CHAPTER TWO | Roofing

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ASPHALT SHINGLES

Asphalt shingles, which cover 80 to 90% of residential roofs, have undergone much change in the last 20 to 30 years. Until the late 1970s, all asphalt shingles were manufactured from a heavy organic felt mat that had established a reputation for both strength and flexibility and generally outlasted their 15- to 20-year life expectancy. Since their introduction in the late 1970s, fiberglass shingles have come to dominate the market, accounting for over 90% of shingles sold today. However, premature failure of some fiberglass shingles in the 1980s and 1990s tarnished the product's reputation and spawned a number of lawsuits and resulted in a toughening of standards and a general improvement in fiberglass shingle quality.

Shingle styles have changed as well. The common three-tab shingles of the 1950s and 1960s are now joined by no-cutout shingles, multitab shingles, and laminated "architectural" shingles (Table 2-1). Laminated shingles provide deep shadow lines and a heavily textured appearance, some simulating wood or slate. These now account for over half the shingles sold.

Shingle Quality

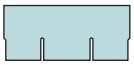
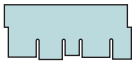
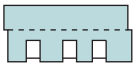
Shingle quality is often difficult to determine visually since it is based largely on hidden factors such as the strength of the reinforcing mat (organic felt or fiberglass), the strength and flexibility of the asphalt, and the amount and type of fillers used. In most cases, however, the guidelines outlined below can help to select shingles that perform as promised.

Organic Felt vs. Fiberglass. Organic shingles are built around a thick inner mat made from wood fibers or recycled paper saturated with soft asphalt. Fiberglass shingles, on the other hand, use a lightweight nonwoven fiberglass held together with phenolic resin. Both shingles are then coated on top with a layer of harder asphalt and fillers and topped with colored stone to create a decorative surface and protect against ultraviolet light. A thin layer of asphalt on the bottom is coated with a nonsticking dusting that keeps the shingles from sticking in the bundle. Each type has its pros and cons (Table 2-2).

Organic. In general, organic shingles have better tear resistance and resistance to nail pull-through than fiberglass shingles, making them less likely to blow away during a cold weather installation when they have not yet had a chance to seal. Also, some roofers find that organic shingles are more pliable and easier to work with in cold weather. On the downside, the organic mat is neither fireproof nor waterproof. Organic shingles therefore typically carry only a Class C fire rating.

Although uncommon, manufacturing defects that allow water penetration into the mat can lead to premature curling and cupping of organic shingles. Blistering and curling in warm climates has also been occasionally reported. Organic shingles cost more than comparable fiberglass shingles, but remain popular in colder regions and

TABLE 2-1 Asphalt Shingle Types

	Weight per square	Length	Width	Exposure	ASTM Fire Ratings	ASTM Wind Ratings
Three-tab 	200–300 lb.	36–40 in.	12–13 1/4 in.	5–5 5/8 in.	A or C	Wind resistant
Multi-tab 	240–300 lb.	36–40 in.	12–17 in.	4–7 1/4 in.	A or C	Many wind resistant
No-cutout 	240–360 lb.	36–40 in.	11 1/2–14 1/4 in.	4–6 1/8 in.	A or C	Many wind resistant
Laminated 	200–300 lb.	36–40 in.	12–13 1/4 in.	5–5 5/8 in.	A or C	Wind resistant

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TABLE 2-2 Organic vs. Fiberglass Shingles

	Pros	Cons	Recommendations
Organic Shingles	Better resistance to tearing and nail pull-through. Easier to install in cold weather with fewer blow-offs.	More expensive. Occasional blistering or curling from moisture penetration or excessive heat. Only Class C–fire rating.	Good for cold climates or cold-weather installations. Look for ASTM D255 certification.
Fiberglass Shingles	Less expensive. Less prone to cupping or curling from heat or moisture. Class A–fire rating. Lighter weight.	Less tear-resistant. More prone to blow-offs in cold weather. Some premature failures reported, primarily with lightweight, low-end products.	Best in moderate and warm climates. Look for ASTM D3462 certification from an independent lab such as UL.

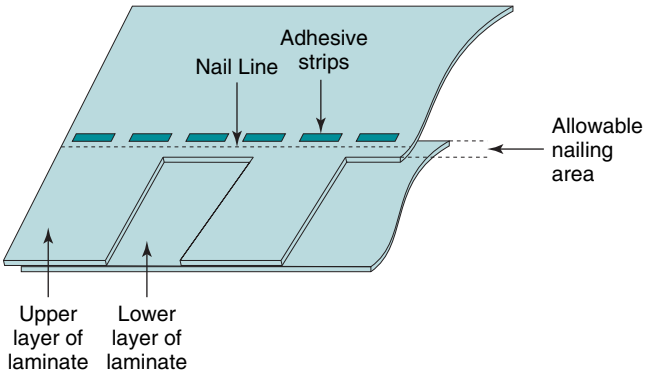
throughout Canada. With organic shingles, shingle weight tends to be a good predictor of performance and longevity since the added weight usually indicates a thicker mat saturated with more soft asphalt.

Fiberglass. Fiberglass shingles, built on a thin nonwoven fiberglass core, were first introduced in the late 1970s and now account for over 90% of the shingles sold. Because they use less asphalt, they are lighter and generally less expensive than organic shingles. Because fiberglass mats are more fire-resistant and moisture-resistant than felt, most fiberglass shingles carry a Class A (severe exposure) fire rating and are less prone to cupping and curling from moisture damage. On the downside, fiberglass shingles are generally not as tear-resistant as organic shingles, making them more prone to blow-offs in cold weather when the shingles have not properly sealed. After they have sealed, they can still tear from movement in the sheathing, since fiberglass shingles have little give, unlike organic shingles. In this situation, if the bond strength of the adhesive strip exceeds the tear strength on a lightweight shingle, the shingles can crack.

Premature failure of some fiberglass shingles due to splitting or cracking led to a number of class-action lawsuits in the 1980s and 1990s. The problems were primarily with lower-end shingles with lightweight mats, types that have been largely eliminated from the market. But it still pays to buy ASTM-rated products from a reputable company that provides a good warranty.

Laminated Shingles. Also called "architectural" or "dimensional" shingles, these have two layers laminated together at the lower half of the shingle, giving the roof a thicker textured appearance with deeper shadow lines. Depending on the shape and size of the cutouts, half or more of the exposed shingle area is triple thickness and the rest double. With the added thickness and without the tabs, which typically wear out first in three-tab shingles,

FIGURE 2-1 Laminated Asphalt Shingles.



In general, laminated or "architectural" shingles perform well due to their heavy profile and lack of cutouts. Nails placed too high, however, may miss the lower layer of laminate, allowing it to come loose over time.

most laminated shingles carry longer warranties as well as higher wind ratings, some as high as 120 mph.

While not immune to the problems of other shingles, such as premature cracking, it is reasonable to expect good performance from a reputable brand. One problem unique to laminated shingles is the loosening of the bottommost piece of the shingle caused, in part, by nailing above the line where the double thickness ends (Figure 2-1).

On many laminated shingles, nails must be precisely placed so they are high enough to stay hidden while still penetrating both layers.

Wind Resistance. Most shingles carry a wind-resistance rating of 60 miles per hour as tested under ASTM 3161 or UL 997, while specialty shingles may be rated to as much as 130 miles per hour. While laboratory tests may not predict actual performance in a storm, a higher rated shingle will likely perform better than a lower rated one. Shingles rated at over 100 mph are often special-order items and typically require six rather than the usual four nails per shingle. Adding two extra nails and extra dabs of plastic roofing cement to a regular shingle can also increase its performance in high-wind conditions (see "Fastening," page 58, and "Manual Sealing," page 57).

A wind-resistance rating is not the same as a warranty. Shingles that carry a wind-resistance warranty generally require that the shingle tabs have been adequately sealed to the adhesive strip and most limit wind coverage to five or ten years from installation. In cold, cloudy weather or on a steep north-facing slope, manual sealing with roofing cement may be necessary.

Algae Resistance. Black streaks on shingles caused by algae or fungal growth used to be limited to warm, humid climates, but now this can be seen on houses as far north as Canada. Some experts attribute the spread to the increased use of crushed limestone as a filler material in asphalt shingles. Limestone is economical and makes a durable shingle, but the calcium carbonate in the limestone supports algae growth. In algae-resistant (AR) shingles, zinc or copper granules are mixed in with the colored stone topping. When the shingles get wet, the zinc or copper is released, inhibiting algae growth. Warranties for algae resistance are usually for less than 10 years since the protection ends when the mineral washes away. Some shingles have longer lasting protection than others due to a higher percentage of AR granules.

Manufacturing Standards. Fiberglass shingles are covered by ASTM D3462, which includes a tear test as well as a new nail-pull-through test added after fiberglass shingle failures started occurring in the late 1980s. A new pliability test was also added in recent years. Organic asphalt shingles are covered under their own standard, ASTM D255. In the past, most companies did their own testing, but under pressure from contractors' associations and others, most now use independent certifiers such as UL. With fiberglass shingles, look for the UL label next to the ASTM D3462 certification. This is not the same as a UL listing for a fire rating, which is printed on most fiberglass shingle packages. More and more jurisdictions are requiring compliance with ASTM standards, but discount shingles are still available with no certification.

As with many consensus standards, the ASTM D3462 requirement for tear strength of fiberglass shingles is considered by many experts to be a bare minimum rather than a guarantee of high quality. Also, once installed the shingles' strength will likely diminish. So finding products that exceed the minimum is recommended for demanding applications.

Warranties. Shingle warranties run from 20 to over 50 years. Although products with longer warranties are usually of higher quality, in some cases, the longer warranties are more of a marketing strategy than an accurate predictor of shingle life. While the specific terms of the warranty are important, more important is the manufacturer's reputation for warranty service in the local area. All manufacturers retain the right to void the warranty if installation instructions are not closely followed, and they can often find a way to avoid honoring a claim if so inclined. Key issues to consider in a warranty are as follows:

- Is the warranty prorated from the date of installation, or is there an introductory term of 5 to 10 years when the full value can be recovered?
- How long are warranties valid against wind damage, algae growth, or other types of damage?
- Does the warranty cover a portion of the labor costs of tear-off, disposal, and installation, or does it cover materials only?
- Is the warranty transferable?

- Perhaps most importantly, does the manufacturer have a strong reputation for warranty service in the local area?

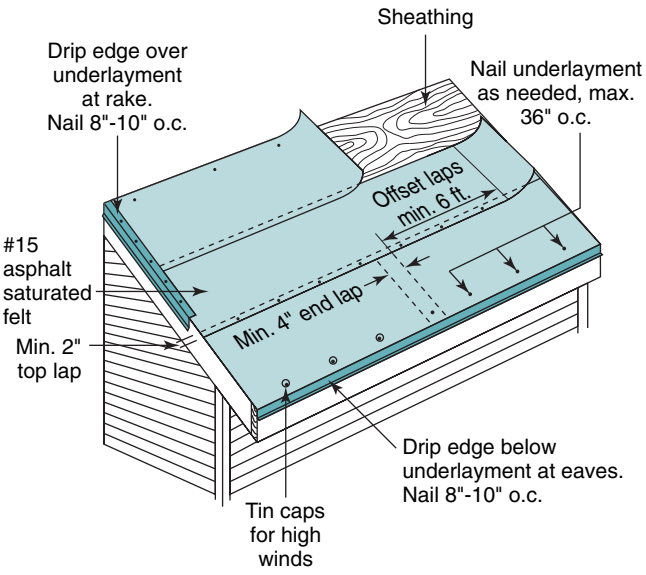
Underlayment

The roof deck should be sound and level before laying the underlayment. Fifteen-pound or heavier felt underlayment is required by code in some areas. Whether or not it is required, underlayment is cheap insurance against problems. There are several good reasons to install underlayment:

- It protects the roof deck from rain before the roofing is installed.
- It provides an extra weather barrier in case of blow-offs or water penetration through the roofing or flashings.
- It protects the roofing from any resins that bleed out of the sheathing.
- It helps prevent unevenness in the roof sheathing from telegraphing through the shingles.
- It is usually required for the UL fire rating to apply (since shingles are usually tested with underlayment).

Standard Slopes. On roofs with a slope of 4:12 or greater, use a single layer of 15 lb. asphalt-saturated felt, starting at the eaves and lapping upper courses over lower by a minimum of 2 inches. Vertical joints should lap a minimum of 4 inches and be offset by at least 6 feet in successive rows (see Figure 2-2).

FIGURE 2-2 Underlayment for Asphalt Shingles.



On roofs with a slope of 4:12 or greater, use a single layer of minimum No. 15 asphalt-saturated felt, starting at the eaves and lapping upper courses over lower. Run the felt 6 inches over ridges and hips from each direction, and 6 inches up any adjoining walls.

Secure each course along seams and edges with enough corrosion-resistant nails to hold it in place until the roofing is installed. In high-wind areas, apply fasteners a maximum of 36 inches on-center along overlaps.

For best protection against leaks, run felt 6 inches over ridges and hips, from each direction, and 6 inches up any adjoining walls. Valleys should be lined with a full width of roofing felt (or bituminous membrane) pushed tight into the valley so there is no slack. Side courses of underlayment should run over the valley lining and extend 6 inches past its edge. (See "Valley Flashing" page 59.)

Low Slopes. Asphalt shingles can be used on roofs with a slope of 2:12 to 4:12 if double-coverage underlayment is used. Start with a 19-inch strip of 15 lb. asphalt-saturated felt along the eaves, and lap succeeding courses by 19 inches as shown in Figure 2-3.

Wherever there is a possibility of ice or snow buildup or the backup of water from leaves or pine needles, install a self-adhering bituminous membrane along the eaves that extends up the roof to a point at least 36 inches inside the interior wall line. An alternative approach, not widely used anymore, is to seal all laps in the lower courses of roofing felt with lap cement or asphalt plastic cement.

In areas with extensive snowfall or windblown rain, the best protection against leakage is to cover the entire low-slope roof area with a bituminous membrane, as shown in Figure 2-4.

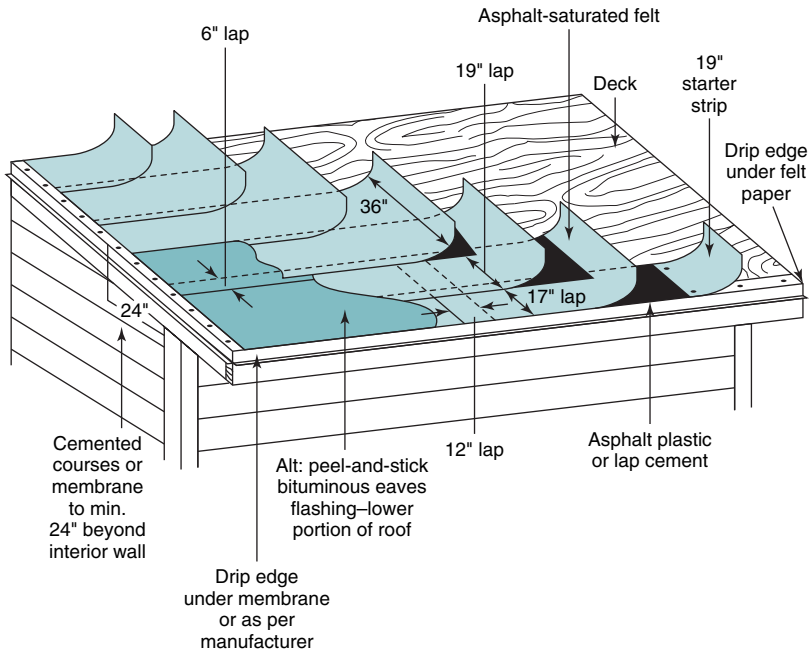
Vertical end laps should be at least 3 inches and horizontal laps 6 inches. If the roof changes to a steeper slope, for example, where a shed dormer joins the main roof, extend the membrane 12 to 18 inches up the main roof slope. Bituminous membranes are self-healing around nail holes, and because they bond fully to the sheathing, any leaks that occur cannot spread. As a safeguard against expensive callbacks, many roofers now apply membrane to the entire surface of any roof with a slope of 4:12 or less.

Eaves Flashing. The best defense against ice dams in cold climates is a so-called "cold roof," consisting of high levels of ceiling insulation separated from the roof surface by a free-flowing vent space (see "Preventing Ice Dams," page 97). Where a cold roof cannot be achieved due to complex roof shapes, unvented roofs, or retrofit constraints, ice dams may form during severe winters, in some cases, causing pooled water to wet wall cavities and interior finishes.

Where adequate insulation and ventilation cannot be assured, self-adhering bituminous eaves flashing should be installed. The membrane should go from the lower edge of the roof to a point at least 24 inches inside the interior wall line (Figure 2-5).

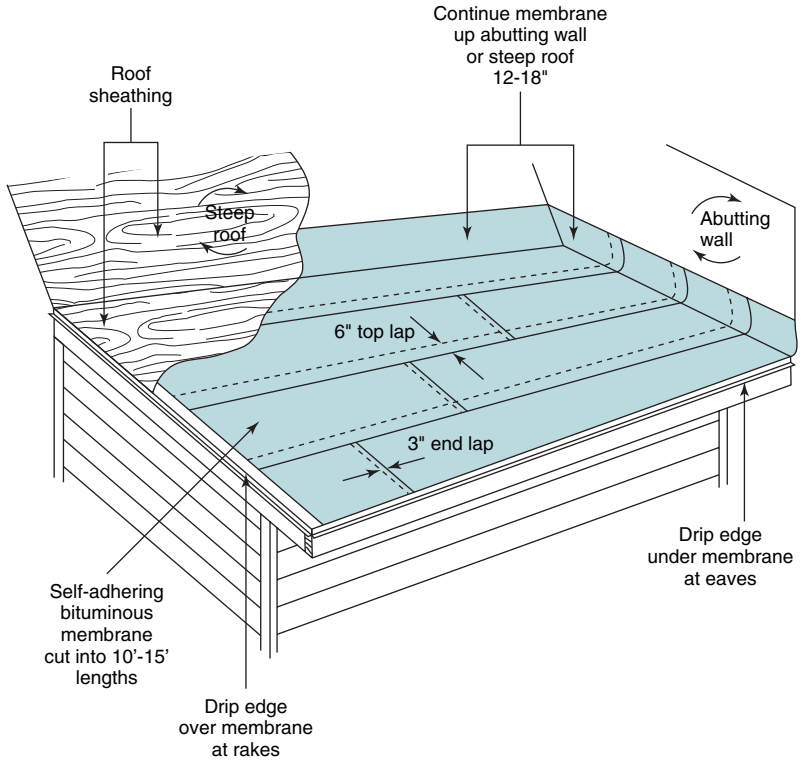
Where two lengths of eaves flashing meet at a valley, run each across the valley, starting with the length from the roof with the lower slope or lesser height. The valley flashing should later lap over the eaves flashing.

FIGURE 2-3 Low-Slope Underlayment.



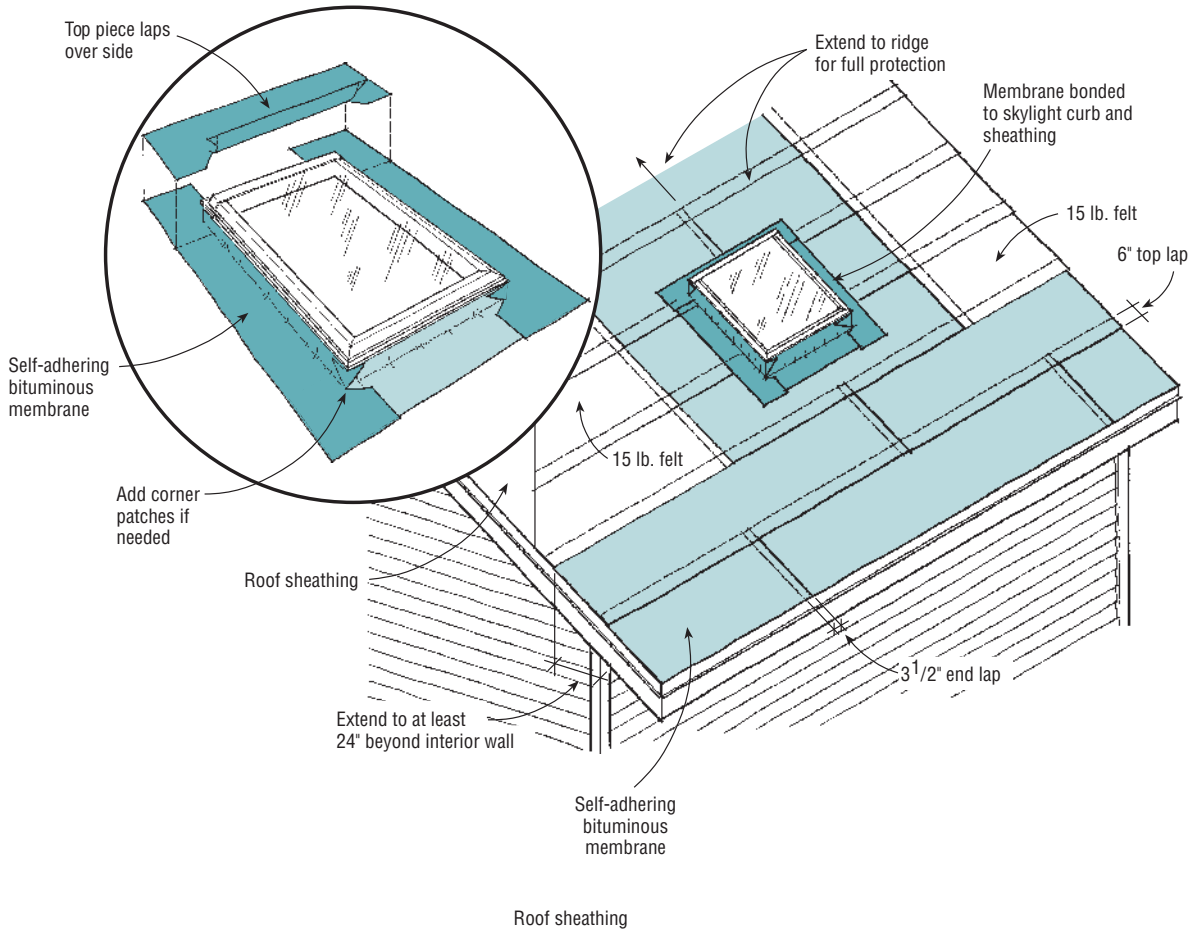
With slopes from 2:12 to 4:12, use a double layer of No. 15 underlayment as shown. Where water may back up from ice or debris from trees, protect the lower portion of the roof with a bituminous eaves flashing or fully cemented felt, as shown.

FIGURE 2-4 Low-Slope Underlayment in Cold Climates.



In areas with extensive snowfall or windblown rain, the best protection against leakage is to cover the entire low-slope roof area with a bituminous membrane. Extend the membrane to the top of skylight wells and up any adjacent walls or roof slopes by 12 to 18 inches.

FIGURE 2-5 Eaves Flashing.



Where adequate roof insulation and ventilation cannot be assured, install a bituminous eaves flashing to a point at least 24 inches beyond the inside surface of the wall. Also, continue the membrane up to and around skylights where heat leaks can melt snow and contribute to ice dams.

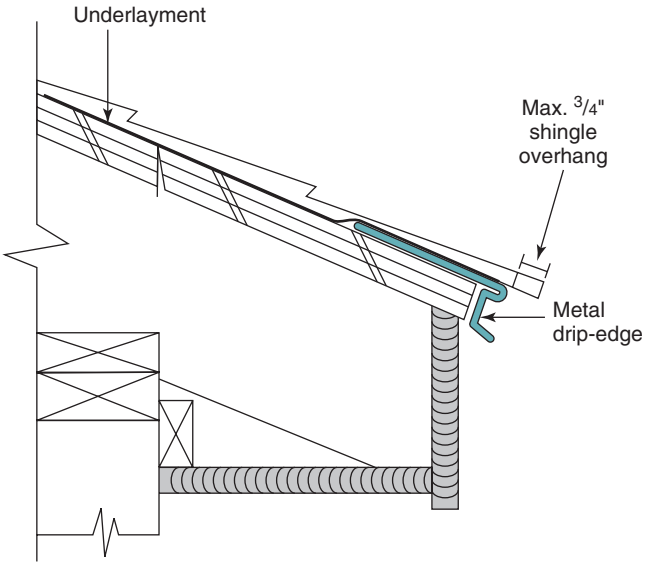
Skylights. With deep snow, melting water from above and around the skylight can lead to ice dams below. For full protection, some contractors extend the eaves membrane up to the bottom of any skylights and continue it around the sides and top of the skylight. By wrapping the skylight curb with membrane as well, any potential flashing leaks are also eliminated as shown in Figure 2-5 (see also "Skylight Flashing," page 127.)

If it is impractical to install membrane all the way from eaves to skylight, install a 3-foot-wide band of membrane below the skylight, lapping the bottom edge of the membrane over the row of shingles where the membrane terminates.

Drip Edge. Drip edge should always be used along the eaves to kick water away from the fascia, and it is a good idea along rakes as well. Drip edge should lap over the underlayment at the rakes and under it at the eaves (as shown in Figure 2-6). Overlap joints in the drip edge by 2 inches. Shingles can be set even the with the drip edge or overlap by up to $\frac{3}{4}$ inch.

Some manufacturers of eaves membranes specify that the drip edge be installed on top of the membrane along the eaves, violating the principle that upper layers of flashing

FIGURE 2-6 Drip Edge.



Install the drip edge over the underlayment at the rakes and under it at the eaves. Shingles may lie flush with the metal edge or overhang by up to $\frac{3}{4}$ inch.

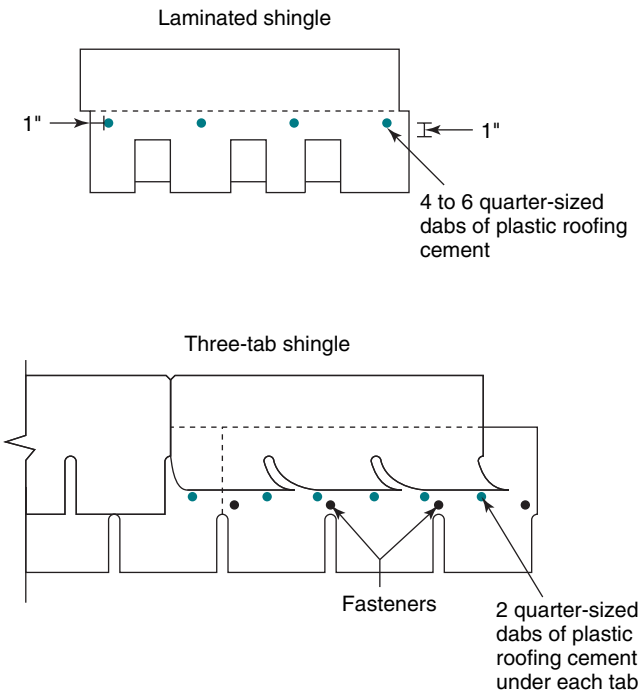
should overlap lower layers. To remedy the problem, the manufacturers suggest using a second strip of membrane to seal the top of the drip edge to the eaves membrane. In practice, however, most installers place the drip edge first and lap the eaves membrane over it, consistent with good building practice.

Installation

Installation Temperature. Ideally, shingles should be installed at temperatures ranging from 40°F to 85°F. Below 40°F, shingles are brittle and crack easily when hammered or bent. Above 85°F, it is easy to tear the shingles or mar the granular coating. In hot temperatures, roofers often start very early in the morning and break at midday. In cold temperatures, it is best to store the shingles in a heated enclosure until they are installed.

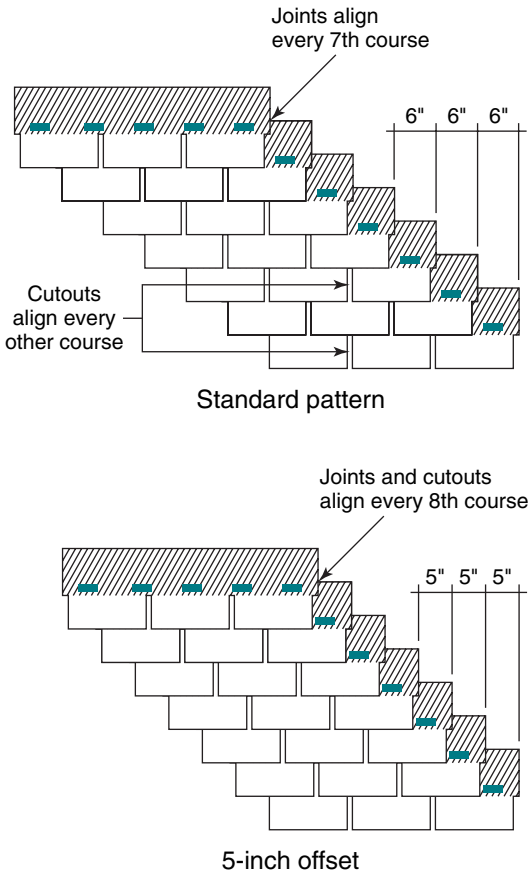
Manual Sealing. In cold climates, the sealant strip may not set up properly and may require manual sealing. For three-tab shingles, place two quarter-size spots of plastic roof cement under the lower corners of each tab (as shown in Figure 2-7). With laminated shingles, place four to six quarter-sized dots, spaced evenly, about one inch above the bottom of the overlapping shingle.

FIGURE 2-7 Manual Sealing of Asphalt Shingles.



Manual sealing of shingles may be required in cold weather or on slopes over 21:12. Three-tab shingles (bottom) require two spots of plastic roof cement under the lower corners of each tab. Laminated shingles (top) require four to six spots spaced evenly about one inch above the lap line.

FIGURE 2-8 Asphalt-Shingle Offsets.



In the standard installation pattern (top), cutouts line up every other course and generally wear out first from channeled water. A 5-inch offset (bottom) creates a more attractive random appearance with less wear in the cutouts.

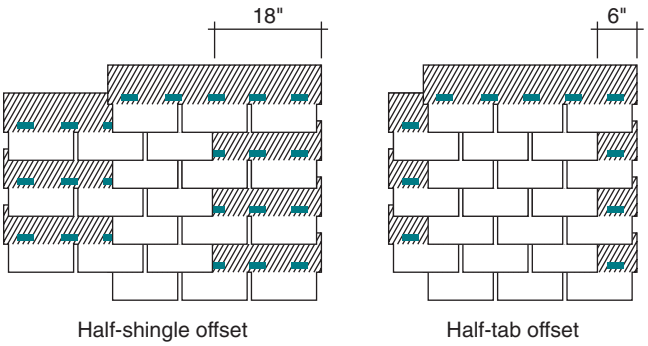
Starter Course. After the underlayment and drip edge are installed, a starter course of asphalt shingles, with the tabs removed, is nailed along the eaves so its sealant strip seals down the first course.

