UNDERSTANDING TILE ROOF DESIGN AND PERFORMANCE

By Edward L. Fronapfel, PE

Tile roofs may be made of clay, concrete, or manufactured material: strong, versatile, durable materials. For over a century, these roofs have been used successfully. They are now available in many architectural dimensions, adding an aesthetic appeal, be it American Colonial, Spanish Hacienda, or French Provincial. However, as with any moisture-managed product, the proper application of underlayments and flashing and integration with the building's other weather-resistant systems are crucial. The key to the proper installation of the systems is understanding them and the need for their integration. Any product that has a life expectancy of greater than 50 years will require that the adjoining and underlying systems also meet this life expectancy. Sometimes an expert should be engaged to properly integrate these systems into a project.

BUILDING CODES

Standard building codes in the United States, including the Uniform Building Code (UBC), the International Building Code (IBC), and the International Residential Code (IRC), as well as adoptions in specific local jurisdictions, provide only the minimum prescriptive requirements for installing roofing products. Industry and manufacturer standards supplement the minimum standards of building codes and help ensure quality installation of tile roof systems. These guidelines include those provided by the National Roofing Contractors Association, the Roof Tile Institute, and the Western States Roofing Contractors Association. Standards for the manufactured product are provided in the Evaluation Service Reports and the specific manufacturer's installation instructions.

The basic idea of the guidelines and

Photo 1 – Damage due to snow and ice accumulation in the valley area. The edge of the tile and the supporting valley flashing must provide structurally sound products in this area.

Photo 2 – Roof layout and an understanding of ice and snow accumulation are extremely important and should be fully considered by the design and construction team prior to applying the roofing and integrating the building veneers.

good industry practice is that water should be allowed to flow freely downhill and exit at the horizontal terminations. This is fundamental to understanding the complete building envelope system, of which the roof is a part. Managing moisture on the roof involves installing waterproofing at the deck level, not on top of the products.

THE BASICS – WEATHER PROTECTION

The first component when properly constructing a roof is the decking. Although a vertical slope of 2½ in 12 inches is the minimum allowed by code, a slope of 3 inches vertical to 12 inches horizontal should be considered as the minimum. Where slopes come together, a sawtooth effect is created; with lower-slope conditions, water, snow, and ice are prone to accumulate in these valleys. The installer and designer should consider these issues when determining the slope of the roof, as well as the needs for additional waterproofing beyond the minimum standards of the codes and industry standards.

The second important component is the underlayment and how it is installed. Minimum code lapping is not sufficient in these valley areas. Using proper, fully sealed underlayments, single-ply roofing or, better yet, open-valley construction, are considerations that are key to successful roofing installation and design. See *Photo 1*.

Depending on the climatic conditions, it is possible that two layers of underlayment or ice and water shield products will be needed for protection that meets the minimum code standards. These products should extend 2 to 4 ft inbound of the vertical thermal insulation line of the interior of the building to provide protection from the slush fill located behind the ice dams. Particular attention to detail is necessary where valleys come within 3 ft of sidewalls. The valley liner should be extended up the wall, similar to curb-base flashing. This valley liner protects the sidewall from snow and ice accumulation and manages concentrated water flows that will be directed toward the wall and can splash beyond the standard flashings and weather barriers. See *Photo 2*.

The tile roofing material provides both an aesthetic function and protection for the weather barrier placed below it, shielding it from direct exposure to the elements. Tile roofs are unique in this aspect, as the primary drainage plane is the underlayment, not the topmost layer as with other roofing materials, such as asphalt or wood shingles. That is why underlayments are the crucial components for the roof's weather-resistant performance. Any puncture or tear in the underlayment should be corrected during construction prior to installing the tile. Damage from leaks can result in either immediate or long-term progressive water entry. Discovering the point of entry is typically difficult, as water runs down the roof deck, below the underlayment, until it can find a breach to enter the structure.

