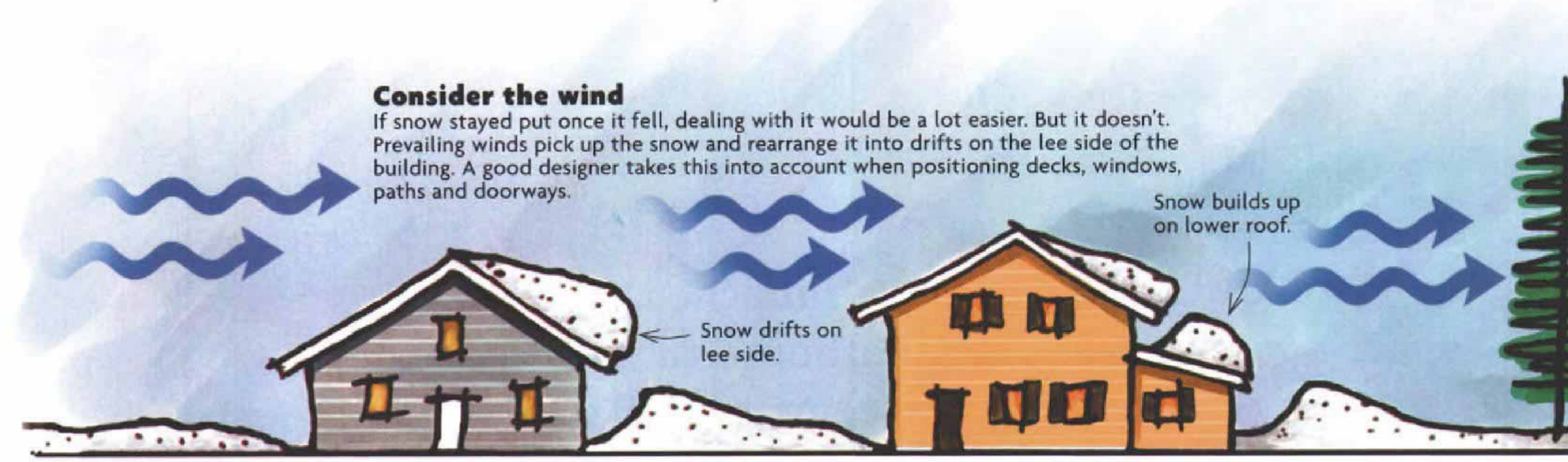


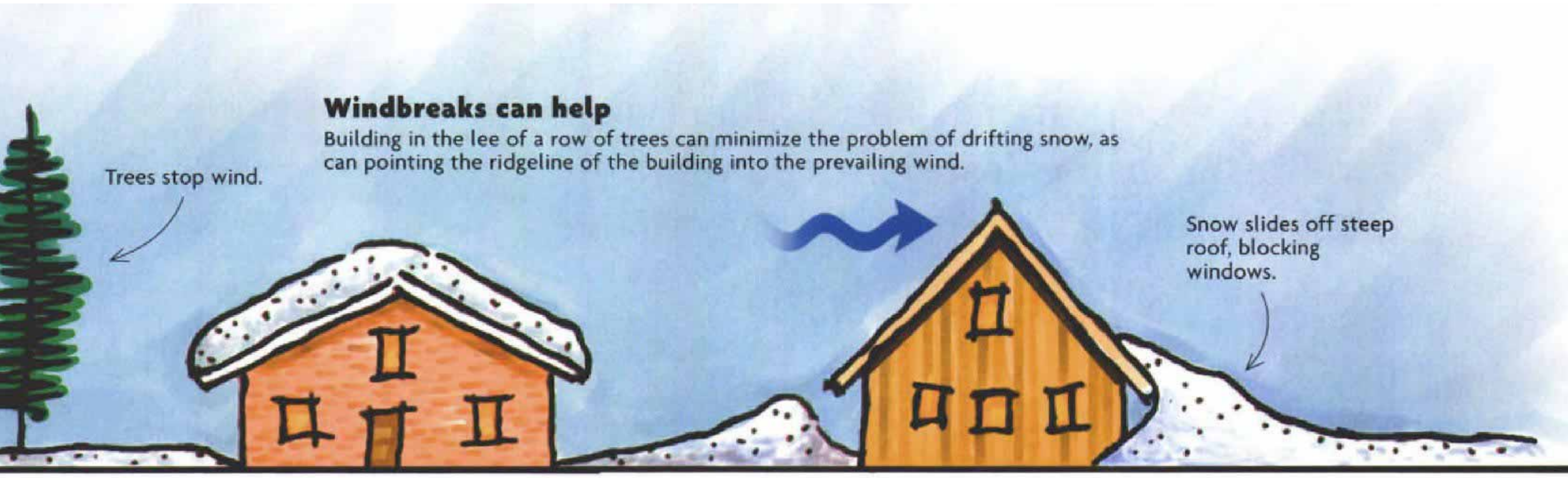
Designing Roofs for Snow Country

The right roof slope, materials and venting will lengthen the life of the roof and the structure under it

