated and open structures and the special problems with roof slopes with southern exposure.

6. Insulation: In addition to interior air loss, heat loss through a roof is the greatest cause of snow melt. Preventing heat loss is relatively easy through the use of insulation. Fiberglass insulation is the predominant type of insulation utilized in the United States in steep-slope construction. The most beneficial location of insulation is as close to the heated space as possible, such as on the ceiling instead of in the rafters. The relatively low cost of insulation and its great benefits leads the authors to recommend utilizing two layers of unfaced batt insulation with a total R-value of 50 or more. The first layer should be placed between the rafters; the second should be placed perpendicular to the first, thus minimizing thermal shorts at the rafters. It is suggested unfaced material be utilized with a separate vapor/air barrier installed to the warm side of the insulation that will provide superior results over faced insulation, which produces too many laps and gaps.

7. Air/vapor barriers: In association with thermal insulation, providing quality air/vapor barriers is of paramount importance. Minimizing the flow of warm, moisture-laden air upward into an attic will significantly reduce snow melt and condensation within the attic. All penetrations in a ceiling need to be taped and

sealed, including vent pipes, exhaust ducts, recessed lighting and conduits. Proper termination at structure walls is an important consideration too.

8. Mechanics of snow sliding: An understanding of how and why snow slides is important to roof system design. No matter the roof slope or surface texture, snow slides when the coefficient of friction approaches zero and a near-perfect shear plane exists. Of course, there are a number of parameters that affect when this actually occurs, including the type of snow, how long the snow has been on the roof, the number of freeze-thaw cycles it has gone through and roof slope and material type. When spring or extended periods of thaw occur, even ice locked to the roof may break free. Momentum is a snow slide's greatest ally. If sliding snow/ice can gain substantial momentum, there is little to stop the slide, and serious damage can occur. Friction and barrier can be designed, and momentum can be controlled.

9. Ice-dam protection waterproofing membranes: The use of self-adhering ice-dam membranes for protection against roof-trapped water and water migrating into a roof system has become commonplace and is a catchall for poor roof system design. Few realize ice-dam protection waterproofing membranes are a recent material and should not take the place of good roof system design. There are a number of membranes in the marketplace of varying thickness, material and quality. Designers are encouraged to become cognizant of membrane, SBS-modifier percentages and infield workability. Priming a substrate prior to installation is recommended in many conditions--even in summer--to achieve a tenacious bond with the deck. Cold temperature applications should be kept to a minimum but, if required, should include rolling a membrane and heat welding the laps. Experience has shown that traditional waterproofing systems composed of roof felts and asphalt-based mastics can provide greater thickness, strength and sealant properties and, by implication, longer life. The amount of waterproofing membranes to be included in a roof system design is a subject of much debate. Amount of snow, freeze-thaw, rafter lengths and pitch all contribute to its use. Membrane and shingle manufacturers' guidelines are most often of little use. Not only is application above the eave important but the distance upslope beyond the vertical plane of the interior void is, too. The authors recommend, as a base condition, that all steep-slope roof systems begin with the application of membrane over the roof overhang no matter the width and 3 feet (1 m) upslope beyond the inside face of the interior wall. For slopes of 6-in-12 and below, the amount of ice-dam waterproofing membrane applications should increase by 18 inches (.46 m) for every 10 feet (3 m) of rafter length.

    For example, a roof slope of 5-in-12, rafter length of 70 feet (21.3 m), 4 foot (1.2 m) eave overhang along the slope (or rafter), and 12-inch (.3 m) wall will require the following amount of self-adhering membrane:

Base parameter 4'-0" eave coverage + 1'-0" wall width + 3'-0" upslope of interior wall = 8'-0"
8'-0". + 70'-0" rafter length/10 = 7
7 X 1.5' = 10'-6"
8'-0" base parameter + 10'-6" calculated coverage = 18'-6" total coverage.

For slopes 6-in-12 and greater, the base parameter is the same, but the additional coverage is reduced to 1 foot (.3 m) for every 10 feet (3 m) of rafter length.

