

# How much is too much?

## Evaluation and removal of excess snow from roofs of post-frame buildings

By Gary A. Anderson, Ph.D.



Gary Anderson photos

Top: The roof on this post-frame building pulled loose from the end wall, leaving the gable in place as the roof failed under the snow load. Right: Side walls buckling due to snow load.

Properly engineered post-frame buildings have excellent strength properties. They can efficiently resist vertical loads imposed upon them by snow and the weight of building components.

All buildings are designed to withstand the weather phenomena that may be reasonably predicted to occur over the building's lifespan. That means that all buildings, including post-frame buildings, are built to withstand all snow loads that may be met or exceeded every 25, 50, or 100 years depending on the design importance factor of the building. The importance factor for agricultural buildings dictates those types of buildings should withstand the heaviest snow load that it is expected to see within a 25-year time span, but post-frame struc-

tures built for other purposes may be designed to withstand snow loads only seen, on average, once every 100 years.

Generally speaking, it is very unlikely such a tremendous snow load will accumulate that it may be beneficial to remove excess snow from a roof. However, there may be rare occasions when excess snow removal may be beneficial for a building's long-term structural performance, regardless if it is post-frame or another type of structure. This article is intended to provide guidance when these rare instances may occur, specifically for post-frame structures.

Researchers have known for years that the strength of wood members, as well as the deflection caused by loads on wood members, are time dependent.



Wood members, when subjected to a load, undergo an initial deflection. If the load remains on the member, the initial deflection will remain relatively constant for a period of time. After this period of time, the deflection will increase until it fails under the load. The greater the stress (load) on the member, the shorter the time period of this relatively constant deflection will be.

Because the structural components primarily intended to carry snow load (trusses carriers, purlins, columns, rafters or trusses, etc.) are generally wood, they may naturally lose strength with repeated stress over time. An abnormally heavy snow load increases stress on the structure. Therefore, to avoid structural damage, building owners or their maintenance or building contractors may wisely remove abnormally heavy snow loads from roofs whenever possible.

The reasons why the strength and deflection of wood is time dependent are not well understood. One reason for the time dependency may be that, at the molecular level, the wood material moves (flows) away from areas of high stress, thereby weakening the member in the high stress area where it needs to be the strongest. A load applied for a short period of time does not provide enough time for the wood to flow from the stressed area. Also, if the load is small there is little stress at the molecular level to cause it to flow. Similar behavior is observed in polymers (plastics).

Engineers typically design wood struc-

tural components to resist the designed snow load for 60 days. The 60-day load duration factor is cumulative for the life of the structure, not just for one winter. For example, a building intended to be used for 30 years should, on average, have a maximum design snow load on it for two days per year. Therefore, the longer a snow load that is near or exceeds design stays on the structure, the more likely it is to fail under a heavy load in the future.

Engineers usually design post-frame buildings for snow loads that statistically are met or exceeded once in either 25 years, or once in 50 years. The likelihood the full design snow load will be placed on the building multiple times in 25 years is very small. However, prudence dictates that one should keep the duration of design snow loads on the building to a minimum, because many factors that affect snow accumulation on the building may change over the life of the building.

Several factors affect the accumulation of heavy snow loads on the roof of a building. These factors include:

1. Roof slope
2. Roof material
3. Temperature maintained in the building and insulation
4. Water content of the snow
5. Location of the building relative to taller obstructions
6. Unbalanced snow loads
7. Effects of freezing rain

### Roof slope

The steeper the slope of the roof, the

less likely it is that snow will accumulate on the roof. Also, the steeper the roof slope, the more likely it is that snow that has accumulated on the roof will slide off the roof.

### Roof material

The roof material plays an important role in determining if the snow will slide off the roof. Slippery roof surfaces, such as painted light-gauge metal roof decking, allow snow to slide off the roof much more easily than an abrasive roof surface, such as asphalt or wood shingles.

### Inside building temperature and insulation

The temperature of the roof surface affects how much snow accumulates on it. Heating the enclosed space in the building and solar heating may raise roof temperature. Increasing insulation in the attic or ceiling may lower roof temperature.

### Water content of the snow

A roof temperature above freezing will melt some of the snow on the roof at the roof surface. Some of the water from the snow melt will run down the roof surface to the eave or roof overhang. The eave in a heated building is usually colder than the roof, so water may refreeze as it flows onto the eave when it is below freezing. As the melted snow re-freezes at the eave, it forms an ice dam that may block and back up water that should have flowed off the roof. As the ice dam grows, the freezing water may lift up shingles or water may



Top: The wall sheathing of this building was pushed out by knee braces due to snow load stress. Right: Roof failure under the snow load caused the wall posts to push out because the post-truss connection did not fail.



flow underneath them, causing moisture to enter the building.

