Risk Management Series

Snow Load Safety Guide

FEMA P-957 / January 2013

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1 Introduction

1.1 General Objective

The objective of the Risk Management Series *Snow Load Safety Guide* is to inform building stakeholders about the risks a snow event poses to their buildings, provide them with information about preventative measures to take before the snow season, and inform them of actions that should be taken before, during, and after a snow event.

1.2 Objective and Scope

Most buildings are not at risk of snow induced failure. More often than not, attempting to remove snow from a roof is more hazardous than beneficial, posing a risk to both personnel and the roofing structure. However, snow accumulation in excess of building design conditions can result in more than a temporary loss of electrical power and inaccessible roads. Buildings may be vulnerable to structural failure and possible collapse if basic preventative steps are not taken in advance of a snow event. Knowledge of the building roof framing system

and proper preparation in advance of a snow event is instrumental in reducing risk to the structure.

Structural failure due to roof snow loads may be linked to several possible causes, including but not limited to the following:

- Actual snow load significantly exceeds design snow load
- Drifting and sliding snow conditions
- Deficient workmanship
- Insufficient operation and maintenance
- Improper design
- Inadequate drainage design
- Insufficient design; in older buildings, insufficient design is often related to inadequate snow load design criteria in the building code in effect when the building was designed

This document is not intended to provide a comprehensive discussion of the underlying issues or forensics of snow-induced structural failure. The purpose is instead to:

1. Inform building stakeholders of susceptible snow loading conditions
2. Identify potentially vulnerable roof framing systems
3. Outline a general methodology to monitor buildings for signs of potential failure so that steps can be taken to reduce the potential risk of snow-load-induced structural failure

1.3 Intended Users of this Document

- The intended audience of this guidance document is building stakeholders. Stakeholders may include:Property owners
- Building and facility managers
- Homeowners
- Emergency managers
- Other decision-makers

1.4 Reasons for Preparing this Document

The northeastern part of the United States suffered multiple major snow storms in the winter of 2011 that resulted in numerous building failures. Unlike national safety and response guidelines for flood and seismic events, currently there does not exist a unified document that discusses mitigating damage to roof systems resulting from excessive snow loading.[1] State governments and local jurisdictions throughout the United States may publish snow safety guidelines, but the guidelines might not be issued until a snow event has occurred.

1.5 Limitations

This document is not a commentary on existing building codes nor a guidance manual on how to compute snow loads. It is not intended to be a technical reference for the design of the building structural roof system.

For concerns about the safety of a building or for information about structural engineering, contact a local building official or design professional.

1 Snow load design information is available in ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2010), and in *Snow Loads: Guide to the Snow Load Provisions of ASCE 7-10* (O'Rourke, 2010).

2 Snow Loads

A snow event is not necessarily a single large snow storm. A snow event can be a series of storms that result in additional snow loads on a building. No two snow events are identical, and the resulting snow loads on nearby buildings from one snow event may be different. One foot of snow on the ground does not necessarily equal 1 foot of snow on a roof. Further, differing snow load conditions are a function of the variables associated with an individual building. The characteristics of snow can differ significantly from snow event to snow event.

This chapter contains the building code definitions of snow load, types of snow, the variables that factor into roof snow loads, and the risks various snow conditions pose.

2.1 Building Code Definitions

Structural engineers use building codes to determine design snow loads on building structures. Currently, the International Building Code (IBC) is used throughout the United States for snow loads.

States and/or local jurisdictions may amend or supplement the IBC or adopt their own code. The building code identifies the ground snow load, which building designers use as the starting point to calculate the uniform design snow load on a building roof.

Ground snow load is defined as the weight of snow on the ground surface (IBC, 2012). Ground snow load values are established using data collected by the National Weather Service. Maps of ground snow loads in IBC and in ASCE 7 indicate a 2 percent probability of the indicated load being equaled or exceeded in any given year. Ground snow loads do not discount that actual snow loads may exceed them, only that the risk of snow-load-induced failure is reduced to an acceptably low level.

Roof snow load is defined as the weight of snow on the roof surface used in design of the building structure (IBC, 2012). It is determined based on multiple factors, including:

- Ground snow load value
- Importance, occupancy, and use of the building
- Wind exposure of roof
- Roof slope
- Roof shape
- Roof obstructions
- Thermal condition of the building

Before acceptance of the IBC as a national code, multiple building codes were used throughout the United States. The Building Officials Code Administrators (BOCA) was used on the East Coast and throughout much of the Midwest, used. In parts of the Midwest, the Standard Building Code was referenced. In the West and Alaska, the primary building code used was the Uniform Building Code (UBC). Drifting loads were first incorporated into BOCA in 1975. Unbalanced roof snow loads were not introduced in UBC until 1988. Only relatively recently have drifting and sliding snow loads been addressed in building codes. A building constructed 40 years ago may not have been designed for snow loads as they are understood today.

2.2 Snow Types

Snow comes in many forms and is affected by numerous atmospheric and geographic conditions. Regional differences in season, altitude, humidity, and other variations result in a range

of snow densities. For example, the weight of 1 foot of snow in Utah does not necessarily equal the weight of 1 foot of snow in Vermont.

2.2.1 Range in Snow Weight

The weight of 1 foot of fresh snow ranges from 3 pounds per square foot for light, dry snow to 21 pounds per square foot for wet, heavy snow (Gooch, 1999).

2.2.2 Ice

One inch of ice weighs a little less than 5 pounds per square foot, and 1 foot of ice weighs approximately 57 pounds per square foot. Ice weighs significantly more than heavy, wet snow per inch depth. In part, this is why it is important to prevent ice buildup on a roof structure.

2.2.3 Regional and Local Considerations

Snow in the western part of the United States is typically lighter and less dense than snow on the East Coast, which tends to be wetter and denser. There are exceptions based on locality and unique weather conditions, such as the Pacific Northwest around Seattle, WA, and the southwestern coast of Alaska. Local authorities and structural engineers are most familiar with regional snow characteristics.

2.3 Other Variables

The uniform roof snow load, as determined by the factors discussed above, is a value determined for a flat, wide open roof free of obstructions and protrusions. Rarely is a roof such. Variables from the ideal condition are accounted for by designers as dictated in the building codes. These refined design loads are predicated on real world snow conditions. Although the process for determining these special load conditions is beyond the scope of this document, awareness of what these circumstances are will increase understanding of potentially vulnerable areas of the roof. This section addresses unbalanced snow loading resulting from drifting and sliding snow, as well as other environmental factors involved in managing snow.