FLASHINGS AND LAPPING

The direction and order of lapping of the underlayment with flashing are important to properly manage the water flow, especially at roof penetrations, eaves, and rakes. The underlayment should lap over the top of penetration flashings and under the bottom, creating a shinglelike order directing water to the top of every layer lower in elevation. This technique of water shedding is important at all penetrations, whether plumbing and roof vents or large penetrations such as skylights and chimneys. The flashing surrounding these large penetrations consists of several pieces, so the same shinglelike lapping is essential to achieve waterproofing performance at these locations.

Coordinating the trades–the framer, roofer, plumber, and mechanical subcontractors–ensures that this simple premise of correctly lapping the materials is achieved. At penetrations with a width greater than 30 inches, a cricket flashing is recommend-

Photo 3 – The vertical batten prevents water in the channel from draining into the gutter below. The ice and water shield products must be properly integrated with the thermal envelope and the weather-resistive decking materials.

ed to protect the area from snow and debris buildup (2006 IRC) and direct water away from the vertical walls. At rakes, the underlayment should be lapped under the rake flashing to protect the underlayment from moisture intrusion through wind-driven rain or snow. At eaves, the underlayment should be lapped over the eave flashing in order to provide a continuous avenue for water to drain off of the roof. In all of these cases, reverse-lapped underlayment and flashing interfaces can result in damaged components and can eventually lead to leaks. See *Photos 3 - 6*.

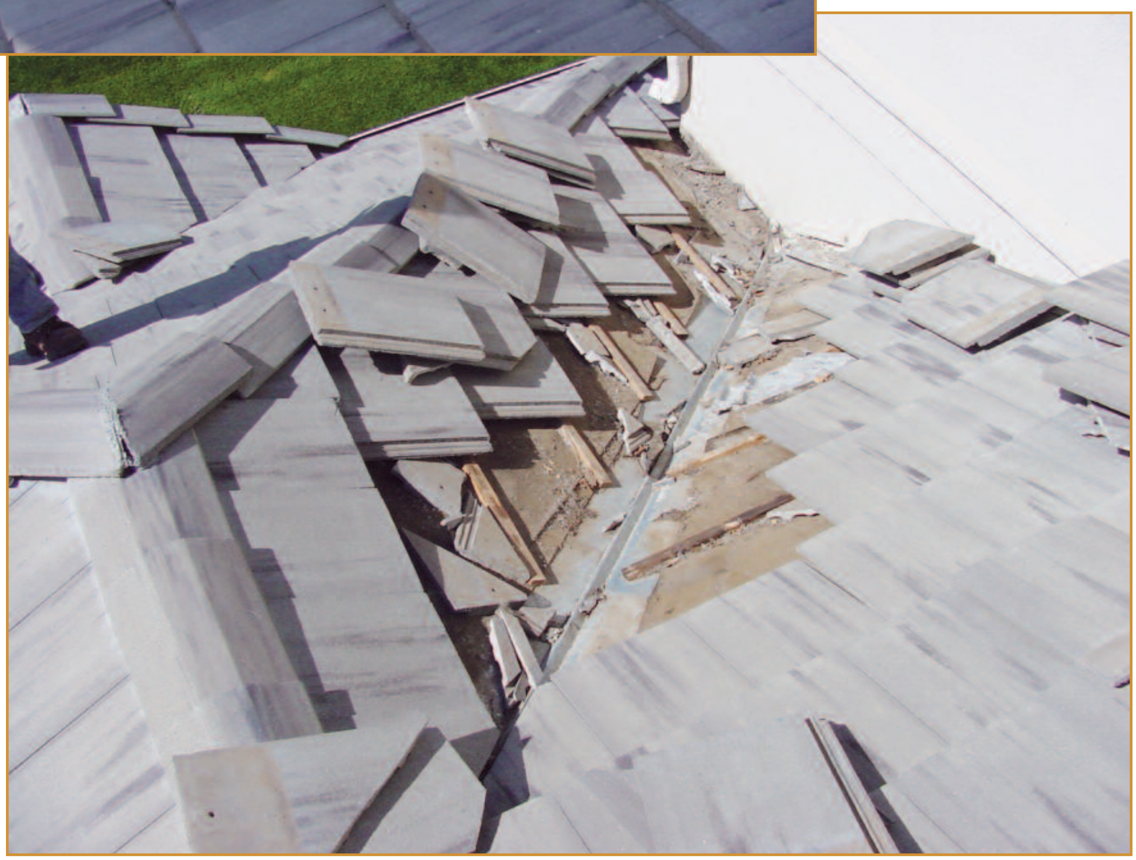
Photo 4 – The integration of penetrations through the roofing requires that the roofing subcontractor work with the plumbing subcontractor to ensure that the lower flashings are integrated in a shingle-lapped manner and sealed, and that the upper flashings are integrated with the tile and sealed. In this case, the penetration near the valley is a problematic detail that should not occur. Simply put, keep holes out of valley construction.

