Use of Snow Retention Devices—Science or Science Fiction?

By Rob Haddock

METAL ROOFING IS PROBABLY THE SINGLE FASTEST GROWING SEGMENT OF THE ROOFING INDustry. With the sharp rise in popularity of metal, the growing market attitude that steeper is better, and the proliferation of metal in cold climates, more and more structures are donning steep-sloped, Kynar™-coated metal panels. At the same time, awareness that metal is also prone to rooftop avalanche has prompted a list of snow retention devices in the market place which seems be growing year by year.

In the course of conducting seminars for and business with designers, engineers, contrctors, product manufacturers, sales people and construction owners, I am amazed at the mythology which seems to surround the subject of snow phenomena on roofs, including the subject of snow retention. I read editorials, advertisements, and even "technical articles" which attest to this mythology, promoting conjecture as fact. There seems to be a general lack of understanding and a preponderance of misunderstanding in this field which, hopefully, this writing will help to dispel.

Indeed, there is much that is not known about snow. The properties of snow are widely variant, and the densification, thaw, and migration phenomena are subject to many variables. Yet there is much about the behavior of snow which is quite predictable and scientific.

Myth #1: The Use of Snow Retention Devices Will Cause or Promote Ice Damming.

Ice damming is caused by variations in roof surface temperatures. If the surface temperature is above freezing upslope, and the eave temperature is below freezing, meltwater runs down the roof and re-freezes at the eave area. Such differences in rooftop temperatures occur when ambient air is below freezing and heat loss from the building envelope warms the roof surface above it to temperatures above freezing. Because the eave is outside the building envelope, it is governed by, and usually equal to, the ambient air temperature. This re-freezing builds up little by little, and can form quite an iceberg at the eave area. I have seen such ice formations accumulate to thicknesses of several feet. This is a problem which is certainly not unique to metal roofs, but is experienced on roofs of all types. (*Figures 1 and 2*)

When such a phenomenon occurs, the result is actually an unintentional (and unreliable) snow guard of sorts. The adhesion of the ice to the eave area, and the build-up of the bank of ice, retain the snow blanket above it. When the bond frees at some point, the result can be rather dramatic. Not only does the snow blanket avalanche from the roof, but very large and dangerous ice formations come with it.

This ice-damming phenomenon will occur with or without a mechanical snow retention device—if the rooftop is prone to differing temperatures. Occasionally photographs are presented which show a snow retention device "encased" in such an ice formation. To the uninformed, it may look as though the device is the cause, but it is not; its presence is simply coincidental.

Myth #2: Retaining Snow on the Roof Will Cause Excessive Build Up, Exceeding the Loads for Which it Was Designed, and Leading to Collapse.

Rooftop design loads are a function of "ground snow" by all model codes. Such loads are expressed in pounds per square foot. This load is the expected total accumulated snow weight in any given season. Contrary to common belief, structural designers do not normally assume the snow is going to vacate the roof. Nor do most model codes. Codes do allow for reduction of ground-to-roof snow due to the effect of wind scouring of roofs. They also allow for reductions based on extreme roof slope (BOCA's provision is 7:12 [30°] or greater), but such reductions are not based on fallen snow evacuating the roof, but rather on snow which is falling not accumulating to as significant depths on the roof in the first place.

There is a design provision in ASCE-7 which allows for load reductions of "slippery" roof surfaces based on slope and