Offsets. Successive courses are typically offset 6 inches (half a tab) on a 36-inch shingle in a stepped fashion, making cutouts align every other course and butt joints align every seventh course (Figure 2-8). For a more random pattern where cutouts align only every eighth course, offset shingles only five inches. Both of these patterns effectively resist leakage, but the 5-inch offset may provide longer wear since water will not be channeled down the cutouts thereby eroding the stone topping.

For ease of installation some roofers install shingles straight up the roof, staggering shingles 6 inches or 18 inches back and forth (Figure 2-9). Since this lines up butt joints every other course, this is considered a less watertight roof and may leak under extreme situations, such as windblown rain on a low pitch. It is not recommended by any roofing manufacturers. Manufacturers also claim that shingle color patterns may create splotches or stripes if laid this way.

Fastening. The preferred fastener is galvanized roofing nails with a minimum 12-gauge shank and head diameter of at least $\frac{3}{8}$ inch. Although staples are allowed in some jurisdictions, they do not provide the same holding power. Both nails and staples should be long enough to penetrate the roof sheathing by $\frac{3}{4}$ inch or penetrate $\frac{1}{4}$ inch through the sheathing if it is less than $\frac{3}{4}$ inch thick. Fasteners should be driven straight and flush with the shingle surface (Figure 2-10). Overdriven nails or staples can cut into the shingle or crack it in cold weather.

FIGURE 2-9 Straight-Up Installation of Asphalt Shingles.



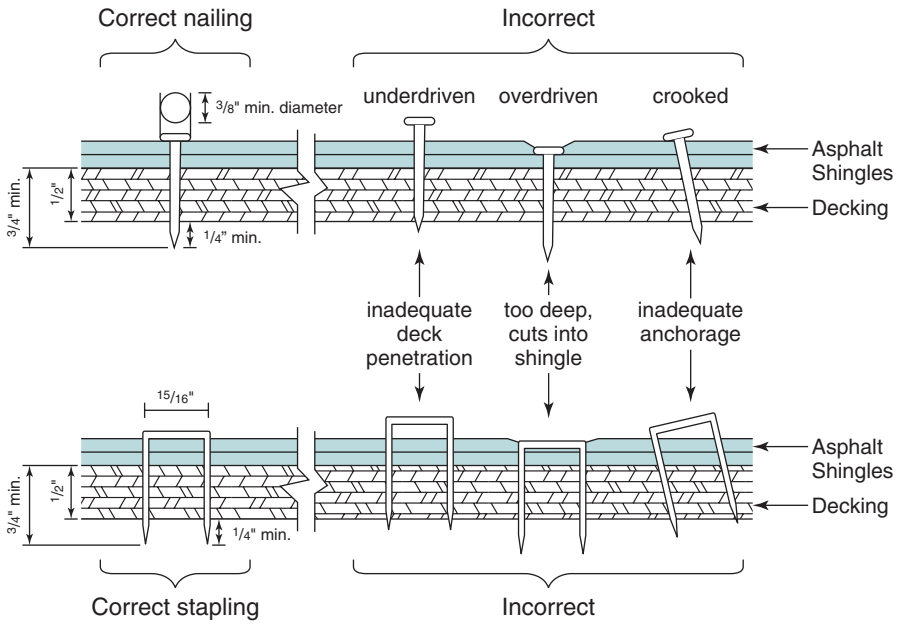
While some roofers install shingles straight up the roof, staggered by either a half tab or half shingle as shown, manufacturers recommend against this approach. With butt joints lined up every other course, leaks could occur on shallow slopes or with windblown rain.

Fastener Location. Standard nailing for three-tab shingles is four nails per shingle, about 1 inch in from either end and one over each slot. Placement should follow manufacturers specs, which typically require nailing and stapling just below the sealant strip (Figure 2-11).

Nailing too high can allow wind to get under the shingles. Nailing too low will expose nails to the weather and to view from below. Nailing through the sealant strip can interfere with sealing.

- ***High winds.*** For areas subjected to high winds, use six nails as shown in Figure 2-11 or add two dabs of sealant at the bottom of each tab (as shown in Figure 2-7). Also special wind-rated shingles with heavier sealing strips are available by special order and may be required in some jurisdictions.
- ***Laminated shingles.*** With laminated shingles, standard nailing is four fasteners spaced equidistant as shown in Figure 2-12, or six fasteners equidistant for heavy-duty installations. It is important that fasteners go in the designated nail area where they will penetrate both laminations. Nailing too high will leave the bottom lamination loose and subject to slipping out of place.

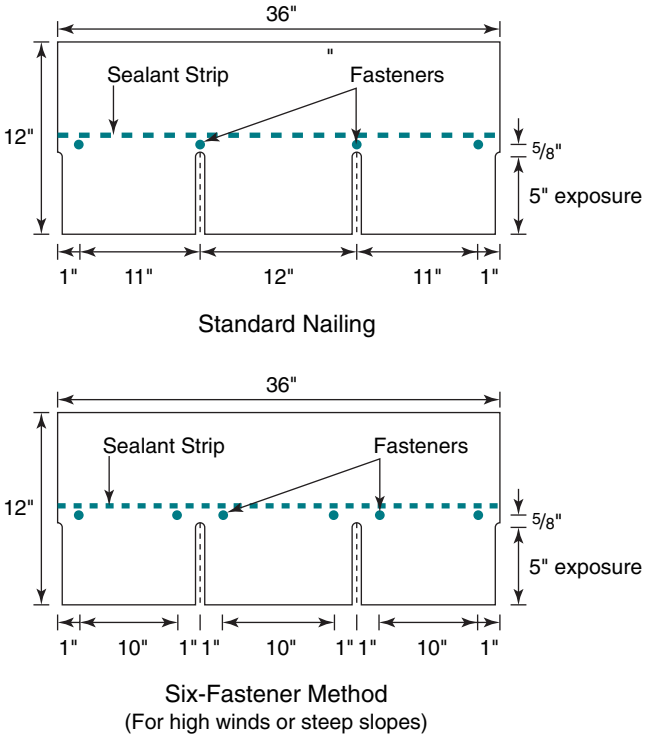
FIGURE 2-10 Asphalt-Shingle Fasteners.



Nails provide better holding power than staples. Either type of fastener should be driven straight and flush with the surface. Overdriving or under-driving weakens the fastener's holding power.

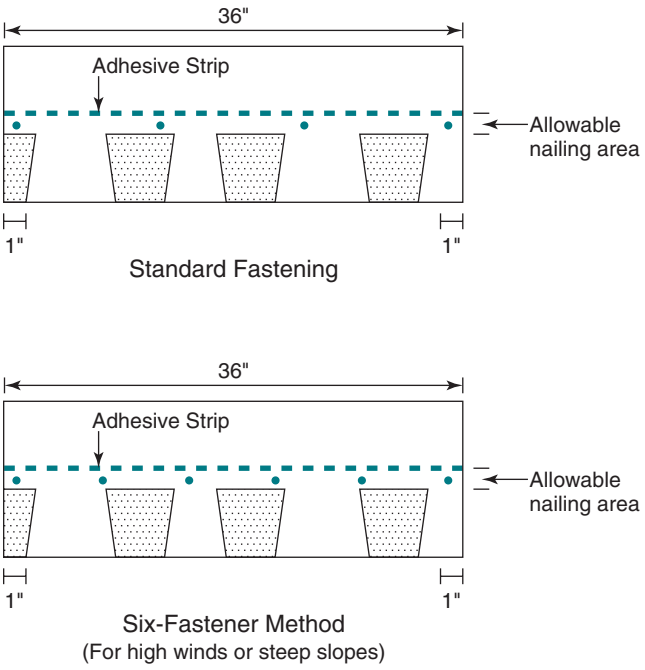
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FIGURE 2-11 Fastening Three-Tab Shingles.



Standard nailing for three-tab shingles is four nails per shingle just below the sealant strip. For more demanding conditions, such as high winds or steep pitches over 21:12, use six fasteners, as shown.

FIGURE 2-12 Fastening Laminated Shingles.



Standard nailing for laminated shingles is four nails per shingle; six per shingle for high-wind conditions or slopes over 21:12. Nails must penetrate both laminations or the bottom layer may come loose.

Low Slopes

Asphalt shingles can be installed on roof slopes of 2:12 to 4:12 if special procedures are followed for underlayment (see "Low Slopes," page 54). Eaves flashing to a point at least 24 inches inside the interior wall is recommended if there is any possibility of ice dams or water backup from leaves or pine needles. A conservative approach is to run self-adhering bituminous membrane over the entire low-slope area. Once the underlayment is complete, shingles are installed in the standard fashion. In cold weather, manual sealing may be required as wind uplift will be greater on shallow roofs (see "Manual Sealing," page 57).

Steep Slopes

Asphalt shingles should not be installed on vertical walls, but they can be used on steep slopes, such as mansard-style roofs. For slopes greater than 21:12, apply underlayment in the normal fashion. However, shingle sealing may be a problem, particularly on shaded portions of the roof. For best performance, use the six-fasteners-per-shingle method (Figure 2-11) and manually seal the shingles with plastic roofing cement (see "Manual Sealing," page 57).

Flashings

Flashings for asphalt shingles should be corrosion-resistant metal with a minimum thickness of 0.019 inch. A cricket or saddle should be installed on any chimney greater than 30 inches wide and can be covered with flashing or the same materials used as a roof covering.

Valley Flashing

Because valleys catch water rushing down two roof planes, they are likely places for roof leaks. Leaks can be caused by water rushing up the opposite side of the valley or from wear and tear caused by the channeled water, snow and ice buildup, or traffic on the roof. For that reason all valleys should start with a leakproof underlayment system to back up the shingle or metal valley detail.

Valley Underlayment. Start by cleaning any loose nails or other debris and nailing down any sheathing nails that are sticking up. If eaves flashing is used, it should cross the valley centerline each way and be installed before the valley underlayment (see "Eaves Flashing," page 54). Next install a 36-inch-wide strip of self-adhering bituminous membrane in 10- to 15-foot lengths up the valley. Keep the membrane tight to the sheathing at the valley center, since any hollow sections could be easily punctured. Next install the 15-pound felt underlayment across the roof, lapping over the valley flashing by at least 6 inches. Roll roofing is also an acceptable underlayment for asphalt shingle valleys, although it is more prone

TABLE 2-3 Asphalt Shingle Valley Types

	Pros	Cons	Recommendations
Woven	Minimal cutting and no sealing required. Very weather resistant due to double coverage across valley.	Both sides must be shingled together. Hollows left under weave may be torn or punctured. Heavy laminated shingles create uneven appearance.	Make sure shingles are pushed tight to sheathing. Use extra nail in top corner of end shingles.
Closed Cut	Each side can be shingled separately. Provides clean appearance with any shingle type.	Single coverage at valley center. Shingles on overlapping side must be clipped at corners and sealed with roofing cement.	Push lower shingles tight to sheathing and use extra nail in top corner of end shingle. Seal shingles carefully. Use bituminous underlayment as backup.
Open Metal	Most durable if appropriate metal is used. Attractive appearance with heavy laminated shingles.	Most costly. Metal lining requires prefabrication. Shingles on both sides must be clipped at corners and sealed with roofing cement.	Use with heavy laminated shingles where decorative appearance is desired. Avoid uncoated aluminum. Best with copper, lead-coated copper, or steel (enameled, galvanized, or stainless)

to crack and is not self-healing around nails. After the underlayment is complete, the valley can be completed in any of the following ways (Table 2-3).

Woven Valley. On the first course across the valley, the shingle from the larger or steeper roof plane overlaps the shingle from the smaller or shallower plane. Extend the end of each shingle at least 12 inches beyond the valley centerline and avoid placing any butt joints near the valley center. Press the shingles tight into the valley when nailing and place no fasteners within 6 inches of the valley center. Add an extra nail at the end of each shingle that crosses the valley (see Figure 2-13).

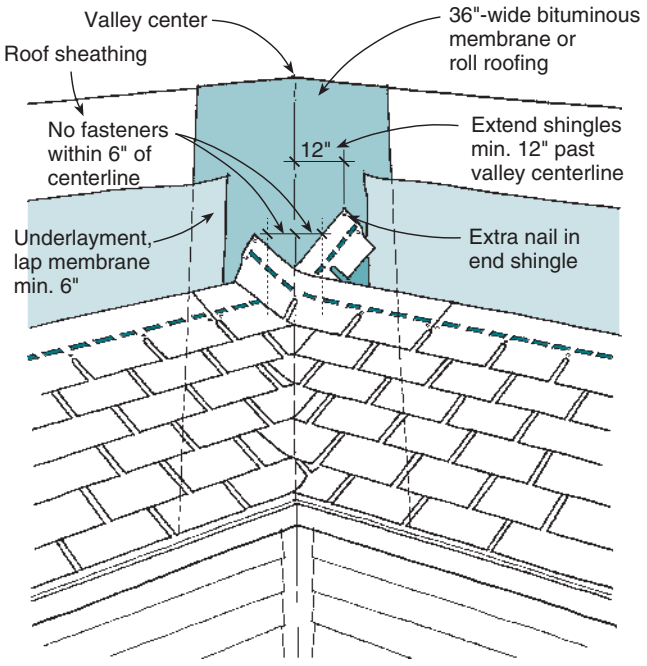
Continue to the top of the valley. Done correctly, woven valleys are very weather-resistant and best for high wind regions, but they are somewhat slow to install. They work better with three-tab shingles than with heavy laminated shingles, which do not conform well to a crisp valley line.

Closed-Cut Valley. This starts the same way as a woven valley, with the first course of shingles run across the valley from both roof planes, lapping the shingle from the larger or steeper roof plane over the shingle from the smaller/shallower plane. Then continue roofing the smaller or lower-slope roof plane, running each course at least 12 inches past the valley centerline. Press the shingles tight into the valley and nail in place, locating no fasteners within 6 inches of the valley center and adding an extra nail at the end of each shingle that crosses the valley (see Figure 2-14). Do not allow any butt joints to fall in the valley.

Next, snap a chalk line 2 inches out from the valley centerline on the opposite slope and shingle up the other side of the valley, holding nails back 6 inches from the valley center. Trim each shingle to the guide line as you go, or run them long and trim them later. In either case, clip about 1 inch off the uphill corner of each shingle to help direct rushing water into the valley. Finally seal each shingle to the valley and to the overlapping shingle with a 3-inch-wide bead of plastic roofing cement.

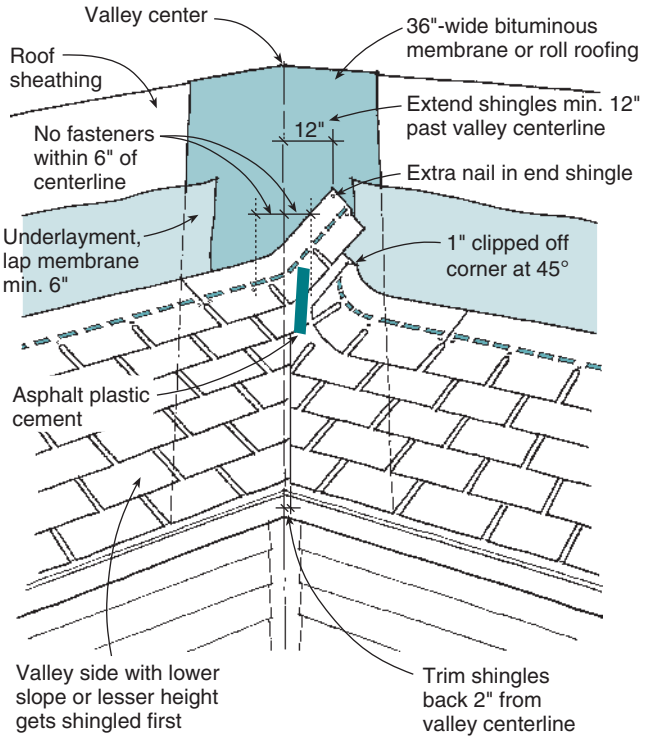
Closed valleys go up quickly and provide a clean appearance with either standard or laminated shingles. If sealed well, they provide adequate protection.

FIGURE 2-13 Woven Valleys.



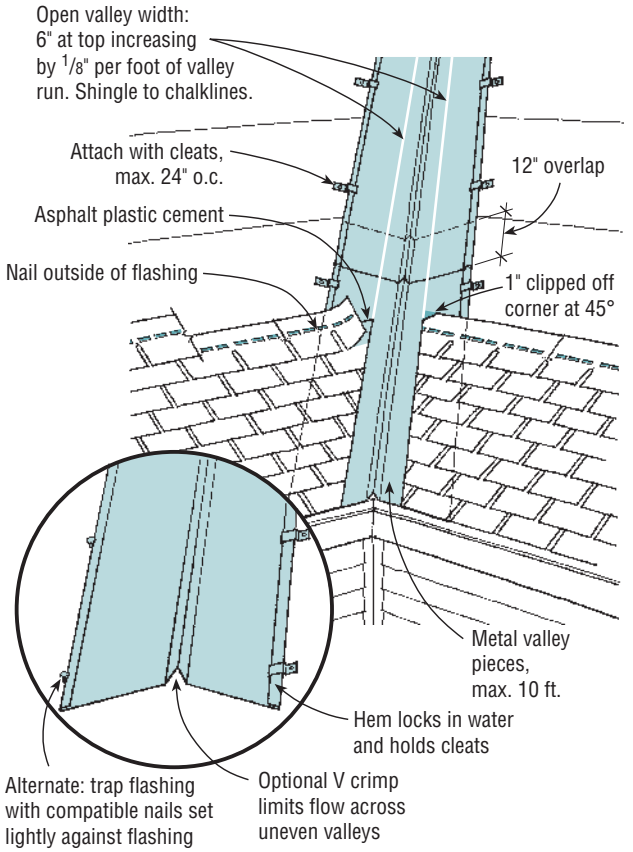
Woven valleys do not rely on roofing cement for a water seal and are very weather-resistant. However, thick laminated shingles may not conform well to a crisp valley line.

FIGURE 2-14 Closed-Cut Valleys.



Closed valleys are popular since they go up fast and allow one roof plane to be shingled at a time. However, they only provide single coverage at the valley center and rely on a good sealant job for weatherproofing.

FIGURE 2-15 Open Valleys.



Open valleys should be wider at the bottom to handle the increased water flow along the valley. To avoid wrinkling in metal valleys, limit sections to 10 feet in length, and fasten with cleats that allow movement. A V crimp in the valley center keeps water from flowing across the valley where the two roof slopes are uneven in size or slope.

Open Valleys. With a heavy-gauge, noncorrosive metal lining, open valleys are the most durable valley and the most costly (see "Flashing Materials," page 6). An economical version uses two layers of roll roofing for the lining, which should last as long as an asphalt roof. The bottom layer of roll roofing goes on with the gravel facing downward; the top layer with the gravel facing upward. Nail along the edges every 12 to 18 inches, keeping the material tight against the roof sheathing.

The valley lining, whether asphalt or metal, should have 6 inches open at the top (3 inches on either side of the valley centerline) and increase by $\frac{1}{8}$ inch for each foot of valley length to accommodate the greater flow further down the valley. So a 16-foot valley would have 6 inches open at the top and 8 inches at the bottom (see Figure 2-15).

Metal valley linings should be 2 to 3 feet wide and no more than 8 or 10 feet in length to prevent wrinkling from lengthwise expansion. Overlap valley sections by 12 inches, and seal the lap with a flexible sealant, such as polyurethane or butyl, on roofs shallower than 5:12. Where two valleys meet, for example above a gable dormer, a soldered joint is likely to break from the movement. A lead cap overlaid 6 inches onto each valley is an effective way to seal the top.

Where the roof slopes are uneven or one roof is larger than the other, a 1- to $1\frac{1}{2}$-inch-high V crimp in the middle of the metal valley will prevent the uneven flow from running up one side of the valley. The crimp also stiffens the valley. A hem is also desirable, both to stop any overflow water and to provide a place to attach nailing clips, which hold the flashing securely while allowing movement. Nails wedged against the edge of the flashing and driven lightly against the flashing may also be used. Clips and nails should be the same metal as the valley or a compatible metal that will not cause galvanic corrosion (see "Galvanic Corrosion," page 83).

Shingles should overlap the valley lining by at least 6 inches. With a roll roofing valley, keep the nails at least 6 inches from the valley centerline. With a metal liner, nail $\frac{1}{2}$ inch outside the liner. Seal each shingle to the liner and overlapping shingle with a 3-inch-wide bead of plastic roofing cement.

Reroofing

Reroofing saves the cost, trouble, and risks (water damage while the roof is exposed) associated with a tear-off. If the roof is structurally sound, most building codes allow for two layers of asphalt shingles and some allow for a third on roofs with a 5:12 or steeper pitch. If the original shingles are not badly curled and the sheathing is sound (check for bouncy areas), then a reroof is a good alternative.

Shingle Type. The heavier the shingle on the new layer, the less likely it is that irregularities in the surface below will telegraph through. Laminated or other heavy-textured shingles work well, as they do not need to be carefully fitted to the existing shingles, and the irregular texture will conceal any small bumps or dips from the original roof.

Prep Work. Clip any curled shingle corners and remove any curled tabs, replacing them with new shingle scraps as shims. Install new drip edge on rakes and eaves. Specialty drip edge profiles designed for retrofitting wrap around the exposed roof edge, leaving a neat protected edge. If the roof had no eaves flashing and one is needed, use a retrofit membrane such as AC Evenseal (NEI, Brentwood, New Hampshire).

Starter Course. If laying three-tab shingles over three-tab shingles, it is important to nest the new shingles against the old to create a flat surface. This process starts with a 5-inch starter strip fit along the eaves and set against the second course of existing shingles (see Figure 2-16).

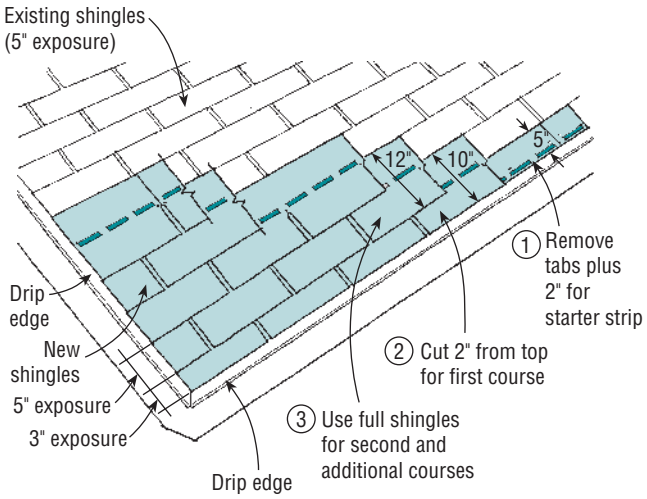
Next install a course of shingles cut down to 10 inches wide, so they fit against the bottom edge of the existing third course (this creates a new 3-inch first course). After that, shingling should proceed normally, fitting each course up against the bottom of an existing course.

Fastening. Use galvanized roofing nails long enough to fully penetrate the sheathing, typically $1\frac{1}{2}$ inches for a second roof and $1\frac{3}{4}$ inches for a third. Nesting each new row below an existing one keeps the new nails 2 inches below the existing, which will help minimize any splitting of the sheathing.

Flashings. Depending on their condition and accessibility, some flashings can be reused. New shingles may be able to tuck under existing step flashing, chimney flashings, and front-wall flashings. If they are deteriorated, they must be replaced along with vent boots.

Valleys. Any type of valley flashing will work and simply lays over the existing flashing (except in a tear-off, where all flashings should be replaced). Unless a metal valley flashing is used, the first step is to line the existing valley with a new underlayment consisting of either 90-pound roll roofing or a more durable modified bitumen membrane. Then install either a closed or woven valley as described above.

FIGURE 2-16 Reroofing with Asphalt Shingles.



When laying new three-tap shingles over existing ones, it is important to nest the new shingles against the old to create a flat surface. Begin with a 5-inch starter course, followed by a 10-inch first course—each set against the bottom edge of the existing shingles. Proceed with full-size shingles, each nested under the existing course above.

CLAY, CONCRETE, AND COMPOSITE TILE

Tile roofing accounts for about 8% of new residential roofs in the United States, primarily in the Southeast, Southwest, and on the West Coast. In addition to its durability and natural beauty, tile is impervious to fire, insects, and rot, and it can be formulated to withstand freeze-thaw cycles. When colored white, tile roofing has been shown to reduce cooling costs by up to 22% for barrel or flat tile (compared to black asphalt shingles in tests conducted by the Florida Solar Energy Center). Since most tile roofs carry a 50-year warranty and a Class A fire rating, they are a popular choice for high-end projects, particularly in warm climates.

Nearly all roofing tiles in the United States were traditional clay until the 1960s when concrete tile first gained acceptance. Concrete tile now dominates most tile roofing markets, primarily due to its lower cost (see Table 2-4). Where weight is a concern, options include lightweight concrete tiles or fiber-cement shingles, which typically weigh even less. Fiber-cement roofing typically simulates

TABLE 2-4 Roof Tile Materials

	Material Costs (typical)	Advantages	Disadvantages	Recommendations
Clay Tile	$400–600 per square	Traditional material. Colorfast, lasts 50+ years, and is virtually maintenance-free. Impervious to fire, insects, and decay. Resists high winds. Can be formulated to resist freeze-thaw cycles. Class A fire rating.	More expensive than concrete tiles. Typically weighs 800–1,200 lb per square. Roof structure may need extra support. High shipping costs unless manufacturer nearby. Very susceptible to breakage from foot traffic.	Confirm structural support is adequate. In cold climates, use vitrified tile with low water absorption. Choose larger tiles for best prices.
Concrete tile	$100–$300 per square	Less expensive than clay tile. Lasts 40–50 years in Southwest; 20–30 years in Southeast. Impervious to fire, insects, and decay. Resists high winds. Can be formulated to resist freeze-thaw cycles. Can simulate shakes or slates. Lightweight version available (550–800 lb per square). Class A fire rating.	Installed costs about three times asphalt shingles. Typically weighs 900–1,200 lb per square. Roof structure may need extra support. High shipping costs unless manufacturer nearby. Colors tend to fade. Lightweight type are very susceptible to breakage from foot traffic.	Confirm structural support is adequate. In cold climates, check warranty for freeze-thaw resistance. Use through-color tiles in cold climates.

slate or wood shakes and provides a Class A fire rating at a cost comparable to wood shakes.

Tile Shapes

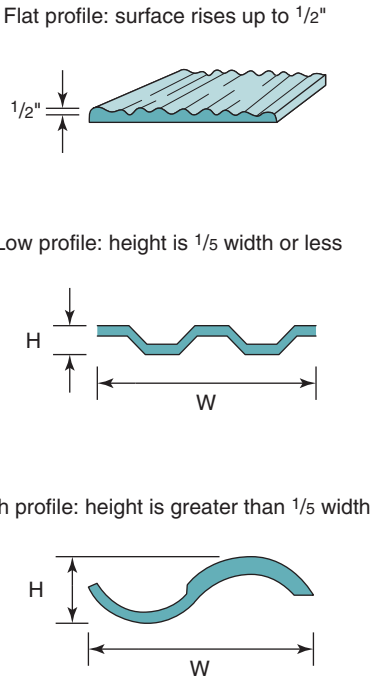
All tiles can be classified as high-profile, low-profile, or flat (see Figure 2-17). Common high-profile tiles include two-piece pan-and-cover Mission tile and one-piece Spanish S-tiles. Low profile styles include a wide variety, many with a double-S shape that creates multiple water courses. Many flat tiles are shaped and colored to simulate slate or wood shakes. In general, patterns using smaller tiles cost more per square for both materials and labor than patterns using larger tiles.

Clay Tile

To make tiles, moist clay is extruded through a die or cast in a mold and then fired in a kiln until the clay "vitrifies," fusing the particles together. Complete vitrification will create a strong tile with very low water absorption, which protects tile from freeze-thaw damage in cold climates or damage from salt air in coastal areas. Where regular freeze-thaw cycling is expected, roof tiles should comply with ASTM C1167 Grade 1, which allows minimal water absorption. Grade II tile provides moderate resistance to frost action, and Grade III tile is porous and should not be used in freeze-thaw areas.

When buying clay tile, look for at least a 50-year warranty on both durability and fading. Costs vary widely, depending on quality, style, and the shipping distance required. In general, patterns using smaller tiles will cost more for both materials and labor.

FIGURE 2-17 Tile Shapes.



The industry generally classifies tiles as high-, low-, or flat-profile depending on the ratio of width to height. Flat tiles often mimic slates or wood shakes.

Color. Clay tiles come in a wide range of colors. Color-through tile takes the natural color of the clay, ranging from light tan to pink and red. Other colors can be added to the tile surface as a clay slurry before firing, but slurry

coatings are only suitable for warm climates, as they cannot withstand freeze-thaw cycles. Clay tile can also be colored with ceramic glazes to create a durable, glass-like surface in just about any color. In general, clay tiles do not fade in the sun.

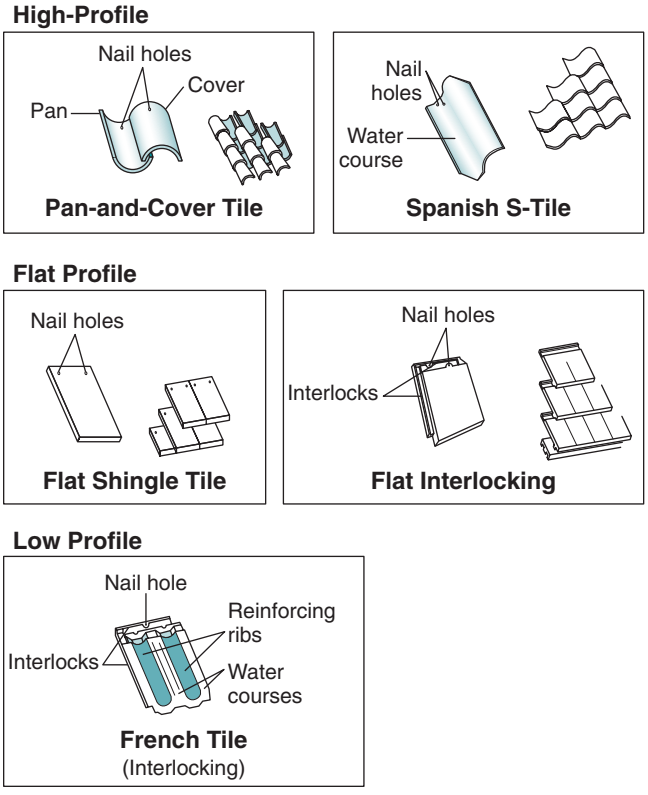
Blended Patterns. Some jobs require the installer to mix two or three different colors in a random pattern. The best way to achieve this is to premix bundles on the ground with the correct proportion of each color, then send them up to the roof for installation. Periodically inspect the roof from the ground for hot spots or streaking.