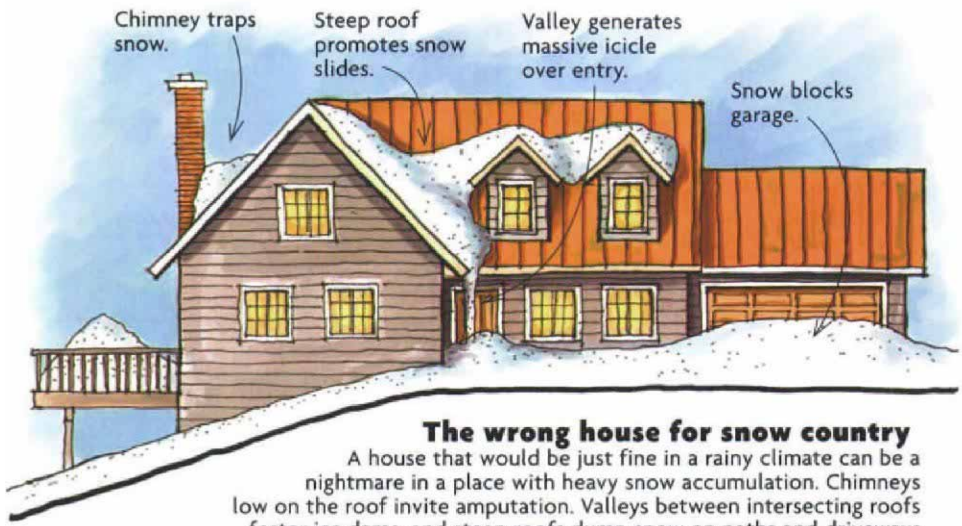
BY HENRIK BULL

Fixer-upper for sale. Snow tends to slide off slippery metal roofs, even if the roof isn't especially steep. This unfortunate deck is the constant target of the snow that departs this roof. Note, too, how the snow is stuck in the valley, where it can cause an ice dam.

Photo this page: Courtesy of Raychem Icestop



Windbreaks can help
Building in the lee of a row of trees can minimize the problem of drifting snow, as can pointing the ridgeline of the building into the prevailing wind.



The wrong house for snow country
A house that would be just fine in a rainy climate can be a nightmare in a place with heavy snow accumulation. Chimneys low on the roof invite amputation. Valleys between intersecting roofs foster ice dams, and steep roofs dump snow on paths and driveways

I grew up in Stowe, Vermont, in a house that had a roof with intersecting gables. My room was right under the valley where the gables met one another, and every time we had a good snowstorm, a massive ice dam would form over my bed. Then the leak would start its steady drip. Aside from the fact that clearing snow off the roof was one of my chores, I had considerable incentive to keep the ice dam under control if I wanted to sleep in a dry bed.

Ice dams are but one of several challenges that confront a person designing a house for a snowy climate. I've spent a good portion of my 40-year career as an architect learning about and trying to solve those problems. Here's what I've found out.

Managing snow begins on the drawing board

Signs proclaiming "Danger, Watch Out for Sliding Snow and Ice from Roof" are best-selling items in building-supply stores in snow country. These signs might as well say "Danger, Badly Designed Building." A lot of designers think they can transplant a house that works just fine in a nonsnowy climate to a snowy one. It just isn't so.

A designer has to think about where the snow will go when it slides off the roof. All building entries, driveways and stairs should be protected from sliding snow and ice as well as roof drip. It is amazing to me how many garages are designed so that snow falls off the roof where it can block garage doors (drawing above right). Equally prevalent are roofs that intersect over the entry, creating a valley that will generate a massive icicle over the front door.

Next, think about what the prevailing wind does to the snow (top drawing). The wind can take the snow off one side of a roof and deposit it on the house's lee side; on lower roofs; or on driveways, paths and stairs. Roof valleys and roofs lower than the main roof can also collect large amounts of snow.