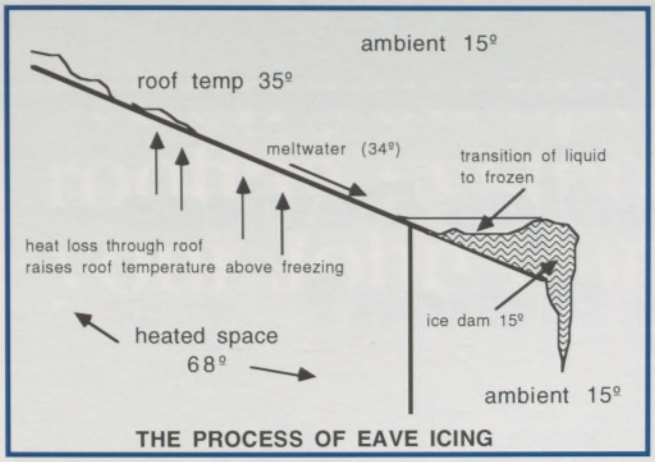


Figure 1: Eave icing is caused by warm roof temperatures upslope and colder roof temperatures at the eave.

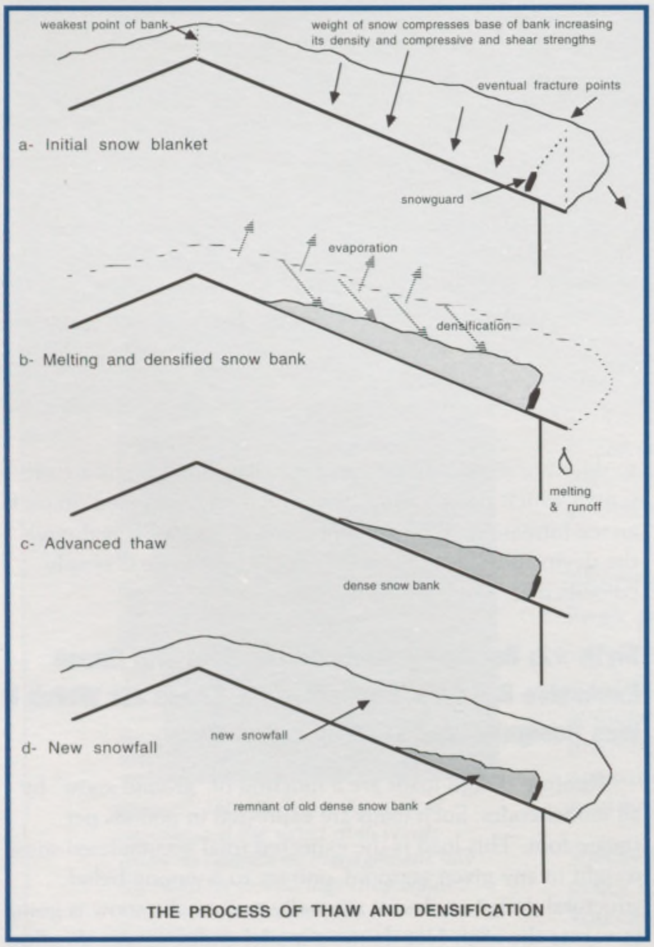


Figure 3

other factors, but every design professional that I have ever spoken with will not use it because: A) If the structure is re-roofed at some point in the future with a non-slippery roof surface, the structure may then be in jeopardy; B) if the roof is prone to ice damming phenomena, the snow will not slip off the roof as this provision assumes.

Figure 2: This restroom facility on a Keystone, Colorado ski slope typifies the eave icing effect with its cold overhangs and heated space upslope. Notice that where the heated space has melted the snowbank, the meltwater has run down to a cold eave, forming an ice-dam, which then functions as an unintentional snow guard. At the right, where the roof temperature is consistent from eave-to-ridge, no eave icing.