Clay Tile Styles. Clay roof tiles are available in traditional two-piece styles, one-piece profiles, and flat profiles (Figure 2-18).

Designs are either overlapping or interlocking, with protruding lips that lock the tiles together and form a weather seal. Many flat clay tiles interlock. Interlocking designs are recommended for regions with heavy rain or snow. Manufacturers provide special trim tiles to seal the voids formed at ridges, rakes, and hips.

- ***Pan and cover.*** This traditional two-piece style, also called barrel- or Mission-style, is installed in pairs with the cover tile overlapping the pan tile. It provides an attractive high-profile look but is labor-intensive and expensive to install. Variations include Roman and Greek profiles, which have flat, rather than curved, pan tiles. Tiles typically range from 8 to 12 inches in width and from 16 to 19 inches long.
- ***Spanish S-tile.*** These one-piece tiles provide the high-profile look of traditional pan-and-cover tile but with simpler installation. The most popular S-tiles measure about 13 inches wide by $16\frac{1}{2}$ inches long. Other common sizes are $8\frac{3}{4}$x11 and 9x14 inches.
- ***Flat shingle tile.*** These are laid in a double thickness, like slate. Widths range from 6 to 8 inches, lengths from 12 to 18 inches.
- ***Interlocking tile.*** These are either flat or low profile and are laid in a single thickness with a 3-inch overlap. They have interlocks on the sides with channels or ribs, and butts may also lock into the tops of the underlying shingles. Contours and ribs add strength to the tiles. Widths typically range from 9 to 13 inches and lengths from 11 to 16 inches.

FIGURE 2-18 Typical Clay-Tile Profiles.



Concrete Tile

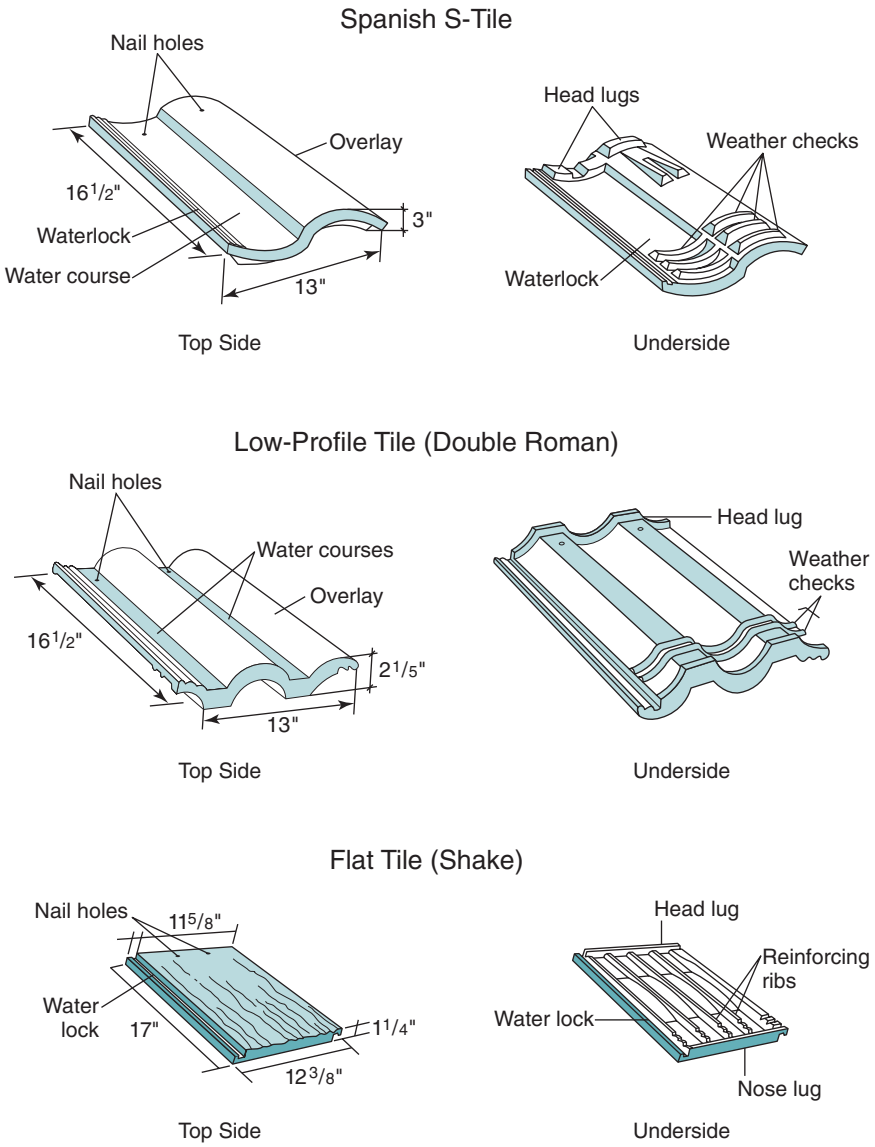
Concrete tiles were introduced to the United States in the early 1900s, but they did not catch on until the 1960s. They now account for more than half the tiles sold in the United States. In Europe, over 90% of new houses have concrete tile roofs. Concrete tiles cost as little as half as much as clay and offer both traditional and flat styles that simulate slate roofing and wood shakes.

High-quality concrete tiles should last up to 50 years in arid climates and up to 30 years in hot, humid climates. While some early products faced problems with freeze-thaw cycling, most newer formulations are made to withstand winter weather. In cold climates, make sure the product is warranted for freeze-thaw durability.

Special lightweight concrete tiles weighing under 600 lb per square are gaining in popularity. Although they cost more than standard concrete tiles and are more prone to breakage, they are easier to handle and suitable for applications where the roof structure cannot support the weight of standard tiles. Lightweight tiles cannot support foot traffic without adding walking pads to distribute weight or filling the space under the tiles with polyurethane foam. They are also not recommended for high-snow regions.

Color. Concrete tiles can be surface colored with a slurry of iron-oxide pigments applied to the surface or have the color added to the concrete mix for a more durable, and expensive, through-color. Through-color choices are more limited, and the colors are more subdued. Either type of tile is also sealed with a clear acrylic spray to help with curing and efflorescence. While the color-through tile will hold its color better than the slurry type, particularly under freeze-thaw cycling, all concrete tile coloring can be expected to fade and soften over time. Surface textures can also be added to flat concrete tiles to simulate wood shakes or shingles.

FIGURE 2-19 **Typical Concrete-Tile Profiles.**



Concrete Tile Styles. Concrete tiles are available in shapes that simulate traditional clay styles as well as flat profiles that simulate wood or slate (Figure 2-19).

Most are designed with an interlocking channel on the left edge that is lapped by the next tile. Underneath each tile is a head lug at the top and series of ridges at the bottom. The head lug fits over the top of a horizontal 1x batten, if these are used. Otherwise it sits directly on the roof deck. The ridges at the bottom (called nose lugs or weather checks) match the profile of the tile below, creating a barrier against windblown rain and snow. Manufacturers provide special trim tiles to fill in the large voids that profile tiles leave at ridges, rakes, and hips. While many sizes are available, the most common concrete tiles measure 12 to 13 inches wide by $16\frac{1}{2}$ or 17 inches long.

- ***Spanish S-tile.*** These provide the look of traditional two-piece Mission tiles but with simpler installation. Nearly all have interlocking side channels.
- ***Interlocking low-profile tile.*** These have a less pronounced double-S shape and interlocking joints and side channels. Heads and butts may also interlock or simply overlap.
- ***Interlocking flat tile.*** These simulate clay roof tiles, wood shakes, and slate. Ridges, hips, and rakes are easier to seal than with curved tiles.

Fiber-Cement Tile

Early generations of fiber-cement roofing products using asbestos fibers were used successfully in the United States for over 50 years. Newer formulations introduced in the 1980s and 1990s used wood fibers instead of asbestos and were marketed widely in the western United States as a fire-resistant alternative to wood shakes. Made from a mixture of Portland cement and wood fibers, they weighed 400 to 600 pounds per square and were designed to imitate

slates or wood shakes. They promised excellent resistance to insects, fungus, fire, and weathering and carried warranties ranging from 25 to 50 years.

Performance Problems. Within five years of installation, however, many of the fiber-cement shakes began to deteriorate. Problems included surface crazing, cracking, delamination, and softening and resulted in a number of lawsuits against key manufacturers and several companies abandoning the product. The problems were generally linked to high water absorption, which created an alkaline solution that was corrosive to the wood fibers.

Some products have fared better than others. In general, products that are steam-cured in an autoclave will have lower water absorption, but they tend to be more brittle. Many products are represented as complying with ASTM C1225, a standard for nonasbestos fiber-cement roofing shingles; but in its current form, this standard does not guarantee long-term durability. Only a product with a proven long-term track record in a specific climate zone should be considered.

Roof Slope

Most manufacturers recommend minimum slope requirements for their tiles as well as special underlayment and fastening techniques for low-slope installations. Typical minimums are shown in Table 2-5. Some manufacturers allow specific tile types to be installed on roofs as shallow as $2\frac{1}{2}$:12 if a full waterproofing layer, such as a built-up roof or single-ply membrane, is installed. Reduced exposure and special fastening techniques may also be required for low slopes. On slopes less than $3\frac{1}{2}$:12, roofing tile is considered decorative only. The underlying roof provides all the necessary waterproofing.

In general, there is no maximum slope for tile roofs. However, on extremely steep roofs above 19:12 or on vertical applications, wind currents may cause tiles to rattle. To avoid this, use wind clips on each tile along with a construction grade silicone sealant or other approved sealant.

TABLE 2-5 Minimum Slope Recommendations (Typical)

	Type	Minimum Slope
Clay	Flat shingle tile	5:12*
	Interlocking flat tile	3:12
	Interlocking low-profile (French) tile	3:12
	Pan-and-cover tile	4:12–5:12*
	S-tile	4:12*
Concrete	Interlocking flat tile	4:12
	Interlocking low-profile tile	4:12
	Interlocking S-tile	4:12

*May be reduced to $2\frac{1}{2}$:12 or 3:12 by using full waterproofing underlayment as per manufacturer and code.

Roof Sheathing

While spaced sheathing is allowed under the codes, most installations today are done on solid wood sheathing with or without battens. The sheathing must be strong enough to support the required loads between rafters. Minimum requirements are nominal 1 inch for board sheathing or $\frac{15}{32}$ for plywood and other approved panel products.

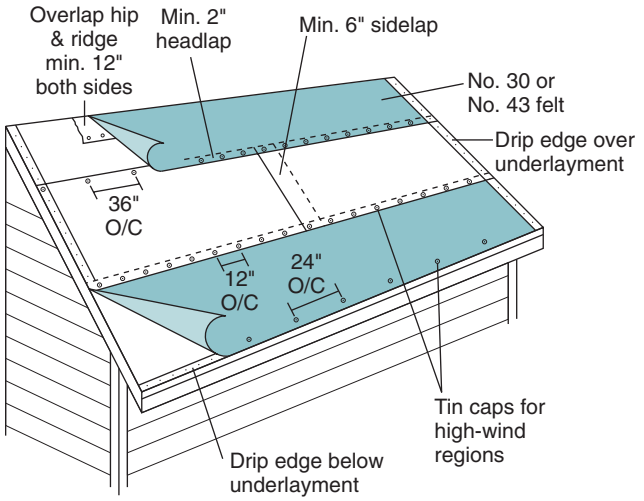
Underlayment

Because of the long service life of tile, a long-lasting underlayment should be used as well. Underlayments play a key role in tile roofing, since most tile roofs are not completely waterproof. At a minimum, use a Type II No. 30 or No. 43 felt, lapped 2 inches on horizontal joints and 6 inches at end laps. The underlayment should lap over hips and ridges 12 inches in each direction and turn up vertical surfaces a minimum of 4 inches (Figure 2-20).

At tricky areas, such as around roof vents, chimneys, and skylights, self-adhesive bituminous membrane can help achieve a watertight seal. In windy areas, use tin caps or round cap nails to hold the underlayment securely. The fastening schedule for the underlayment will depend on local wind conditions.

For harsher conditions or shallower slopes, use mineral-surface roll roofing, self-adhering bituminous membrane, or other durable waterproofing systems. For slopes below $3\frac{1}{2}$:12, the underlayment must provide complete weather protection, and the tiles are considered merely decorative. Underlayment recommendations for different types of tiles and climate conditions are shown in Tables 2-6 to 2-8.

FIGURE 2-20 Underlayment for Roofing Tile.



Use minimum No. 30-felt underlayment for moderate climates and No. 43-felt or mineral-surface roll roofing for high-wind and coastal regions. Tin caps or round cap nails are recommended in windy regions.

TABLE 2-6 Underlayments for Mechanically Fastened Tile Roofing Without Head Lugs

	Roof Slopes from $2\frac{1}{2}$:12, to Less Than 3:12*	Roof Slopes from 3:12 to Less Than 4:12	Roof Slopes 4:12 and Greater
Moderate climates	• Three-ply built-up roofing membrane. • An approved single-ply membrane.	• Two layers of type II No. 30 felt, lapped 19 inches on horizontal (36-inch roll), and 6 inches on vertical. • One layer Type 90 granular surface roll roofing. • An approved single-ply membrane.	Type II No. 30 felt, lapped 2 inches on horizontal, 6 inches on vertical.
Subject to windblown snow, ice dams, or high winds	• Three-ply built-up roofing membrane. • An approved single-ply membrane.	Two layers of type II No. 30 felt, lapped 19 inches on horizontal (36-inch roll), and 6 inches on vertical. Also eaves flashing of self-adhered membrane, or two layers No. 30 felt fully cemented.	Type II No. 30 felt, lapped 2 inches on horizontal, 6 inches on vertical. Also eaves flashing of self-adhered membrane, or two layers No. 30 felt fully cemented.

*Tile considered decorative only at this slope.
SOURCE: Based on recommendations of the Tile Roofing Institute and Western States Roofing Contractors Association.
All recommendations subject to local code.

TABLE 2-7 Underlayments for Tile Roofing with Projecting Head Lugs

	Roof Slopes Less Than 4:12	Roof Slopes 4:12 and Greater
Moderate climates	Consult manufacturer and local codes.	Type II No. 30 felt, lapped 2 inches on horizontal, 6 inches on vertical.
Subject to windblown snow, ice dams, or high winds	Consult manufacturer and local codes.	Type II No. 30 felt, lapped 2 inches on horizontal, 6 inches on vertical. Also eaves flashing of self-adhered membrane or two layers No. 30 felt fully cemented.

SOURCE: Based on recommendations of the Tile Roofing Institute and Western States Roofing Contractors Association. All recommendations subject to local code.

Prep Work

Battens. Tiles with projecting head lugs can be installed either directly on the deck or with the lugs fitting over pressure-treated wooden battens nailed horizontally across the roof. Battens are typically nominal 1x2 or 1x4 lumber, but they may be larger to accommodate snow loads or unsupported spans over counterbattens. Battens should be made from pressure-treated lumber except in very dry climates. They are nailed at minimum 24 inches on-center with spaces for drainage every 48 inches. Lay out battens to provide equal courses with a minimum 3-inch head-lap, unless the tile profile is designed for a specific head-lap. Fasten with 8d galvanized nails or corrosion-resistant $1\frac{1}{2}$-inch 16-gauge staples with $\frac{7}{16}$-inch crowns.

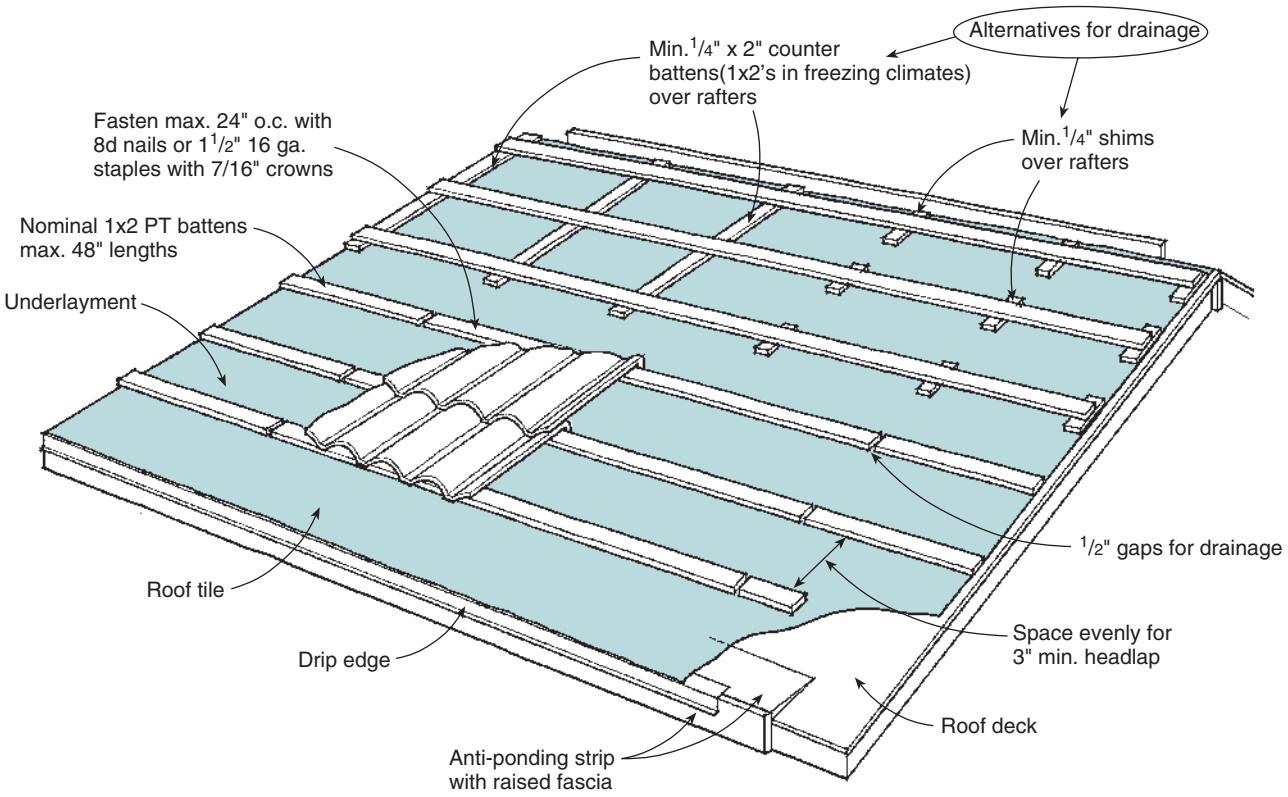
Battens are recommended on roof slopes greater than 7:12 to provide solid anchoring and on slopes below 3:12 to minimize penetration of the underlayment. On low slopes and in areas subject to ice damming, counterbattens

TABLE 2-8 Underlayments for Tiles in High Wind and Coastal Conditions

	Roof Slope 2:12 and Greater	Roof Slope 4:12 and Greater
Mechanically fastened tile (battens or direct deck)**	• Hot-mop or cold process: No. 30 or No. 43 felt base ply plus 90 lb roll roofing or modified cap sheet.* • Self-adhered underlayment applied to wood deck. • No. 30 felt plus self-adhered underlayment.	• Single-ply No. 43 or 90 lb organic or modified cap sheet.* • Two-ply No. 30 or No. 43 underlayment (battens only)
Mortar set tile (direct deck)	Hot-mop or cold process: No. 30 or No. 43 base ply sheet plus 90 lb roll roofing or modified cap sheet*	
Adhesive set tile (battens or direct deck)	• Single-ply 90 lb roll roofing or modified cap sheet. • Hot mop or cold process: No. 30 or No. 43 felt base ply plus 90 lb roll roofing or modified cap sheet. • Self-adhered underlayment to wood deck. • No. 30 felt plus self-adhered underlayment.	

*Plastic cement or approved sealant at fasteners penetrating underlayments.
** All applications below 3:12 must have both vertical and horizontal battens. Above 7:12, battens required for tiles with head lugs.
SOURCE: Based on recommendations of the Florida Roofing, Sheet Metal, and Air Conditioning Contractors, Inc. and the Tile Roofing Institute.
All recommendations subject to local code.

FIGURE 2-21 **Tile Installation Over Battens.**



Horizontal battens are recommended for tiles with projecting head lugs on roof slopes greater than 7:12. Battens are also used on low slopes to minimize penetration of the underlayment. Vertical counter-battens are recommended to promote drainage on low slopes and in regions with high snowfall.

nailed vertically up the roof slope are also recommended to promote drainage. Counterbattens should be minimum $\frac{1}{4}$x2 inches thick in moderate climates, $\frac{3}{4}$ inch thick in areas subject to ice damming. When battens are nailed directly to the deck, allow a $\frac{1}{2}$-inch gap every 4 feet or set the battens on minimum $\frac{1}{4}$-inch shims placed at each nail (see Figure 2-21).

Layout and Stacking. Lay out the courses so that tile exposures are equal with a head-lap of at least 3 inches (unless the tile specifies a different lap). Snap lines on the underlayment along the top of each course or along each batten. One or more vertical lines can also be helpful in keeping the tiles aligned. Accurate layout is critical with most tile patterns.

Next, carry tiles up to the roof and distribute the weight equally across the roof, as tiles weigh as much as 10 pounds each. Depending on the tile, stacks of about 6 to 10 tiles is workable. If mixing different colored tiles, arrange bundles with the correct proportions on the ground before stacking them on the roof.

Fastening Tile

The preferred method of attachment depends on the type of tile, climate conditions, and slope of the roof.

Loose Laid. For standard concrete tiles with lugs set on battens, building codes still allow tiles to be laid loose at slopes less than 5:12 (except for one nail per tile within 36 inches of hips, ridges, eaves, or rakes). Loose-laid tiles are not allowed, however, in snow regions, areas subject to high winds, or with tiles weighing less than 9 pounds per square foot installed.

Nail on. Nails are the least expensive and most common method for attaching concrete and clay tiles. Tiles can be nailed either directly into the roof sheathing or tiles with lugs can be nailed to battens. Corrosion-resistant nails must be minimum 11 gauge, with $\frac{5}{16}$-inch heads, and long enough to penetrate the sheathing by $\frac{3}{4}$ inch—typically 8d nails. Ring-shank nails or hot-dipped galvanized nails hold better than smooth-shank nails in areas subject to heavy winds. Whether driven by hand or pneumatic nailers, nails should be driven so heads lightly touch the tile but not so tight as to risk cracking tiles. Because of the longevity of a tile roof, some contractors use copper or stainless-steel roofing nails. No. 8 or 9 stainless-steel or brass screws also work well and are sometimes used in high-wind regions.

Most tiles have two prepunched nail holes. On curved tiles, use the hole closest to the deck surface unless a nail there would penetrate a critical flashing. The other hole is

TABLE 2-9 Minimum Nailing for Concrete and Clay Tile in Moderate Climates[1]

Roof Slope	Spaced or Solid Sheathing With Battens	Solid Sheathing Without Battens	Spaced Sheathing Without Battens	Perimeter Tile All Sheathing Types[2]
Less than 5:12	None required[3]	One per tile	As per manufacturer	One per tile
5:12 to less than 12:12	One per tile every other row	One per tile	One per tile every other row	One per tile
12:12 to 24:12[4]	One per tile	One per tile	One per tile	One per tile

[1]For roofs 40 ft high or less in areas without significant snowfall or repeated winds of over 80 mph. In snow regions, min. two nails per tile.
[2]First three tile courses, but not less than 36 in. wide, at any ridge, hip, eave, or rake. Also any roof overhang.
[3]Tiles less than 9 psf installed require one nail.
[4]On roofs over 24:12, the nose end of all tiles should also be securely fastened with wire clips or roofing cement.

also used for cut tiles or applications requiring two nails. For example, all flat, noninterlocking tiles require two nails. And in snow regions, codes require two nails per tile for all types and slopes. Otherwise follow the guidelines in Table 2-9, or the manufacturer's guidelines if they are more stringent.

High-Wind and Seismic Installations

In areas prone to high winds, such as Florida, setting the tiles in mortar was once considered the strongest system. However, newer anchoring systems using wires, special clips, and, in some cases, specialized adhesives have proven more reliable and have replaced mortar-set systems as the preferred approach. Wire and clip systems also perform better than rigid attachment systems in seismic zones, as the flexible systems tend to absorb the shockwaves of an earthquake and protect the tiles from cracking.

Codes vary in their requirements for high-wind and seismic areas but most permit one or more of the anchoring systems described below. Model specifications for high-wind installations are available in the *Concrete and Clay Roof Tile Installation Manual,* jointly published by the Florida Roofing, Sheet Metal and Air Conditioning Contractors Association and the Tile Roofing Institute. General guidelines for high-wind installations or roofs over 40 feet above grade include:

- Fasten the head of every tile.
- Fasten the nose of every tile with clips or other approved methods.
- Secure all rake tiles with two fasteners.
- Set the noses of all ridge, hip, and rake tiles in a bead of approved roofer's mastic.

Twisted Wires. This approach is used on roofs ranging from 2:12 to 24:12 in seismic zones and areas with moderate winds. Rather than nail the tiles to the roof, each tile is wired to a length of twisted 12-gauge wire (galvanized, copper, or stainless steel) running from eaves to ridge under each vertical course of tiles. The twisted wire has a loop to tie into every 6 inches and is attached every 10 feet with special anchors, making relatively few holes in the underlayment (see Figure 2-22).

Because wire systems allow some movement, seismic forces do not tend to break the tiles. Also, damaged tiles are easy to replace by snipping the tie wire and wiring in a new tile. Installation is labor-intensive, however, compared to nailing.

Hurricane Clips. A hurricane clip, also known as a storm clip or side clip, is a concealed L-shaped metal strap designed to lock down the water-channel side of a roofing tile near the nose (Figure 2-23).

Clips are well-suited to concrete tile and are used in conjunction with nails, screws, or other systems that secure the head of the tile. They are approved for use in some hurricane areas, but they should be combined with a nose clip or similar device for maximum protection. Used alone, they may deform or loosen after several storms.

Nose Clips. Also known as nose hooks, butt hooks, or wind locks, these simple metal clips hold down the bottom (nose) end of a roofing tile to prevent strong winds from lifting and breaking the tiles (Figure 2-24).

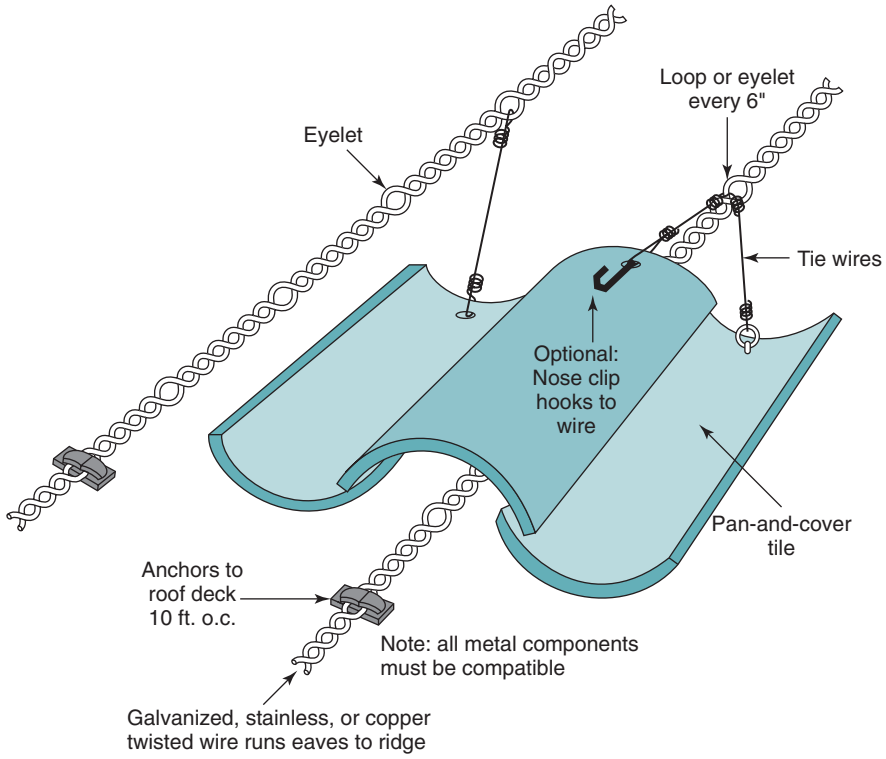
Nose clips are nailed in place through the underlying tile or attached to the tie wires in wire systems. They are compatible with all methods of tile attachment and are recommended for high-wind areas and slopes greater than 7:12. The main drawback to nose clips is that they are visible at the nose of each tile, which some homeowners find objectionable.

Tile Nails. This innovative fastener, used mostly with S-tile or two-piece Mission tile, functions as both a nail and a nose clip. Because the nail is driven about 6 inches above the tile, there is no risk of breakage and the nail hole can be easily sealed with mastic (Figure 2-25).

Tile nails are approved for all slopes and are especially useful in high-wind areas and on very steep pitches such as mansards. They are also useful for securing the first course of two-piece Mission tile. Examples include the Tyle Tye® tile nail from Newport Tool & Fastener Co. and the Hook Nail from Wire Works, Inc.