In addition to eave locations, the use of ice-dam protection waterproofing membranes is often prudent to be utilized in valley conditions; around roof penetrations, such as roof exhaust fans and chimneys; and along vertical wall terminations and under any spillways. Coverage recommendations for valley conditions are 6 feet (1.8 m) out from the center of the valley for roofs with slopes greater than 4-in-12 and 9 feet (27 m) for roof slopes below 4-in-12. For penetrations on roofs 4-in-12 and 9 feet, coverage of 3 feet (.9 m) out beyond the curb and valley created by the saddle to the high side. For those roofs less than 4-in-12, 6 feet (1.8 m) out is recommended.

Areas of shadow below exposed roof sections should also be considered because snow melt will freeze in the shadows and create ice-damming conditions within the field of the roof.

10. Heated versus unheated buildings: Although the potential for dangerous snow and ice conditions on unheated buildings is considerably less than that for heated structures, they nonetheless need to be given careful consideration. Interior building use such as animal husbandry creates a good deal of heat as does solar radiation. Shopping mall overhangs and other open shelters often disregard these concerns and are saddled with dangerous conditions each winter.

11. Attic temperature: As peripherally reviewed with insulation and air/vapor barrier, attic temperature can play a strategic part in how a roof will act once it holds accumulated snow. As one may assume, a cold attic is the most desirable. Attaining it without mechanical means can be challenging, if not impossible, in most residential and light industrial and educational buildings. As a consequence, as ASHRAE suggests, a roof system designer is recommended to design a roof system as if a perfectly cold attic space will never be attained. Being conservative in this approach will allow for any gain achieved by a cold attic to be complementary to the roof design, and not achieving perfect cold will not be a detriment.

12. Heated Roof Areas: Depending on the building type and situations, there may be times when a warm attic, eave or base of interior gutter is actually designed into the roof system as a preventative measure of ice buildup. Knowing how, when

and where to utilize cold and warm attics will offer the roof system designer one more element in the arsenal of preventative design measures.

PREVENTION AND CONTROL

One unique property of snow and ice conditions is that, at times, it is a proper design consideration to try and control a condition known to occur rather than trying to prevent it from occurring. Depending on a building's type, location and climate, it will be up to a roof system designer to use this knowledge, experience and perception in making these types of discretionary design decisions.

In the next section of this paper, the prevention and control of the following conditions will be discussed: ice dams, snow sliding and falls, and icicles. Roof system designers are encouraged to thoroughly review building design, geometry, roof system design considerations and budget constraints prior to committing to a method of prevention and control.

Ice Dams

The occurrence of ice dams on residential homes in the United States is so commonplace and, at times, problematic one would think design practices would have evolved to successfully prevent them from occurring or to least control them. The current standard practice is to provide some semblance of attic ventilation and to utilize ice-dam protection waterproofing membrane. When these methods are not thought out and well implemented, the result is moisture intrusion during periods of heavy snow and ice accumulation. As previously mentioned, a main concern is that roofs are not designed for snow accumulation totals as recommended by the authors.

Incorporating full eave and ridge ventilation into an attic is the initial step in minimizing snow melt and its resultant ice buildup. Gable ends, dormers and attics utilized as living spaces complicate this design element. Incorporating a well-installed, quality air/vapor barrier in association with sufficient thermal insulation also is a must. Err on the side of conservatism, and provide great amounts of insulation. It's imperative all penetrations be sealed to the air/vapor barrier and that the air/vapor barrier at exterior walls be properly transitioned and sealed. Access panels to the attic should also be insulated and have vapor seals.

Additionally, all interior ventilation plenums, such as kitchen and bathroom exhausts, must be ducted to the exterior and insulated. Taking these precautions will minimize but not eliminate the creation of ice dams as exterior forces outside a designer's control. Solar radiation, temperatures above freezing, etc., will also act to create snow melt and freezing near the eave.

Understanding that ice dams can be minimized but not eliminated will lead a roof system designer toward methods of control. As reviewed above under "Design Considerations", the use of self-adhered ice-dam protection waterproofing membranes is a common method. Installation coverage should follow the authors' recommendations. It has become common practice by some to cover an entire roof deck surface with these nonpermeable membranes. Although this practice is appropriate for some special conditions or constructability purposes, roof system designers are cautioned to proceed carefully with this practice and fully study the effects of double vapor barrier construction. The entrapment of moisture within an attic is of great concern.