Traditional alpine communities avoided some of these problems by keeping the roof to a simple gable form with the ridge pointing into the prevailing wind. Whole villages often have the ridges of all the houses pointing in the same direction. It's not a coincidence. The fashionable Verbier resort in Switzerland mandates such a traditional building form and orientation for all houses and hotels. Another way to neutralize the effect of the wind is to build in the lee of trees tall enough to the block the wind. Ideally, the entrance is on the sunny side, under the gable end of the building. But with sun, wind, sloping ground and access routes all influencing the design, there will inevitably be compromises.

Snow is a good insulator; why not keep it on the roof?

All snows are not created equal. On the lightweight end of the scale, at about 7 lb. per cu. ft., is the classic powder snow that skiers fly to Utah or to the Canadian Rockies to enjoy. Old snow or wet new snow can be as much as 50% water, weighing over 30 lb. per cu. ft., or 100 lb. per sq. ft. if the snowpack is 3 ft. deep.

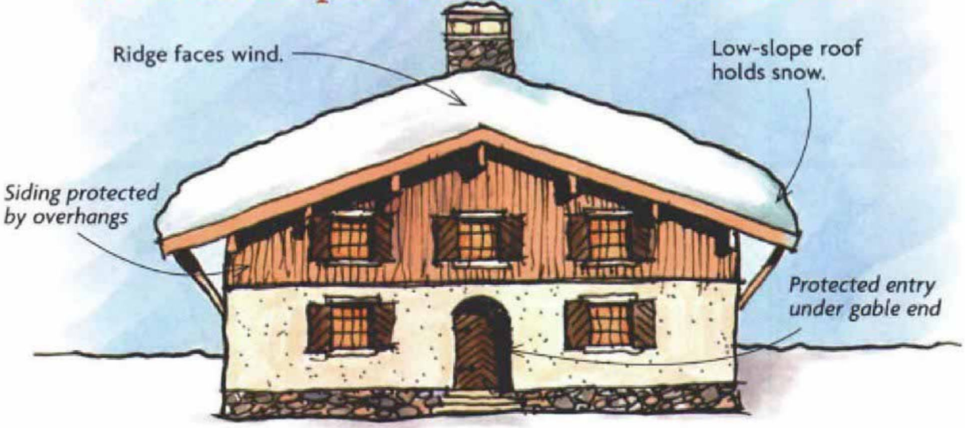
Building codes consider snow loads as pounds per square foot bearing on a horizontal surface. These numbers can vary from a minimum of 30 lb. per sq. ft. in the lowlands of Eastern and Southeastern states to over 400 lb. per sq. ft. at the higher elevations of some Western states.

A common misconception is that only steep roofs are appropriate in snow country. The theory is that the snow will slide off a steep roof, eliminating the problem of heavy snow loads. Generally speaking, this notion is faulty because building codes are conservative and require structures to carry a lot of weight on the roof.

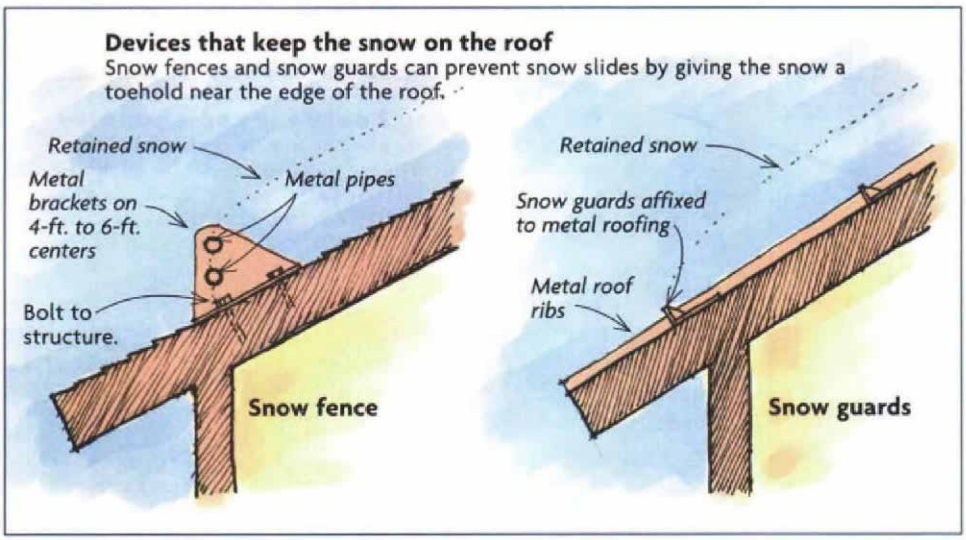
More damage is done by sliding snow than structural failure from the weight of snow. Sliding snow can damage the roof, rip off chimneys and vents, and harm whatever it hits (photo facing page). Worse, people are occasionally killed by snow sliding off roofs.