2.3.1 Unbalanced Snow Load

Unbalanced snow loading is the condition in which snow accumulates at different depths in different locations on a roof, resulting in differential snow load. Unbalanced snow load poses a greater risk to the roof structural system than a uniform snow load. Hence, the danger of drifting and sliding snow is that both create an unbalanced snow load

condition. Figures 1a and 1b illustrate various unbalanced snow load scenarios resulting from drifting and sliding snow. Notice the snow is deeper at roof protrusions, obstructions, and elevation changes than in

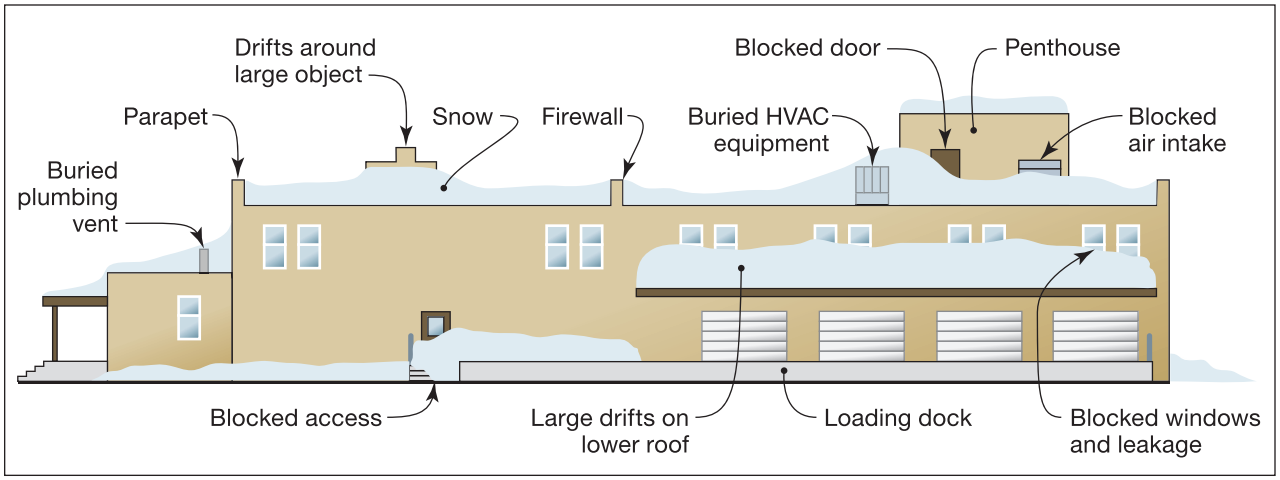

Figure 1a. Unbalanced snow load from drifting and sliding snow on typical commercial or industrial building

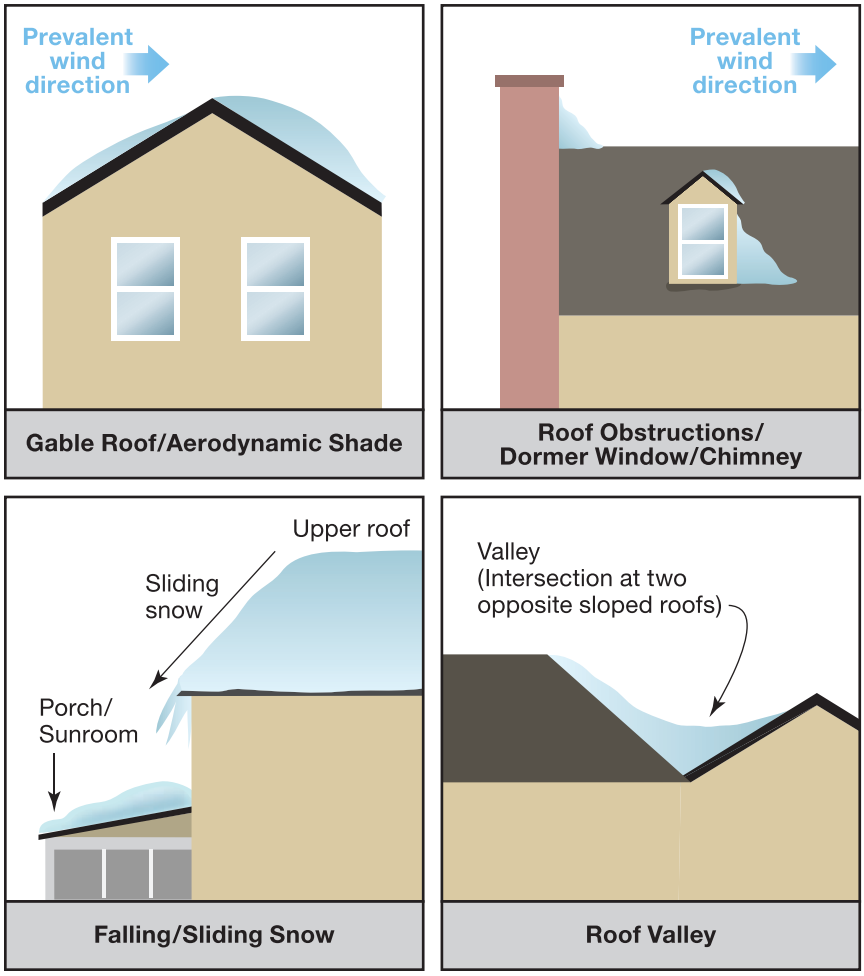

Figure 1b. Unbalanced snow load from drifting and sliding snow on residential structure

more open sections of the roof. The influence of these conditions on snow load is discussed in further detail in Chapter 3.

2.3.1.1 Drifting Snow

Drifting snow is the result of wind transporting snow from one portion of the roof to another. Snow drifts often form on a lower roof in the wind shadow of the higher portions of the building. Snow can also be blown up against and accumulate next to an obstruction (e.g., high roof framing, rooftop equipment, parapet, adjacent building, dormer windows). The snow depth at this obstruction is greater than the overall roof snow depth and therefore creates a larger load on the roof structure at the location of the drift.