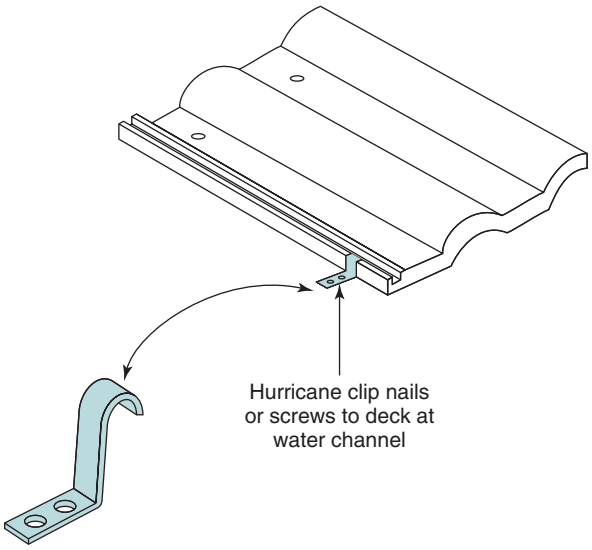
Tile Adhesives. Another way to prevent uplift in windy conditions and to keep tiles from rattling on steep slopes is

FIGURE 2-22 Twisted-Wire Systems.



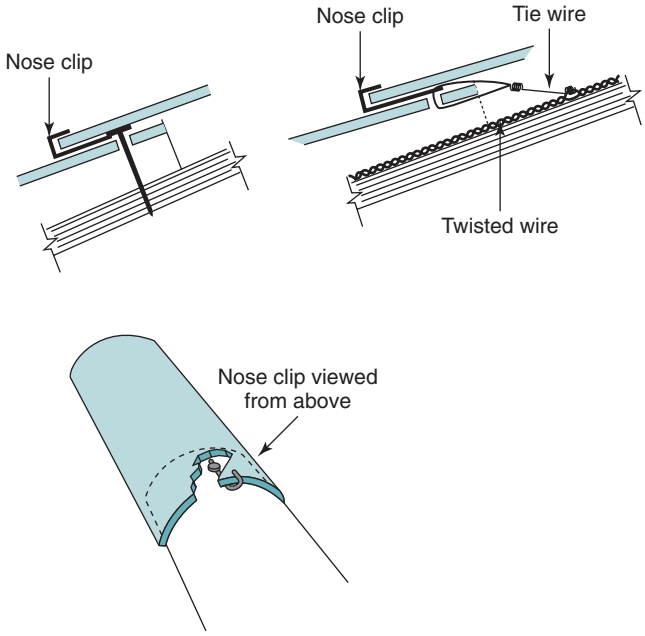
Popular in high-end construction and commercial jobs, twisted wire systems create a nonrigid attachment that performs well in seismic zones. Wires are secured from eaves to ridge with special anchors. High-wind performance can be further enhanced by adding nose hooks, hurricane clips, or adhesives. Avoid mixing components of different metals.

FIGURE 2-23 Hurricane Clips.



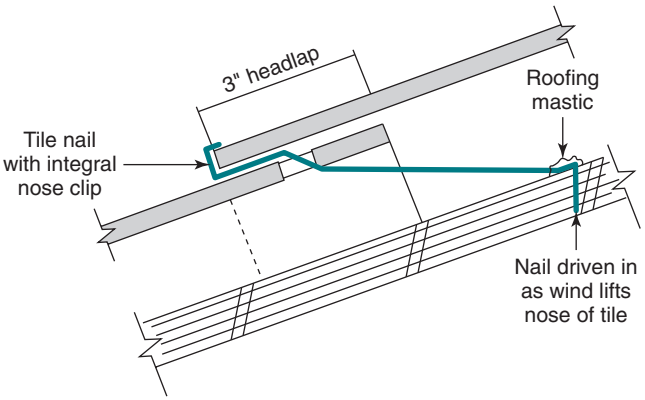
Hurricane clips clamp onto the side of one-piece roof tiles and help prevent tile rotation or movement in high winds. They install quickly and are concealed, but other devices, such as nose clips, may offer better protection. For best performance, secure with screws rather than nails.

FIGURE 2-24 Nose Clips.



Nose clips are recommended for steep slopes and high-wind regions to prevent tiles from lifting in the wind. They are nailed in place through the underlying tile (left) or attached to the tie wires in wire systems (right). Their main drawback is their visibility from the ground, particularly on low roofs.

FIGURE 2-25 Tile Nails.



This innovative fastener functions as both a nail and nose clip. Because it is driven about 6 inches above the tile, there is no risk of breakage. Also, uplift pressure on the nose of the tile tends to drive the nail deeper rather than pull it out. Tile nails are useful in high-wind areas and on very steep slopes such as mansards.

to set the butt edge of each tile in a dab of roofing cement. Over time, however, roofing cement may become brittle and fail. New proprietary tile adhesives promise to last longer and stay flexible over time. In hurricane-prone areas, some contractors are applying adhesive to every tile—in some cases combined with other fastening methods, such as twisted wires. While long-term performance has not been well-established, testing by manufacturers has demonstrated that adhesives can outperform mortar systems in hurricane-force winds.

Installation Details

A number of specialized flashings, tiles, and fittings simplify modern tile installations. Key details for interlocking flat and profile tiles are shown in Figures 2-26 and 2-27.

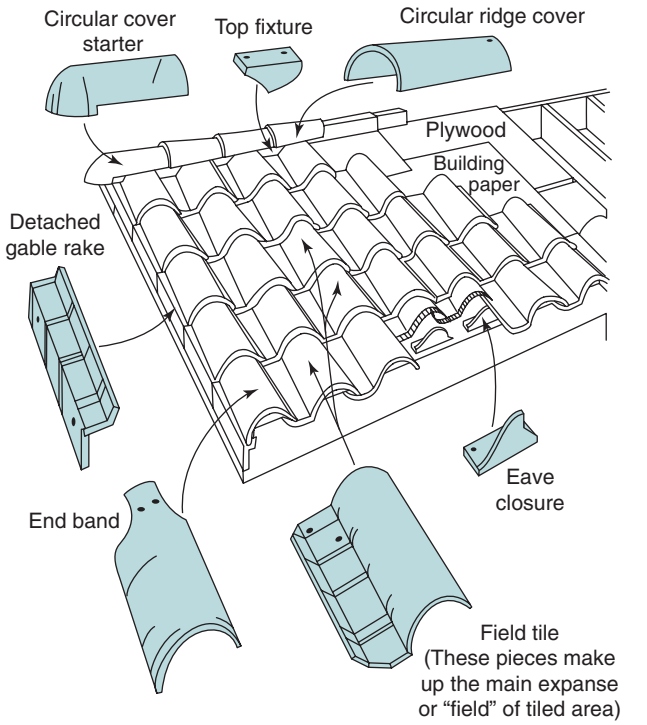
Eaves Closure. Both profile and flat tile need special treatment at the eaves to raise the bottom edge of the first tile to the correct height and to close off any openings to birds and insects. For profile tile, many contractors use a metal *birdstop,* a preformed L-shaped strip with the vertical leg cut to match the underside of the first tile and fit snugly between the weather checks (see Figure 2-28).

With some high-profile tiles, a special eaves-closure tile achieves the same effect as shown in Figure 2-26.

With flat tiles, the first course may be raised with a special starter tile, as shown in Figure 2-27, or by a metal eaves closure, raised fascia, or wood cant strip. With a cant strip or raised fascia, a beveled wood or foam *antiponding strip* is required to prevent ponding of water along the eaves (Figure 2-29).

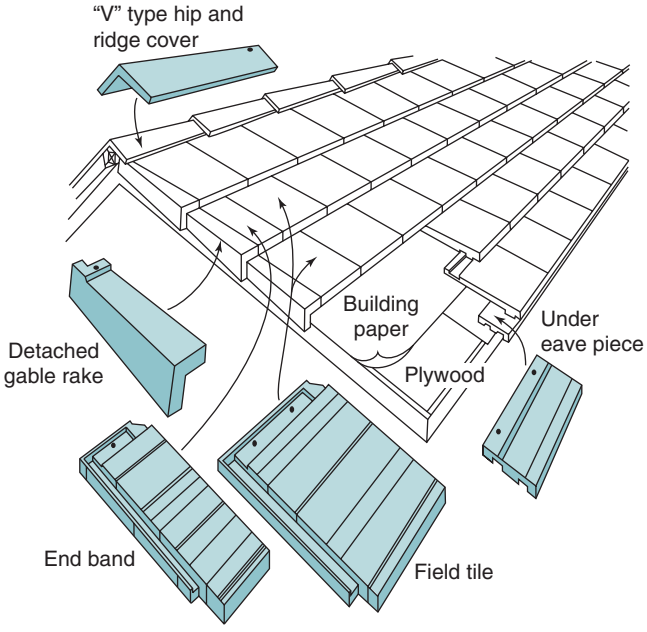
Ridges and Hips. Unless hip and ridge tiles are going to be set into a continuous bed of mortar, special nailers are required to install them. The hip and ridge boards

FIGURE 2-26 Spanish S-Tile—Typical Installation.



SOURCE: Adapted from *Architectural Graphic Standards, Residential Construction,* with permission of John Wiley & Sons, © 2003.

FIGURE 2-27 Flat Interlocking-Tile—Typical Installation.



SOURCE: Adapted from *Architectural Graphic Standards, Residential Construction,* with permission of John Wiley & Sons, © 2003.

are typically 2x3s to 2x6s set on edge to hold the trim tiles in an even plane. They are toenailed in place and individually wrapped with felt (Figure 2-30).

Hip and ridge tiles are later nailed on with a 2-inch head-lap, and the lower ends are sealed at the overlap with roofing cement or an approved tile adhesive. Finally, mortar, special trim tiles, or other weatherblocking is applied to fill in gaps between the ridge and hip tiles and the field tile.

Rakes. Rakes may be finished with detached gable-rake tiles (as shown in Figures 2-26 and 2-27) or with high-profile tiles, trimmed simply with half-round trim tiles as shown in Figure 2-31.

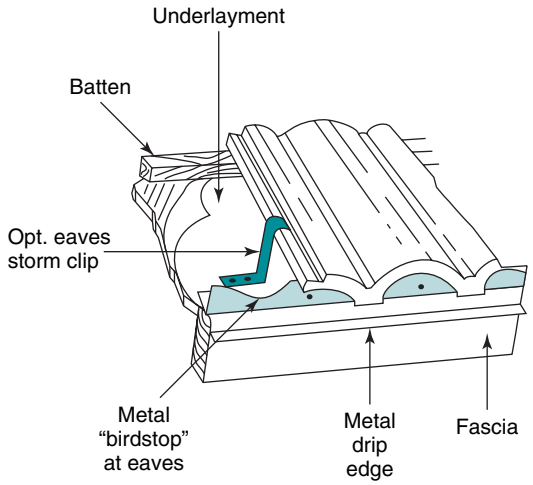
Flashings

Because of the longevity of a tile roof, high-quality flashing materials should be used. The International Residential Code calls for a minimum 26-gauge metal. Galvanized steel should have a minimum of 0.90 ounces of zinc per square foot (G90 sheet metal). More expensive options include prepainted galvanized steel or 16-ounce sheet copper.

At Openings and Walls. At walls, dormers, chimneys, and other vertical surfaces, extend the flashing up at least 6 inches and counterflash. Extend flashing under the tile a minimum of 6 inches or as specified by the tile manufacturer. With flat shingles, use step flashing with a minimum 6-inch vertical leg and 5-inch horizontal leg with a hemmed edge. Profile tile along a wall should receive channel flashing turned up at least one inch on the lower flange (Figure 2-32).

Pipe Flashing. Pipe flashings generally get both a primary flashing when the underlayment is installed and a secondary soft-metal underlayment that conforms to the tile. For profile tile, this can be $2\frac{1}{2}$-pound lead or dead-soft aluminum with an 18-inch-wide skirt (Figure 2-33).

FIGURE 2-28 Eaves Closures for Profile Tile.



With profile tile, many contractors use preformed metal birdstop, which is contoured to fit under the first course of tile and lock into the tiles' weather checks.

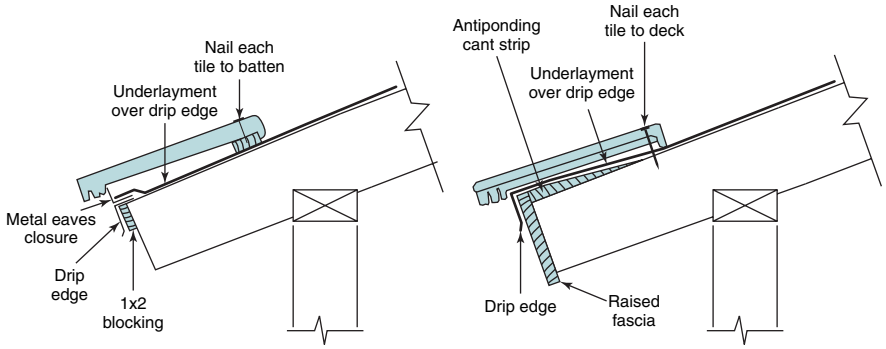
Valleys

According to the International Residential Code (IRC), valley flashing in tile roofs should extend at least 11 inches each way from the valley centerline, and the flashing should have a formed splash diverter at the center at least one inch high. The code requires a minimum underlayment at the valley of 36-inch-wide Type I No. 30 felt in addition to the underlayment for the general roof areas. In cold climates (average January temperature of 25°F or less), a self-adhering bituminous underlayment is recommended. Battens, if used, should stop short of the valley metal.

Tiles along the valley edge may be laid first and cut in place along a chalked line. Cut pieces are attached by roofing cement or a code-approved adhesive, or they may use wire ties, tile clips, or batten extenders.

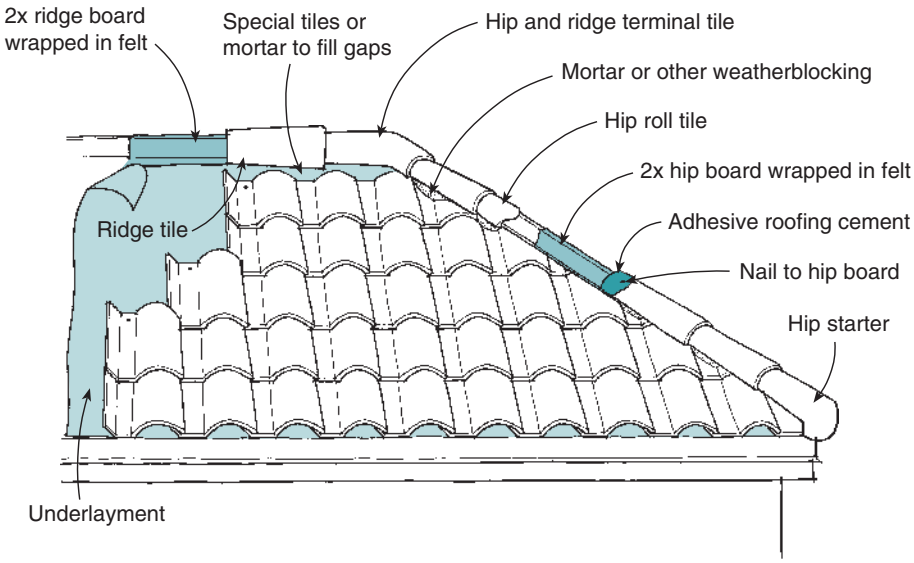
Open Valleys. Open valleys permit free drainage and are recommended in areas where leaves, pine needles, and other debris are likely to fall on the roof. They are also recommended in areas subject to snow and ice buildup.

FIGURE 2-29 Eaves Closures for Flat Tiles.



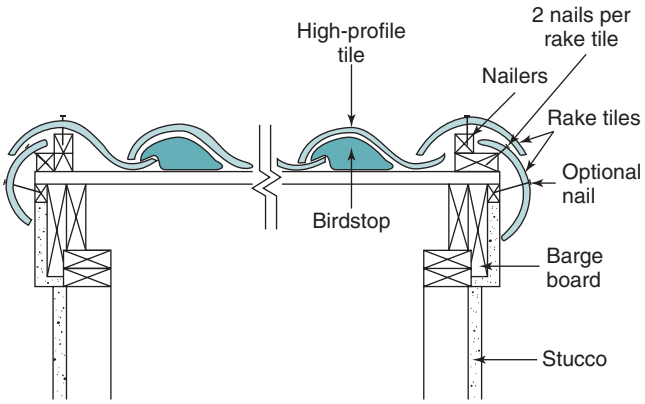
With flat tiles, use either a metal eaves closure (left) or a raised fascia with a beveled cant strip (right), to prevent ponding at the eaves. With a metal closure, no additional antiponding detail is required.

FIGURE 2-30 Tile Ridge and Hip Boards.



Unless hip and ridge tiles are set in continuous mortar, 2x nailers are required to hold them in place. Hip and ridge tiles are later nailed at their heads and cemented where they overlap. Gaps between the hip and ridge tiles and field tiles are sealed with mortar, mastic, or special trim tiles.

FIGURE 2-31 Tile Rake Trim.



With profile tiles, rakes may be trimmed with simple rolled tiles nailed into a nailer or barge board.

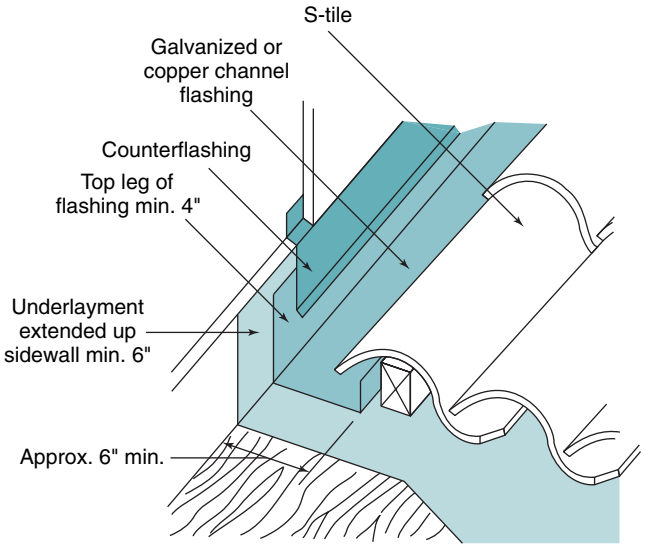
The valley flashing should have hemmed edges and be installed with cleats that allow individual sections to expand and contract (Figure 2-34).

Closed Valleys. In this type of valley, the flashing carries the runoff and the tile in the valley is only decorative. These are not recommended where debris from trees may fall on the roof or where the two roof planes joining at the valley have different pitches or length, causing uneven flows.

Foot Traffic

To prevent breakage, walk on tiles with extreme caution. Profile tile and lightweight tile are the most vulnerable,

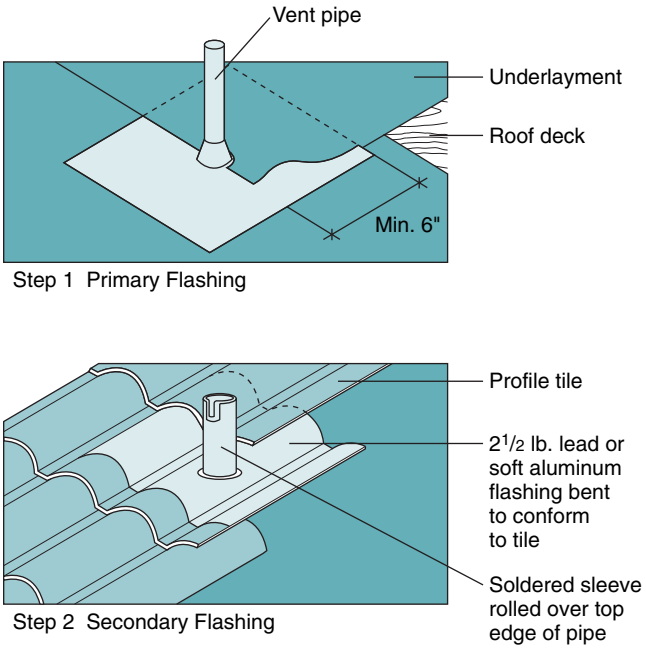
FIGURE 2-32 Channel Flashing for Tile Roofs.



Where profile tile runs along a chimney, wall, or other vertical surface, place a channel flashing of 26-gauge galvanized steel or 16-ounce copper.

and concrete tiles are more fragile when they are freshly manufactured or "green." If possible, place antennas and other roof-mounted equipment where it is easy to access without crossing many tiles. When it is necessary to walk on tiles, step only on the head-lap (lower 3 inches) of each tile. With Mission- or S-tiles, it is best to step across two tiles at once to distribute the weight. When significant rooftop work is required, place plywood over the tile to distribute the load.

FIGURE 2-33 Pipe Flashings for Tile Roofs.



Vent pipes in tile roofs generally get a primary flashing, when the underlayment is installed, and a secondary soft-metal flashing that conforms to the tile surface.

Replacing Broken Tiles. If a tile is cracked, gently lift the overlapping tile and wiggle loose the damaged tile. Remove the tile nail, screw, or clip with a slate ripper or hacksaw blade. Seal any nail holes with roofing cement and slip a new tile into place, securing the butt end with an L-hook or bent copper wire (as shown in Figure 2-35).

METAL ROOFING

Residential installations of metal roofing have more than doubled in the past several years, and they are now estimated to account for over 10% of residential roofs. Originally associated with agricultural and commercial buildings, new metal roofing products aimed at the residential market are designed with simplified installation systems and offer more choices in materials, finishes, and design. The installed cost of premium metal roofing is three to four times more than asphalt shingles, but metal roofing offers a variety of attractive benefits:

- ***Fire resistance:*** Many metal roofs carry a Class A fire rating.
- ***Low weight:*** Most metal roofing products range from 125 to 175 pounds per square. Some lightweight aluminum shingles weigh as little as 40 pounds per square.
- ***Wind resistance:*** Many systems have earned a Class 90 wind-uplift rating, UL's highest rating.
- ***Impact resistance:*** Metal roofing systems offer moderate to excellent resistance to impact from hail, some earning UL's Class 4 rating.
- ***Mold-resistant:*** Metal roofing resists the type of algae and mildew growth that attacks asphalt and wood roofs.
- ***Energy efficiency:*** In a test conducted by the Florida Solar Energy Center, white metal roofing showed the greatest reductions in cooling loads of all roofing types, with 23 to 30% savings (compared to a control home with dark asphalt shingles).
- ***Recycled content:*** Many metal roofing products use recycled material, ranging from 25% with some steel products to over 90% with some aluminum modular shingles.
- ***Longevity:*** Metal roofs typically carry a 30-to 50-year warranty.

Noise Transmission. One frequently cited disadvantage of metal roofing is that it generates a noticeable noise when struck by rain, hail, or even dropping acorns. If installed directly to purlins with no roof sheathing, the noise might be heard in the building interior. However, when installed over a solid substrate, with normal levels of insulation, the noise should not be noticeably different than with other roofing types.

Walkability. Panels laid flat on solid decking are generally walkable. However, if panels are installed on battens, workers should be careful to step directly over battens or to use planking that spans multiple battens. Modular shingle panels generally use fairly light-gauge material, but it is stiffened somewhat by the stamped textures. In general, modular steel panels are walkable, but aluminum ones should be reinforced by foam inserts in sections expected to see a lot of foot traffic.

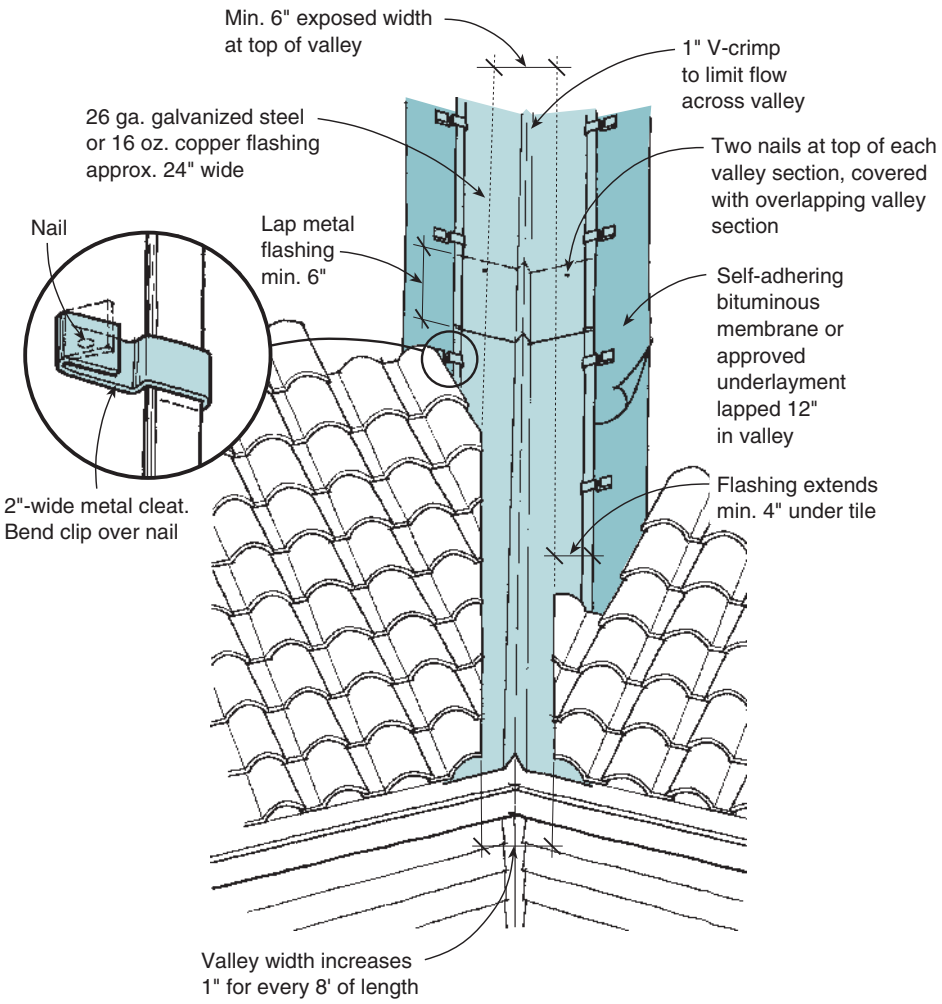
Minimum Slopes. Most metal roofing systems can be installed on slopes of 3:12 and greater and standing-seam systems from 2:12 and greater. Special standing-seam systems designed for slopes as shallow as $\frac{1}{2}$:12 require field crimping machinery and have sealant in all seams. The height of the ribs at seams and whether they are protected with a sealant affect how weathertight a roof will be under extreme weather.

There are three general types of residential metal roofing: Exposed-fastener panels, standing-seam, and modular panels.

Exposed-Fastener Panels

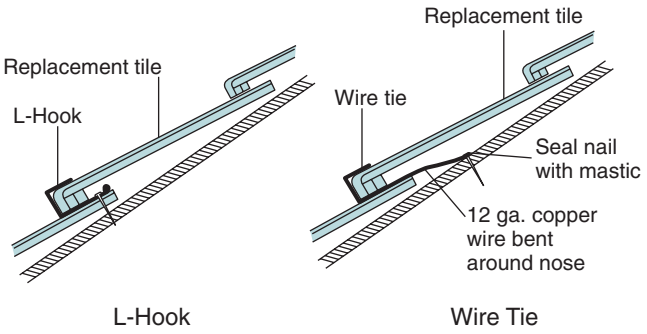
Steel and aluminum panel roofing with exposed fasteners has been a popular choice on agricultural buildings for decades. In recent years, these "ag panels" have grown increasingly popular for rural homes as well, since they can provide a long-lasting roof at a cost comparable to asphalt shingles. The products installed on homes, while essentially the same material as the agricultural panels, generally use better metal coatings, and installers pay more attention to sealing and watertight detailing.

FIGURE 2-34 Open Valleys in Tile Roofs.



Open valleys provide clear drainage and are recommended for areas subject to tree debris. Code requires fully waterproof underlayment and a flow area free of nail holes. Secure cut tile pieces with adhesive, clips, or wires.

FIGURE 2-35 Replacing Damaged Tiles.



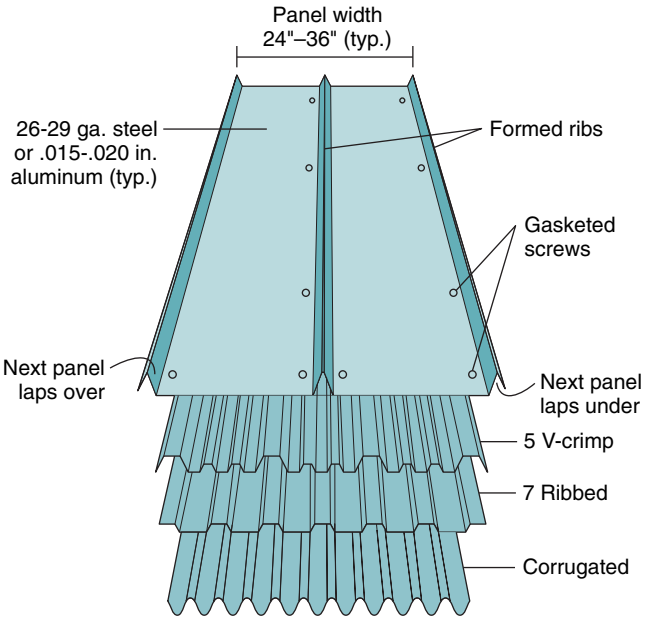
Gently lift the overlapping tile and twist loose the damaged tile. After filling any nail holes, slip in a new tile and secure with an L-hook (left) or bent copper wire (right).

While a carefully installed exposed-fastener roof should be free of leaks upon completion, small installation errors can result in leakage later as the metal panels undergo normal thermal movement that places stress on the fasteners. With so many exposed holes in the panels, periodic inspections are recommended. Also, the exposed fastener heads, in addition to lending a rural look to the building, tend to catch leaf debris and restrain sliding snow.

Materials. Exposed-fastener panels are typically 26 to 29 gauge, compared to the heavier 22 to 26 gauge used in standing-seam roofing. The ribs in exposed fastener roofing are also lower and closer together than in standing-seam roofing and may be squared, rounded, or v-shaped (see Figure 2-36). Most panels are 2 to 3 feet wide and formed with galvanized steel, Galvalume®, or aluminum.

- ***Panel length.*** While some stock sizes are available, ordering panels factory-cut to exact lengths simplifies installation and reduces corrosion at field cuts. Panels can be ordered in any shippable length, although excessive thermal movement can be a problem for steel panels longer than 40 feet or for aluminum panels

FIGURE 2-36 Exposed-Fastener Metal Panels.



Exposed panel roofing typically uses light-gauge stock and stiffens it with square, round, or V-shaped ribs. Some patterns imitate standing-seam roofing, but most have more frequent ribs to provide greater rigidity.

FIGURE 2-37 Gasketed Screws.