The use of metal roofing in a variety of designs and constructions can help control ice-dam buildup, too. Standing seams, Bermuda seams, flat-seam constructions have all worked. The use of solderable metals, such as copper, is recommended for the sealing of joints assumed to be under water. The use of low-slope membrane systems for locations that can be anticipated to be within reach of ice-dammed water can also be utilized. Modified bitumen systems installed with mastics can have long service lives.

Technology has also entered the roofing realm. Proprietary heating systems such as heated shingles and heat-trace systems may be appropriate. Although such heating systems may be appropriate, it's impingent upon a roof system designer to become completely knowledgeable of the systems, and know their limitations, electrical requirements, attachment methods and service lives. It's not uncommon to observe heat-trace systems that are hanging over an eave having been ripped from the roof by a snow slide, thus opening points for moisture penetration and requiring repair.

Snow Sliding and Falls

Designing conditions that prevent snow sliding and falls is so restrictive to the building design effort that it's virtually a nonexistent practice. Designing buildings and roof geometries to control snow sliding and falls, directing them away from locations of foot and vehicular traffic, landscaping and building components susceptible to damage is not only prudent but highly recommended and advisable.

The first step to controlling snow movement on a roof is having a roof system designer recognize conditions that will lead to snow movement. Thus, appropriate design elements can be implemented and designed as part of a roof system rather than being attached to a roof at a later date.

If possible, allowing snow to slide off a roof to the ground or roof location appropriate to receive such a dynamic load is the most practical. Doing so removes snow that could later melt and contribute to structural loads, ice damming, icicles and ice cornices. Designing gables and snow walls to divert sliding snow away from locations of concern can assist in achieving this type of control.

When manipulating a roof's form to protect life and property is not appropriate to the building design, controlling snow accumulation on the roof takes precedence. The concept to remember here is "prevent the snow from moving." The use of snow fences and snow guards needs to be incorporated into the roof system design. The number and location of these fixtures is a rather inexact science, but if incorporating a manufacturer's product, abide by its experience and recommendations. If incorporating a "designed fence" for instance, abide by quality construction and installation techniques, remembering that these fixtures are structural elements and must be fully capable of withstanding considerable loads. The authors have had great success utilizing fully welded bracket construction and fence components of minimum .125-inch-thick 280 brass alloy plate and 230 brass alloy .75-inch pipe with a wall thickness of .114 inch. The brackets should be mechanically fastened to a roof structure with the roof system flashed around the bracket base. In no case should brackets be attached to just a roof deck unless the roof deck is structurally capable of withstanding the loads that will be imposed. Avoid transferring loads through a roof system. An excellent primer article on the mechanics of determining loading conditions on bracket fasteners was by Rob Haddock in the February 1999 issue of the Roof Consultants Institute's *Interface Magazine*.

In locations that require extreme safety, fences of considerable height can be installed incorporating meshing to prevent the falling of snow and ice during periods of melt.

When conditions, design or retrofit applications require, snow fences that resist dynamic snow movement can be designed. These fences should have their structural elements designed by a professional engineer to resist anticipated dynamic loads. Fences can be designed to act as part of a slide guard system for roof maintenance and restrain loose or falling building materials. Intermittent fences on large roof surfaces can also be implemented. Traditionally spacing of 25 feet (7.6 m) has been used, but this is a function of loading, slope, bracket and bolt strength.

As reviewed previously, a roof's slope and covering texture will affect anticipated snow movement, but the shear slippage between snowfall accumulations must not be forgotten. A past snowfall that has experienced some melt, has refrozen and resulted in a glazed-over top surface that is then covered with new snow creates a situation where the first snow is locked into the roof covering, but the new snow is held tenuously in place atop the first and may slide at any given moment.

When reviewing snow slides and falls, a roof system designer must, at all times, remember that the condition he is designing for can be life-threatening and take a conservative and precautionary thought process in the design of the preventative and control methods.

Icicles

Of all snow and ice conditions, icicles, ice columns and overhanging ice cornices seem to cause the most concern. This concern is for good reason because the thought of dagger-sharp stalactites overhead is not a comforting one. Unfortunately, overhanging ice is a characteristic of snow regions. As with ice-dam conditions, a roof system designer may be able to minimize the conditions that lead to icicle formation, but ultimately Mother Nature will prevail. At some time, icicles will form.

As reviewed under “Ice Dams”, incorporating substantial ventilation, thermal insulation and a quality vapor/air retarder is an essential beginning to prevent icicle formation. These types of prevention techniques are considered passive design elements.