2.3.1.2 Sliding Snow

Unless a sloped roof has snow guard or cleats (Figure 2), a sliding snow condition can occur. Snow from a higher roof can become unstable and slide onto a lower roof where it accumulates. Common instances of this are on porch/sunroom roofs and entrance canopies beneath gabled roofs of residential buildings (Figure 1b). Consequently, the snow depth on the lower roof within the fall zone of the sliding snow is greater than the overall roof snow depth, an unbalanced load condition. Again, this creates a larger load on the structure at the location where the snow fell

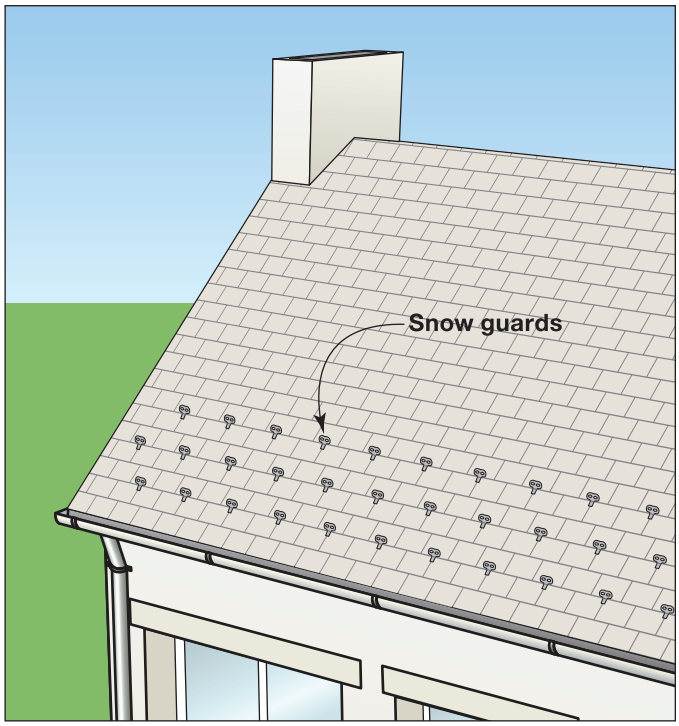

Figure 2.
Snow guards or snow cleats

from the upper roof. Furthermore, the dynamic force of the sliding snow onto the lower roof may produce a significant impact force on the lower roof framing, which can potentially overload the roof structure.

2.3.2 Snow Fall Rate

Snow fall rate is not a direct variable of the calculated roof snow load.

Snow fall rate does not influence the snow load. Instead, the rate of accumulation factors into when to begin monitoring a structure during a snow event. A faster snowfall rate means the stakeholder should start monitoring the snow condition earlier. A faster snowfall rate also means less time to remove the snow before it reaches the critical threshold.

2.3.3 Ambient Temperature

Temperatures fluctuating above and below freezing can produce hazardous conditions. Snow melts and then refreezes, creating ice and ice dams and resulting in higher concentrated loads at roof low points (if not properly drained) and at eaves on sloped roofs. Also, when temperatures hover around freezing, precipitation tends towards a "wintery mix" that can result in a rain-on-snow condition, which current building codes address.

2.3.4 Rain-on-Snow Load

Building code provisions for design snow loads incorporate light rain on snow, but heavy rainfall is not included. Therefore, this additional load must be taken into account separately by the structural engineer. Factors influencing the rain-on-snow load include rain intensity, roof geometry, and drainage characteristics of the roof. Duration is also considered because continuous rain can wash away snow, effectively reducing the risk of snow-induced collapse. Conversely, a period of short rain may cause snow to melt and become further saturated, significantly increasing the load on the roof structure.

2.3.5 Snow Melt between Storms

Snow melt between snow events may be beneficial or potentially hazardous depending on weather conditions. Snow melt between storms on properly designed, functioning roof drainage systems will reduce snow load. However, if the roof drainage system is blocked, improperly designed or maintained, snow melt may pose risks. Ice dams may form, which creates a concentrated load at the eaves and reduces the ability of sloped roofs to shed snow. This topic is discussed further in

Chapter 3. On flat or low slope roof systems, snow melt may accumulate in low areas on roofs with poorly designed or blocked drainage systems. This condition is referred to as ponding. Ponding creates a concentrated load on the roof structural system and a potential hazard.

3 Building Basics

The risk of structural failure from snow load is influenced by the characteristics of the building. Some roof structures and materials are more susceptible to snow-induced collapse than others. Building configurations create conditions in which drifting and sliding snow may pose a risk.

This chapter discusses building characteristics, materials, structural systems, and their respective vulnerabilities.

3.1 Building Characteristics and Shapes

As noted in Chapter 2, roof snow loads differ from ground snow loads. The variables in roof snow load are roof geometry and roofing material, exposure to wind, and insulation.

3.1.1 Use Type

Building structures are categorized as residential, commercial, industrial, institutional, or agricultural.

3.1.2 Roof Geometry and Roofing Material

Roof construction comes in many forms. The geometry has an influential role in the distribution of roof snow loads. Snow loads on an open flat roof, free of obstructions and rooftop equipment tend to be uniform, whereas roofs with defining geometric irregularities and obstructions accumulate snow in an unbalanced pattern. Intuitively, steep roofs are more likely to shed snow through sliding than flat and low slope roofs, although other variables factor in. Commercial, industrial, and agricultural buildings typically use one roof configuration throughout the structure, sometimes with varying roof and ridge elevations. Architecturally influenced design, such as residential, often incorporate multiple roof geometries.

Figures 3a through 3e illustrate common roof configurations:

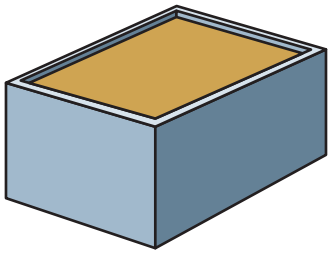

Figure 3a. Flat or low-slope roof with or without roof drains

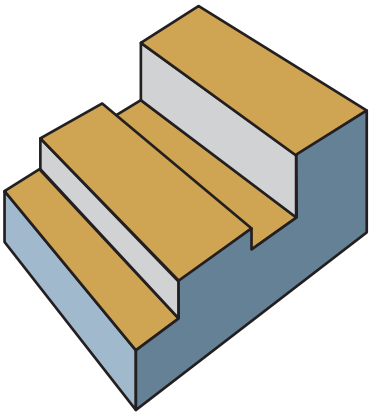

Figure 3b. Stepped roof

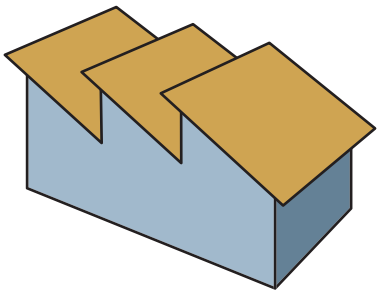

Figure 3c. Saw-tooth roof

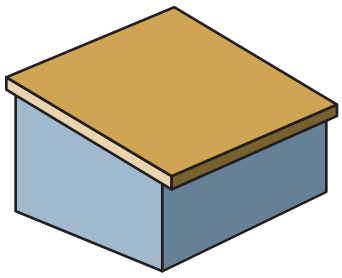

Figure 3d. Mono-slope roof

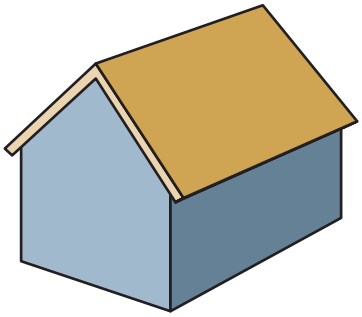

Figure 3e. Gable/multi-span gable roof

Roof geometric characteristics provide an opportunity for snow accumulation and drifting resulting in an unbalanced loading condition, including:

- A geometric feature that blocks wind from blowing snow, known as an aerodynamic shade, creates an opportunity for snow to drift. This commonly occurs at the leeward side of the ridge on gable and mono-slope roofs (Figures 3d and 3e) or rooftop protrusions such as mechanical penthouses and stair towers.
- Parapets on flat and low slope roofs and at changes in roof elevation of stepped roofs (Figures 3a and 3b) are common locations for snow drifts
- Valleys of saw-tooth roofs (Figure 3c) and at the intersection of sloping residential roofs (Figure 1b) accumulate greater snow depth than elsewhere on the roof
- Roof impediments, such as mechanical screen walls, rooftop vents, and skylights collect snow drifts (Figure 1a)
- Roof top equipment, such as heating and cooling units or solar panels, provide a place for snow to drift (Figure 1a)
- On residential roofs irregularities such as chimneys, dormer windows, porch roofs, and skylights may collect snow drifts (Figure 1b)

Roof geometry and roofing material influence the tendency of snow to slide from a roof as follows:

- Low slope roofs retain snow more so than pitched roofs. However, roof pitches as low as 10 degrees have been observed to shed snow.
- Steeper roof slopes shed snow more effectively. Thus, greater roof slopes are common on buildings in the northern States and in mountainous snow-prone regions.
- Roof pitch that exceeds the angle of repose of snow results in snow sliding; the angle of repose is the maximum angle at which snow will not slide, approximately a 30 degree roof slope, often referred to as 6:12 or 7:12. This is not to say that snow on roofs with a shallower slope will not slide.

- More tactile, abrasive roofing materials are less slippery and do not shed snow as easily as a slippery surface. Tactile roof materials include asphalt shingles and aggregate surface built-up membranes. Slippery roof materials include metal roof panels and single-ply membrane roofing.
- The presence of snow guards or snow cleats will inhibit snow from sliding off the roof (Figure 2 in Chapter 2).

3.1.3 Exposure to Wind

A building's exposure to wind greatly influences the snow load on a roof. In fact, wind exposure has the largest effect on roof snow of the variables that are discussed. A building constructed in an open area is less likely to retain snow on the roof than a building in a sheltered location. However, wind also dictates snow drifting. If a building in an open area has varying roof elevations, parapets, or rooftop equipment, snow drifting may occur at these locations resulting in an unbalanced loading condition.

3.1.4 Insulation

A roof assembly's thermal properties affect roof snow load in several ways. A well-insulated or well-ventilated roof typically retains more snow than a poorly insulated roof or a roof over a poorly ventilated attic. Well-insulated roofs do not permit heat from within a building to melt roof snow from beneath. Similarly, a well-ventilated attic space has a temperature similar to ambient air; therefore, as illustrated in the bottom graphic of Figure 4, heat within the building does not cause roof snow melt. This condition is analogous to the roof of an open carport, where both the top and underside of the roof have the same temperature. Because there is no temperature difference, the rate of snow melt is unaffected.

For gabled and sloped roof systems, uninsulated heated attics increase the propensity for snow to melt or slide. However during freezing temperatures, discontinuous thermal characteristics at roof eave overhangs can inhibit snow shedding by causing ice dams, as shown in the top graphic of Figure 4. Melt water flows down the roof slope and freezes at the eave. The problem propagates as the ice dam becomes bigger, resulting in more melt water blockage at the eave.

Ice dams create several problems. First, they prevent snow from sliding off the roof. Snow and ice accumulation at the eave creates an undesirable unbalanced snow loading condition. A second (and potentially larger) problem that may arise from ice dams is water infiltration into the building interior.