Exposed-fastener panels are vulnerable to leaks if screws are installed poorly or if excessive thermal movement loosens the screws or stretches the screw holes. To minimize leaks, place screws in the flat sections between ribs, and drive screws straight and snug but not overtight. Also, do not exceed the maximum panel length recommended by the manufacturer.

longer than 16 feet. In regions with very wide temperature swings, contractors should use shorter lengths (see "Thermal Expansion" in Table 2-10, page 83).

Installation. While traditionally installed over battens, most panels in residential installations are now installed over a solid plywood deck with minimum No. 30 felt underlayment. Metal roofing manufacturers recommend plywood over oriented-strand board (OSB) due to plywood's better screw-holding ability. Roofing felt should be installed with plastic cap nails rather than metal buttons, which can deteriorate the metal roofing by galvanic action (see "The Galvanic Scale," page 83).

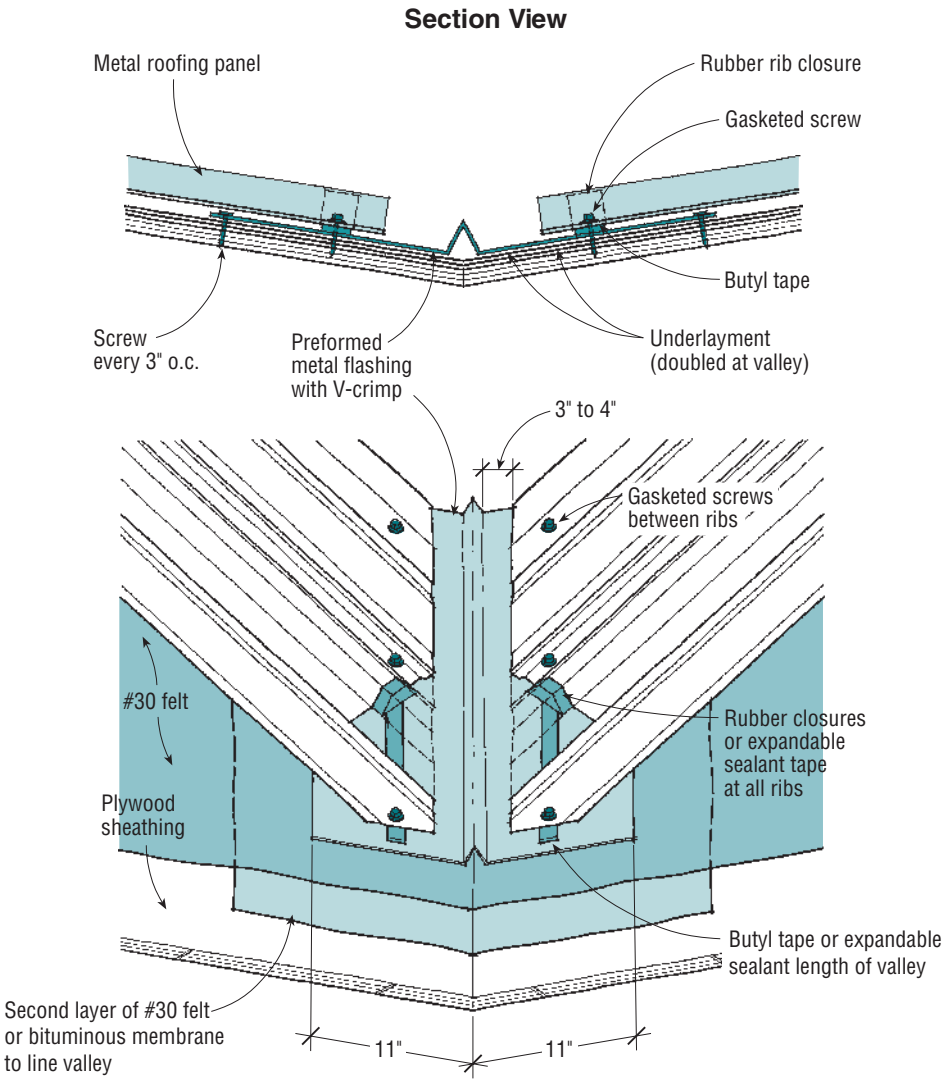
- ***Align to eaves.*** After installing drip edges and valley flashing, the first panel is fit along one rake, square to the bottom edge of the roof. If the roof is not square, the first panel may need to be cut at a bevel along the rake. Start at the downwind end of the roof, so the edge of each overlapping panel faces away from the prevailing winds.
- ***Cutting panels.*** Where panels need to be cut, use snips or shears rather than an abrasive blade, which overheats the steel coatings and leaves a rough edge prone to rust. Abrasive blades also produce hot metal filings that can embed in the paint and cause rust on the face of the panels.
- ***Side and end laps.*** After the first panel is screwed down, the next panel is set in place, lapping over the first. Side laps are typically sealed with butyl tape and held together with gasketed sheet-metal screws. Where more than one panel is used up the run of the roof, the upper panel laps the lower by 6 inches and is sealed with butyl tape.
- ***Fasteners.*** Fasteners are typically special wood screws with integral EPDM or neoprene gaskets that compress under the screw head to seal the hole. Fasteners should be driven at a right angle to the roof plane and should be snug but not so tight as to deform the washer (see Figure 2-37). Nearly all manufacturers recommend placing screws in the flat sections between ribs. Although making holes in the flat section may seem unwise, placing screws in the ribs is discouraged for two reasons. First, the long exposed screw shaft passing through the rib is prone to snap over time due to thermal movement of the panels. Second, it is easy to overdrive the screws and crush the panels. Higher-cost EPDM washers are less likely to leak than neoprene.

Reroofing. Panels can go directly over a single layer of asphalt shingles in good condition. If the shingles are curled or uneven, install 2x horizontal purlins at 16 inches on-center. In either case, put down a new layer of No. 30 underlayment before installing the panels.

Flashings and Accessories. Most manufacturers supply preformed flashings, drip edges, rake moldings, and ridge caps color-matched to their roofing panels, as well as color-matched coil stock for fabricating custom pieces on-site. They also provide rubber closure strips or expandable foam tapes to seal panel ends against water and insect intrusion at eaves, valleys, ridges, and other terminations.

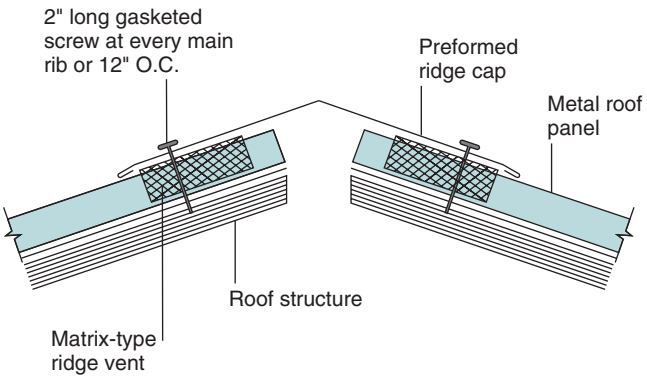
Pay particular attention to panel ends at valleys. Some manufacturers supply special closures for the angled cuts through ribs, but closures may need to be fashioned by cutting up standard closure strips. Some manufacturers also provide an expandable foam sealant tape that conforms to the rib pattern for a tight seal up the valley. Depending on the panel profile, the end treatment will vary, but ends should be fully sealed. Remember to place screws in flat sections and to use extra screws up the valley (Figure 2-38). For a vented ridge, place short sections of a matrix-type ridge vent between the ribs and secure with a preformed metal cap (Figure 2-39).

FIGURE 2-38 Valley Flashing for Exposed-Fastener Panels.



Line valleys with bituminous membrane or two layers of No. 30 roofing felt. To seal the open ribs facing into the valley, manufacturers provide self-adhesive neoprene closures or an expandable asphalt-impregnated tape that conforms to the profile of the roofing.

FIGURE 2-39 Vented Ridge for Exposed-Fastener Panels.



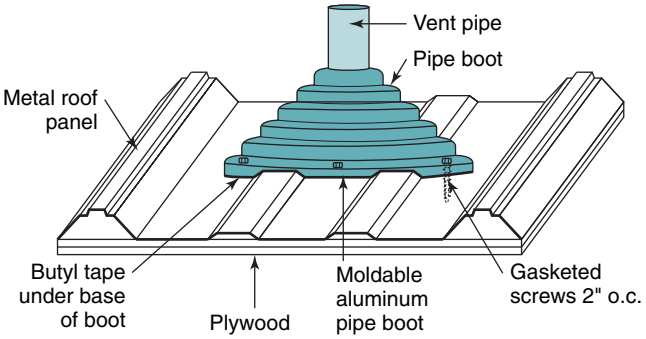
For a vented ridge, use a preformed ridge cap with short sections of matrix-type ridge vent installed between the ribs.

For plumbing vents, most manufacturers recommend a moldable aluminum jack bent to conform to the profile of the roofing (Figure 2-40).

Rectangular openings, such as skylights and chimneys, typically require both base and counterflashing so roof panels are free to move with changes in temperature. Depending on the panel profile, either use a pan flashing or an L-flashing sealed to the top surface of the roofing panel with sheet metal screws and butyl tape. On large openings, a cricket is needed on the upslope to divert water around the penetration. Custom-made, one-piece curbs with built-in diverters simplify this type of installation. All flashing joints should be sealed with butyl tape or a manufacturer-recommended sealant.

Sealing. For the watertight performance required on homes (as opposed to barns), metal roofs need careful

FIGURE 2-40 Plumbing Vents for Metal Roofing.



At plumbing vents, most exposed-panel manufacturers recommend a surface-mounted soft aluminum jack that molds to the profile of the roofing.

sealing around all penetrations, side laps, and end laps. On side seams and lap joints, the sealant should always go on the uphill, or "dry," side of any fasteners (Figure 2-41). Sealant should also be used at ridge caps, valleys, and wherever flashings lap over or under the metal roofing.

The preferred sealant for most concealed seams in roof panels is butyl tape, which absorbs movement and will not shrink. Gunnable terpolymer butyl or urethane caulk can also be used, as specified by the manufacturer. But never use acid-cure silicone caulking (the common type with vinegar odor) or asphalt roofing cement, as they will damage most metal coatings.

Panel Movement. Metal panels were originally designed for installation on purlins that can absorb the normal movement as the panels expand and contract from temperature changes. The thermal movement of a long panel installed over solid plywood, however, can cause problems. Typically, either the hole in the roofing elongates—creating a potential leak—or the screw becomes loosened, making the roof vulnerable to blow-off. The problems are greatest with aluminum, which has 70% more thermal movement than steel and less tensile strength. To avoid problems, experts recommend the following:

- With exposed-fastener panels, avoid lengths over 40 feet for steel or 16 feet for aluminum—less for climates subject to wide temperature swings. Break the run into two panels.
- On long runs of painted roofing, choose lighter shades, preferably white.
- Use screws in the flat part of the panel, not on the ribs. Screws should penetrate the sheathing fully, plus $\frac{1}{4}$ to $\frac{1}{2}$ inch.
- Where leak-free performance is critical, fasten the roofing to Z-shaped metal purlins screwed horizontally across the plywood sheathing. Or switch to a concealed fastener system.

Oil-Canning. Thermal expansion in light-gauge metal panels can cause a wavy appearance called "oil-canning" in the flat areas. In general, this does not signal a performance problem, but it may be visually objectionable. Oil-canning tends to be most visible in bright light from a close distance, and it is generally more noticeable on shiny metals, such as Galvalume®, than on colored metal panels. It is primarily a problem in profiles with few ridges to stiffen the panels. To reduce the effect, some manufacturers provide self-adhesive foam strips that are attached lengthwise to the bottom of metal panels.

Standing-Seam Roofing

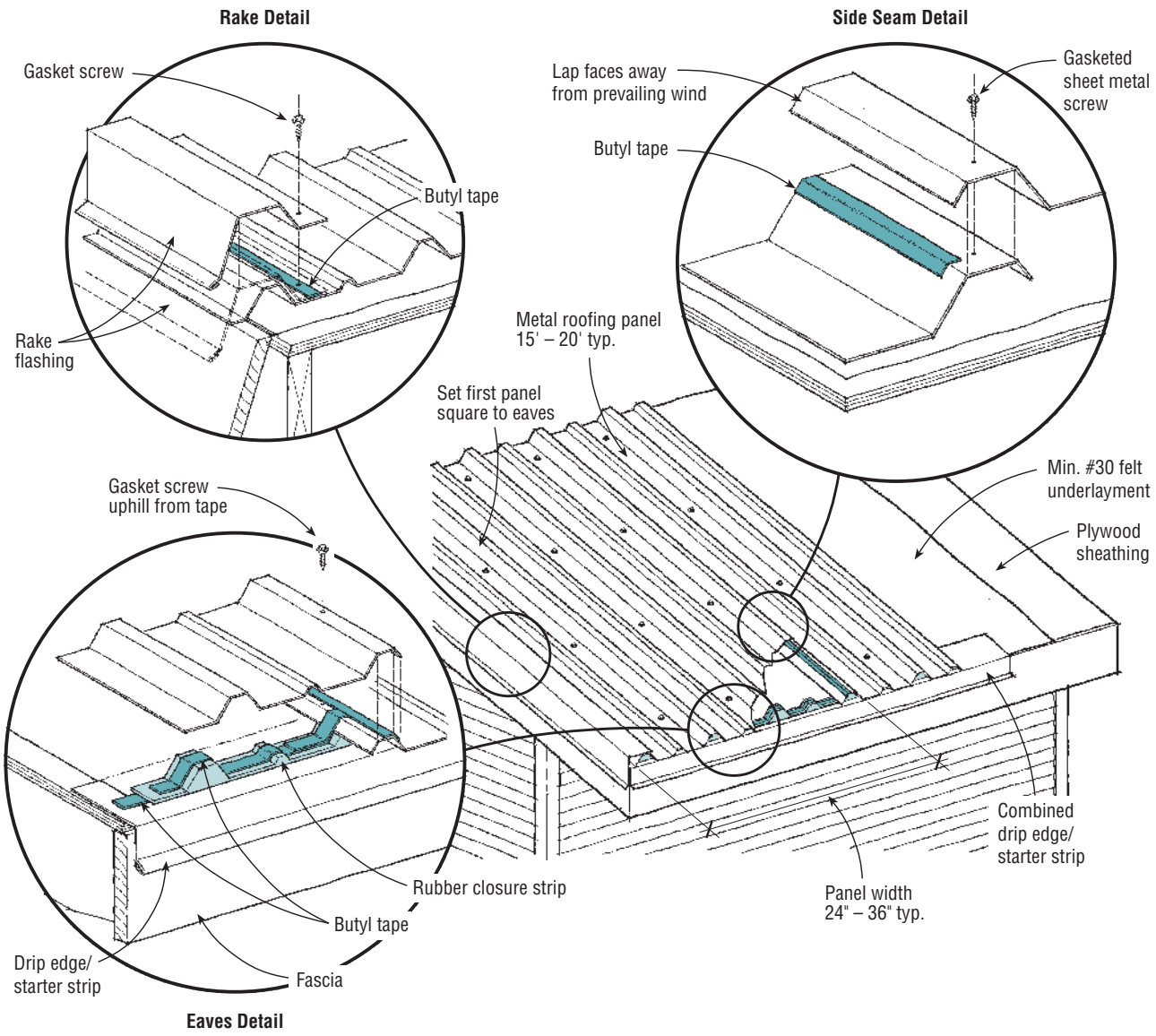
Standing-seam roofing consists of individual panels that run the length of the roof with a high rib up each side of the panels. The ribs overlap and lock together, concealing the fasteners and giving the roofing its name. The hidden fasteners allow thermal movement in the panels and are less likely to leak than exposed fasteners. However, some trim pieces are still fastened with exposed screws.

The smooth surface of a standing-seam roof provides a cleaner appearance and is easier to keep clear of leaf debris than tile, wood, or other textured roofing surfaces. Also, it can be walked on when necessary. Snow slides off easily as well, making this a popular choice in high snow regions. The cost is generally 25% to 50% more than an exposed-fastener roof of similar materials.

Materials. Standing-seam panels are 8 to 24 inches wide and available in steel, copper, and aluminum with a wide array of finishes (discussed below). Stiffening ribs may be added to wider panels to reduce waviness (oil-canning). Thicknesses for quality residential applications are typically 24 or 26 gauge, but lighter and heavier stock is also available. Installers can form panels on-site from coil stock with portable roll-forming equipment, or they can order factory-made panels from a growing number of metal roofing manufacturers. Most factory-made panels have snap-together seams, eliminating the need for special crimping equipment used by site fabricators. In most cases, panels are fabricated to run from eaves to ridge, eliminated the need for end lap joints.

- ***Clips vs. flange.*** Standing-seam panels either have an integral screwing flange (through-fastener panels) or are installed with clips placed 20 to 24 inches on-center (Figure 2-42). Clip systems are more costly to manufacture and to install, but they have better wind resistance and a higher water-lock at the seams. Also, because the clips allow unlimited panel movement, panels can be fabricated to any length. The flange type should be limited to 40 feet for steel and 20 feet for aluminum for normal climate conditions.
- ***Site vs. factory fabrication.*** For those with the equipment, site fabrication provides flexibility and saves on shipping costs, which can be high. Site fabricators can

FIGURE 2-41 **Exposed-Fastener Metal Roofing—Typical Details.**



For profiles with deep ribs, manufacturers provide rubber closure strips to seal ends at eaves, valleys, and other terminations. Butyl tape is the preferred sealant for panel laps, joints, and flashings. Position panels carefully on the tape, as they are difficult to adjust afterward. Note that screws go either through the sealant or on the "dry side" of the butyl tape.

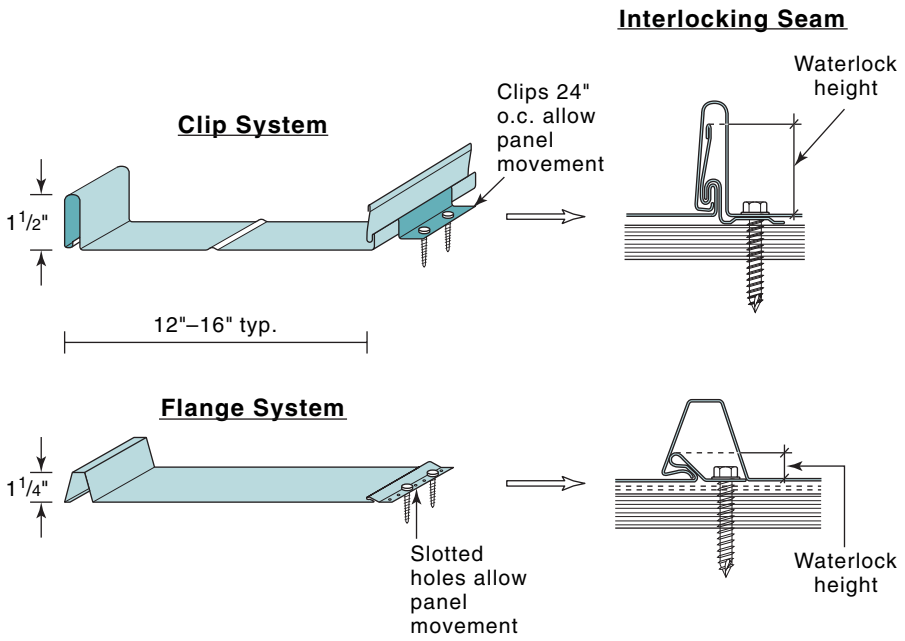
also produce matching flashings and accessories to match the specific needs of the job. Factory-made panels, on the other hand, offer consistent quality, as well as preformed flashings and fittings that simplify installation. Using factory-produced panels, however, requires detailed planning since every piece of roofing must be preordered to length.

Installation. On new homes, most panels are installed over a solid plywood deck with minimum No. 30 felt underlayment. Metal roofing manufacturers recommend plywood rather than OSB due to plywood's better screw-holding ability. Install the felt with plastic cap nails rather than metal buttons, which can cause corrosion when in contact with the roofing panels (see "Galvanic Corrosion," page 83).

After installing the drip edge, install the first panel, making sure it is square to the bottom edge of the roof. If the roof is not square, pull the panel away from the rake so the first rib does not overhang the rake edge. Later, the rake trim piece will cover any small discrepancies. If the panels have an integral screw flange, keep the screws just snug so the panels can move with temperature changes. The clips are designed to allow thermal movement.

The next panel fits over the first with an overlapping rib. Fit each panel to a line snapped up the roof, marking the edge of each panel. Without layout lines, the panels can build up an incremental error, throwing off the layout.

FIGURE 2-42 Standing-Seam Fasteners.



Factory-made standing-seam panels are secured with either clips (top) or an integral nailing flange (bottom). Both systems interlock at seams, using hand pressure. Clip systems are more costly but have better wind resistance and a higher water lock. Also they can better accommodate thermal movement, allowing longer panel lengths.

As panels are installed and secured, the joints are easily locked together with hand pressure. Traditional standing-seam roofing required special motorized crimpers to lock the seams. While these are still used on some low-slope systems, most residential installations now use snap-together panels. Unless the layout works perfectly, the last panel will need to be cut along the opposite rake and bent with a hand seamer to form the end rib.

Reroofing. Many installers will not install standing-seam roofing over existing asphalt shingles since the rough surface will tend to bind the panels and cause "oil-canning," as the panels move with temperature changes. One option is to install the new metal roofing over 2x4 purlins nailed through the old roofing and shimmed to form an even plane. Follow manufacturer's recommendations for spacing of purlins, typically no more than 24 inches on-center.

Flashing and Sealing. Manufacturers of preformed roofing panels provide eaves and rake flashings, ridge caps, and sidewall flashings in matching finishes, as well as coil stock for site fabrication. Many flashings are designed with hidden fasteners; others require exposed gasketed screws. Typical details are similar to those found in Figure 2-41. Follow manufacturers' recommendations regarding which sealants to use for compatibility with the roofing (typically butyl tape, or gunnable terpolymer butyl or urethane sealant). In general, avoid acid-cure silicone (the type that smells like vinegar) as it can be corrosive to many metal finishes.

MODULAR SHINGLES

Modular metal shingles comprise the fastest growing segment of the metal roofing industry. Using light-gauge steel, copper, or aluminum, panels are stamped to imitate slates, shakes, asphalt shingles, or tiles. Some have aggregate stone finishes that closely resemble asphalt shingles. Most carry warranties from 20 to 30 years against fading and from 50-year to "lifetime" warranties against cracking or delamination of the shingle itself.

Modular shingles carry a Class A or B fire rating, depending on the material and installation details, and are highly resistant to wind uplift and damage from hail. Installed prices range from two to three times the cost of premium asphalt shingles. Installers accustomed to asphalt shingles or tile should have little trouble adjusting to metal shingles.

Materials. Modular shingles are typically stamped from lightweight .0165-inch metal, which is thinner than other types of metal roofing but stiffened by the textured patterns. Typical rectangular panel sizes range from 24 to 48 inches long by 12 to 16 inches wide, but they also include tile and diamond shapes and other specialty patterns. Weights range from 40 pounds per square for aluminum shingles to 140 pounds per square for steel shingles with a

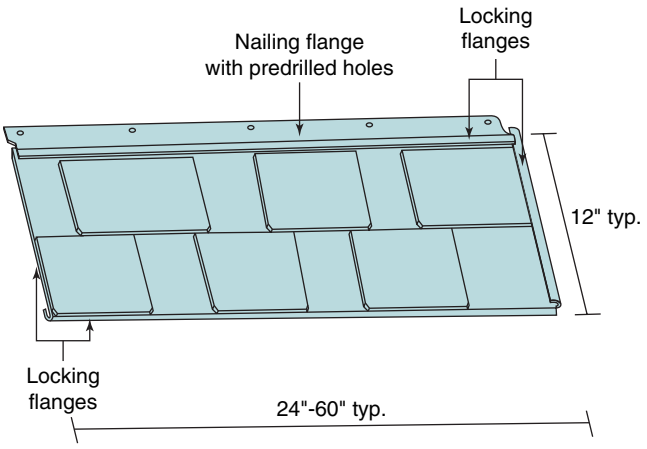
heavy stone aggregate. The lightweight patterns are well-suited to reroofing where weight is a concern. Most panels can be walked on, if done with care, but areas with heavy foot traffic should be reinforced with foam backers provided by the manufacturer.

Installation. Modular shingles are either nailed directly to the wood deck or attached to 2x2-inch battens installed at the exposed panel width, usually about 15 inches. Installation on battens allows more deeply etched patterns, such as simulated tiles. Either type can be installed with pneumatic nailers.

Underlayment is minimum No. 30 asphalt felt held with plastic caps to avoid contact between incompatible metals. Many manufacturers recommend proprietary laminated underlayments, such as VersaShield (Elk Premium Building Products, Inc.), which are tougher and less slippery than felt and provide better fire ratings. Aluminum shingles require fire-resistant underlayments to achieve an A or B fire rating.

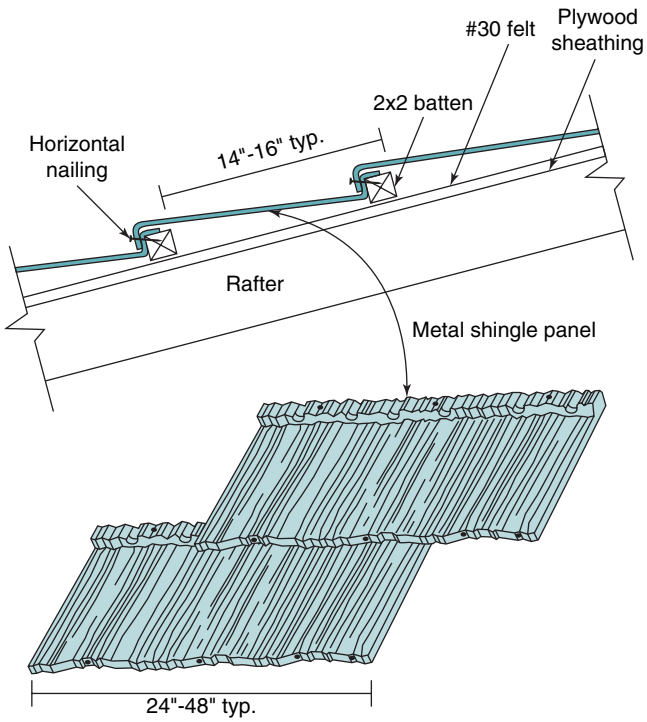
- ***Direct to deck:*** Shingle panels installed directly to the deck are attached with concealed nails, either through clips or a nailing flange along the top, and have interlocking edges along all four sides (Figure 2-43). As they are installed, each panel locks to the panel below and to the left.
- ***Over battens:*** Modular panels designed for installation on battens have a nailing flange along the bottom of each shingle panel with nails going horizontally into the batten (Figure 2-44). Battens are useful for retrofits where the surface is irregular. Also, the air space boosts energy savings, especially when using shingles with solar-reflective surfaces.

FIGURE 2-43 Modular Metal Shingles Installed Direct-to-Deck.



Shingle panels installed directly to the deck are attached with concealed nails either through clips or an integral nailing flange. Panels interlock along all four sides, providing excellent wind resistance.
SOURCE: Photo courtesy *of Accel Roofing Products.*

FIGURE 2-44 Modular Metal Shingles to Battens.



Modular shingle panels with deep profiles typically install over battens. Nails are driven horizontally into the batten through predrilled holes at the bottom lip of each shingle. The air space created boosts energy savings, especially when combined with new solar-reflective finishes.

Both systems begin with the installation of a drip edge and gable trim designed for the specific system. Working from left to right, the first shingle panel hooks into the drip edge, which also serves as a starter strip. Successive courses are staggered as specified by the manufacturer.

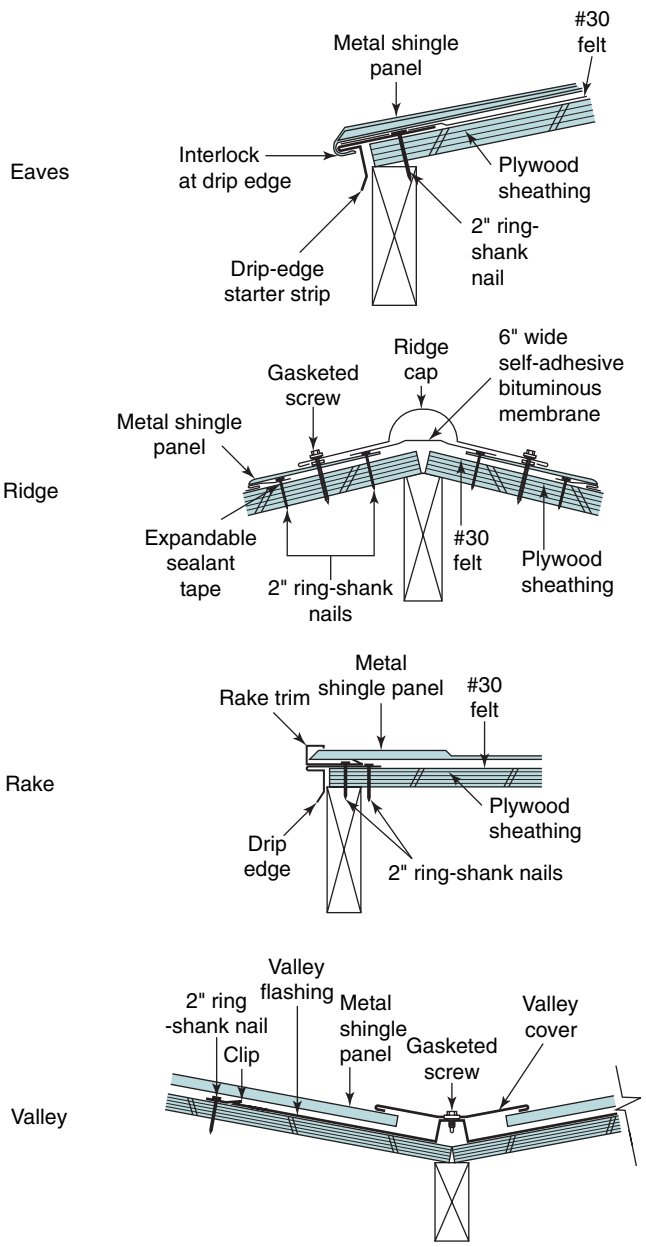
Reroofing. In general, most modular shingles can be installed over existing asphalt shingles if they are in good condition without excessive curling and deformation. Shingles designed to go over battens have more flexibility, since the battens can be shimmed to create a level surface.