Another passive approach that has been utilized successfully for years in snow regions prior to the use of the products developed to overcome design shortfalls is metal roof coverings at the eave in association with the main roof covering of choice. One author successfully incorporated a copper Bermuda seam roof panel 5½ feet (1.75 m) upslope from the eave. Enormous icicles and ice cornices have since been eliminated in all but the most severe conditions. Even then within the first few days of melt, the small accumulation of ice is removed from the roof.

Building design and roof geometry can also be utilized to minimize this concern. Eliminating eaves above pedestrian and vehicular traffic or protecting such traffic by use of dormer gables is effective. By not incorporating gutters into a roof edge and designing in eave drips whenever possible, a designer can also prevent future gutter damage and minimize the formation of large icicles. Taking a more active approach involves heating systems for use in the gutters, conductor boxes, downspouts below metal flashing, and along the roof eave utilized as individual solutions or in conjunction with one another. Glycol systems have been successfully incorporated into the substrate under large gutters and saddles. These systems involve the same elements used in heated floors or walkways and driveways.

Heat trace can also be incorporated into a roof edge design, but this takes well-thought-out design to be successful. The objective is to control the melted water and keep it liquid as it travels from the roof edge area where it may refreeze down to a ground level drain area or sewer. First, the heat-trace cable should be of an industrial size and function, be wired directly to power, and function on humidistats and thermostats. The industrial size cables will melt an area out from the cable of approximately 2 inches to 3 inches (5 cm to 7.6 cm). This 4- to 6-inch (10- to 15.2-cm) area of melt around each cable requires that the cable pass itself every 12 inches (.3 m) or so. As a result, a great deal of back-and-forth is required. Downspouts should include passes down the pipe to grade or below into subgrade drainage pipe systems to an elevation of 12 inches (.3 m) beyond the frost line and then back up.

Another challenge of installing a heat-trace cable is securing the cable to roof coverings, gutters and downspouts without jeopardizing the waterproof integrity of the roof system clips attached to the roof deck. The connection needs to successfully resist the pull of snow slides from above, and ice locked around the cable during periods of intense cold will tend to pull on the connection. One manufacturer has ingeniously protected the cables below metal pans that also act as heat conductors, which increases the area of snow melt.

The long-term performances of most heat-trace systems are not in line with the service lives of the roof coverings. With its inherent shortcomings and potential for jeopardizing a roof system, it is the authors' recommendation heat-trace cable systems be utilized as a last resort.

Recently, the marketplace has seen the introduction of an asphalt product incorporating heat trace within the roll product. It is granule-surfaced to closely resemble asphalt shingles but is a roll roofing product. This may pose an aesthetic concern, especially on steep-slope systems where a roof covering is often utilized as a major design element. The product is considered by the authors to still be in its experimental stages, and designers are recommended to proceed with caution.

Many existing structures were built with no thought given as to how the roof systems would function under severe snow accumulation. Incorporating solutions to prevent and control snow and ice within a roof removal and replacement scenario and a given budget can be challenging and require innovative solutions.

One recent project in Chicago found adjacent gables and three slopes draining to a small conductor box that was located within 3 feet (1 m) of front entries and garage entrances. Following the snowfalls of December 2000, the ice formations above the conductor box were more than 2 feet (.6 m) thick, and ice-encased downspouts extending more than 25 feet (7.6 m) were up to 18 inches (45.7 cm) in diameter. In addition to interior leaking, the ice columns facilitated moisture penetration through many windows, and the ice columns created life-threatening situations.

The solution to prevent interior and exterior moisture penetration and creation of water overflow and resultant ice column was restricted by budget constraints that did not allow for redesign, enlargement and installation of new conductor boxes. Heat-trace systems were deemed to be too expensive and inappropriate for this application.

The solution involved a three-part design. First, it was known that substantial snow and ice accumulated at the confluence of the three roof slopes and two valleys. This snow and ice resulted in large amounts of water being held on the roof, which were backing up under the asphalt shingles. This was considered a water retention situation and produced concern. As such, a low-slope roof material, EPDM, was designed to be installed in this area and to extend upslope 18 inches (45.7 cm) beyond the maximum anticipated height of the water. The transition to the new asphalt roof system involved the installation of a copper transitional flashing piece set in mastic compatible to the EPDM membrane and nailed with ring-shank copper nails at 8 inches (20.3 cm) on center through staggered predrilled pilot holes. The top of the copper transitional flashing was primed and stripped in with a self-adhering ice-dam protection membrane that was extended another 6 feet (1.8 m) upslope. No. 30 roofing felt, starter and field shingles were then installed.