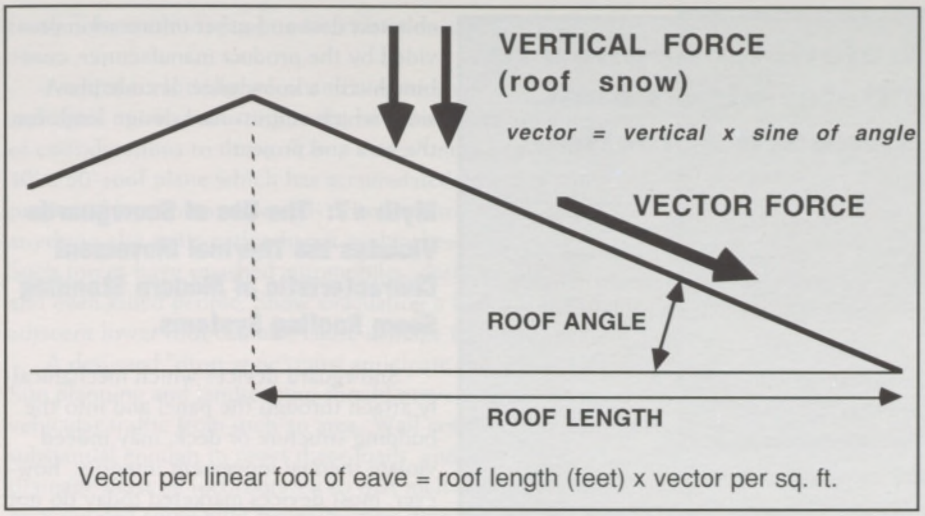
Myth #3: Using Snow Retention Devices Will Lead to Seam Submersion and Water Infiltration of the Roof System.

Normal roof snow thawing occurs with meltwater adjacent to the panel, not at the top of the panel seam. Snowbanks on roofs usually thaw from the bottom up as a result of both building heat loss and solar absorption of the roof surface. (Solar radiation travels through the translucent bank of snow, warming the roof beneath.) When some degree of thaw occurs from the top down (due to warm ambient air), the meltwater migrates through the bank of snow to the panel surface and runs down that panel surface to the eave or gutter.

Panel seams can and do become submersed when ice dams form at the eave line (*Figure 1*), but the myth that snow retention devices cause ice dams is dispelled above (MYTH #1).

Myth #4: When Using Snow Guard Devices, They Should be Distributed All Over the Roof Surface, and Not Localized at the Eave.

One argument for this approach is that the roof surface must be evenly loaded with snow so that an unintended point load doesn't overload the structure. Such a point load at the eave does not occur. A blanket of snow has considerable strength within itself. Generally, the more dense the blanket, the greater that strength. A snow blanket on a roof may gradually densify and "creep" down the roof slope toward its eave end (*Figure 3*), but this process takes place as the snow bank is melting and the total weight is being reduced. To suggest that the entire design snow load of the roof can get all piled up on a snowguard placed at the eave simply does not conform with reality. When the blanket is far along in the thaw process, a small build up may be witnessed at the eave snowguard (*Figure 3-c*) as the last traces of snow are melting from the roof, but this has never been known to "overload" the structure. In fact, the eave is normally the bearing point of the roof structure.



Slope:12	Degrees	Sine
1	4° 45'	0.08281
2	9° 28'	0.16447
3	15°	0.25882
4	18° 30'	0.3173
5	22° 30'	0.38268
6	26° 30'	0.4462
7	30° 15'	0.50377
8	33° 45'	0.55557
9	36° 45'	0.59832
10	39° 45'	0.63944
11	42° 30'	0.67559
12	45°	0.70711

Sine of Roof Angles

Figure 4: Simple math can be used to determine the "drag" loads caused by snow.

This myth is also propagated by companies who make devices which serve this intent. Generally the load-to-failure values of these devices is such that they must be used in this redundant fashion to restrain the snow bank and avoid the over loading of a single device. The truth is that either the "peppered" method or the "continuous fence" method have both proven to be effective, provided they are properly designed and installed so as to surpass anticipated in-service loads (see MYTH #6).

Myth #5: The Deeper the Snow, the Taller the Snowguard Device Must Be.