Flashing and Sealing. Manufacturers provide standard flashings similar to those for standing-seam products. Eaves and rake flashings typically have concealed fasteners and lock the shingles in place. Ridge and headwall flashings often require exposed fasteners. Depending on the shingle profile, sidewall, chimney, and skylight flashings are either pan or step flashings. Typical details are shown in Figure 2-45.

Metal Choices

While some companies offer roofing products in copper, zinc, and stainless steel, the vast majority are coated steel

FIGURE 2-45 **Modular Metal Shingles—Typical Details.**



Modular metal shingle systems include prefinished flashings, sealing tapes, and accessories to handle most common details. For some situations, installers may need to bend prefinished coil stock on site.

and aluminum. Coated steel products are the most common and least expensive. In its favor, steel moves relatively little with temperature changes, has good structural characteristics, and resists denting. Its high melting point gives it a Class A fire rating. All coated steel materials, however, are vulnerable to corrosion at field-cut edges—although Galvalume® is the least affected (Table 2-10).

Galvanized Steel. To protect against corrosion, the steel is bonded to a layer of zinc, which works as a sacrificial coating on the surface and also offers some protection to cut edges and nicks by flowing to these areas. The heavier the zinc coating, the longer the protection. The Metal Roofing Alliance recommends G-90 galvanized steel for roofing, which has 90 ounces of zinc per square foot. Unpainted G-90 galvanized steel is typically warranted against corrosion for 20 years under normal conditions. It often lasts longer, but it may show visible corrosion in as few five years under harsh conditions, such as salt spray, significant air pollution, or low-slope applications in wet climates. Field cuts made with an abrasive saw are prone to corrosion.

Aluminized Steel. Developed in the 1950s, this is similar to galvanized steel, but it uses aluminum as the coating instead of zinc. The aluminum provides a physical barrier against corrosion and creates a reflective surface that helps reduce heat transfer to attics. However, aluminum does not have the self-healing properties of zinc, so exposed edges and scratches are more susceptible to rust. Aluminized steel generally outlasts galvanized steel but has largely been replaced in the market by Galvalume®.

Galvalume. Also sold under the tradenames Zincalume® and Galval®, Galvalume® was developed in the early 1970s. The underlying steel is coated with a zinc-aluminum alloy that combines the long-lasting protection of aluminum with the self-healing properties of zinc. It also has the reflective qualities of aluminum, reducing attic temperatures and cooling loads. The most common application weight is AZ 55, which has about a 1-mil-thick coating on each side. Unpainted Galvalume® is warranted against corrosion for 20 years, but it has stood up well in weathering tests for 30 years and is projected to last up to 40 years under normal conditions. Cut edges hold up very well, but cutting the material with an abrasive blade is discouraged as the filings will mar the surface. Galvalume® costs about 10% more than standard galvanized steel.

Aluminum. Aluminum that is anodized or painted is highly resistant to corrosion, making it well-suited to coastal environments (although lightweight aluminum flashings tend to pit and oxidize in salty air). Its light weight is an advantage in reroofing. Because of its high coefficient of expansion, however, attachment systems must be designed to accommodate the movement of long panels. And since it has a lower tensile strength than steel, more fasteners may be required to achieve wind ratings comparable to a steel roof. Also, aluminum has a low melting point so it relies on two layers of fire-resistant underlayment, such as VersaShield, to get a Class A fire rating. Most aluminum used in roofing has a baked-on paint finish rather than an anodized finish. Although anodized aluminum is less costly, new paint technologies such as Kynar® and Hylar® carry better warranties and are available with a low-gloss finish generally favored on roofs. Some coated aluminum products come with transferable lifetime warranties.

TABLE 2-10 Metal Roofing Characteristics

Material	Advantages	Drawbacks	Incompatible Materials	Longevity*	Thermal expansion** (10^{-6} in/in/°F)
Galvanized steel	Least expensive. Strong and dent-resistant. Zinc coating heals small cuts and scratches.	Rusts after zinc wears away from oxidation. Field-cut edges vulnerable to corrosion.	Brass, bronze, untreated iron and steel, redwood, cedar, pressure-treated (PT) lumber.	Unpainted: 15 to 30 years. Exposed to salt spray: 5 to 10 years.	7.5
Aluminized steel	Provides a true barrier to corrosion rather than sacrificial coating.	Cuts and nicks not self-healing and prone to corrosion.	Brass, bronze, lead, copper, wet mortar, redwood, cedar, PT lumber, graphite (e.g., pencil marks).	Unpainted: 20 to 40 years.	7.5
Galvalume	Combines barrier protection of aluminum with healing characteristics of zinc. Reflects solar radiation.	Field-cut edges vulnerable to corrosion in coastal areas.	Lead , copper, unprotected steel, wet mortar, PT lumber, and graphite.	Unpainted: 30 to 40 years.	7.5
Aluminum	Superior corrosion resistance. Lightweight. Good for coastal areas.	Expensive. High level of thermal expansion. Relatively soft. Low melting point.	Brass, bronze, lead, copper, unprotected iron and steel, wet mortar, redwood, cedar, or PT lumber, and graphite.	Unpainted: 30 to 40 years	12.7
Copper	Easily roll formed. Superior corrosion resistance. Attractive green patina.	Very expensive. Greenish runoff can stain building. Avoid contact or runoff from cedar shingles.	Aluminum, stainless steel, zinc, unprotected iron and steel, galvanized steel, lead, brass, bronze.	60+ years	8.8
Zinc	Easily formed into intricate patterns. Superior corrosion resistance. Bluish-white patina.	Very expensive. Runoff can stain building.	Brass, bronze, copper, untreated iron and steel, stainless steel, redwood and cedar.	60+ years	15.1

* Longevity is affected by many variables, including slope of roof, wet vs. dry climate, air pollution, and exposure to salt spray.
**Average values. To find predicted expansion in inches, multiply the length of the metal (inches) times the change in temperature (°F) times the number in the chart. Divide the answer by 1,000,000.

Copper. This high-end material is highly resistant to corrosion and easily formed into panels. Copper roofs have been known to last for over a century and are a common sight on churches and historic buildings. Left unfinished, the material will oxidize to the familiar green patina that protects the underlying metal. In arid areas, the color may be more reddish-purple. Special clear acrylic coatings can be applied that will help copper retain its original color. One concern is that runoff from a copper roof can stain building components below if not managed with gutters. Also, premature failure of copper flashing and roofing has been linked to acid rain and runoff from cedar shingles (see "Flashings" under "Wood Shakes and Shingles," page 92).

Clients interested in copper should consider a newly developed proprietary sheet metal called Suscop™, which has copper plating over a stainless-steel core. The material combines the strength and durability of steel with the natural patina of real copper . Because of its greater strength, a lighter-weight sheet (0.4mm) can be used in place of 16-ounce copper, significantly reducing material costs.

Zinc. Zinc roofs are similar to copper in their durability but weather to a bluish-white color rather than green. The material is very malleable and can be formed into intricate patterns for metal shingles.

Galvanic Corrosion

With metal roofing or any metal building components, the safest strategy is not to mix metals that come in direct contact with one another. Use aluminum flashing and fasteners with aluminum roofing, copper flashing and copper nails with copper roofing, etc. When this is not possible, choose a second metal that is not likely to lead to galvanic corrosion or use a physical barrier to separate the two metals.

The Galvanic Scale. The galvanic scale (see Table 2-11) ranks a metal's tendency to react in contact with another metal in the presence of an electrolyte, such as water or even moisture from the air. Metals at the top of the chart are called *anodic,* or active, and are prone to corrode;

metals at the bottom are *cathodic,* or passive, and rarely corrode. The farther apart two metals are on the chart, the greater their tendency to react and cause corrosion in the more active metal. Metals close to each other on the scale are usually safe to use together.

The Area Effect. The rate of corrosion is controlled by the area of the more passive metal. For example, a galvanized steel nail (active) will corrode quickly if surrounded by a large area of copper flashing (passive). If a copper nail is used in galvanized steel flashing, however, the corrosion of the steel will be slow and spread over a large area, so it may not be noticeable. In each case, the active metal corrodes, and the passive metal is protected.

Galvanic Corrosion of Roofing. Because they are made from active metals, aluminum and zinc roofing panels, as well as steel roofing with aluminum and zinc coatings (galvanized steel, Galvalume®, etc.), are vulnerable to galvanic corrosion if allowed to come in contact with more passive metals. For example, never use copper or lead flashings with aluminum, zinc, or galvanized roofing materials. Even water dripping from a copper pipe, flashing, or gutter can lead to corrosion of coated-steel or aluminum roofing materials. How common flashing materials react with metal roofing and other metal building materials is shown in Table 2-12.

Where incompatible metals must be used in close proximity, use the following precautions:

- Separate the two dissimilar metals with building paper, bituminous membrane, durable tapes, or sealants so they are not in direct contact.
- Coat the cathodic (less active) metal with a nonconductive paint or bituminous coating.
- Avoid runoff from a cathodic metal (e.g., copper gutters) onto an anodic metals (such as galvanized steel).

TABLE 2-11 The Galvanic Scale

Most anodic or active (likely to corrode)	Zinc
	Aluminum
	Galvanized steel
	Mild steel, cast iron
	Lead
	Tin
	Brass, bronze
	Copper
	Silver solder
	Stainless steel (passive)*
	Silver
Most cathodic or passive (protected from corrosion)	Graphite
	Gold

*Most stainless steel used in light construction is passive, typically Type 304. Type 316 is recommended for exposure to salts or saltwater.
Note: Avoid placing dissimilar metals in direct contact unless they are close together on the galvanic scale.

Other Incompatible Materials

In addition to galvanic corrosion, a number of other common building materials can harm the finishes on metal roofing or lead to etching or corrosion of the material itself:

Wet Mortar. Aluminum roofing materials and aluminum-based coatings can be damaged by alkali solutions such as wet mortar. Where contact with wet mortar cannot be avoided, one option is to spray the metal with lacquer or a clear acrylic coating to protect it until the mortar is dry.

Pressure-Treated Wood. Roof panels treated with aluminum and zinc coatings should not come into direct contact with pressure-treated (PT) wood, which can damage the finish and accelerate corrosion.

Sealants. Use only sealants recommended by the manufacturer. Never use acid-cure silicones (the most common type, with a vinegar smell) or asphalt roofing cement with coated-steel roofing, as these will mar the finish. Commonly recommended products include butyl tape and gunnable terpolymer butyl or urethane sealant.

Salt Spray. Saltwater spray is very hard on metallic-coated–steel products and may lead to corrosion within

TABLE 2-12 Galvanic Corrosion Potential Between Common Metals

	Zinc	Alum.	Galvanized Steel	Iron/Steel	Lead	Brass, Bronze	Copper	Stainless Steel (passive)
Zinc	—	low	low	high	low	high	high	high
Aluminum	low	—	low	medium	medium	high	high	low
Galvanized steel	low	low	—	medium	low	medium	medium	medium
Lead	low	medium	low	low	—	medium	medium	medium
Copper	high	high	medium	high	medium	medium	—	high
Stainless steel	high	low	medium	medium	medium	high	high	—

Low: No significant galvanic action is likely to occur.
Medium: Galvanic corrosion may occur under certain conditions or over a long period of time.
High: Galvanic corrosion is likely so avoid direct contact.

5 to 7 years. In these areas, the best choices are copper, stainless steel, or painted aluminum. Hylar/Kynar® finishes hold up best.

Paints and Coatings

While unpainted metal roofs are common on utility buildings and some rustic homes, most homeowners prefer a painted surface. In addition to improving the appearance, a high-quality factory finish can significantly extend the life of metal roofing. In general, factory finishes are durable and flexible enough to tolerate factory roll-forming and bending on-site. The best finishes carry decades-long warranties against cracking and peeling, and "excessive" chalking and fading (as defined by the manufacturer). The quality of the finish is determined by the type of resin and the stability of the pigments.

Polyester. Polyester-resin paints are the least expensive and are commonly used on exposed-fastener panels. These have a medium to high gloss when applied, but they will fade significantly within 5 to 7 years on surfaces exposed to direct sun. Bright red, for example, may fade to pink. Fading will be less noticeable on light colors, making them a better choice. Warranties are typically for 3 to 5 years and rarely cover fading or chalking.

Silicone-Modified Polyesters. SMPs (silicone-modified polyesters) use polyester resins blended with silicone additives to improve performance. In general, the higher the silicone content, the more durable the finish. These are available in medium- and high-gloss colors, and they resist fading and chalking much better than standard polyester paints. Warranties against excessive fading and chalking typically run from 10 to 20 years, depending on the formulation.

Fluoropolymers. Based on a fluorocarbon-based resin called PVDF, these are the most technically advanced and most expensive finishes. Sold under the trade names Kynar 500® and Hylar 5000®, fluorocarbon-based paints provide a smooth and dense medium-gloss finish that offers excellent durability and long-lasting resistance to fading and chalking, even under intense sun exposures. The Teflon-like coating also resists dirt retention and holds up better in coastal environments than other finishes. The finish is softer than SMPs, however, and can be damaged by the roofing installers, if they are not careful. Typical warranties run 20 years or greater, with 10- to 20-year protection against excessive fading.

Reflective Finishes. White metal roofs can reduce cooling loads by as much as 30%, according to tests conducted by the Florida Solar Energy Center. More modest savings are now available with dark colors as well by using metal shingles coated with special paints formulated to selectively reflect the sun's infrared and ultraviolet radiation. These "Hi-R" paints are now standard options with Hylar/Kynar® finishes. Tests indicate that aluminum shakes with a reflective brown finish reject 30% to 40% of the total solar radiation compared to 67% for a white metal roof.

Granular Coatings. Some metal shingles are available with a textured finish consisting of crushed stone or ceramic granules blended into an acrylic resin. These are applied over a special primer and sealed with a clear acrylic sealer. The multicolored granules give the appearance of an asphalt shingle and protect against scratching from foot traffic. The finishes also help protect against denting from hail and help conceal any small dents.

WOOD SHAKES AND SHINGLES

Wood shakes and shingles are traditional American roof coverings dating back to Colonial times. They remain popular in many coastal areas and are common or even mandated in certain historic districts. Traditionally, wood roofs were laid on spaced sheathing, which provided good ventilation around the shingles and contributed to a service life of 30 years or more. New wood roofs set on solid sheathing have been known to fail in 10 years or less unless the installer takes adequate precautions to allow for good drainage and drying of the wood roofing materials. With installed costs of over $600 per square for premium materials, it is important to design a roof that will last.

Materials

Wood shakes and shingles soak up water through their end grain, dry unevenly in the sun, and slowly erode on the surface from a combination of ultraviolet radiation, wind, and precipitation. In humid conditions, wood shingles may become a breeding ground for moss, lichen, and decay fungi. To survive those harsh conditions, wood roofing should be made from a durable wood species that is either naturally decay-resistant or pressure-treated.

Wood Species. The most commonly used wood on roofs today is western red cedar. The heartwood of red cedar is rich in extractives that provide natural decay resistance. Eastern white cedar also has good decay resistance and is commonly used on the East Coast. However, white cedar is typically flat-sawn and has a mix of heartwood and sapwood, making it less durable on a roof and more prone to cupping and splitting. Other less common species with good track records are Northern white cedar, Alaskan yellow cedar (actually a cypress), and white oak.

Whatever species is selected, use the best grade available. With red cedar and other decay-resistant species, the heartwood is far more decay-resistant than the sapwood.

Edge-grain wood is more stable and less prone to cupping and splitting than less expensive flat-grain wood. The best choice for wood roofing is all-heart, edge-grained shakes or shingles.

Grades. Make sure the lumber to be purchased has been graded under the authority of a recognized grading agency such as the Cedar Shake and Shingle Bureau for red cedar or the Southern Pine Inspection Bureau for yellow pine. A blue label on the packaging, for example, may simply be a marketing tactic and does not necessary indicate that the shakes or shingles are certified as Grade 1.

Warranties. If installed in accordance with the Cedar Shake and Shingle Bureau's specifications by a certified installer, the CSSB will guarantee wood roofing for 20 to 25 years, depending on the thickness of the shake or shingle. Some pressure-treated shakes and shingles carry warranties of up to 50 years.

Preservative Treatment. If premium red or white cedar is too expensive, consider pressure-treated southern yellow pine shakes and shingles. In its favor, yellow pine is a tougher and stronger wood, and although not as pretty as red cedar when new, over time they will both weather to a similar silver gray. Because penetration of the treatment is nearly 100%, pressure-treated pine shingles carry guarantees against decay for up to 50 years, making them well-suited to high-moisture environments, shallow slopes, and shady wooded sites where organic matter may collect on the roof. The preservatives should not leach out over time.

One drawback to yellow pine shingles and shakes is that many are flat-grained, so most come pretreated with a water repellent to help them resist cupping and splitting. However, retreatment with a water repellent at some point may be required for optimal performance. Western red cedar shingles are also available pressure-treated for severe applications where standard cedar shingles are prone to decay.

Shingles. Shingles are sawn from blocks of wood, which gives them two smooth faces. They are relatively thin and cut to a taper. Red cedar shingles come in four grades, but most roofs use No. 1 or No. 2, which are all edge-grain heartwood (Table 1-6, page 16). They are available rebutted and rejointed (R&R), where a uniform appearance is desired, or machine-grooved for a textured surface.

Eastern white cedar shingles are also available in four grades. Most roofing work uses Grade A (Extra), which is all-clear, all-heartwood, or Grade B (Clear), which has no knots on the exposed face (see Table 1-7, page 16).

Shakes. Shakes are split from large blocks of wood and may be resawn to create a taper. They are heavier than shingles, less uniform in thickness, and are generally rough-textured on one or both sides creating a more rustic appearance. Grades and characteristics for red cedar shakes and shingles are found in Table 1-6, page 16. Red cedar shakes come either tapered or untapered and are usually installed on roofs in Premium or No. 1 grade.

Fire-Retardant Treatment. Once popular on the West Coast, wood roofs have been banned in many residential areas by fire regulations designed to slow the spread of wildfires. Fire-retardant treated (FRT) shingles and shakes have been developed to address these issues and can obtain a Class B or C rating when combined with other components in a fire-resistant roof system. With pretreated shingles, consult with the treating company regarding fastener requirements and any special application instructions.

Slope and Exposure

Recommended exposures for shakes and shingles are shown in Tables 2-13 and 2-14.

TABLE 2-13 Wood Shingle Roofing Weather Exposure

Shingle Length (in.)	Grade (label)	Maximum Exposure (in.) 3:12 to < 4:12 Slope	Maximum Exposure (in.) 4:12 or Steeper Slope
16	1	$3\frac{3}{4}$	5
	2	$3\frac{1}{2}$	4
	3	3	$3\frac{1}{2}$
18	1	$4\frac{1}{4}$	$5\frac{1}{2}$
	2	4	$4\frac{1}{2}$
	3	$3\frac{1}{2}$	4
24	1	$5\frac{3}{4}$	$7\frac{1}{2}$
	2	$5\frac{1}{2}$	$6\frac{1}{2}$
	3	5	$5\frac{1}{2}$

SOURCE: Based on the 2003 International Residential Code and recommendations of the Shake and Shingle Bureau.

TABLE 2-14 Wood Shake Roofing Weather Exposure (4:12 and steeper)

Type of Shake	Size (in.)	Grade	Max. Exposure (in.)
Hand-split shakes of naturally durable wood	$24 \times \frac{3}{8}$	1	$7\frac{1}{2}$
All other naturally durable wood shakes or pressure-treated taper-sawn shakes	18	1	$7\frac{1}{2}$
	18	2	$5\frac{1}{2}$
	24	1	10
	24	2	$7\frac{1}{2}$

SOURCE: Based on the 2003 International Residential Code and recommendations of the Shake and Shingle Bureau.

- ***Minimum slopes.*** The minimum recommended slope for standard installation of shingles is 3:12, and 4:12 for shakes.
- ***Low slopes.*** On lower slopes, shingles or shakes may be installed over a fully waterproof built-up roof (BUR) or membrane roof. Over the membrane, install vertical 2x4 battens lined up with the rafters, then spaced sheathing as described below.
- ***Climate factors.*** In warm, high-moisture climates, low-slope wood roofs need extra maintenance, particularly in areas with overhanging trees. If pine needles, leaves, or other organic debris is allowed to accumulate on a shaded section of the roof, moss, lichen, and algae will grow and retain moisture. This, in turn, will lead to premature curling, splitting, and decay of the shakes or shingles. Periodic cleaning, as well as chemical treatment, helps to avoid these problems (see "Maintenance," page 93). Pressure-treated shakes or shingles are recommended in these conditions.

Sheathing and Underlayment

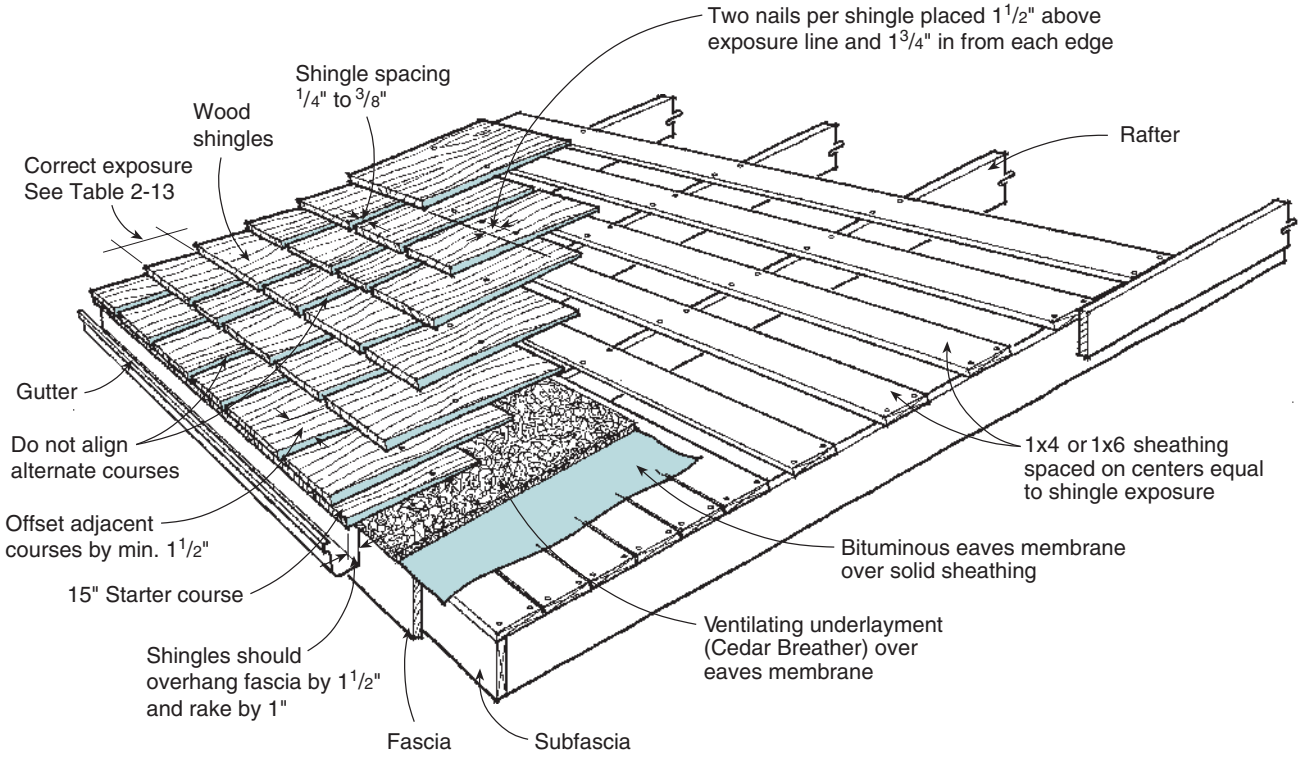
Other than selecting a durable wood, the most important factor in determining a wood roof's longevity is its ability to dry out from both top and bottom when wet. While this was a natural feature of traditional installations over spaced sheathing, new methods and products are required for installation over solid sheathing. The two main approaches are:

- Create a system of spaced sheathing above the solid sheathing using vertical and horizontal battens; or
- Use a breathable underlayment applied over the sheathing.

Spaced Sheathing. The traditional way to lay wood shakes and shingles on spaced sheathing was ideal for wood roof longevity, but it has largely fallen by the wayside. Spaced sheathing is especially beneficial in warm, high-moisture climates, since the gaps in the substrate allow the shakes or shingles to dry out from both sides. It is not recommended in areas of windblown snow and not always permitted structurally. Where allowed, spaced sheathing typically uses nominal 1x4s for shingles or 1x6s for shakes. Code requires a minimum 1x4, and the spaces between battens should not exceed $3\frac{1}{2}$ inches (Figures 2-46 and 2-47).

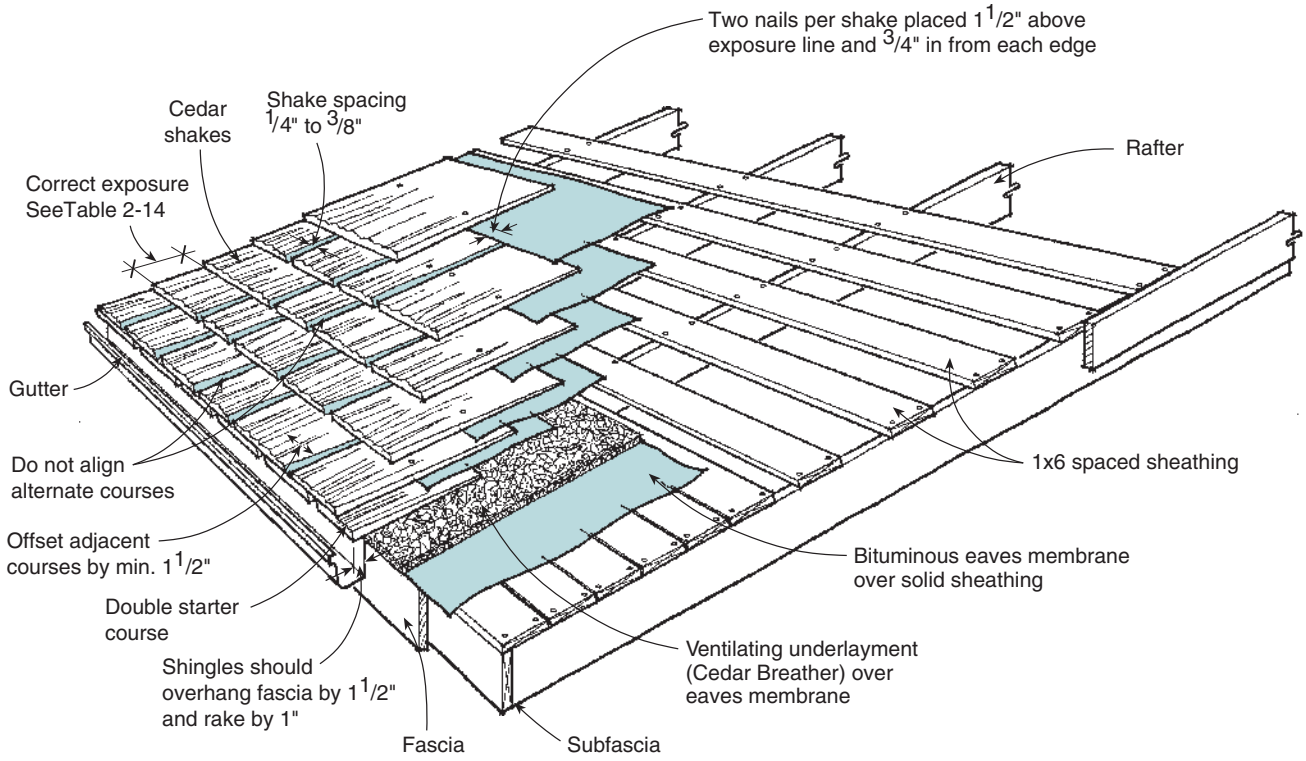
The boards are spaced on centers equal to the weather exposure of the shakes or shingles, and they are lined up so the nailing falls in the center of each board. In areas where the average daily temperature in January is 25°F or less, solid sheathing is required on the lower section of the roof to support an eaves membrane. The eaves membrane

FIGURE 2-46 Wood Shingles Over Spaced Sheathing.



Where permitted by code, spaced sheathing provides the longest life to cedar shingles, but it is not recommended in areas of windblown rain or snow. Where an eaves membrane is required, use a ventilating underlayment to promote drying over the area of solid sheathing.

FIGURE 2-47 **Shakes Over Spaced Sheathing.**



Because their irregular surface provides some self-ventilation, shakes can be installed over solid sheathing. However, in warm, humid climates, spaced sheathing is recommended for best performance. Interlaid strips of roofing felt are required in all installations to keep out windblown snow and rain.

should extend into the house 24 inches past the interior face of the outside wall.

Solid Sheathing. This is required in areas of high wind or seismic activity and wherever else a solid roof diaphragm is required by code. Solid sheathing is also recommended in areas subject to windblown snow. Because of their irregular surface, rustic-style shakes are partially self-ventilating and may perform adequately on solid sheathing in relatively dry climates. Pressure-treated shingles or shakes can also be installed over solid sheathing. Shingles or smooth-surface (taper-sawn) shakes, however, are more prone to moisture buildup over solid sheathing, so a batten system or a ventilating underlayment is recommended, as described below.

Battens Over Solid Sheathing. This provides the full benefit of spaced sheathing on top of a solid roof deck. After laying down No. 30 felt underlayment, install vertical 2x battens lined up with the rafters beneath for solid nailing. Next, place horizontal 1x4 or 1x6 battens (see "Spaced Sheathing," above) and nail into the vertical battens (Figure 2-48).