Through hundreds of years of trial and error, the designers and builders of houses in

"The old alpine designers and builders were well aware of the destructive power of avalanches, and a roof snow slide has all the destructive power of a small avalanche."



Sheltered by a shallow-pitched simple gable, this house is designed to keep snow on its roof. Its lack of multiple roof planes eliminates the source of potential leaks at intersections.



the heavy-snow country of the Alps and of Scandinavia developed an architecture with gentle roof slopes that keep the snow where it belongs: on the roof, insulating the building from extremes in temperature (top drawing). That's right. Snow is an effective insulator, keeping the roof temperature at about the freezing point, considerably warmer than a bare roof when it's -10°F and windy.

Generally, a roof slope of 4-in-12 (18°) will prevent snow from sliding unless the surface is a slippery material, such as metal. A 5-in-12 roof (22.5°) is okay under most circumstances, and a 6-in-12 roof (26°) can be okay if snow fences are used (more on this later).

The old alpine designers and builders were well aware of the destructive power of avalanches, and a roof snow slide has all the destructive power of a small avalanche. Those designers also knew about snow creep, the glacial action of snow moving inexorably downhill. Alpine builders mounted rocks and lashed logs across the roof slope to prevent snow creep.

Valleys, chimneys, roof vents, dormers and other obstructions will stop snow from sliding off a roof, at least for a while. But when the snow loads build to the breaking point, the gravitational forces become enormous. All of those dormers, vents, valley flashings and chimneys can be sheared right off the building. Snow-country sheet-metal contractors have a yearly bonanza replacing sheet-metal chimneys.

Mountain folklore (and some building codes) suggests that snow splitters will prevent damage from sliding snow. A snow splitter can resemble a little tent made of sheet metal that fits over a plumbing vent, or a cricket with steep sides above a chimney. Snow splitters are analogous to the bow of a boat, directing the water, or in this case the snow, around the obstacle. Snow splitters may work with powdery new snow, which is no problem anyway, but they won't work with old snow. I found this out the hard way, having designed a 10-ft. tall snow splitter of welded ¼-in. steel sharpened to a knife edge. The roof was a 12-in-12 pitch. In the winter of 1983, the chimney was holding back an 8-ft. thick triangle of snow. Gravity won the battle, shearing off the chimney like a guillotine. The lessons here: Don't rely on snow splitters, and don't locate chimneys downslope. Locate them near the ridge, if possible.

Skylights should also be located at or near the ridge of the roof. Not only will snow shed away from the flashings, but there also will be less snow at the ridge because of wind action. Don't worry about snow load. Even with double glazing, the heat from the building will melt a cave in the snow above the skylight, with light coming through the snow in mysterious ways.

High-friction and low-friction roofing materials

Simply put, a high-friction roof may prevent snow from sliding, and a low-friction roof functions like a waxed ski, letting the snow slide off. Use a metal roof if you want the snow to slide, but keep the roof form simple, without obstructions, and know where the snow will land.

Many metal roofs have been installed to replace shingled high-friction roofs that have had ice-dam problems (more on this later). Conversely, shingled roofs have replaced metal roofs where sliding snow has been a problem. Which set of problems do you want? There is no ideal roofing material in snow country.

In roofing, as in life, you get what you pay for. Cheap metal roofs will literally come apart at the seams, causing leaks. Light-gauge metal will not lie flat and will look unsightly. Exposed fasteners are also unsightly and will eventually cause trouble because of expansion and contraction. Use only concealed-fastener systems.

Clay-tile and concrete-tile shingles are brittle and, in my opinion, not suitable for severe winter conditions. At Beaver Creek, Colorado, the design guidelines mandated a handsome slatelike clay tile. The manufacturer guaranteed the tiles for the life of the building. When the tiles failed massively the first year, the manufacturer made good on the guarantee, providing the replacement tiles but not the labor to install them or the cost of repairing damage due to leakage. Read the fine print.