Water between a roof surface and a snow mass tends to act as a lubricant. Aqueous lubrication allows a snow mass to more easily slide off the roof, depending on the roof slope and surface type. If the lubricating water refreezes on a cold roof section, or if the snow mass sliding upon it runs into an ice dam, the mass may stop abruptly. As the sliding snow stops abruptly, it may cause dynamic loads on the building.

### Location of the building

Buildings located close to taller obstructions upwind will accumulate more snow on their roofs. As wind goes over an obstruction, it tends to lose snow that it is carrying due to reduced air speed and changes in air pressure. The snow lost by the wind accumulates downwind from the obstruction in an area sometimes called the Aerodynamic Shaded Area (ASA). The ASA usually covers a distance roughly equal to 10 times the difference in height between the obstruction and the lower building or terrain. Obstructions may include buildings, trees, hills, or any other objects that are upwind, if they are taller than the building under consideration.

The Aerodynamic Shaded Area may change for a building over time. Trees in a grove will grow and newer, larger structures will be built. A building may not be aerodynamically shaded for 20 years, then suddenly be shaded by a new building, silo, or other structure.

Drifts may form on buildings because of their proximity to higher structures. When the building is on the windward side of a taller structure, the height of the drift formed on the lower structure depends upon the difference in height of the two buildings and the length of the lower building's roof. When the building is on the leeward side, the difference in height of the two buildings and length of the taller structure's roof determine the drift depth.

Buildings erected adjacent to taller structures are in danger of having snow slide off the taller structure onto them. If snow sliding off a taller structure is dense and in large sections, its impact load may be substantially greater than its own weight.

Cupolas, air handing equipment, or



Top: The top of the end wall posts and gable were pulled into the building when the roof failed under the snow load. Middle: Roof failure caused the top of the wall posts to push out. Bottom: The knee braces slipped relative to post and truss chord, but did little damage to the wall as the roof failed under the snow load.

other obstructions on a roof may also cause snow drifts. Upgrading the ventilation system of a building may call for more and higher ridge inlets (ventilators), which will increase the snow load by causing deeper drifts to form around the inlets on the leeward roof slope.

### Unbalanced snow loads

Wind can remove most of the snow from the windward side of the roof and deposit it on the leeward side, causing an unbalanced snow load. The unbalanced load may cause problems by changing the direction forces act in a truss member.

For example, due to an unbalanced snow load, a web member normally in tension may become compressed as forces try to push the ends of the web member toward each other. Member size, bracing requirements, and connection to the chords or other webs (metal-toothed plates, plywood gussets) usually are different for a compression web and a tension web.

Snow found on the roofs of buildings is generally denser than the snow reported by weather organizations. Weather organizations generally report that about ten inches of snow equals approximately 1 inch of water, or 5 psf of snow load. The added weight of light rain on existing snow pack and consolidation or settling of the snow over time increases the snow pack density. Also, wind often



drives snow, which tends to break the snowflakes up into smaller crystals that pack more densely. Therefore, ASCE-7 uses a higher snow density than weather organizations do.

Snow densities for roofs in the eastern side of South Dakota tend to be in the range of 19.0-20.5 psf. Each inch of snow on a roof in Eastern South Dakota would yield a snow load of 1.6-1.7 psf compared to 0.5 psf for an inch of snow at the density used by weather organizations for snow on the ground.

### Freezing rain effects

The density of snow on a roof given for eastern South Dakota in the preceding paragraph is for snow packs that include light rain. However, the given snow density does not include heavy rain on the snow

pack, which will tend to saturate the snow pack and make it more dense and heavy.

Generally, rain water will drain away from the snow pack on steeper-sloped roofs. Therefore, we often assume the very dense/heavy snow pack resulting from rain will only exist on flat roofs (slope is less than 1/2:12). However, it is possible that the rain water will not drain away from steeper-sloped roofs. For instance, if the roof and snow pack are very cold when a heavy rain occurs, the rain may freeze to the roof surface or in the snow pack and not drain away. The frozen rainwater will not only add weight to the existing snow pack, it will make the roof less slippery by freezing the snow pack to the roof slope. This will allow more snow to accumulate on the roof from future snow events.

Frozen water or ice is much denser than snow. An inch of ice on the building's roof will weigh approximately 5.1 psf. An inch of ice is nominally three times heavier than an inch of snow, given (1.7 psf x 3 = 5.1 psf) for eastern South Dakota. The ice

may also accumulate on a cold roof surface in the absence of a snow pack.

### Guidelines for inspection and removal of excessive snow loads

Based on discussions with post-frame contractors, material suppliers, and designers, the following general guidelines will help qualified registered professional engineers to evaluate the integrity of post-frame buildings subjected to high snow loads. It also outlines a procedure for removing excess snow from the roof of the building.