Photo 5 – The integration of the flashing from the roofing and the sidewall cladding is extremely important. The roofing subcontractor must ensure that the roofing felts, waterproofing, continuous flashing, and diverter flashing are all coordinated so they lap properly. A situation like the one in the photograph above should be brought to the attention of the designer of record. The window is damaged due to the location of the gutter, and because without flashings, water is directed into the jamb of the window. Contractors and subcontractors should not proceed with their work until such situations are fully resolved.

Photo 6 – The lapping of flashings and all moisture-management materials should ensure that water is directed down, out, and away from the roofing felts. In no case should mastic or sealant be relied upon to correct deficient construction.

Photo 7 – This valley is constructed with horizontal battens that will trap debris. The use of a closed valley requires that tiles be removed in order to perform the required maintenance.

Photo 8 – Poor valley design by the architect is shown here. The design directs water into the vertical unit-demising wall and allows buildup of ice and snow against the cladding.



VALLEYS

It is important to pay close attention to the design and construction of the underlayment in the valleys. Valleys are created at the intersection of two sloping roof planes; this intersection creates a natural area of concentrated water flow. Where water and ice are concentrated, additional protection of the underlayments is required. Simply placing more underlayment or using sheet metal flashing at valleys isn't enough; the installation must carry both the lateral and longitudinal concentrated flow of water without becoming saturated or allowing water to pass through gaps or penetrations.

Properly lapping components in a shinglelike manner directs water from above each layer of underlayment and flashing; as water flows down the roof, it remains on top of the moisture-management materials. It is preferred to use open valleys rather than tiling across the valley. An open valley makes it easier to clean out debris. Additionally, the damage from ice accumulation in an open valley is more limited than in a closed valley with cut tiles over battens or flashings. Valleys should never terminate within 6 inches of a sidewall, as the concentrated flow will result in water impacting the vertical veneer systems. See *Photos 7* and *8*.

ICE DAMS

Ice dams are not an uncommon problem in mixed or cold climates; ice damming conditions can result in premature damage to the roof, walls, or interstitial space from moisture intrusion, the weight of the dam, or ice falling on lower surfaces or other building components. These ice dams can

Photo 9 – Snow damage of the cleats and tiles due to build-up of ice and snow behind the retention bars. The clips do not have structural capacity to resist the loads imparted from the sliding ice and snow.

also cause serious injury if they fall on pedestrians. The formation of ice dams can be minimized by good design and construction. See *Photo 9*.

Two events are necessary to create an ice dam: a warm interior attic or rafter and a cold exterior surface that freezes. When snow accumulates on a roof with a warm attic, the snow sitting on the warm part will melt and become liquid; when this water reaches the eaves, which are cooler than the attic space, it freezes. Over time, this ice accumulates and can create a potentially hazardous ice dam. Additionally, exposing the moisture-management materials underneath to ice and water for prolonged periods of time accelerates the deterioration of the materials. Deteriorated moisture-management components lead to damage of the building. See *Figure 1*.