The final design element was the installation of an ice-dam wall. This wall was constructed at the conductor box location. At the bottom, a 4- by 12-inch (10 cm by 30.5 cm) scupper was created. The wall height was determined by the maximum anticipated snow accumulation—in this case, approximately 3 feet (1 m). The entire wall was constructed on the ground and composed of 2- by 4-foot framing and ¾-inch plywood. The top cap was left off for final attachment. Prior to installation, this wall was clad in EPDM. Set in mastic, the wall was bolted to the existing structure and the cap 2 by 4 set and clad in EPDM. The exterior side was faced with metal standing-seam siding and coping; the interior EPDM was left exposed. Two substantial snowfalls have shown the solution to be performing exactly as anticipated.

This example exemplifies the thought and consideration that needs to be given to the prevention and control of snow and ice conditions on new construction and retrofitted work. Spending time and effort prior to construction will save time, defending oneself in court or, worse yet, apologizing for personal injury. Following are recommendations for the design of preventing and controlling snow, ice and water backup conditions.

RECOMMENDATIONS

1. Prior to roof system design, research and obtain site-specific historical climatological data with regard to snowfall accumulation amounts, wind, freeze/thaw cycles, and any other localized weather phenomenon that will affect and influence snow melt and ice creation.

2. Design for 100-year totals, including the total accumulation of all snowfalls across the winter as if there were no melting of the previous snowfall.
3. Consider roof slope and rafter length in the design analysis; steeper slopes and shorter rafter lengths are best.

4. When possible, use building design and roof geometry to prevent the creation of dangerous conditions.

5. Realize the importance of the "robust roof" and the use of quality materials.

6. Design roof coverings, underlayments, and ice and snow controls as a system, remembering that a roof is only as good as its weakest link.

7. Incorporate air/vapor retarders, thermal insulations and ventilation to minimize the effects of heat loss on snow melt.

8. Incorporate heating systems only as a last resort after all passive prevention and control concepts have been considered.

9. Observe and study existing roof systems during periods of heavy snow to understand and learn how snow behaves under various conditions.

10. Observe installation procedures to verify installation to design and specification.

11. Design in redundancies.

ROOF COVERING SPECIFIC RECOMMENDATIONS

Asphalt shingle roof systems

1. Provide waterproofing membranes and underlayment at eave, valley, wall and penetration locations.

2. Utilize reinforced gutter systems to handle anticipated ice loads.

Slate and clay tile roof systems

1. Provide a waterproofing system and underlayment with adequate service life at eave, valley, wall and penetration locations.

2. Provide snow fences or snow guards as needed to prevent injury or damage to people and property.

3. Protect penetrations, such as vent and flue pipes and roof curbs, from the effects of snow slides.

4. Utilize reinforced gutter systems to handle ice loads.

5. Keep front gutter edge below projected slope line where snow slides may occur.

Wood roof systems

1. Provide a waterproofing membrane and underlayment at eave, valley, wall and penetration locations.

2. Utilize reinforced gutter systems to handle anticipated ice loads.

Metal roof systems

1. Utilize machine-locked seams on slopes less than 4-in-12.

2. Provide a waterproofing membrane and underlayment at eave, valley, wall and penetration locations.

3. Provide a method for moisture intrusion into a metal roof system to exit out of the eave rather than penetrating into the building.

4. All roof-to-wall conditions need to be designed to withstand submersion.

5. Realize that rooftop equipment (exhaust fans, etc.) are heat-producing, and melt snow even in the coldest weather, creating micro-climate conditions that need to

be analyzed and given consideration; ice damming and snow sliding are typical conditions that will result.

6. Snow slides will occur with ease.

7. Snow fences and guards must be installed so metal panels can move yet be structurally sound.

8. Protect penetrations, such as vent and flue pipes and roof curbs, from the effects of snow slides.

9. Utilize reinforced gutter systems to handle ice loads.

10. Keep front gutter edge below projected roof slope line where snow slides may occur.

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