Genuine slate and heavy-stone roofs have been used in the mountains in Europe for centuries. Slate is probably suitable for moderately severe winter conditions, but not in the deep-snow areas of the West, where the glacial action of the heavy snowpack can break the slates at their fastening points. Cost is extremely high. Fiber-cement imitation slate is increasingly popular because the cost is considerably less than the genuine material. Both imitation and real slate are brittle and unpredictably slippery.

Wood-shingle and wood-shake roofs can look wonderful, but increasingly, they are not allowed by code officials and insurance companies because of a perceived fire hazard. Fire-treated shingles and shakes increase fire resistance but may also make shingles and shakes more susceptible to splitting. In turn, splitting can cause leaks. Cost is moderately high. Wood shakes and shingles make high-friction roofs and typically retain snow at pitches less than 5-in-12.

Asphalt-shingle roofs are the most popular principally because they are the least costly. Higher-quality asphalt shingles, with 30-year and 40-year ratings, are worth the extra money. There are hundreds of patterns and colors to choose from, including many that profess to have the textured look of wood shakes. I don't think they succeed and prefer the quieter look of the standard three-tab versions. Asphalt shingles are high-friction roofs, but their granules can be worn off by creeping or sliding snow, particularly near the eaves.

When the design is appropriate, a flat roof can be the most practical in snow country—but only if it is properly sloped at a minimum of ¼ in. per ft. toward drains in the heated part of the building. Keep all flashings higher than any standing water. Until recently, I would have discouraged any decks over occupied space. Modified bitumen and rubber-membrane roofs, however, have become reliable. Wood decks can be built over such roofs, but be sure to detail them so that the sleepers don't impede drainage.

Heated eaves are one cure for ice dams. Warmed by electric cables, the copper eave in the foreground prevents ice dams that can cause leaks in the roof. The icicle-encrusted eaves in the background don't have heated metal eaves.

Snow guards help to keep snow on the roof

Having promoted the idea that snow should slide off roofs, metal-roofing manufacturers have since found that it is not always a good idea. Recently, dozens of products have come onto the market to keep snow on metal roofs. Some of these devices are bars clamped on the ribs of the roofing. Others are brackets fastened with glue or tape (I have my doubts about their longevity, but at least the roof won't be damaged if they fail). These variations of traditional snow fences and snow guards are used to prevent snow slides at areas such as entrances. Snow fences (bottom drawing, facing page) should be installed near the bottom of the roof, with additional fences upslope if the roof is big and slippery or steep. In heavy-snow regions, snow fences should be sized to deal with strong forces and should be anchored solidly into the structure. Otherwise, the fences will be bent or ripped off the roof.

Snow guards (bottom drawing, facing page) are typically small (1½ in. by 2 in.) L-shaped brackets that stick up from the roof. Snow guards are installed in a 45° diamond pattern in locations where snow sliding is to be prevented.

As a general rule, snow fences and guards are a good idea on any low-friction roof, and on high-friction roofs steeper than 6-in-12. They will perform well if properly designed and installed, but there can always be a rain followed by a freeze, creating the ultimate low-friction condition. In subsequent storms, the snow will slide on the icy surface.

Rain gutters can be a problem in snow country. The water in the gutter freezes, and the ice expands. Often, the weight of the ice tears the gutter off the building or at least weakens the gutters enough to be torn away by sliding snow. If you must have gutters, install them below the snow-slide plane, and run heat cable in the gutter. The cable must extend down the downspouts to below the frost line.