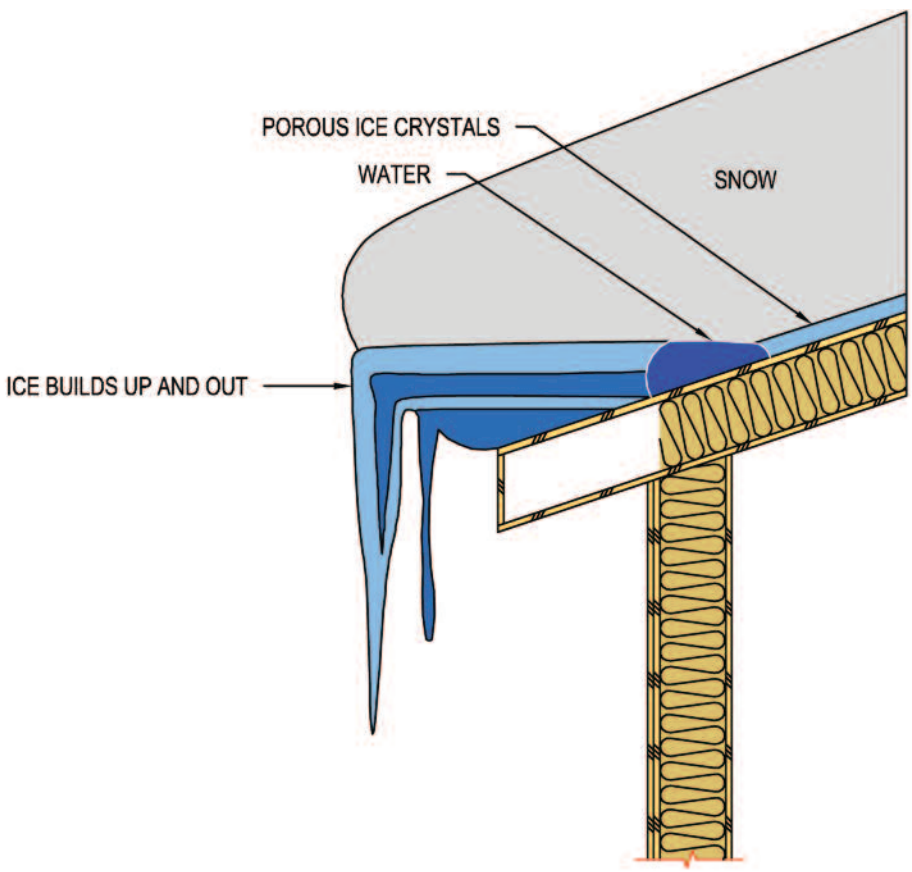


Figure 1 – A warm attic space can heat the field of a roof during winter conditions. Snow will then melt, flow to the colder, exterior edges of the roof, then refreeze. This creates ice dams that can lead to the deterioration of the roofing materials, as well as pose a life-safety hazard from falling ice.

There are various options when designing attics that will minimize the warming effects that result in snow melt, ice formation, and subsequent ice dams at the colder roof areas. The design should include a good thermal and pressure boundary. The pressure boundary, like the building envelope on the exterior, controls the movement of air and water or water vapor. There are several important things to consider when creating this boundary. The first is to clearly establish a pressure boundary that coincides with the thermal boundary, which is most commonly insulation in the walls and ceilings. Convective air should not move from the interior side of the home into the unconditioned spaces. The key to preventing this movement is placing the insulation in direct contact with the air barrier. Using kraft-faced batts will not provide the vapor diffusion or air pressure boundary necessary for thermal continuity; instead, using expanding insulations will likely establish the best air and thermal line, but other options include overventing a well-insulated attic to minimize the temperatures within the attic.

The caution of this design, however, is there is a potential of creating higher negative pressures that bring in air from the eaves or birdhouse ridge; it's important to ensure snow is not pulled into the attic space due to this negative pressure.

Photo 10 – The installer must determine the proper fastening and location. This as-built condition shows the nail size chosen and that there are missing nails in the tile roofing.

Photo 11 – The vertical battens must be nailed in order to transfer the wind load; after that, the horizontals must be nailed to the verticals, then the tiles to the horizontals. If not, there must be sufficient weight to resist wind uplift. Roof edges will have sufficiently increased uplift loads and will require additional fastening or clipping.