Integrity of design and engineering, quality of materials and construction errors may affect a building's integrity. Agricultural buildings in most areas are exempt from engineering requirements, and may not be designed in accordance with ASCE-7. Extreme caution must be observed around any building that may be unstable due to excessive snow loads, especially if you are unsure what the building's design snow load is.

### Initial evaluation

(A): Walk around the outside of the building.

(1) Is there any evidence, such as sheet buckling or denting of the siding, which may indicate that the knee braces, if used, have slipped?

(2) Does the roof appear to be lower in the middle of the building than at the end walls?

(3) Does any portion of the roof appear to be lower than the remainder of the roof?

(4) Is there any evidence that the walls are pushed out or buckling?

(5) Does the building, or any portion of the building, appear to be leaning in any direction?

(i) If the answer to any of the above questions is yes, do not enter the building or get on the roof. Seek further assistance before entering or working on the building.

(ii) If the answer is no to all of the above questions, continue the evaluation of the building by going to step B

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Here the knee braces slipped relative to the truss chord and post, and eventually failed as the roof failed under the snow load.

or C as appropriate.

(B): If the building does not have a ceiling, proceed to step C. If the building does have a ceiling:

(1) From the doorway, look to see if the ceiling is flat and level or if the ceiling is wavy or bulging.

(2) From the doorway, check to see if the knee braces appear to be buckled or if they have slipped relative to the post or ceiling.

(i) If the ceiling is bulging or wavy or if the knee braces have slipped or have buckled, do not enter the building or get on the roof. Seek assistance before entering the building or working on it.

(ii) If the ceiling is not wavy or bulging and the knee braces have not buckled or slipped, continue the evaluation by looking into the attic area and follow step C.

(C): If the building does not have a ceiling, inspect the trusses and purlins from the doorway. If it does have a ceiling, inspect trusses and purlins at the attic entrance before entering.

(1) Does the top chord appear wavy?

(2) Are any of the truss webs buckling or appear to be bulging?

(3) Do any large gaps appear between members under the metal truss plates or at nailed joints?

(4) Do metal roofing or siding components show evidence of sheet buckling?

(5) Are the metal truss plates bulging or lifting up from the truss members?

(6) Observing wood color, does it appear the truss members have pulled away from any plywood or wood gusset plates?

(7) Do the knee braces appear to be buckled?

(8) Have knee braces slipped relative to the posts (pushed back to the wall), truss top chord (pushed up to the roof), or the truss bottom chord?

(9) Do the purlins appear to be bending downward or twisting?

(10) Do the walls appear to have buckled?

(i) If the answer is yes to any of the above questions, do not enter the building or get on the roof. Seek assistance before entering or working on the building.

(ii) If the answer is no to all of the above questions, continue below.

### Estimate snow load on the roof.

(A): Weighing method.

(1) Determine the weight of the container you will use to weigh snow removed from the roof.

(2) Take proper safety measures to ensure safe access to the roof. Leaning a ladder or otherwise disturbing a building excessively loaded may cause building failure. Plan how to deal with all roof hazards, such as slips, falls, overhead power lines and other hazards, before you approach any roof. Working around or walking on the roof of any structurally

unsound building poses a deadly hazard.

(3) Select a small area of the roof near the eave representative of the snow on the roof. Pick an area that is average from the areas you test with the probe.

(i) It may be helpful to probe several locations on the roof to determine a representative snow depth and density.

(ii) Density is indicated by how hard it is to push the probe into the snow pack on the roof.

(4) Remove the snow from the selected area and place it in the previously weighed container.

(5) Use a tape measure to determine the area of the roof in square feet that the snow was removed from.

(6) Weigh the snow and container.

(7) Determine the snow weight by subtracting the container weight from the snow and container weight.

(8) Determine the roof snow load in pounds per square foot by dividing the snow weight by the roof area it was removed from.

(B): Measurement method.

(1) If a suitable scale or container is not available, estimate the snow load by measuring the depth of the snow.

(i) With a stiff ruler or tape, probe the snow pack at several locations to determine the average depth in inches.

(ii) Determine the roof snow load in pounds per square foot (psf) by multiplying the average depth by:

(a) 0.5 psf/inch of snow depth for light snow

(b) 2.0 psf/inch of depth for wind driven, consolidated, and/or wet heavy snow.

(c) 5.0 psf/inch of depth for ice.

(2) When probing the snow, you may notice it is harder to push the ruler into the snow pack at different depths than other depths, which indicates the snow pack is layered with snow of different densities or ice. If this is the case:

(i) Remove the snow pack from a section of roof so that the layers may be observed.

(ii) Measure the thickness of each layer in inches.

(iii) Determine the roof snow load in psf by multiplying the depth of each layer by the appropriate density given previously in this section, then adding all the snow layer weights together.