Ice dams are a big problem in snow country

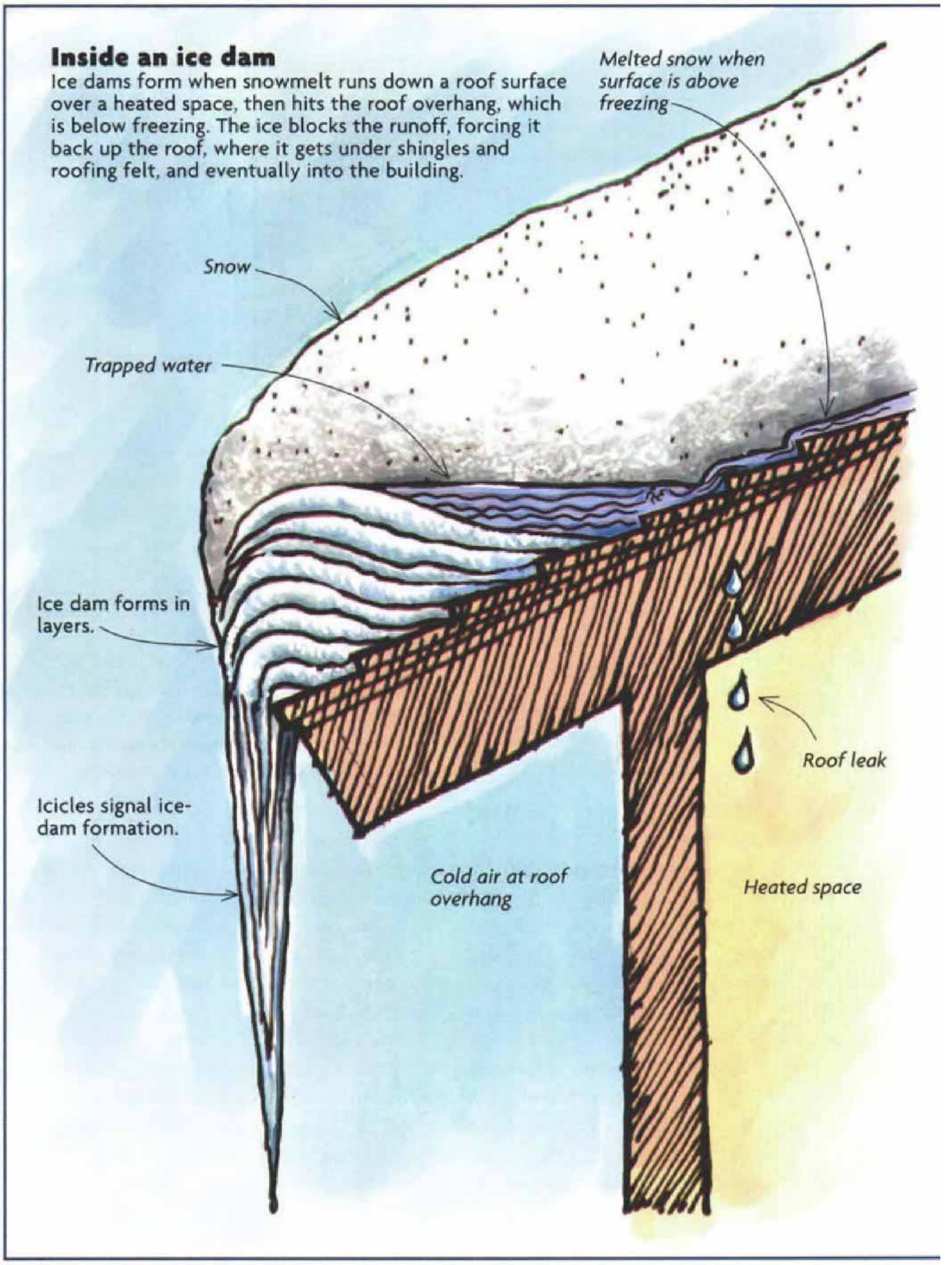
Although it's a good idea to keep snow on the roof, it's an equally bad idea to keep ice on it. At about 60 lb. per cu. ft., ice can exert enormous forces on a structure, especially when it builds up on cantilevered members such as roof eaves. And that's right where ice dams typically occur. What are they, and how do they form?

Heat from the inside of the building or from solar radiation causes the snow on the roof to melt. The resulting water flows downslope until it reaches the lowest edge of the roof, which is colder than the roof over the heated space. If the temperature outside is below freezing, ice starts to form. This ice builds up in layers until it becomes a dam trapping the water that does not freeze (drawing p. 100). The water is usually hidden under the snowpack, and there's no indi-

Photo this page: Courtesy of Bylin Engineered Systems cation of trouble until a leak shows up inside the building.

Icicles are another clue (photo p. 99). They look great on holiday greeting cards, but they are not the homeowner's friend. The problem is at its worst with shingled roofs. This type of roof is watertight when water flows down it, but an ice dam forces water back the other way. Water gets under the shingles and leaks through the nail holes or laps of the building felt and finds its way into the house.

Depending on the roof area above the ice dam, the amount of trapped water can be truly amazing—hundreds of gallons. Releasing the water usually means chopping through the ice with axes or saws. And because you're either working from a ladder or at the edge of the roof from above, the work can be extremely hazardous. Standing on a ladder when the ice dam is breached and 200 gal. of ice water hits you in the chest leads to strong language and bad thoughts about the designer of the building.



Inside an ice dam
Ice dams form when snowmelt runs down a roof surface over a heated space, then hits the roof overhang, which is below freezing. The ice blocks the runoff, forcing it back up the roof, where it gets under shingles and roofing felt, and eventually into the building.