A bank or blanket of snow has significant cohesive strength within itself. Except under extremely unusual circumstances, the base of the bank of snow has the greatest compressive and the greatest shear strength (*Figure 3*). This is due to the densification process of snow. Simply put, if you restrain the base, you restrain the entire bank. I have seen thousands of snowbanks on roofs that are several feet in height restrained by snowguards that are a few inches in height. Some people seem to think that if you have a high design load—let's say 60 pounds per square foot—that a taller snow guard device must be employed. So they will use something that stands 16" or so in height, rather that the usual 4" to 6". The phobia is that the bank will shear and the upper portion of the snow bank may slide over the top of the shorter device. Sixty pounds per square foot of snow can translate to as much as 12 feet of snow depth. If the snow loses cohesion and the bank shears somewhere between its top and the roof surface, it really won't matter whether it is 4" above the roof or 16" or 4 feet; a serious avalanche will occur. I have never seen or heard of this kind of shear actually happening, but the only way to prevent such an event would be to build a chain link fence 12 feet high on the roof.

Myth #6: Proper Use and Placement of Snowguard Devices Can Only be Determined By the Product Supplier Because the Force of Snow on the Snowguard Cannot be Calculated; it Must be Determined By Some Sort of Art and Magic Known Only to the Supplier.

The vector load (or angular force) of snow on any given roof can be easily calculated and is the same, regardless of the type snowguard used. It is found by multiplying design load by sine of roof angle, and extending that figure for the (plan) area of the roof (*Figure 4*). This formula assumes no friction between roof and snow, and of course safety factors should be followed (*Figure 5*).

Any snowguard manufacturer should be able to tell you the ultimate strength of his device, verified by independent testing. Depending upon the importance in use and the reliability of testing done (relevance to real world application), appropriate safety factors should be employed to arrive at allowable loads for the device and project. Devices should then be used at a frequency sufficient to restrain loads as determined above.

Note: When testing an adhesively-mounted device, the test should be done with a load sustained on the device for a significant period of time. This is because most adhesives used are somewhat elastic in behavior and may fail at lower sustained loads than if tested simply on a load-to-failure basis. A sustained load more accurately reflects the in-service condition. We have tested a number of such devices with sustained load and found load-to-failure values far below manufacturer claims.

As simple as it is, when I did some market research several years ago, this engineering of snowguard load calculation was known to few, if any, manufacturers of these products. If snowguard frequency is left to the supplier, in many cases the resulting recommendations may in fact be a combination of voodoo, witchcraft, and educated guesswork. The number of devices on the market which are either untested or inappropriately tested is also alarming.

The best recommendations will likely come from a licensed engineer or architect who is familiar with snow effects and the specific project involved, and based upon reli-

Force and Cost Calculations Applied to Job Specifics to Determine Panel Pinning and Snowguard Selection

A school building has a gabled roof which is 40' in plan length from eave to ridge. The vertical roof snow load is 42 pounds per square foot, and the slope is 6:12. The panels have seam-to-seam dimensioning of 18", and there are 500 linear feet of eaves (167 panels per side; 334 panels total). The designer wishes to calculate attachment for the panels using a factor of safety of 3.0. The fasteners to be used have a published ultimate shear into this deck type of 572 pounds.

To determine the vector forces from the vertical, we calculate:

vertical x sine of angle = vector

42 psf x .4462 = 18.74 psf

To calculate the tributary vector load to each panel:

vector (psf) x roof length (ft) x panel width(ft) = panel tributary vector (lbs)

18.74 x 40 x 1.5 = 1124 pounds

For the panel attachment to the structure, using a safety factor of 3.0, and the published shear of 572 pounds:

1124 x 3 = 3372 allowable

then, 3,372 pounds/572 pounds per fastener = 5.89 fasteners

So six fasteners are required for each panel.

The designer also wants to select a snowguard product and frequency to retain snow using a factor of safety of 2.0. He is looking at three different snowguard products:

- "Snowguard A" is a unitized device with ultimate load of 425 pounds. It must be glued to the panel between seams. Part, glue, and labor is $11.20 per unit.
- "Snowguard B" is a "fence" type assembly which clamps to the panel seams. The ultimate load is 705 pounds per seam. Installed cost is $11.50 per linear foot.
- "Snowguard C" is also a "fence" type assembly which clamps to the seams. Its ultimate load is 2349 pounds per seam and the cost is $12.86 per linear foot.