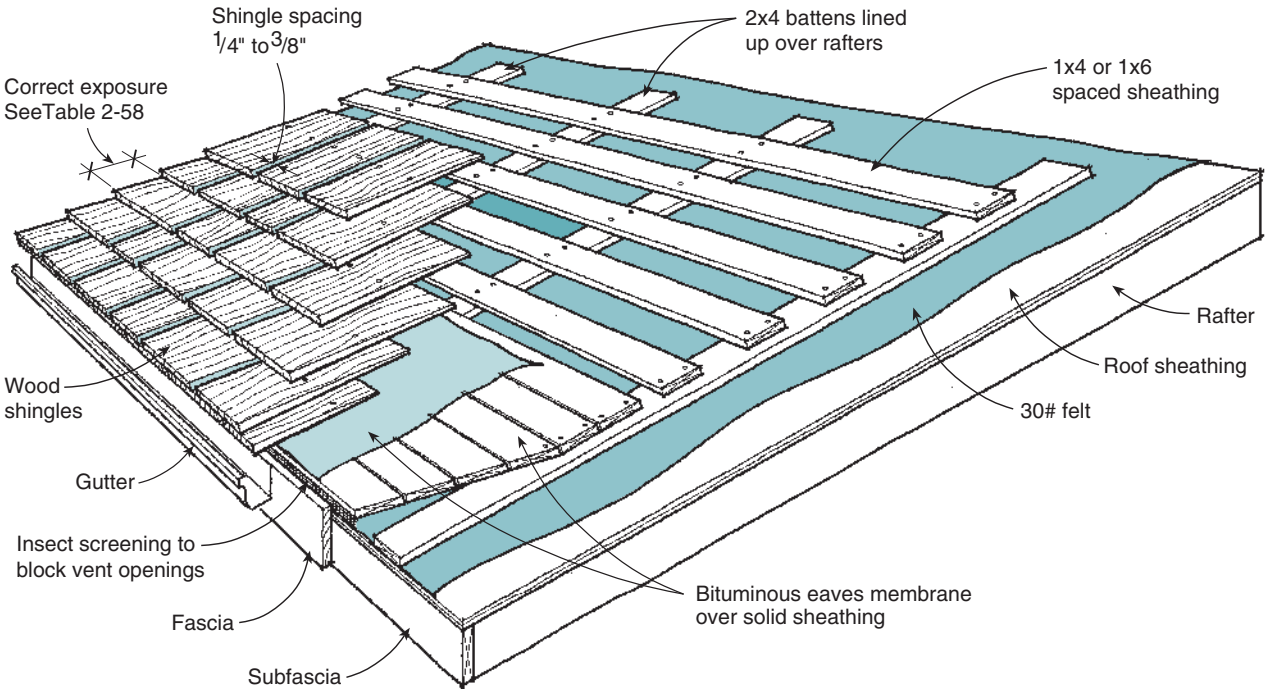
At the upper and lower edges of the roof, use insect screening or matrix-style roof vent material to block the entry of insects and other pests. Shake and shingle installation proceeds as for spaced sheathing.

Underlayment

- ***Shingles:*** Over solid sheathing, use minimum No. 30 felt lapped at least 3 inches horizontally and 6 inches at end laps. Over spaced sheathing, no underlayment is used except at the eaves if eaves flashing is required.
- ***Shakes:*** Over solid or spaced sheathing, use 18-inch-wide "interlayment" strips of No. 30 felt installed between shakes, as described below (Shake Installation, next page).

Ventilating Underlayments. Many installers are shifting to a ventilating underlayment such as Cedar Breather (Benjamin Obdyke), which is easy to install and only adds about 10% to the cost of a wood roof. Cedar Breather is three-dimensional nylon matrix with dimples on the bottom and a smooth top surface. It lays over the felt paper and is tacked in place. It creates a continuous air space below the roofing, helping the shingles to dry out more rapidly and evenly. Although the air space is only about $\frac{1}{4}$ inch, contractors report that it reduces cupping and splitting. And by speeding up drying time, the air space should also help reduce the growth of decay fungi. However, ventilating underlayments are too new to draw conclusions about long-term performance. Installation details are shown in Figure 2-49.

FIGURE 2-48 **Wood Shingles Over Solid Sheathing with Battens.**



Where solid roof decking is required, it is best to provide ventilation under the shingles or use pressure-treated shingles. A system of spaced sheathing laid over 2x4 vertical battens provides optimal ventilation for either shingles or shakes.

Eaves Flashing. Apply eaves flashing to either spaced or solid sheathing in regions with an average daily temperature of less than 25°F (under the IRC) or in other areas prone to ice and snow buildup. The eaves flashing should extend up the roof to a point 24 inches inside the building. Where eaves flashing is required with spaced sheathing, install solid sheathing along the bottom section of the roof to support the eaves flashing.

Fasteners

All nails should be either stainless steel (type 304 or 316), hot-dipped galvanized, or aluminum. Staples should be either stainless steel or aluminum. Galvanized staples will not last the life of the roof. Treated shingles may require stainless steel or other special fasteners. Consult with the treatment company for recommendations. Stainless steel is also the first choice in coastal environments.

- ***Nails*** should be box type and penetrate the sheathing by $\frac{3}{4}$ inch (Table 2-15, page 91).
- ***Staples*** should have crowns between $\frac{7}{16}$ and $\frac{3}{4}$ inch wide and penetrate the sheathing by $\frac{3}{4}$ inch.
- ***Drive flush.*** Do not drive nail heads or staple crowns below the surface of the shingle. Underdriving or overdriving weakens the shingle attachment.
- ***Placement.*** Each shake or shingle should receive only two nails. Place one fastener $\frac{3}{4}$ inch in from each edge and about $1\frac{1}{2}$ inches above the exposure line (Figure 2-50).

Shingle Installation

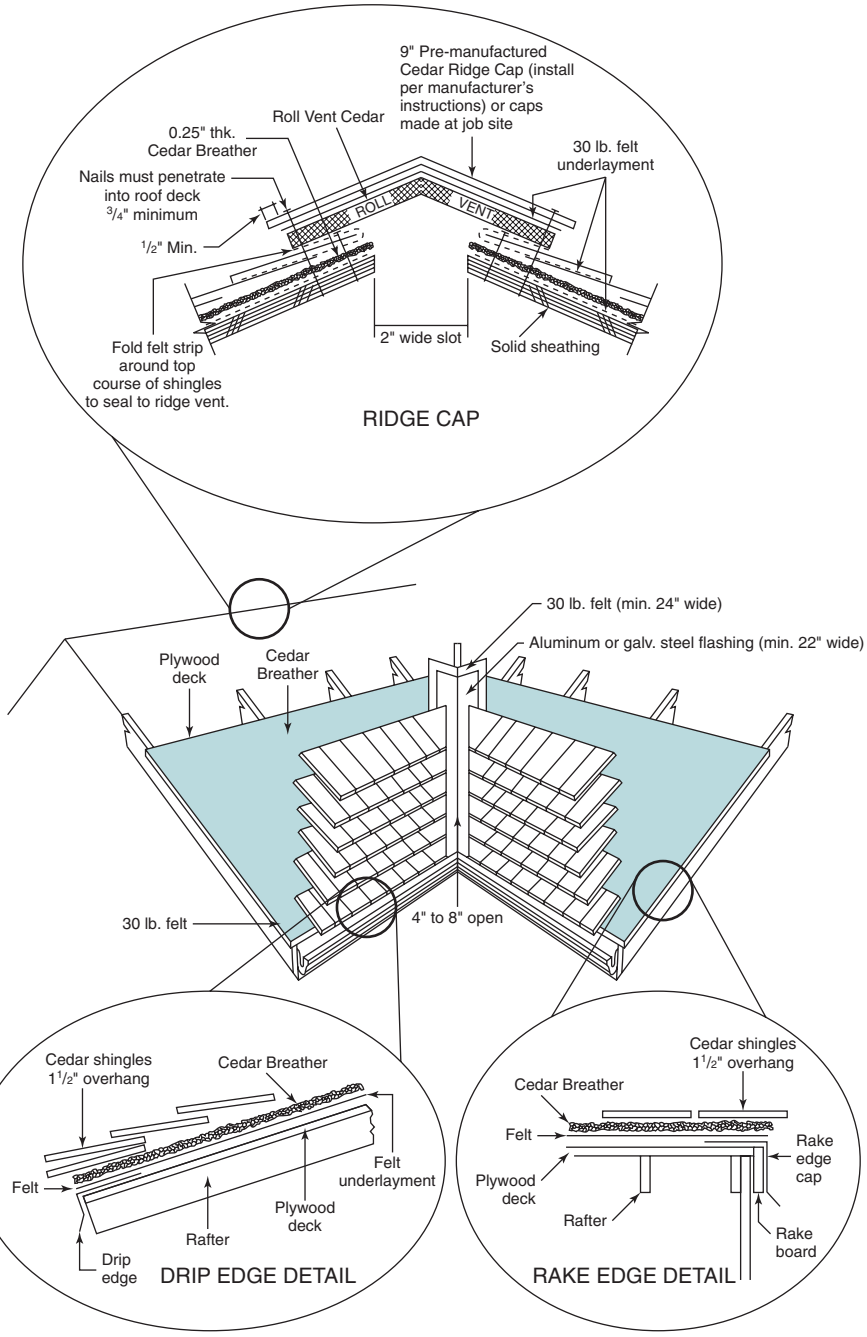
Whether installed over solid sheathing or spaced sheathing, follow these guidelines:

- For the starter course, double or triple the shingles in the first row.
- Each shingle gets two nails about $\frac{3}{4}$-inch in from each end, and $1\frac{1}{2}$ inches above the butt line of the overlaying shingle.
- The first course should overhang the fascia by $1\frac{1}{2}$ inches. All courses should overhang the rake by about 1 inch.
- Leave a gap of $\frac{1}{4}$ to $\frac{3}{8}$ inch between adjacent shingles for expansion when wet.
- Offset joints in successive courses by at least $1\frac{1}{2}$ inches (Figure 2-50). Also, no more than 10% of joints should line up with joints in alternate courses (two courses away).
- Flat-grain shingles wider than 8 inches should be split into two shingles before installing.
- Treat knots, similar defects, and centerline of heart as if they were joints between shingles, and locate the defect $1\frac{1}{2}$ inches from joints in the row above or below.

Shake Installation

Whether installed over spaced or solid sheathing, shakes should always be interlaid with 18-inch-wide strips of No. 30 roofing felt. The felt strips acts as baffles to keep

FIGURE 2-49 Wood Shingles with Ventilating Underlayment.



New ventilating underlayments have simplified the job of creating a vent space below wood shingles and shakes. Cedar Breather, shown above, is a three-dimensional nylon matrix that creates a $\frac{1}{4}$-inch air space, helping to reduce cupping, splitting, and premature failure of shakes and shingles. Increase roofing nail lengths by $\frac{1}{4}$ inch.
SOURCE: Drawings courtesy of Benjamin Obdyke Inc.

windblown snow and other debris from penetrating the roof system during extreme weather. The felt "interlayment" also helps shed water to the surface of the roof. It is important to locate each felt strip above the butt of the shake it is placed on by a distance equal to twice the weather exposure (Figure 2-51).

Placed higher, the felt strips will be ineffective. Placed too low, they will be visible in the keyways and will wick up water, leading to premature failure of the shakes. In addition, follow these guidelines:

- For the starter course, use either a single layer of shakes or two layers separated by a strip of felt interlayment (installed up from the eaves by a distance equal to the weather exposure). Fifteen-inch shakes are available for the bottom layer of a double starter course.

- Each shake gets two nails about $\frac{3}{4}$ inch in from each end and $1\frac{1}{2}$ inches above the butt line of the overlaying shake.
- The first course should overhang the fascia by $1\frac{1}{2}$ inches.
- All courses should overhang the rake trim by about 1 inch.
- Leave a gap between adjacent shakes of $\frac{3}{8}$ to $\frac{5}{8}$ inch for expansion when wet.
- Offset joints in successive courses by at least $1\frac{1}{2}$ inches.

TABLE 2-15 Fasteners for Red Cedar Shakes and Shingles on Roofs

Type of Certi-label Shake or Shingle	Nail Type and Minimum Length
Certi-Split & Certi-Sawn Shakes	
18 in. Straight-split	5d box ($1\frac{3}{4}$ in.)
18 in. and 24 in. Handsplit-and-Resawn	6d box (2 in.)
24 in. Tapersplit	5d box ($1\frac{3}{4}$ in.)
18 in. and 24 in. Tapersawn	6d box (2 in.)
Certigrade Shingles	
16 in. or 18 in. Shingles	3d box ($1\frac{1}{4}$ in.)
24 in. Shingles	4d box ($1\frac{1}{2}$ in.)

Courtesy of Cedar Shake & Shingle Bureau © 2005 CSSB. All Rights Reserved.

Reroofing

Under some conditions, shakes and shingles can be installed over existing roofing, as follows:

Existing Asphalt Shingles. If the existing asphalt shingles are not overly cupped or deteriorated, split or rough-sawn shakes can be installed over the shingles using interlaid strips of felt, as described above. Installing wood shingles over asphalt, however, requires a ventilating underlayment such as Cedar Breather or a system of battens (as shown in Figures 2-47 and 2-48).

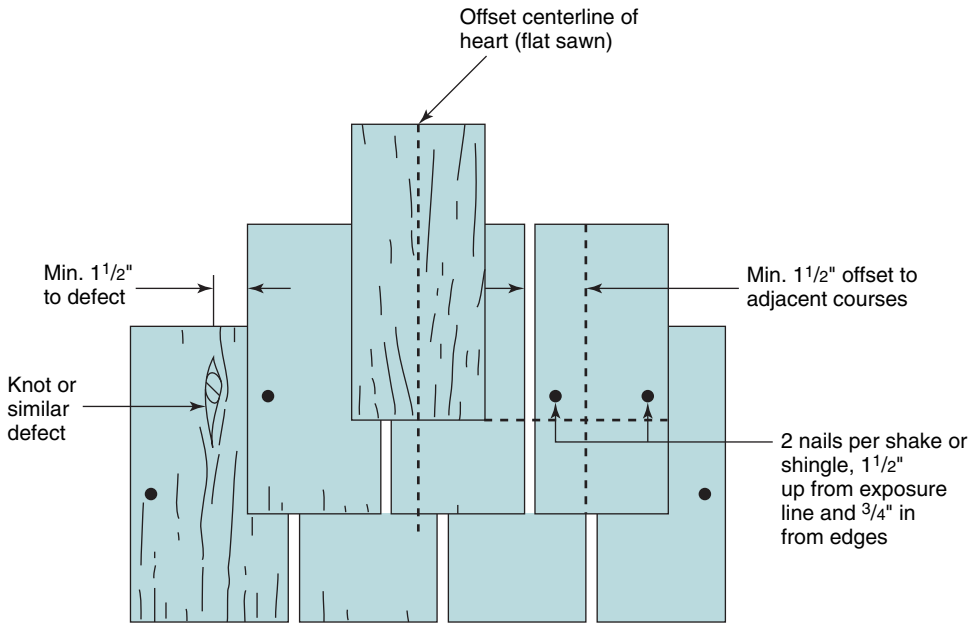
Existing Wood Shingles. If the shingles are not badly curled or deteriorated, they can form an adequate surface for new shingles or shakes. Do not place building felt under the new shingles as that could inhibit drying, but if there is a high risk of decay (moist environment, low slope, overhanging trees), a layer of Cedar Breather is recommended. Shakes should be installed in the normal fashion with interlaid felt. Use nails long enough to penetrate the sheathing.

Existing Shakes. In most cases, these will need to be removed before reroofing, as the surface is too irregular, and nailing through the shakes into solid sheathing is impractical.

Hip and Ridge Details

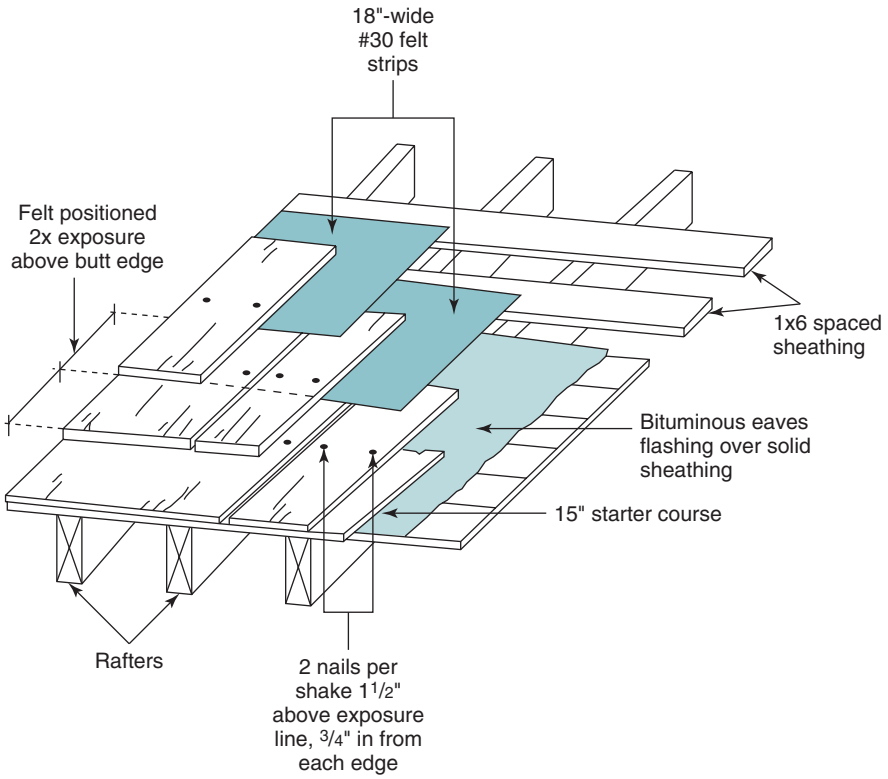
The traditional treatment at hips and ridges is a labor-intensive "woven" cap, consisting of alternating sets of

FIGURE 2-50 Shake and Shingle Alignment and Nailing.



Joints in successive rows should be at least $1\frac{1}{2}$ inches apart and the same distance from knots and other defects. In lower grade shingles with flat grain, do not align joints with the centerline of heart. Only use two nails per shingle, as shown.

FIGURE 2-51 Shake Installation.



Whether installed over spaced or solid sheathing, shakes are always interlaid with strips of roofing felt. The felt interlay helps shed water to the roof surface, and keeps windblown rain and snow from penetrating the roof system during extreme weather.

two beveled shingles. Many installers now use factory-assembled cap pieces that speed up the process.

Hips. Lap the underlayment over the hip before installing the shingles. Then install a strip of roofing felt or metal flashing up the hip on top of the shingles before nailing the caps in place. Use nails or staples long enough to penetrate the sheathing by $\frac{3}{4}$ inch.

Ridge. For a vented ridge, use a plastic, matrix-type ridge vent. Cover the ridge vent with a strip of roofing felt and install factory-assembled ridge cap pieces. To prevent splitting of ridge-cap shingles, it is best to install them with a pneumatic nailer or stapler.

Flashings

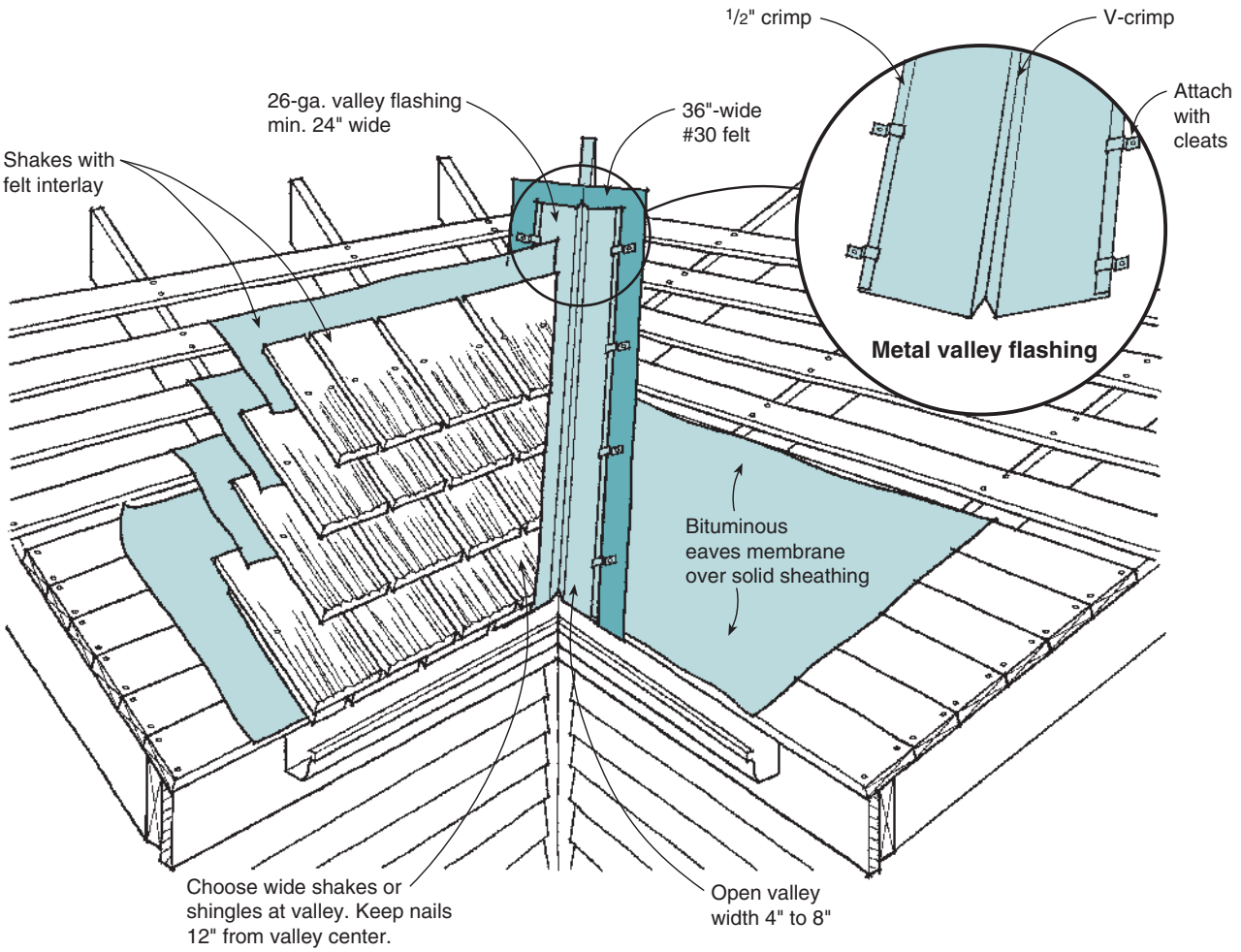
Roof flashings should be at least 26-gauge, corrosion-resistant sheet metal, preferably painted galvanized steel or painted aluminum.

Copper and Cedar. Copper is a popular flashing material with wood roofs, although some experts caution against using copper in direct contact with red cedar or its runoff, since the soluble tannins in cedar can etch copper and, in extreme cases, lead to perforation of the flashing within 10 to 20 years (see also "Copper," pages 7, 83). Premature failures have been documented in areas of the eastern United States that are subject to acid rain, leading the Cedar Shake and Shingle Bureau to advise against using copper flashing in areas east of the Great Lakes that are exposed to acid rain. Another approach endorsed by the Copper Development Association is to design flashing joints with a cant or hem that holds the edge of the cedar shingle slightly away from the flashing. The gap prevents water from being wicked into the joint, bathing the copper in the acidic solution.

Valleys. Wood roofs typically use open valley designs. While the International Residential Code (IRC) only requires the valley flashing to extend a minimum of 10 inches up each side of the valley for shingles and 11 inches for shakes, most contractors install 24- to 36-inch-wide valley flashing based on the area and pitch of the roof planes being drained. The valley metal should be protected by an extra layer of 36-inch-wide No. 30 felt installed directly under the metal or a layer of self-adhesive bituminous membrane applied directly to the sheathing. It is best to set aside the widest shingles or shakes for use in the valley to keep nails at least 12 inches from the valley centerline (Figure 2-52).

Chimneys and Skylights. These are flashed conventionally, using step flashing on the sides in accordance with Table 2-16. Use a soldered apron flashing below the

FIGURE 2-52 Valley Flashing for Shakes and Shingles.



Use a minimum 24-inch-wide crimped metal valley protected by an extra layer of No. 30 felt installed directly under the metal. Choose the widest shingles for use in the valley and keep nails at least 12 inches from the valley centerline.

TABLE 2-16 Step Flashing Dimensions

	Horizontal Leg	Vertical Leg
Shakes	4 in.	3 in.
Shingles	2 $\frac{1}{5}$ in.	2 $\frac{1}{5}$ in.

chimney and a soldered head flashing at the top. Larger chimneys with significant water flow behind them should have a cricket above.

Maintenance

A number of factors affect the longevity of a wood roof. Key factors include the durability of the wood, local humidity and precipitation levels, and whether the roofing was installed with adequate ventilation. Other factors include the slope of the roof (steeper slopes shed water faster) and the presence of overhanging trees that shade the roof and drop organic debris onto the roof, trapping moisture on the surface. Some of these factors can be controlled by the contractor; some managed by the homeowner. Others, like the weather or the reduced durability of second-growth cedar, are beyond our control.

Some simple steps that a homeowner can take to prolong the life of a wood roof include:

- Trim overhanging branches that drop pine needles or leaves on the roof.
- Clean debris out of gutters and off the roof, both the surface areas and the keyways between shakes or shingles. A garden hose can do an adequate job.
- Ensure adequate year-round ventilation of the attic or roof assembly.
- Install strips of zinc or copper at the ridge (can serve also as a ridge cap) and midway across the roof on long slopes. Runoff from these strips forms a mild solution that reduces the growth of moss, mold, and mildew. This is effective for up to 15 feet downslope from the metal.
- If moss or lichen begin to grow, scrape it away and scrub the area with a solution of 1 quart household bleach, 1 ounce detergent, and 3 quarts warm water.

Over time, the natural extractives in cedar and other decay-resistant species will leach out, making the wood vulnerable to decay. Also, as the shingles dry out, they are prone to cupping, checking, and splitting. At some point, it may make sense to wash and treat the entire roof.

Washing. Cleaning wood roofs with high-pressure equipment is controversial and, in untrained hands, can cause significant damage. It is best to use normal garden hose pressure along with a brush or pump sprayer. To remove dirt, mildew, and weathered gray residue, a consortium of wood technology and coatings experts, including the U.S. Forest Products Laboratory (FPL), recommend a solution of sodium percarbonate (disodium peroxydicabonate) and water. With redwood and cedar, a second wash with a solution of oxalic acid may be needed to remove brown and black discoloration caused by tannins that leached out of the wood. Concentrated oxalic acid is toxic and should be handled with care.

Preservative Treatment. There are a number of commercial treatments available to restore decay-resistance to an aging wood roof. One effective and relatively benign (to plants) treatment consists of a copper-naphthenate compound called Cunapsol 5, which is diluted 1:4 with water and can be applied with a garden sprayer. The treatment needs to be repeated approximately every five years.

Oil-Borne Preservatives. Although Cunapsol 5 and similar waterborne treatments offer good protection against mold, mildew, and decay fungi, they will not do anything to slow down the cupping and splitting caused by weathering. For that, an oil-borne treatment is required. Effective treatments include copper naphthenate with a 3 to 4% metal content and copper octoate with a 1 to 2% metal content. These can be brushed on or dipped (before installation) or professionally applied with spray equipment.

Semitransparent Oil-Based Preservative Stains. Semitransparent oil-based preservative stains work well on rough-textured wood, such as shakes and shingles. They provide some pigmentation and protect the roof from decay for several years. Look for a product with both a wood preservative and a water repellent. Stains with a high percentage of pigment provide the best protection against UV degradation. While preservative stains are best applied before installing the shingles, a surface application can significantly extend the life of a wood roof.

Treatments to Use and to Avoid. According to the Shingle and Shake Bureau, one should use only products that are marketed and labeled as a cedar roof treatment, that have an MSDS available, and that contain one or more of the following: a water repellent, UV inhibitor, or U.S. EPA-registered wood preservative.

The following treatments should never be used:

- Film-forming finishes, including paints, solid stains, waterproofers, sealants, and plasticizers
- Any product with more than 40% solvents
- Any products that contains unfortified linseed oil or diesel fuel
- Any topical treatment marketed with fire-retardant claims

LOW-SLOPE ROOFING

Most roof coverings can be applied on roofs as shallow as 2:12 as long as a fully waterproof membrane is installed over the decking. In this case, the finish roofing material, whether asphalt shingles, wood, or tile, functions mainly as a decorative element but also helps protect the underlying membrane from UV radiation and physical damage.

At slopes lower than 2:12 on residential structures, the primary roofing options are built-up roofing (BUR), often called "tar and gravel," modified bitumen, and EPDM (see Table 2-17). In addition, a handful of proprietary single-ply membranes designed for easy application to small jobs have entered the market and offer a few new choices. While some of these products look promising, how long a new product will perform over 20-plus years is uncertain.

Minimum Slope. With any roofing material, a slope of at least $\frac{1}{4}$ inch per foot is recommended to promote drainage and minimize ponding. Where deflection from snow or other live loads is a concern, a greater slope will be needed to prevent any ponding. Most manufacturers of low-slope roofing products specify a minimum slope of between $\frac{1}{4}$ and $\frac{1}{2}$ inch per foot in their warranties.

While membranes, such as vinyl or EPDM, are unaffected by standing water, it will shorten the life of asphalt-based materials, such as BUR and modified bitumen. With any roofing material, ponding of water increases the likelihood of leakage, increases deflection in the roof framing, and contributes to rooftop growth of mosses, algae, and other plant life. Also, the freezing and thawing of ponded water can harm most roof surfaces.

Roll Roofing

The simplest product to install on a small section of low-slope roof is 90-pound roll roofing. This consists of a heavy, asphalt-saturated organic or fiberglass felt with a granular surface. Rolls are 36 inches wide and weigh 90 pounds. Single-coverage roll roofing typically has a 2-inch lap with exposed nails and is used mainly on utility structures.

Double-coverage roll roofing is installed with a full 19-inch lap joint, leaving a 17-inch exposure, with a 2-inch head-lap. Nails are concealed under the lap joints that are sealed with asphalt lap cement. With two layers of protection, double-coverage roll roofing is acceptable for small roof areas and can be used on roofs as shallow as 1:12.

TABLE 2-17 Low-Slope Roofing Options

Material Type	Pros	Cons	Avg. Longevity
Roll roofing (double-coverage)	Inexpensive. Easily installed by carpenters. Concealed fasteners.	Short life span. Not suitable for cold weather installation.	Approx. 10 years
BUR	Long track record. Forgiving of installation errors due to multiple plies.	Expensive for small jobs. Heavy equipment, odors, potential spills during installation. Ponding water can cause deterioration. Leaks are hard to detect and repair.	15 to 20 years
Modified bitumen (torch-applied)	Durable heat-fused seams do not rely on adhesives. Self-flashing at openings. Easy to inspect and repair. Compatible with asphalt materials. Low temperature installations possible. Self-adhesive and cold-process versions available.	Requires careful installation for proper seaming. Fire risk during installation. Ponding water can reduce longevity. Different chemical formulations difficult to evaluate.	20+ years
EPDM	Relatively easy to install. Proven track record. Lightweight and UV-resistant. Self-flashing. Tolerates building movement and extreme heat and cold. Easy to inspect and repair. Self-adhesive version available for small jobs.	Requires careful installation for proper seaming. Can be damaged by petroleum products, solvents, and grease.	20+ years

BUR

Built-up roofing (BUR) systems dominated the commercial and residential low-slope roofing markets until the 1980s, when single-ply membranes became widely accepted. BUR roofs consist of layers of asphalt-impregnated felt bonded with hot asphalt, or in some parts of the country, hot coal tar. The average life span of a hot-mopped BUR roof is 15 to 20 years, although this can be extended by applying an aluminum coating every three to five years to reduce UV degradation and alligatoring.