Protect against leaks with self-sealing membranes

Self-sealing membranes have gone a long way to stopping leaks due to ice dams. These sheet goods are sticky and stretchable and function by sealing around nail holes and creating a continuous waterproof membrane.

Install the membrane where the ice dam is likely to occur, extending at least 3 ft. inside the wall line and at ridges, valleys and intersections of roofs and walls—all classic locations for ice-dam leaks. Many conservative architects and builders install self-sealing membranes well beyond the manufacturers' recommendations or code requirements. The cost per square foot seems high, but it's worth every nickel. Or as the saying goes, "There's always money enough to do it right the second time."

Self-sealing membranes are not pleasant to install because the membrane sticks to everything. The product called Ice & Water Shield (W. R. Grace Co.; 800-444-6459) has a polyethylene film on one side that helps that situation. When it comes to these membranes, my advice is to beware of imitations. Cheaper products have come on the market as substitutes. If you can tear the product with your hands, it's not acceptable.

We had a project in the Utah mountains last year at which the roofing contractor asked for a substitution. The submitted product looked to be equal. Much to my surprise the roof leaked in several locations. When the roof was torn apart, we found that the roofing contractor had made a substitution for the approved substitute material. It had torn in many places, and it was not sticky or self-sealing. It looked like 15-lb. roofing felt with a thin layer of asphalt on one side. The next summer, the roofing contractor replaced the entire roof at his expense, using the specified Ice & Water Shield. The roof no longer leaks.

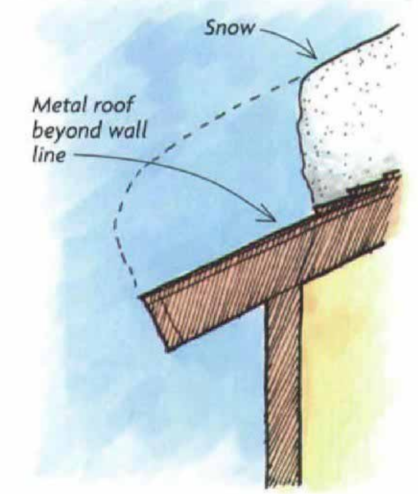
Strategies to prevent ice dams

The best way to prevent leaks from ice dams is to eliminate the dams. One approach is a time-honored New England roofing detail that puts metal in the trouble spots (drawing top left, facing page). This detail works two ways. Because it has no layers, the metal roof is less susceptible to leakage. And because it's slippery, the metal roof is less likely to retain ice or snow. Be aware, however, that under low-temperature and low-humidity conditions, ice will form anyway and will let go only when the temperature changes.

Another way to fight ice dams is with heat tape, insulated electric-resistance wires run in a zigzag pattern atop the roof in areas susceptible to ice dams. Heat tape is a linear heater that melts channels to release water and often results in regularly spaced decorative icicles. The downside is that heat tape is

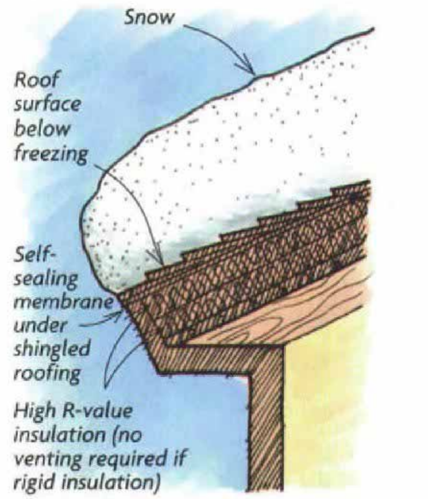
Metal eave discourages ice dams

A low-friction roof surface over the roof overhang lets the snow slide off, minimizing the chances that an ice dam will build up at the eave.