To calculate allowable load using a factor of safety of 2.0:

panel tributary vector x f.s. = allowable (per panel or seam)

1124 x 2 = 2248 pounds

Snowguard A: (2248/425 = 5.28) Six parts/panel required.

(6 x 334 =) 2,004 total parts; @ $11.20/ part

Total Project Cost	$22,445
Cost per foot of eave	$44.89

Snowguard B: (2248/705 = 3.19) Four rows of assembly required.

(4 x 500 ft =) 2,000 ft of assembly @ $11.50/ft

Total Project Cost	$23,000
Cost per foot of eave	$46.00

Snowguard C: (2248/2349 = .96) One row of assembly required.

500 ft of assembly @ $13.25/ft

Total Project Cost	$6,625
Cost per foot of eave	$13.25

In this example, "Snowguard C" is by far the best value at only 30% the cost of the next best option, even though at first glance its unit cost is higher.

Figure 5: Note that the calculation for panel-fixed point attachment is the same, whether snowguards are employed or not. The roof loads do not change with the addition of snowguards. With respect to cost differences of various products, we have seen even more dramatic disparities than those shown here. The uninformed buyer would choose the least expensive unit cost produc, and spend more than three times the money necessary to do the job. The very uninformed buyer would specify one row of the least expensive unit cost product, which would most certainly fail. Of course the vendors of parts "A" and "C" will argue that the increased frequency that their products require is the proper design (see Myth #4).

able test data and other information provided by the product manufacturer, combined with a knowledge of code provisions which address roof design loads for the area and project.

Myth #7: The Use of Snowguards Violates the Thermal Movement Characteristic of Modern Standing Seam Roofing Systems.

Snowguard devices which mechanically attach through the panel and into the building structure or deck, may indeed violate thermal movement integrity; however, most devices marketed today do not attach in such fashion. Some are adhesively mounted, and others attach in some other way to the panels, but not the structure.

Myth # 8: The Use of Snowguards Will Increase the "Drag" Loads on the Roof Panels and Pull Them From the Structure.

So-called "drag" loads are gravity loads which attempt to pull the panel down the slope of the roof. They are calculated as discussed earlier. These loads are composed of live and dead loads acting on the roof panels, and the same math is utilized in calculating the anchorage of the panel to the structure, whether the roof is to have snowguards or not (*Figure 5*). This is because the live loads incurred by the panel are not conditioned upon snow retention. The idea of any snow guard device is to keep the snow blanket on the roof so that it thaws gradually. To keep something in place implies that it was already there to begin with (and so are the loads that it causes). If the panels are not attached to withstand these drag loads (*Figures 4 and 5*), they will likely migrate off the roof—with or without snowguards attached.

When should snowguards be used?

The concept which underlies the use of snow retention systems is simple: It is better in some situations to retain snow on the roof so that it evacuates gradually (by thaw), rather than suddenly (by avalanche). As a general statement, it is usually desirable to let snow evacuate the roof at will. The question becomes: Does the expedience of sudden evacuation (avalanche method) pose undue risk or nuisance? (*Figures 6 and 7*)

Architectural designs for structures in snow country can anticipate snow evacuating roofs; however there are a number of considerations to do so. "Drop zones" must be planned. A 40' x 50' roof plane which has accumulated 25 psf of snow will produce fifty thousand pounds of snow hitting the ground—or anything else in its path when it avalanches from the roof. Such forces have smashed automobiles, destroyed landscapes and even killed people. Snow evacuating a high roof onto an adjacent lower roof can also cause damage to the lower roof.