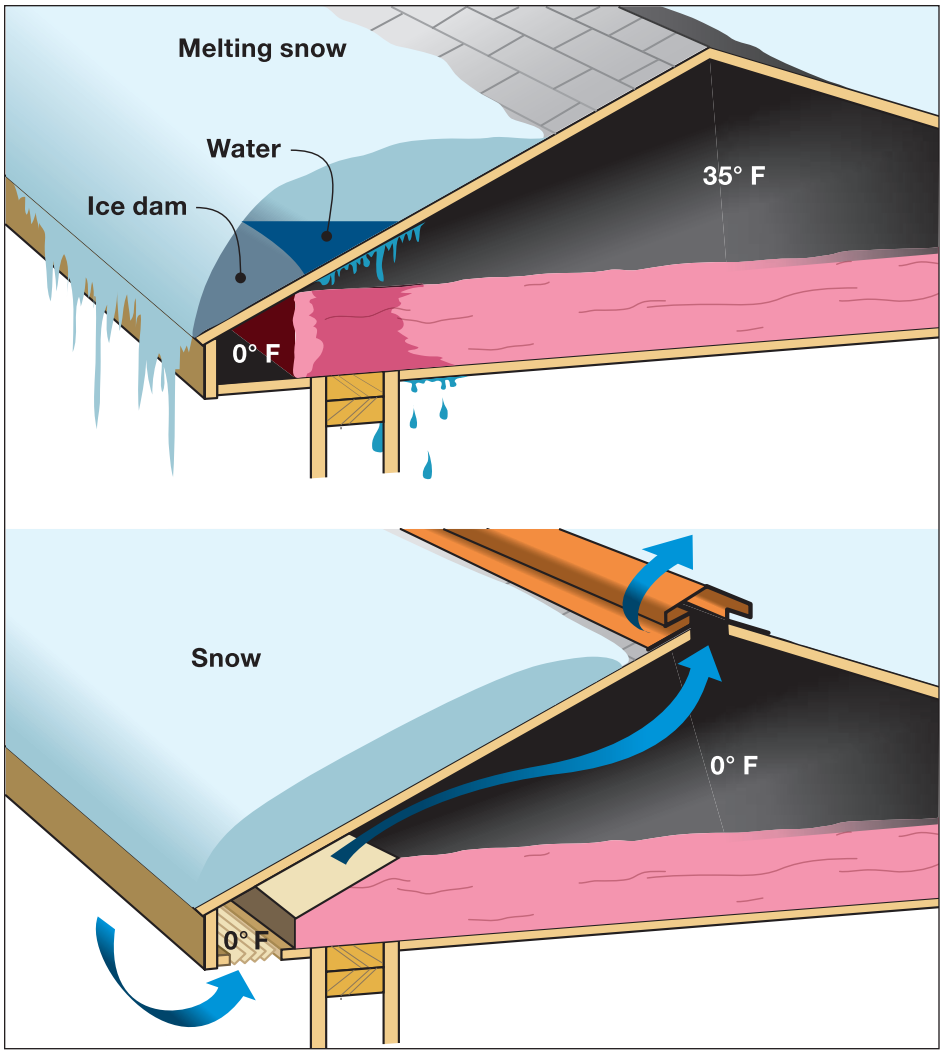

Figure 4.
Insulation – Ice Dam Effect

A properly designed, internally drained flat or low slope roof is not affected by building insulation characteristics to the degree sloped structures are. In fact, on an uninsulated low slope roof, there is the benefit of reduced snow load through melting. Melt water will not encounter a temperature differential that leads to freezing (ice dams) and pose the problem which occurs on sloped roofs with cold eaves.

3.2 Roof Conditions

Span length of the primary roof framing members is also important in determining whether a roof structure may be susceptible to excessive deflection or failure from snow loading. Additionally, what structure the roof is covering should be accounted for when determining susceptibility to snow.

3.2.1 Short Spans

In general, short-span roof structures are less susceptible to excessive snow loading failure than long-span roof structures. Short-span roofs are less prone to deflection and therefore less at risk to ponding and improper roof draining.

3.2.2 Long Spans

Long-span roof framing systems may have less structural redundancy than short-span roof framing systems, which can make failure more catastrophic in a long-span system. Long-span systems typically consist of wood or steel truss construction. It is imperative that adequate bracing of long-span systems is properly installed and maintained. Many long-span roof failures can be attributed to poorly performing or inadequate bracing.

3.2.3 Secondary and Other Structures

Secondary structures include canopies, porches, carports, detached garages, sheds, agricultural buildings, and other usually uninhabited spaces. According to building code, only agricultural buildings and sheds are permitted to be designed to a lower life-safety importance factor than occupied building structures. However, it is important to be aware that secondary structures do not typically perform as well as primary buildings during snow events (SEAW, 2009). Entrance canopies and porch roofs are particularly susceptible to drifting and sliding snow because they are adjacent to the main building structure. These structures are often building additions in which design considerations for the main structure may not have been accounted for.

Agricultural buildings are typically long-span wood-framed or pre-engineered metal buildings. Many older agricultural structures were not required to be designed to a specific snow load.

3.3 Common Roof Framing Materials

Roof construction material is an important factor in determining a structure's susceptibility to failure. To clarify, engineers design structures for a total load comprised of dead load (permanent load) and temporary loads (includes snow load). The weight of the structure itself is a dead load; therefore heavier structural materials have heavier dead load. Buildings constructed of heavier materials are typically less susceptible to snow-induced structural failure. This is because snow load in excess of the design snow load constitutes a smaller percentage

increase of the actual total load above the total design load in heavier structures. A smaller variation from the total design load means less likelihood that a structure will fail from the excess load. Another way to think of this is dead load to snow load ratio. Therefore, a good rule of thumb is that the higher the dead load to snow load ratio, the less susceptible a structure is.

3.3.1 Wood Construction

Wood-framed structures come in a variety of types and are used in the range of small-to-medium sized building applications. Typically, wood structures are relatively lightweight and may be more susceptible to excess snow loads. Beam and joist framing systems are often referred to as "stick framing" and are used in residential construction, although they are also found in other buildings such as warehouses and churches. Sloped roofs, such as gabled or hipped configurations in residential and small commercial buildings, are often framed with wood trusses or rafters.

Wood trusses consist of sawn lumber for both the vertical and diagonal members. Newer wood truss members are typically connected with metal plate connectors. Wood trusses commonly built today are engineered structural elements that are manufactured offsite, transported as bundled trusses, and installed onsite.

Possible failure modes of wood-framed structures are member fracture, joint failures, and lateral buckling from improper or inadequate installation of lateral bracing.

Wood trusses often have a tag that identifies the manufacturer and size designation, and the tag is important if the member capacity needs to be evaluated.

3.3.2 Heavy Timber Construction

Timber-framed structures typically consist of large timber members oriented vertically (post) and horizontally (beam). Timber trusses consist of heavy timber sections for vertical and diagonal members.

Although referred to as heavy timber, this type of construction has a low dead load and often long spans. In a report conducted by the Structural Engineers Association of Washington for the 2008–2009 snow season, heavy timber accounted for the second largest number of failures only to wood trusses.

Possible failure modes of timber-framed roof structures are split or broken truss members and failure of truss connections.

3.3.3 Steel Construction

Common types of steel-framed buildings include beam and girder systems, open web steel joists, steel joist girders, and steel trusses. Steel beam and girders are typically hot-rolled sections, typically in an I-shaped configuration. Structural members in older buildings may be cast iron rather than steel. Open web steel joists are manufactured framing members that consist of small steel angles and solid steel bars arranged in a truss-like configuration. Similarly to wood trusses, steel joists often have a tag that identifies the manufacturer and size designation, and the tag is important if the member capacity needs to be evaluated.