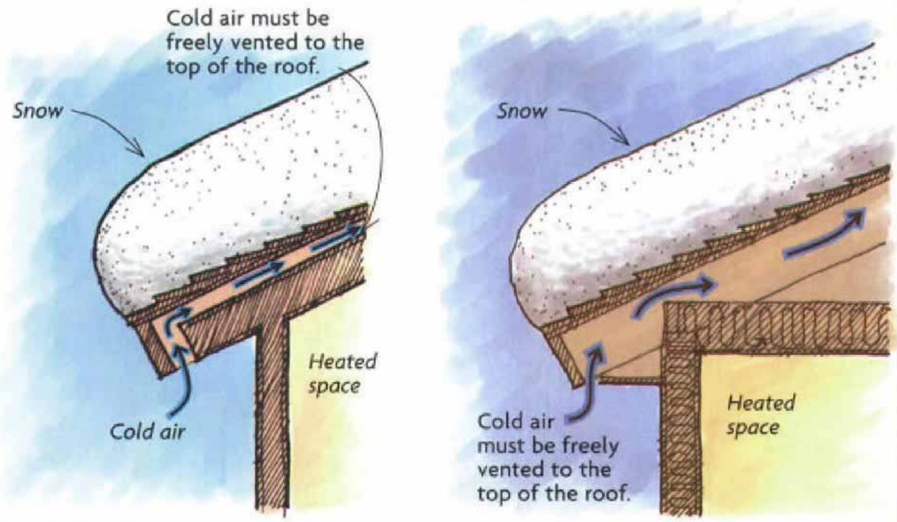
Warm roof keeps the roof cold with lots of insulation

Thick layers of rigid insulation atop the rafters keep interior heat from melting snow on the roof.



Cold roofs isolate the snow from the heated interior

In a flat-ceilinged house, a cold roof is a generously vented attic space that keeps interior warmth from melting the snow. In a slope-ceilinged house, a cold roof is actually two roofs, separated by spacers that create air passages.



flimsy, and if snow slides off the roof, it takes the heat tape with it, often causing short circuits and fires. For this reason, building departments sometimes ban heat tape.

A better product (Raychem Icestop; 800-926-2425) is heavier and tougher than the old versions. Its power draw is also temperature sensitive: more when it cools down, none when it's above freezing. However, moving snow can tear cables off the roof.

The latest step for melting ice dams is the heated metal eave (photo p. 99). The RIM system (Bylin Engineered Systems; 888-313-5666) uses three or more heat-cable lines under a patented metal edge to keep ice dams from forming. Because the cables are under the roofing, they won't be torn away by sliding snow. The RIM system is suitable for both new construction and retrofits.

Cold roofs and warm roofs prevent ice dams without heated eaves

Want to avoid relying on electricity to prevent ice dams? Here are two ways. The European theory of a cold roof is simple: Keep the underside of a roof cold so that heat from the building will not melt the snow. If there is no water flowing down the roof surface, there will be no ice dams or icicles. The equivalent of a European cold roof can be achieved in flat-ceilinged houses built with conventional construction methods by heavily insulating ceilings and generously venting the attic (drawing bottom right). Make sure that the insulation does not block the flow of air at the wall.

You can do the same thing with a slope-ceilinged house, but there must be two separate roofing systems with cold air between (drawing bottom left). This is easy to do on a simple roof but almost impossible in a complicated roof with hips, valleys, dormers and roofs at different levels. There must be a free flow of air from the intake at the eaves to the exhaust at the ridge. Flat 2x4s as spacers do not create enough space for air to flow freely. The bigger the airspace, the better—at least 2x4s on edge. Open-web steel studs have been used to let air flow. One drawback to a cold roof is that you lose the insulating properties of a roof covered with snow.

A cold-roof ridge vent must be generous but needs to be detailed in such a way that blowing snow or rain does not cause a leak. It also has to be protected against clogging in a heavy snowstorm. If the ridge vent gets plugged, your expensive cold roof converts to a conventional warm roof.

Cold roofs were detailed a little differently in traditional alpine houses. In them, the top floor, covered by hay, was the insulated vent space. On the ground floor, hay-burning farm animals pumped heat into the house, setting up a convection loop.

Most folks today do not want to live with farm animals but do want complicated roofs, so more and more architects are opting for so-called "warm" or "hot" roofs (drawing top right). Rigid closed-cell foam insulations are best for such installations. There should be no voids for condensation to form, so venting isn't necessary. It's a good idea to use two layers and to stagger the joints. Because the point is to keep the roof surface cold, the more insulation, the better. A good general goal is to shoot for an R-50 roof. The cost will be less than trying to create a functional cold roof, and more insulation saves on heating costs for the life of the building.

My own preference for practicality would be a simple gable roof with a 4-in-12 pitch, a high-friction roof (maybe sod, but that's another story). I would have cathedral ceilings with a superinsulated warm roof. A simple roof form, pointed in the right direction, can save you a lot of trouble. □

Skier Henrik Bull, FAIA, is a partner in BSA Architects in San Francisco, CA. Drawings by the author.