A designed "drop zone" must anticipate this sudden release. Site planning and landscaping should prevent pedestrian and vehicular traffic from such an area. Wall construction must be substantial enough to resist these loads, and foundation drainage must be incorporated so that melt water from the accumulated snow piles beneath eaves does not migrate into the building or foundation (*Figures 8 and 9*).

When eave designs incorporate guttering or "fascia breaks," or when de-icing cables are used on the roof's surface, snowguards are almost essential to prevent damage to these details and components (*Figures 10 and 11*).

When valleys are incorporated in roof design, often the migration of snow and ice down the valley can mangle and destroy the standing seams of the roof panels near the valley area. Snowguards can prevent this damage.

If roof design and geometry and site planning and other building construction materials and design can be arranged to anticipate rooftop avalanche, then snow should be allowed to evacuate the roof. If not, then well-designed snow retention systems can prevent a lot of damage, hazard, and nuisance. It should be noted that no snow retention system is 100% foolproof and there are no absolute guarantees that some amounts of snow downslope of any device will not shear and fall from the roof at some point in time during the thaw process (*Figure 3-a*).

Figure 6: Snowshed here poses a serious threat to both pedestrian and vehicular traffic, as a walkway and parking area are located directly beneath the eave. Note the loose wires hanging from the eave line where light fixtures used to be. Snowguards would have prevented this. (Colorado Springs)

Figure 7: Hazards exist at schools (even if landscape and pedestrian traffic are planned well) because of the nature of unauthorized pedestrian patterns. (Brekenridge, Colorado)

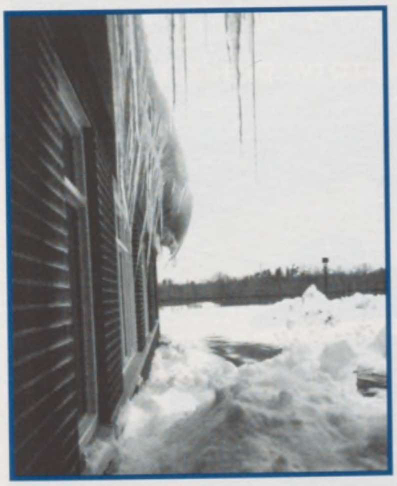


Figure 8: The migration of snow and ice from this roof threatens the glass below the eave. Snow which has previously evacuated the roof is now piled below such that its thaw and drainage from the roof are now directed toward the building wall and foundation. When the pile gets deeper, the runoff will be directed right into the windows.

Figure 9: Snow can exert incredible forces on building walls, and lead to collapse if not designed to sustain such force.

What are the common mistakes made when using snowguards?

Most mistakes are a result of failure to design the snowguard system to the specifics of the project. This can result with the snowguards failing because the design loads exceed their capacity; or it can also result with inadvertent gross over-design, which is a waste of money.

One of the most common mistakes made when using snowguards is under-design. This is usually a result of either not calculating the anticipated loads or using inappropriate factors of safety. Often plans are issued which simply depict a row of snowguards at the eave are, and a callout which says, "provide snowguards at all eaves, typ." Such practice is clearly a roll of the dice. There are many products on the market. They are very different in terms of holding strength. We have seen tested load-to-failure figures of below 400 pounds per device, all the way up to more than 4,000 pounds. If a single row of the 400 pound devices are used on a roof exposed to significant loads, they are likely to fail.

The inverse error is also made. For instance, a designer specifies six rows of snowguards on a given roof without stating any load-to-failure or allowable load criteria. This is silly. "Brand X" is capable of resisting 300 pounds per linear foot of assembly. "Brand Y" is capable of resisting 900 pounds per foot of assembly. If calculations prove that it takes six rows of "Brand X", then "Brand Y" only requires two; using six rows of the stronger system would triple the necessary expense.

Figure 10: The area between these structures in upstate New York is a pedestrian walk. The upper photo shows an avalanche about to occur. The center photo shows it in progress. The lower shows some of the aftermath. Fascia-break details are not a good idea in snow country, but snowguards are essential if they are used.