3.3.4 Pre-Engineered Metal Building Systems

Pre-engineered metal building (PEMB) systems are typically constructed of lite-gage steel members. The primary roof framing and wall system consists of widely spaced rigid frames with steel purlins or steel joists supporting the metal roofing. These systems are used in single-story warehouses, gymnasiums, and similar open-use commercial and industrial buildings. PEMBs are highly engineered with little redundancy or reserve capacity. PEMB may therefore be susceptible to excessive snow loading, but if properly designed, collapse potential is low. If one roof framing member collapses, the failure can propagate because of a loss of integrity of the whole building system. Older pre-engineered metal building systems designed before drifting snow loads (unbalanced loads) were addressed in the building codes may be problematic.

3.3.5 Cold Formed Steel Truss Construction

Cold formed steel (CFS) trusses consist of prefabricated members made up of light gage metal sections. CFS trusses are engineered structural systems that are manufactured offsite, transported, and installed onsite. CFS trusses require proper lateral bracing for bucking stability. CFS systems, similarly to PEMB systems, have a relatively low self-weight.

3.3.6 Reinforced Concrete Construction

Concrete construction can vary widely. Structural systems can be cast-in-place, precast, or post-tensioned. Because of the relatively high self-weight (dead load) of concrete systems, concrete structures have a low susceptibility to snow-induced failure. Historically, concrete structures have performed well under high snow accumulation conditions.

3.4 Additions and Modifications to Roof Areas

3.4.1 Rooftop Equipment

Rooftop equipment acts as an obstruction that can collect drifting snow. Typical rooftop equipment items include solar panels, heating/cooling units, and ventilation units and ducts. The equipment must be accounted for when assessing snow load. Rooftop equipment on older buildings is of special interest because many of these buildings were constructed before drifting snow was addressed in building codes. Furthermore, the structural adequacy of the roof structure may not have been checked for rooftop equipment added during a renovation or retrofit. The additional weight of equipment on the rooftop increases demand of the structure system. Without structural modifications to the existing roof, the available capacity to support additional load, such as snow, is reduced.

3.4.2 Reroofing

The building structure typically outlasts the roofing material. When buildings are reroofed, a roof covering is often placed over the existing roof. This approach increases the weight of the roof assembly, thus reducing the structural capacity to carry the snow load. When buildings are re-roofed, the thermal efficiency of the roof system is often increased by using thicker insulation or a modern, more efficient insulation that may increase snow retention. Additionally, new roofing material can weigh more than the original roofing system, reducing the load carrying capacity. For example, changing from shingles to slate or tile increases the roof weight significantly.

3.4.3 Additions and New Neighboring Buildings

If a roof addition to an existing building is higher than the existing building roof, drifting of snow on the existing lower roof must be considered. Thus, determining whether the existing roof structure has been checked for drifting snow is important.

A new building can act as an aerodynamic shade to the adjacent existing building if the new building's roof elevation is higher than the existing roof, reducing the propensity for shedding snow. Similarly, wind exposure characteristics may also change.

3.5 Age and Building Code Considerations

Knowing the age or approximate age of a building is valuable in determining the structural basis of design for the roof framing with regard to snow loads. As noted in Chapter 2, building codes

only began to address non-uniform snow loads in the 1970s and 1980s. In addition, even though codes are updated, there is typically a lag between the code revision and code adoption. If the original drawings are available, the building code used to design the building should be identified. If the drawings are not available but the age of the building is known, the local building department should be able to provide the code edition that was in place when the building was constructed.

Some building materials deteriorate over time. Steel members are susceptible to corrosion, which can reduce the load-carrying ability of the framing members. Wood members can split or rot, which can reduce the load-carrying capacity of the framing members.

4 Monitoring a Building Structure

Awareness of the warning signs a structure exhibits during a snow event can be the difference between getting safely through the snow event and experiencing structural failure. Property owners should have a contractor or licensed professional engineer conduct a building inspection and vulnerability assessment before the snow season. During a snow event, there are common signs that indicate a building structure is under duress and action is required. In some cases, the skills of a licensed Professional Engineer are required for an assessment before, during, or after a snow event.

4.1 Pre-Season Inspection and Condition Assessment

Familiarity with the building structure before the snow season begins is important in determining whether any changes occurred during a snow event. Knowing a building's characteristics and structural system are part of establishing the baseline condition. In addition to the

as-built knowledge, the current condition of the structure needs to be known.

This section discusses what to be aware of and the steps that should be taken to prepare for a major snow event.

4.1.1 Key Building Information

The following baseline information should be collected for the building:

- Applicable building codes
- Design snow load
- Structural framing system
- Thermal properties
- Renovation history

4.1.2 Items to Inspect

Although all of the roof structure and building should be inspected, closer inspection is warranted at particular roof areas. As detailed in Chapter 3, Roof valleys, low points of saw-tooth roofs, abrupt roof elevation changes, parapets, and other obstructions and protrusions are locations that accumulate greater amounts of snow. Structural members in these locations therefore experience greater snow loads. Roof framing should be checked for deterioration, weakness, damage, or modification. In addition to the building structure, other items that should be inspected for proper function include:

- Gutters and downspouts for disrepair and free of debris
- Seals around rooftop penetrations are intact
- Openings around exhaust vents
- Internally drained roof downspouts are clear of debris
- Flashing around connections of rooftop equipment
- Roof soffit and ridge ventilation
- Cold eave electric heaters are properly functioning
- Vertical position of trusses are not leaning out-of-plane
- Metal plates connecting truss member chords
- Lateral braces are firmly connected to roof structure and do not show signs of over-stress or disrepair
- Attic areas are dry and free of excess moisture

Many of the items on the list above do not require the services of a design professional for routine inspection. However, for a comprehensive inspection or if there is a question that any of these items are deficient, professional services should be retained.

4.1.3 Repairs, Corrective Action, and Mitigation

Managing deficiencies ahead of a snow event is important in ensuring the integrity of the structure during the event. Small disrepairs can propagate into much larger issues. For commercial and industrial buildings, many of the issues can be handled internally through the skilled maintenance personnel. For residential properties, minor mitigation or corrective actions like ensuring gutters and downspouts are not blocked at the discharge point can be handled by the homeowner. It is imperative that safety measures be taken and equipment warnings are heeded. However, for structural concerns such as out-of-plane trusses or corroded metal brackets used in wood construction, the skills of a professional are required. An attempt to mitigate or repair building components vital to the proper function that are beyond the ability of the stakeholder or homeowner can cause additional damage.