## Determine if snow should be removed from the roof or not

(A): Find out the building's designed roof snow load.

(1) Building specifications included with the contract often indicate the design roof snow load. If this is not given, contact the contractor/builders.

(2) Contractors/builders often give the snow load in pounds rather than psf.

(3) The snow load provided is actually the snow load in psf; i.e. a 20-pound snow load is 20 psf snow load.

(4) If the contract cannot be found, or if the design snow load is not provided:

(i) A snow load of 20 psf was often used for agricultural building design in eastern South Dakota in the past. Newer agricultural buildings may be designed for 25 psf or 30 psf snow loads. However, in areas of the U.S. not normally subject to snowfall, the design snow load may be minimal or negligible.

(ii) A design snow load for other areas may be estimated by multiplying the ground snow load from the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE-7) by 0.567 for agricultural buildings, or by multiplying the pertinent factors for your type of building.

(iii) Example: You are considering an agricultural building. Using ASCE-7, the factor 0.567 is the product of:

(a) 0.7 (basic exposure factor);

(b) 0.9 (exposure factor for fully exposed buildings terrain category C);

(c) 1.2 (temperature factor for an unheated structure),

(d) 0.9375 (roof slope factor for a cold slippery roof with a 4:12 slope); and

(e) 0.8 (importance factor for an ag building).

(B): Consider removing the snow from the roof of a post-frame building if the snow load estimated from step 2 is approximately equal to or exceeds the design snow load of the roof, and is less than twice the design snow load and the answers to all the questions from I and II was no.

(1) If the estimated snow load is more than twice the design snow load but less than 2.5 times the design snow load, remove the snow with extreme caution.

(2) If the snow load is more than 2.5

times the design snow load, seek additional assistance before attempting to remove the snow from the roof.

## Use extreme caution if you choose to remove snow from any roof.

(A): Follow a safe snow removal process.

(1) Exercise extreme caution. Human weight on the roof and shifting the distribution of snow may cause collapse of the roof or building.

(2) Avoid walking on an overloaded roof. If someone must walk on the roof, first develop and review a fall protection plan. Fall protection devices, such as body harnesses, may be required for this work.

(3) Begin removing snow from the roof utilizing equipment or scaffolding to elevate workers to eave height.

(4) Use snow rakes or other tools to pull as much snow as possible down from the roof without getting on the roof.

(5) Re-inspect the building as outlined in Step 1 to ensure that the remov-

al process did not damage the building.

(6) If no damage is found, continue removing snow working from the eave to the ridge.

(B): Precautions:

(1) Remove the same amount of snow from each side of the roof.

(i) Unbalanced roof loads (one side of the roof loaded heavier than the other side) may cause more damage to the building than larger, balanced loads.

(ii) If one side of the roof has more snow on it than the other side, start removing snow from the side with the most snow.

(iii) Long buildings may require that you remove the snow from a portion of the roof on one side of the building and then move to the same area on the other side of the roof.

(iv) Repeat the procedure until the snow is removed from the roof.

(2) Once the snow loads are balanced, keep them balanced as discussed in the above section.

(3) Before removing snow or getting

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on the roof of a building next to a taller structure from which snow may fall, remove the snow from the taller structure.

(4) Before removing snow from the building, locate all electrical power lines servicing the building. Have the electrical power turned off or otherwise guard against electrical shock as suggested by the electrical utilities provider.

(C): Roof damage.

(1) Removal of snow may cause damage.

(i) Unless snow and ice next to the roof surface is very thick and dense (one half the design snow load or more), consider leaving it on the roof.

(ii) The paint thickness on light-gauge metal sheeting is thin and can be damaged easily by rakes or shovels.

(iii) Damaged paint may allow early rusting of the sheet.

(iv) Scraping or pounding on asphalt or wood shingles may damage the shingles, necessitating early replacement of the shingles.

(2) Snow racks and other equipment may damage the roof system.

(i) They may hook fasteners that hold sheets to the purlins or that hold sheets together in the rib,

(ii) Fastener damage may compromise the structural integrity of the fasteners, weakening the diaphragm system or causing roof leaks.

(3) Removing snow from the roof should only be done when snow loads are near or above the design load, so that unnecessary wear and tear on the roof is avoided and potential fall injuries are avoided. ■

**Anderson** is an engineering professor at South Dakota State University. This article was prepared based upon discussions with industry personnel over several years. This article is prepared based upon the best information available to the author at the time of its writing. Following procedures described within this article will not guarantee that any particular building is safe. The author, SDSU, NFBA, F+W Publications, and any and all other parties associated with the editing and publication of this article expressly disclaim any responsibility for

reliance upon this material for any purpose. Readers are advised that, if in doubt, they should not enter or come near any building that may potentially have structural damage, whether for inspection or other purposes.

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