Avoidance of this error is achieved by determining the force which must be resisted, and then choosing the product and frequency which will do the job, based upon solid load-to-failure test results of the product and appropriate factor of safety (*Figure 5*). Then specify the product by name, or by tested load-to failure figures and minimums. If substitutions are offered, then equality should be proven by the same methods. If greater frequency of the substitute is required to achieve the same performance, then so be it. Likewise, if lesser frequency is required, this is fine as long as it is proven by testing and calculation, and not simply by some empty verbal claim.

Another common error is to use ground snow loads in calculation. In most cases, roof snow loads are lower than ground snow. In such situations, the use of ground snow in calculation rather than roof just adds an inadvertent factor of safety, and no harm is done; in fact, it may be a good idea. In other situations, however, roof snow is greater than ground—sometimes much greater. This is the case when "shadow" or

Figure 11: A sure-fire design on IBM's world headquarters incorporates snow retention above an internal gutter which is EPDM lined and heat-traced. The dark color of the rubber and the self-regulating heating cable ensure that the gutter will remain unobstructed and freely draining.

Figure 12: Architectural geometries which place roofs adjacent to higher walls result with the design snow load on such roofs being much greater than ground snow, (due to the "shadow" or drift condition which can accumulate very significant depths of snowbank).

"drift" loads occur on a roof. This happens due to building geometries in which walls extend above the plane of a lower roof. Such conditions can result with the lower roof experiencing three or four or more times the load as ground snow would provide (*Figure 12*).

On occasion, some users desire a snow retention device only over certain areas, such as an entrance door. This can be done; however, the tributary load to that snow retention system may be much greater than first thought. Due to the cohesive characteristics of a snow blanket, the tributary area will extend in an angular fashion from each end of such a localized assembly, all the way to the ridge line. This may more than double the expected load, not only on the snow retention device, but on the panels' pinning to the structure, as well.

While it is a myth that snowguards cause eave icing (Myth #1), it is also a myth that they will cure any icing problems. On occasion, snowguards are used as retrofit devices for the misguided belief that somehow they will help alleviate or mitigate icing problems. They will not. Ice on a rooftop is damaging and dangerous. Ice weighs about 5 pounds per inch of thickness per square foot. Freezing water produces enough expansive force to split iron engine blocks, and it is certainly capable of demolishing any snowguard system. Icing problems must be remedied by methods which are the subject of many other writings.

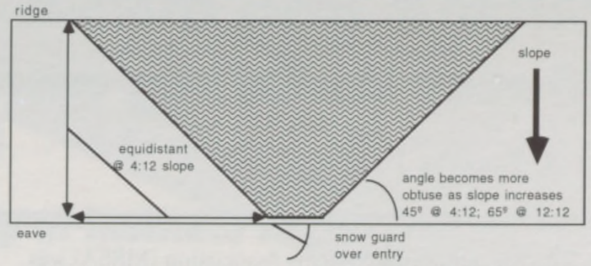


Figure 13: When snowguards are localized over a roof segment, the tributary load can be much greater than imagined due to the cohesive strength of a snowbank.

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About the Author

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Rob Haddock *is director of the Metal Roof Advisory Group Ltd., Colorado Springs. He has a 15-year background in the "nuts and bolts" of contracting, has authored a number of training and educational curricula for various private and trade groups, and is a well-known lecturer on the subject of metal roofing. Rob is a contributing editor for RSI magazine, a course author and faculty member of RIEI, a member of NRCA, and ASTM. He is a lifetime honorary member of the Systems Builders Association and the Metal Construction Association. He holds six U.S. and several foreign patents. Haddock became interested in the subject of snow and ice phenomena as it relates to roofing many years ago. This eventually led to the development of a line of snow retention products called "S-5!" which are designed specifically for metal roofing.*