4.2 Warning Signs of Overstress Conditions During a Snow Event

Overstressed roof deck or framing typically displays some warning signs. Wood and steel structures may show noticeable signs of excessive deflection before failure. The following warning signs are common in wood, metal, and steel constructed buildings:

- Sagging ceiling tiles or boards, ceiling boards falling out of the ceiling grid, and/or sagging sprinkler lines and sprinkler heads
- Sprinkler heads deflecting below suspended ceilings
- Popping, cracking, and creaking noises
- Sagging roof members, including metal decking or plywood sheathing
- Bowing truss bottom chords or web members
- Doors and/or windows that can no longer be opened or closed
- Cracked or split wood members
- Cracks in walls or masonry

- Severe roof leaks
- Excessive accumulation of water at nondrainage locations on low slope roofs

4.3 When to Contact a Professional Structural Engineer

If any of the warning signs identified in the previous section are observed, the building should be promptly evacuated and a qualified design professional should be contacted to perform a detailed structural inspection. A qualified design professional, such as a Professional Engineer, has the experience to make an assessment of structural integrity of the building and identify steps to make the building safe.

5 Measures to Reduce the Potential of Snow Load-Induced Structural Failures

Similar to monitoring a building structure, preventative measures should be taken in advance of the snow season and not only before an actual snow event. The pre-season building inspection and vulnerability assessment should be followed by implementation of mitigation measures for structural vulnerabilities identified during the investigation. Steps should be taken during a snow event to reduce the risk of snow-induced structural failure. Formulating a plan and delegating responsibility prior to the snow season will make dealing with a snow event more manageable and help eliminate confusion about responsibilities during and immediately after the event. A Snow Event Response Plan should address both preventative measures and actions to be taken during the storm. This chapter discusses these two topics

and describes the fundamental items that need to be included in a Snow Event Response Plan.

5.1 Pre-Season Preventative Measures and Planning

Ensuring the building structure and roof are in good repair prior to the snow season will prevent possible problems and potentially save repair and cleanup costs. Developing a Snow Event Response Plan ahead of the snow season is imperative for major facilities, such as manufacturing buildings, warehouses, and big box retail facilities with multiple work shifts. Assigning tasks/roles in advance will help reduce confusion during a snow event and help ensure that nothing is overlooked, such as determining whether snow removal will be done by in-house crews or by a contractor on retainer.

Prepare an Occupational Safety and Health Administration (OSHA)-compliant safety plan to ensure worker safety during snow removal work and inspections. The means of roof access and egress should be identified and all edge fall protection requirements reviewed.

Measures should include locating areas where snow removed from a roof can be stored on the ground away from entrances, exits, canopies, and building equipment. Accessibility for snow removal vehicles should be checked. Necessary snow removal equipment should be acquired and an inspection schedule for the equipment should be prepared.

Snowfall can hide rooftop hazards. Conduits, gas lines, vents, equipment, lightning protection, and skylights should be marked with flags or a similar system to prevent injury to staff and unnecessary damage to these items. Skylights are of particular concern because personnel clearing snow may fall through them if not properly identified. If possible, locations of columns and primary structure members should be marked to help develop a snow removal sequence. Roof drains, gutters, downspouts, and vents should be checked to make sure they are free of debris and other obstructions.

Structural deficiencies identified in the pre-season inspection should be prioritized and addressed by severity and the risk posed. If the construction drawings do not clearly identify the design snow load or the information is not available, contact a licensed Professional Engineer. Familiarity with the roof design and the areas that require closer observation is critical information before a snow event.

5.2 Snow Event Response Strategies

5.2.1 What to Do During a Significant Snow Event

The Snow Event Response Plan should be reviewed. The Plan should define a methodology to determine an approximate snow load and at what point snow removal should be initiated. Snow removal will prevent overstressing of the roof structure. Having an in-house plan for snow removal in place or a contractor on retainer is imperative. Contractors will be in high demand and difficult to find once a snow storm begins.

5.2.2 What to Do After a Major Snow Event

Even if snow accumulation during an individual snow event approaches but does not surpass the threshold of building safety, removal of snow from the roof may still be in order. Roof snow that is exposed to sunlight can soften, become denser, and then harden when the temperature drops below freezing. As noted in Chapter 2, melt water may pool and subsequently freeze, creating a concentrated area of loading on the roof. If subsequent snow events are anticipated, removing snow from the roof will minimize the risk of accumulating snow causing structural damage. One benefit of immediate snow removal is that the effort required to remove the snow from the rooftop is reduced. However, when snow accumulation is minor, the likelihood of damaging the roofing material or risk of being on a roof outweighs the benefits of removal.

5.2.3 What to Do Before Another Snow Event

The steps taken in advance of a subsequent snow event vary only slightly from the approach in advance of any snow event. Key steps include inspection of drains, gutters, downspouts, and vents for snow or ice blockage from the earlier snowfall.

Designated areas for removed rooftop snow must have sufficient capacity to accommodate additional snow. After a major storm, snow may need to be removed from the premises to create space for subsequent snow. For example, if snow is stored in the parking lot, but the amount of snowfall is such that it occupies too much of the lot area, the snow may need to be transported offsite.

5.3 Removal of Snow from Roof

5.3.1 When to Initiate Snow Removal

A number of factors influence when snow removal should begin including, but not limited to, the pre-snow condition of the building structure, snow from a previous snow event still on the roof, the rate of snowfall, and/or the need to keep ahead of additional snow if there is a valid concern of a snow-induced structural failure.

WARNING

If there is any concern that snow loads may cause a collapse of the roof structure, cease all removal activity and evacuate the building.

Knowing the design snow load of the structure is key in determining when to begin removal. Design snow load can be determined from construction drawings. If there are no drawings, retain the services of a licensed design professional before the snow season to determine structural capacity. A local Professional Engineer will be familiar with the snow conditions of the region. Their knowledge of the pervasive snow type can help the stakeholder formulate some benchmarks to when snow accumulation at the building is approaching the snow load capacity. As noted earlier, roof snow loads vary from ground snow based on multiple factors. Therefore, attempting to measure ground snow weight and assuming that it is the same as the roof snow load is incorrect.