Photo 12 – Horizontal battens require that water drain to the slots. In order for that to happen, water must back up and work its way to the drainage slot. In the photo below, the slot appears to have been cut after the installation of the batts; this creates an opening in the roofing felts for the water to drain through. Vertical battens with the horizontal battens applied over the top are preferred over this type of installation because they create a direct and uninterrupted path to the edge of the roof.

Properly isolating mechanical chases thermally from the attic will help minimize increased temperatures originating from the house. The common B-vent discharge is sufficient enough to raise the attic temperature to provide snowmelt.

FASTENING AND BATTENS SUPPORTING TILE ROOFS

Wood battens are used to provide a means to attach the tile system and allow for drainage at the roofing felt level. The tiles can lie over the batten, or they can be fastened through the batten. It is typical to use fully fastened tiles in wind zones over the 100-mph fastest gust. In fact, the code requires this fastening, as well as fastening the rake tiles (tiles on the outside, sloped edges of the roof) with two nails. If design wind speeds are in excess of the 110-mph fastest gust, the installer must fasten the tiles to provide resistance to uplift loads in accordance with the structural load calculated for the zones of the roof under Chapter 16 of the IBC.

When battens have lugs, the slope of the roof dictates the fastening system, up to the 100-mph fastest gust and the structural calculations for wind designs in excess of 110 mph. The tiles with projecting anchor lugs can be relied on without fastening to the battens for winds below 100 mph and slopes under a 5:12 pitch. Interlocking tiles with projected anchor lugs always require fastening to battens. The international codes simply state that for areas with snow, at least two fasteners per tile are required, or one fastener if used with battens. See *Photos 10 - 12*.

The codes are silent on batten type and installation. The battens are defined in guidelines such as the Roof Tile Institute's Design Criteria. One needs to consider the wood type in combination with the use of horizontal or vertical systems. Horizontal battens run perpendicular to the slope of the roof and will trap moisture. A 1-in slot should be placed every 4 ft to provide for drainage, and clearance of at least 6 in from the valley to allow concentrated flow is preferred. When deciding to use horizontal batten-only support, the longevity of the system beneath the tile should be considered because without provisions for drainage, the lifespan of the roof may be reduced. Knowing that the water will be absorbed and retained against the roofing felts, allowing for deterioration, consider using redwood, cedar, or treated wood, as they provide a longer-life product.

When using vertical battens, better known as counterbatten systems, a minimum space of three-quarters of an inch for drainage is created, and the vertical battens provide a flow path for both water and air. This system will outperform horizontal batten systems, and the life of the underlayment matches the life of the tile. The structural loads must be included for counterbatten systems, including the batten sizing, as they act as either simple support beams or multispan beams, depending on location. Snow loads of 30 pounds per sq ft (psf) require the horizontal batten spanning to the vertical battens to be Douglas fir or better when spaced over vertical battens at 16 inches on center. For cedar, 1 x 4s would be required to handle the snow loads.

Roofs are an essential component of the building envelope system for any structure. Tile roofs are an effective and aesthetically pleasing system if installed correctly. Underlayment, directional lapping, battens, and fasteners are frequently overlooked facets of tile roof construction that can make or break any roof assembly. If one is diligent during installation and proper maintenance is performed throughout the life of the roof, tile roofs can protect the interior environment of a building for years.

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Edward L. Fronapfel, PE, holds bachelor's and master's degrees in civil engineering with an emphasis in structural engineering. He is a certified Level 2 infrared thermographer, a certified third-party EIFS inspector, a certified forensic claims consultant (CFCC), and a board-certified building inspection engineer (CBIE). Fronapfel's background includes geohydrology, hydrology, hydraulics, civil engineering, structural engineering, and extensive work in construction forensics for building envelope sciences, including asphalt work to the roof. Ed's work has included deposition testimony, expert witness testimony, mediations, and arbitrations. He is a registered engineer in 23 states. His dedication to the community is demonstrated by his active membership in 25 professional organizations. He has published articles in various industry publications.