If the existing snow load is close to the capacity of the roof structure, snow removal is prudent. If the existing snow load is somewhat close to capacity and additional snow is forecast that could come close or exceed the capacity, snow removal is also prudent.

Snow removal should be performed by a licensed, insured professional roofing contractor who has experience in removing snow from roofs. Using a professional roofing contractor is highly recommended because of the contractor's familiarity with safety protocols.

5.3.2 Safety Measures for Snow Removal

- Any roof snow removal should be conducted following proper OSHA protocol for work on rooftops. Use roof fall arrest harnesses where applicable.
- Always have someone below the roof to keep foot traffic away from locations where falling snow or ice could cause injuries.

- Ensure someone confirms that the area below removal site is free of equipment that could be damaged by falling snow or ice.
- Whenever snow is being removed from a roof, be careful of dislodged icicles. An icicle falling from a short height can still cause damage or injury.
- When using a non-metallic snow rake, be aware that roof snow can slide at any moment. Keep a safe distance away from the eave to remain outside of the sliding range.
- Buried skylights pose a high risk to workers on a roof removing snow. Properly mark this hazard as well as other rooftop hazards prior to snow events.

5.3.3 Method of Snow Removal

- Removing snow completely from a roof surface can result in serious damage to the roof covering and possibly lead to leaks and additional damage. At least 2 inches of snow should be left on the roof.
- Do not use mechanical snow removal equipment. The risk of damaging the roof membrane or other rooftop items outweighs the advantage of speed.
- Do not use sharp tools, such as picks, to remove snow. Use plastic rather than metal shovels.
- Remove drifted snow first at building elevation changes, parapets, and around equipment.
- Once drifted snow has been removed, start remaining snow removal from the center portion of the roof.
- Remove snow in the direction of primary structural members (Figure 5). This will prevent unbalanced snow loading.
- Do not stockpile snow on the roof.
- Dispose of removed snow in designated areas on the ground.
- Keep snow away from building exits, fire escapes, drain downspouts, ventilation openings, and equipment.
- If possible, remove snow starting at the ridge and moving toward the eave for gable and sloped roofs.

- Use a non-metallic snow rake for steep roof slopes if possible. Metal snow rakes can damage roofing material and should be avoided. Snow removal can be conducted from the ground, removing the risk to people on a hazardous roof.
- Upon completion of snow removal, the roofing material should be inspected for any signs of damage. Additionally, a quick inspection of the structural system may be prudent after particularly large snow events.

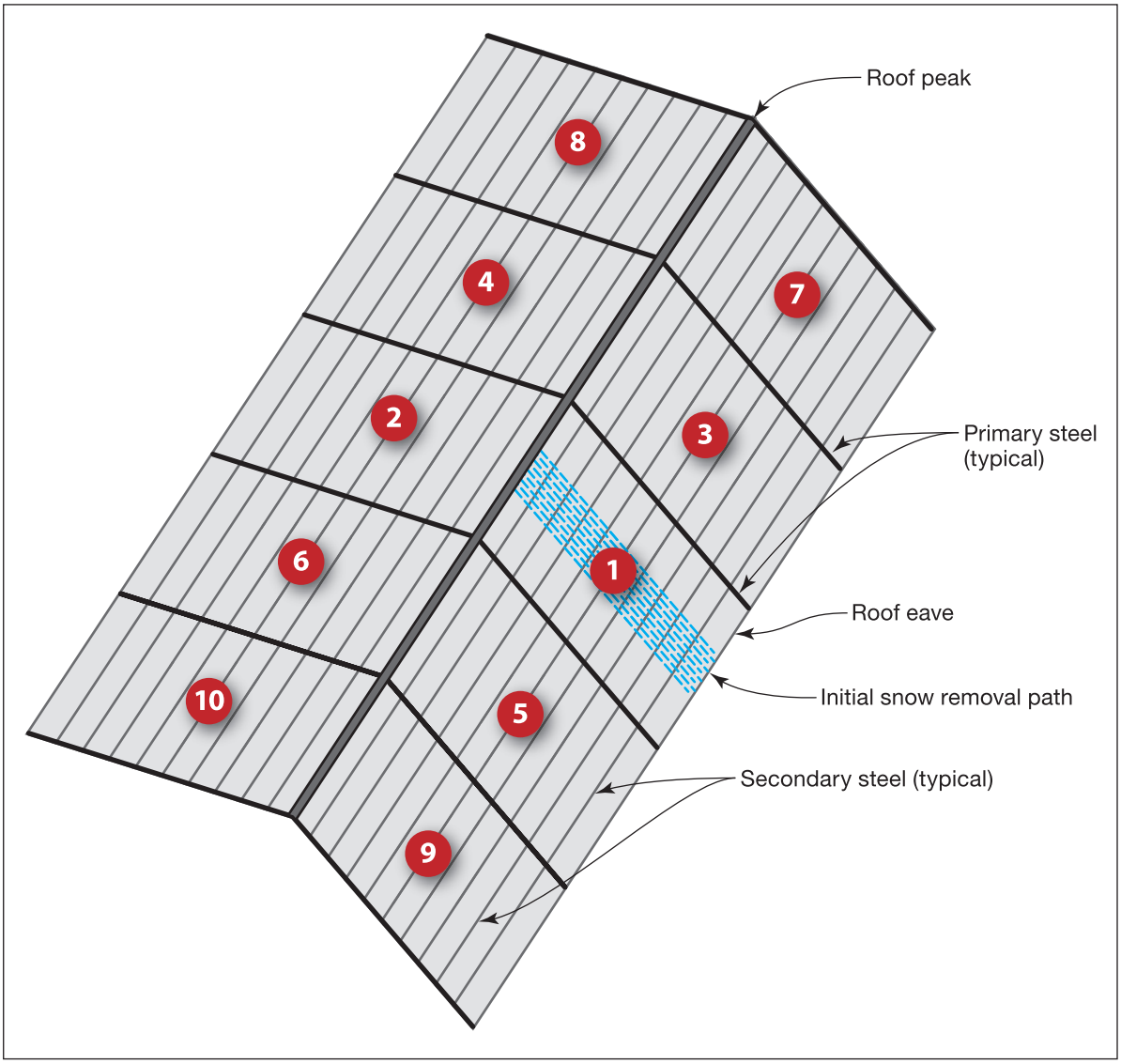

Figure 5. Snow Removal Diagram

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