BUR roofs can have either a smooth coated surface or a stone surface created by spreading crushed stone or gravel into a thick flood coat of hot asphalt or tar. Aggregate-faced roofs are typically more durable due to the heavier flood coat and the protection offered by the stone from UV radiation, hail, and other environmental wear and tear. However, the stone coating makes leaks harder to find and repair.

Proper detailing of metal flashings at openings, parapet walls, and roof edges is critical, and these areas need regular inspection and maintenance. The most likely place for leaks is flashings, particularly metal edge flashings due to their thermal movement. Asphaltic or rubber flashings may also become brittle and crack.

Pros and Cons. BUR roofs are reliable if properly installed, and their multiple layers provide some protection against small installation errors. However, the long set-up time makes BUR expensive for small residential jobs. Also the heavy equipment, odors, and potential spills associated with a hot-mop job are not welcome on many residential job sites.

Modified Bitumen

Most modified-bitumen roofs are torch-applied, although there are also self-adhesive and cold-process systems. The waterproofing membrane, sometimes called "single-ply modified," consists of asphalt bitumen reinforced with a polyester or fiberglass fabric and modified with polymers to give it greater strength, flexibility, resistance to UV degradation, and resistance to heat and cold. A variety of different chemical formulations have been tried over the years. It is best to stick to a product with an established track record. In general, modified-bitumen roofs can be applied to slopes as shallow as $\frac{1}{4}$ inch per foot.

Installation. A torch-applied, or *torchdown,* roof starts with a nonflammable base sheet made of asphalt-saturated felt or fiberglass that is mechanically attached to the roofing deck. In residential construction, the base sheet is usually attached with roofing nails driven through metal caps. The second layer is the waterproofing membrane, or *cap sheet.* This is heated with a torch as it unrolls, fusing it to the base sheet, to itself at seams, and to penetrations such as skylights. Installers must learn to heat the membrane so it is hot enough to fuse but not so hot as to burn through. Membranes may be either smooth or have a granular surface like roll roofing. Smooth-faced membranes need a third coating, which has colored or reflective pigments to protect against UV radiation. The smooth type is preferable where foot traffic is expected or where decking is going over the roofing.

Torchdown roofing is self-flashing and uses no adhesives or solvents to seal around openings. The material can be run up parapets and abutting wall, and patches are used to seal around metal skylight curbs and similar openings. A special patching compound is used to seal to PVC stacks. If applied correctly, the torchdown membrane is essentially seamless.

Pros and Cons. Modified bitumen is easily repaired without solvents or adhesives. It is compatible with asphalt shingles and asphalt compounds, although patching with

roofing cement is not recommended. The reinforced fabric layer isolates the membrane above from building movement and gives the material enough strength to support occasional foot traffic.

The main drawback is the risk of fire during installation. While the risk of fire is low in the hands of trained installers, care must be taken when using torchdown on a wood-frame structure. A number of fires have started with sawdust that has accumulated in empty cavities, such as crickets and parapets. Inspection of the roof for sawdust pockets while it is being framed is advised.

EPDM

While a variety of single-ply roofing membranes are used on commercial jobs, only EPDM has become widely used on residential sites. EPDM, a form of synthetic rubber, owes its popularity to its relative ease of installation combined with exceptional durability. If installed correctly, roofs often exceed 20 years of service and callbacks are exceedingly rare.

While some commercial EPDM systems are loose-laid or ballasted, residential applications are typically fully adhered. Rolls typically vary from 10 to 50 feet in width and from 50 to 200 feet in length, but many distributors will cut a piece to size for smaller jobs. If possible, use a single piece with no seams for the field of the roof. EPDM membranes are available in two thicknesses: .045 inch and .060 inch. For fully adhered applications or any application where foot traffic or decking is planned, the thicker membrane is recommended.

Substrates. EPDM can be bonded to a wide variety of substrates, including plywood, OSB, fiberboard, and urethane insulation board. The substrate should be smooth, even, and free of debris. Fasteners should be driven flush except in the case of insulation fastening caps, which project their shape though the membrane. If the surface is uneven or deteriorated, a layer of fiberboard or thin plywood should be installed first.

Installation. After cutting the material to fit, installers use a roller to apply a proprietary contact cement to both the membrane and the substrate. Typically, a length of roofing is set in place and folded in half lengthwise so one-half can be glued at a time. The adhesive should be fully dry on both surfaces before bonding, or bubbles may develop. Also, care must be taken to smooth out wrinkles and air pockets as the two surfaces are mated. Where seams are required, the material is lapped 4 to 6 inches and sealed with either double-faced seam tape or a special adhesive used for bonding rubber to rubber.

At openings, inside corners, outside corners, and other irregular shapes where the membrane has been cut, patches of *uncured* EPDM are applied using the rubber-to-rubber adhesive. The uncured form of EPDM is highly elastic and can be stretched to conform to irregular shapes.

The material is lapped up abutting walls and serves as its own flashing. Other terminations are usually sealed with an aluminum termination bar or an aluminum flashing covered with a strip of EPDM. Finally all exposed edges of EPDM at laps, patches, and terminations are sealed with a bead of proprietary caulking that protects the edge and acts as an extra water stop.

Self-Adhesive. For small jobs, a few manufacturers offer a peel-and-stick version of EPDM. Installation is similar to standard EPDM but may require a primer on plywood and OSB substrates. Seams generally require a proprietary adhesive with special caulking on exposed edges. Although the square foot cost is greater than with site-glued EPDM, on small jobs labor savings offset the higher material costs.

Pros and Cons. While not intended as a walkway, EPDM works well as a substrate under rooftop decks. Leftover strips of membrane should be used to cushion the roofing from wood sleepers. Leaks are rare and usually can be traced to sloppy sealing of joints. Leaks are also relatively easy to identify and fix. One caution is that EPDM can be damaged by grease and petroleum-based products, a potential problem with outdoor grills and spillage of oil-base finishes used on siding or wood decking.

WALKABLE ROOFING MEMBRANES

For rooftops that will also serve as decks (see "Rooftop Decks," page 150), one option is to use a roofing material designed for foot traffic. Duradek (Duradek U.S. Inc.) is a sheet vinyl membrane similar to Hypalon but with a nonskid wear surface. It was developed over 25 years ago for waterproofing decks, balconies, and outdoor living spaces. For use over a living space, the manufacturer recommends its 60-mil Ultra series, which is warranted against leakage for 10 years.

Duradek is made of reinforced PVC sheet with heat stabilizers and additives for resistance to fire, UV degradation, and mildew. The wear surface is textured for slip resistance and available in a variety of colors.

Installation. Installation is similar to other single plies and must be done by factory-certified contractors. The membrane glues to almost any clean substrate with either a proprietary contact cement or a special water-based adhesive applied with a notched trowel. Seams are heat welded with a heat gun, the most critical step. Like other single-ply membranes, the material is self-flashing at abutting walls and penetrations.

Pros and Cons. Duradek creates an attractive and durable no-skid deck surface that can withstand normal wear and tear, direct sun exposure, high winds, and

freeze-thaw cycles. However, because the membrane is also the wear surface, it can be damaged by cigarette burns, punctures, and heavy abrasion.

ROOF VENTILATION

All residential building codes require some form of roof ventilation. These rules were first developed in the 1940s, when attic spaces first started to develop problems with mold and mildew due to excess moisture. With the growing use of plywood, asphalt shingles, insulation, and better doors and windows, houses were being built tighter. The tighter spaces retained more of the normal household moisture generated by cooking, bathing, household plants, crawlspaces, and exposed basement slabs. As the stack effect drove this moisture up into attic spaces, problems ensued.

Code Requirements

The rules of ventilation developed by researchers in the 1940s were adopted first by the Federal Housing Administration (FHA) and later by all the major residential building codes, including the 2003 IRC, with few changes. Most asphalt shingle manufacturers will void their warranties if these rules are not followed. They require:

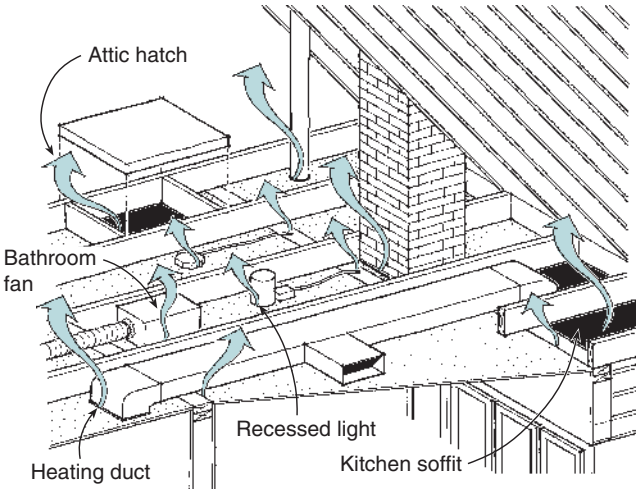
- 1 square foot of *net free vent area* (NFVA) per 150 feet of attic floor.
- 1 square foot of NFVA per 300 square feet of attic floor if a vapor barrier is installed on the ceiling below.
- The IRC adds that the NFVA ratio can also be reduced to 1:300 if 50% to 80% of the required ventilation is located in the upper portion of the attic (or cathedral ceiling) and the rest is located at the eaves, with the upper vents at least 3 feet above the lower.

Tight Ceiling

Although the code-mandated ventilation rate has proven adequate under normal conditions, homes with high-moisture levels and air leaks in ceilings may still experience problems such as moldy sheathing. Cathedral ceilings are at the greatest risk due to the limited ventilation path. The best defense against problems is to create a continuous air and vapor barrier between the living space and attic or roof cavity by carefully sealing all air leaks. The ceiling air barrier may consist of foam insulation with taped seams, taped polyethylene sheeting, or finished drywall that is sealed at corners and top plates with gaskets or sealants.

Penetrations. Pay special attention to penetrations in the ceiling plane, particularly in cathedral ceilings. Chimneys, recessed lights, plumbing chases, and holes drilled through top plates for plumbing or wiring should all be sealed (Figure 2-53).

FIGURE 2-53 Typical Ceiling Air Leaks.



Standard attic ventilation will prevent moisture problems and ice dams as long as the ceiling plane is properly sealed, controlling air and heat leakage from the living space below. Common leakage paths are shown above.

Plug holes with durable materials, such as expandable urethane foam, foam backer rod, EPDM, or sheet metal, and use long-lasting sealants such as high-quality urethanes, silicones, and butyls.

With a tightly sealed ceiling, attic moisture is no longer a significant problem. Attic ventilation is still recommended for three other reasons:

- Preventing ice dams in cold climates
- Reducing cooling loads in hot climates
- Extending shingle life
- Allowing roof components to dry out in the event of a leak

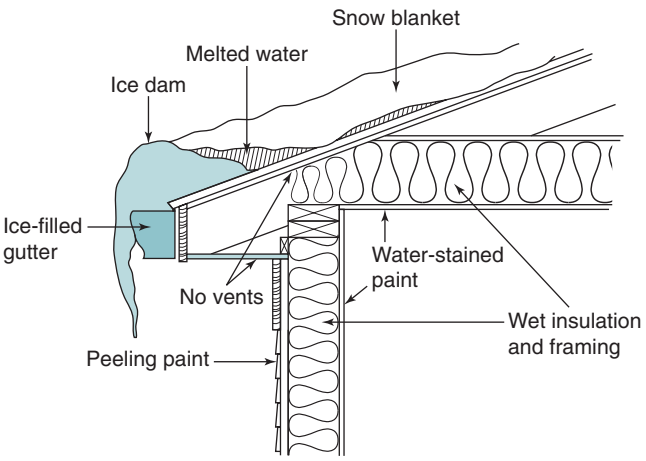
Preventing Ice Dams

Ice dams form when heat leaking into attics or roof cavities from the building below, or from attic ductwork, melts the bottom layer of snow on the roof. The melt water runs down the length of the roof to the eaves, where it refreezes, forming a dam and icicles. In the worst cases, liquid water pools behind the dam and flows under the shingles and into the building (Figure 2-54).

Research has indicated that the ice-dam risk is greatest when temperatures range between 15°F and 20°F—when it is warm enough for snow to melt but cold enough for it to refreeze at the eaves. Also, the greater the depth of snow on the roof, the greater the risk of ice dams due to the insulating value of the snow itself.

Cold Roofs. Ventilation helps prevent ice dams by keeping the roof surface cold enough to limit uneven melting. Tests conducted in 1996 at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL), showed that the traditional 1:150 ventilation

FIGURE 2-54 Ice-Dam Formation.



Ice dams form when melted snow, caused by excessive heat loss through the roof, runs down and refreezes at the eaves. Pooled water behind the dam can flow into ceiling and wall cavities causing extensive damage. The best protection is a well-ventilated "cold roof."

rule was sufficient to prevent ice dams on roofs with R-25 or greater ceiling insulation. The 1:300 rule proved adequate for roofs with R-38 or greater insulation. Since most standard eave and ridge vents sold today meet the higher ventilation rates, most new homes are protected as long as there are no large heat leaks into the attic, or tricky sections of the roof with inadequate ventilation.

Reducing Cooling Loads

Experts recommend using attic ventilation in hot climates as part of an overall strategy to reduce cooling loads. Ventilation helps even more when used in combination with radiant barriers.

Ventilation Alone. Researchers at the Florida Solar Energy Center (FSEC) have found that adequate attic ventilation can modestly lower sheathing and shingle temperatures, and reduce an average home's cooling load by about 5%.

Ventilation and Radiant Barriers. For greater savings on cooling, consider adding a radiant barrier to the underside of the roof sheathing or draped between the rafters. This can reduce peak cooling loads by 14 to 15% and seasonal loads by an average of 9%. By doubling the roof ventilation from 1/300 to 1/150, the annual savings from radiant barriers rises to 12%. These numbers assume R-19 ceiling insulation and cooling ducts located in the attic, which are typical in Florida. With R-30 ceiling insulation, the cooling benefits of radiant barriers are less dramatic.

Roofing Color. Tests at FSEC also indicate that simply switching from dark to white asphalt shingles in a cooling climate can reduce peak cooling loads by 17% and seasonal loads by 4%. The greatest savings resulted from using white metal roofing (see Table 2-18.)

TABLE 2-18 Roofing Color and Cooling Loads*

Roofing Type	Reduction in Peak Load	Annual Savings
Dark gray asphalt shingle (control)	—	—
White asphalt shingle	4%	17%
Terra-cotta tile	3%	13%
White S-tile	20%	32%
White flat tile	17%	34%
White galvanized steel	23%	28%

*Based on an average-sized south Florida home with R-19 ceiling insulation and cooling ducts located in the attic.
SOURCE: Adapted from the FSEC report *Comparative Evaluation of the Impact on Roofing Systems on Residential Cooling Energy Demand in Florida,* 2000, by Danny Parker, Jeffrey Sonne, John Sherwin, and Neil Moyer. Courtesy of Florida Solar Energy Center.

Unvented "Hot" Roofs

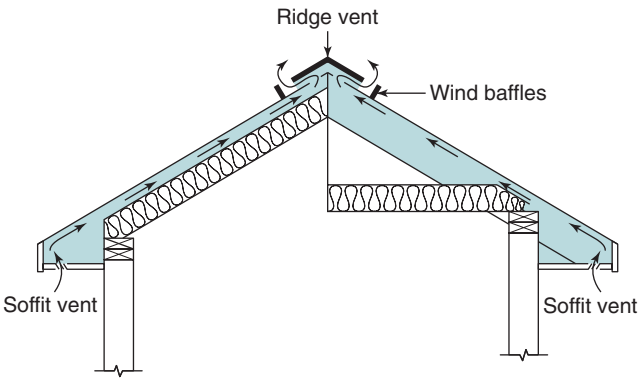
In cathedral ceiling configurations where it is difficult to provide ventilation, some builders have eliminated the vent space, relying instead on careful sealing of the ceiling plane to prevent moisture problems. While experts concede that this should work in theory, most caution that it is difficult to build a truly airtight ceiling assembly. Also, cathedral ceilings are slow to dry out if moisture problems do occur, whether from condensation or roofing leaks. If a hot roof is the only option for a section of roof, take the following precautions:

- Install a continuous air and vapor retarder, such as 6-mil poly, carefully sealed at all junctures.
- Do not use recessed lights or other details that penetrate the ceiling plane.
- Carefully seal all penetrations in the ceiling assembly, including top plates of partitions, with durable materials.
- Use a nonfibrous insulation, such as plastic foam, and install it without voids where moisture could collect.
- In regions prone to ice dams, use enough insulation to maintain a cold roof—preferably R-38 or greater.
- Eliminate all sources of excess moisture in the home (wet basements, uncovered crawlspaces, unvented bathrooms).

Attic Ventilation Details

Soffit and Ridge Vents. For both attics and cathedral ceilings, roof ventilation works best when it is balanced

FIGURE 2-55 Balanced Roof Ventilation.



The soffit vent area should be equal to or a bit larger than the ridge vent area, so there is always sufficient makeup air. Also, ridge vents should have either external or internal baffles to limit the infiltration of windblown rain and snow.

between high and low to take advantage of natural convection (Figure 2-55).

This configuration also tends to evenly wash the underside of the roof with ventilation air. The soffit-vent area should be equal to or slightly larger than the ridge-vent area. Ridge vents should either have external or internal baffles to minimize infiltration of windblown rain and snow. Use insulation baffles or modified framing to make sure that the ceiling insulation does not block airflow at the eaves (Figure 2-56.)

Alternatives. Where ridge vents are not an option, combine any type of upper vent such as gable-end vents, roof vents, or turbines, with soffit vents. Where soffit vents are not possible, use gable-end vents on both ends of the roof, which will ventilate adequately under wind pressure.

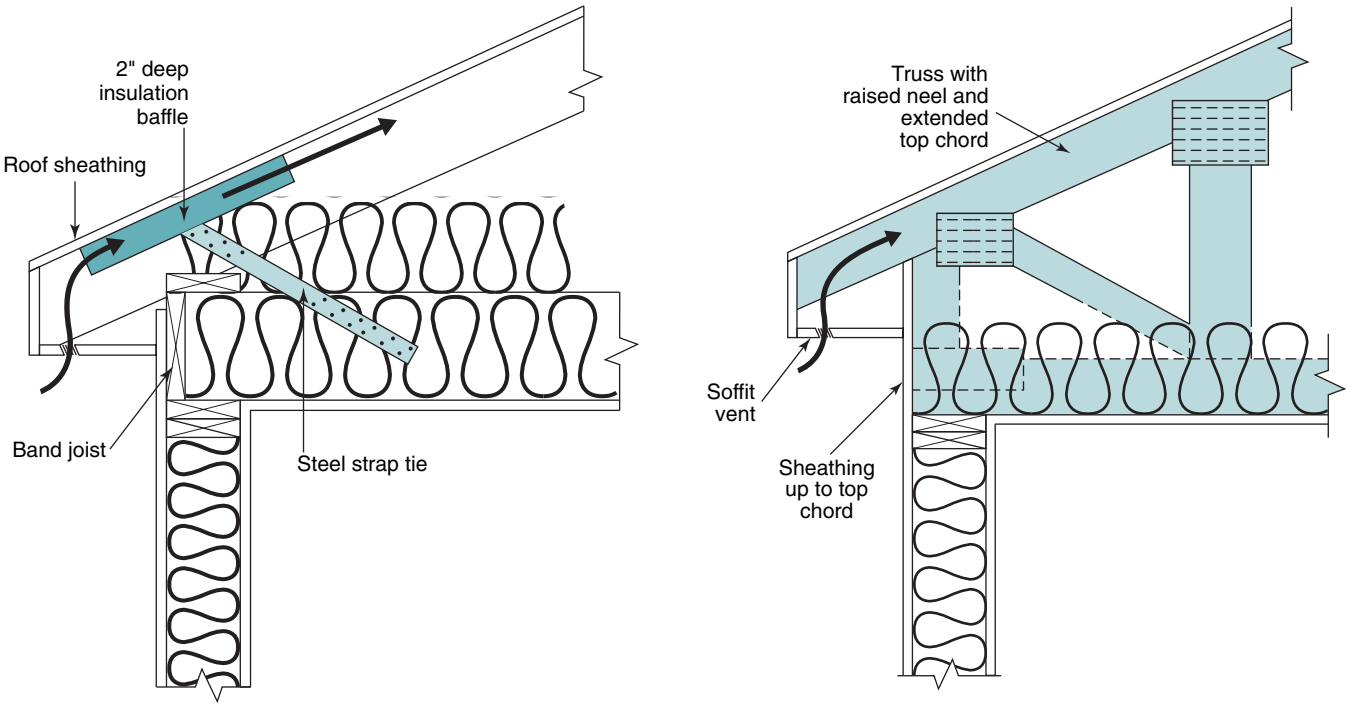
Avoid High Vents Alone. Do not use ridge vents or other rooftop vents without low vents to provide makeup air. The suction created could help pull moist household air into the attic.

Cathedral Ceiling Ventilation Details

Cathedral ceilings require the same continuous air barriers, and balanced soffit and ridge vents, as attics. Both air sealing and ventilation are more critical, however, since any trapped moisture in the roof cavity will remain longer and potentially cause greater damage than in an open attic. Also, since there is little or no communication from bay to bay, an effective ventilation system must reach every bay (Figure 2-57).

Hips and Valleys. Ventilating hips and valleys can be challenging with a cathedral ceiling. One approach is to use a double or triple hip or valley rafter one size smaller than the common or jack rafters. This will create a vent space along the top of the hip or valley rafter that can be used to supply ventilation air to the jack rafters (Figure 2-58).

FIGURE 2-56 Soffit Vents.

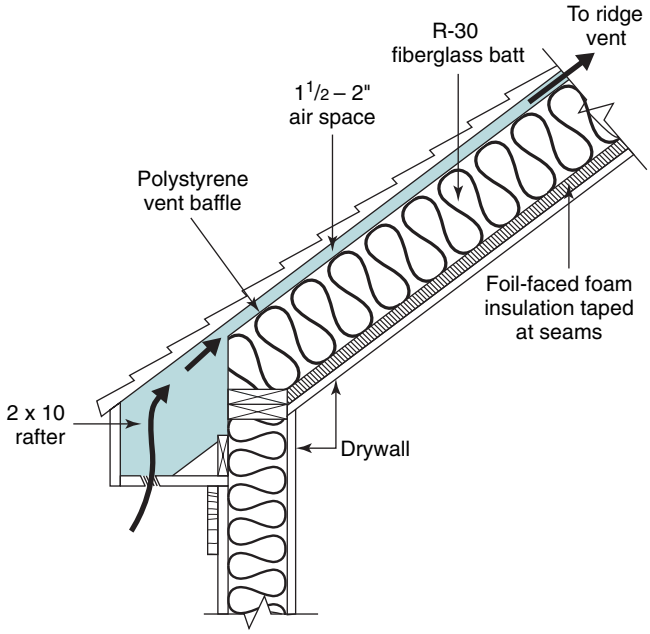


Place soffit vents close to the fascia for best performance. With high levels of insulation, a raised-top plate (left) or raised-heel truss (right) are recommended to allow full insulation at the plate area. With a raised top plate, use steel strap ties or similar connectors to securely anchor the rafters to the joists.

Skylights. Localized hot spots such as skylights can also lead to ice dams below, due to blocked ventilation as well as melt water from skylight heat loss. Notching the rafters on either side of the skylight will help maintain airflow above the skylight (Figure 2-59).

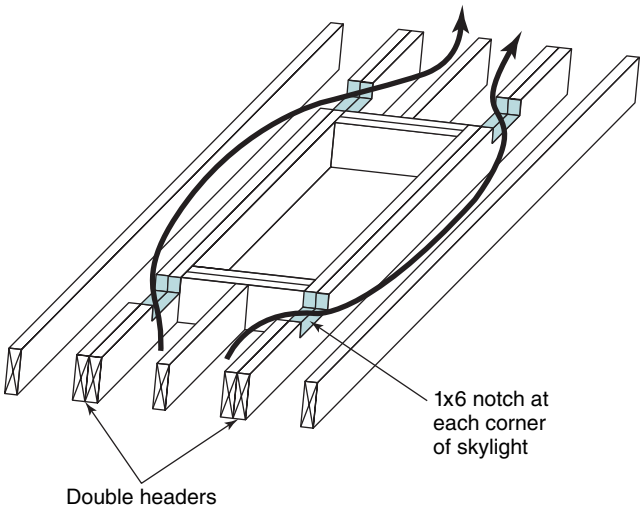
If icing is still a problem, add an interior storm window to reduce heat loss through the glass in cold weather. As a backup, it is always a good idea to seal the skylight curb and surrounding roof area with a bituminous membrane (see Figure 2-5, page 57).

FIGURE 2-57 Cathedral Ceiling Ventilation.



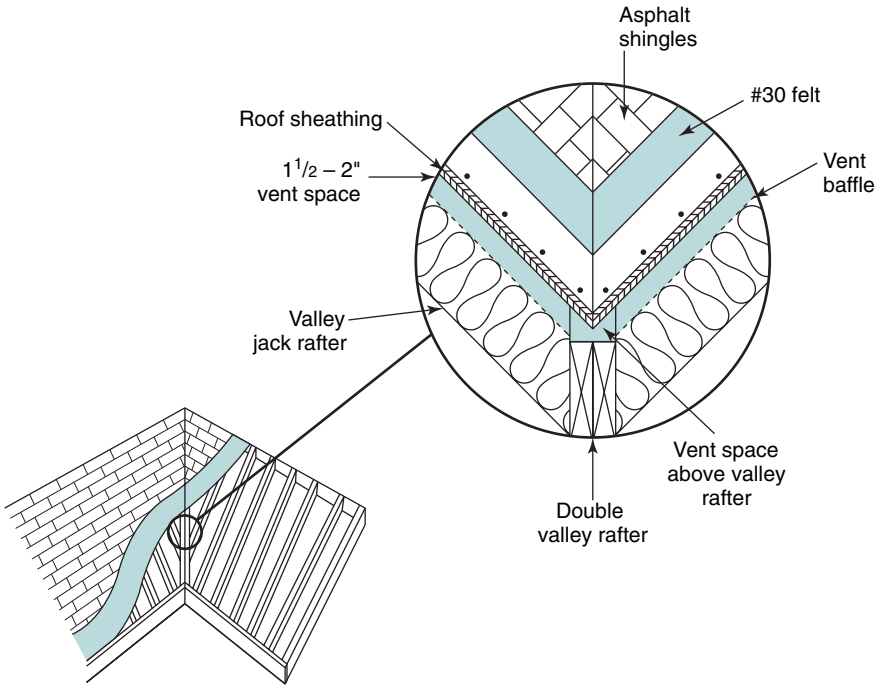
Builders have devised many methods to effectively ventilate cathedral ceilings. The key elements for success are an airtight ceiling plane and a minimum $1\frac{1}{2}$ inch free vent space from soffit to ridge.

FIGURE 2-59 Venting Around Skylights in Cathedral Ceilings.



Notching the tops of the rafters on either side of a skylight will help maintain airflow to the roof area above the skylight.

FIGURE 2-58 Ventilating Cathedral Ceiling Hips and Valleys.



To ventilate the rafter bays between hip or valley jacks, use a double or triple hip or valley rafter one size smaller than the common or jack rafters. The space left above the hip or valley rafter provides an air inlet for hips or an air inlet for valleys.

RESOURCES

Manufacturers

Asphalt Shingles

Atlas Roofing Corp.
www.atlasroofing.com
Fiberglass and organic felt shingles

Certainteed Roofing
www.certainteed.com
Fiberglass shingles

Elk Premium Building Products
www.elkcorp.com
Fiberglass shingles

GAF Materials Corp.
www.gaf.com
Fiberglass shingles

Georgia-Pacific Corp.
www.gp.com/build
Fiberglass and organic felt shingles

IKO
www.iko.com
Fiberglass and organic felt shingles

Owens Corning
www.owenscorning.com
Fiberglass shingles

Tamko Roofing Products
www.tamko.com
Fiberglass and organic felt shingles

Concrete Roof Tiles

Bartile Roofs
www.bartile.com

Eagle Roofing Products
www.eagleroofing.com

Entegra Roof Tile
www.entegra.com

MonierLifetile
www.monierlifetile.com

Vande Hey-Raleigh
www.vhr-roof-tile.com

Westile
www.westile.com

Clay Roof Tiles

Altusa, Clay Forever LLC
www.altusa.com

Ludowici Roof Tile
www.ludowici.com

MCA Clay Tile
www.mca-tile.com

U.S. Tile Co.
www.ustile.com

Tile Fasteners and Adhesives

Dow Building Products
www.dow.com/buildingproducts
Tile Bond polyurethane foam tile adhesive

Fomo Products
www.fomo.com
Handi-Stick polyurethane foam tile adhesive

Newport Fastener
www.newportfastener.com
Twisted wire systems, hurricane clips, nose clips, and the Tyle-Tye TileNail

OSI Sealants
www.osisealants.com
RT 600 synthetic rubber tile adhesive

Polyfoam Products
www.polyfoam.cc
Polyset and Polyset One polyurethane foam tile adhesives

Wire works, Inc.
www.wireworks-inc.com
Tile hooks, hook nails, copper and stainless-steel nails

Metal Roofing

Classic Products
www.classicroof.com
Modular metal shingle panels and standing seam panels

Decra Roofing Systems
www.decra.com
Modular metal shingle, tile, and shake panels

Dura-Lok Roofing Systems
www.duraloc.com
Modular metal roofing shingles with granular coating

Fabral
www.fabral.com
Exposed fastener and concealed clip metal roofing panels

Gerard Roofing Technologies
www.gerardusa.com
Modular metal shake and tile panels with granular coating

Met-Tile
www.met-tile.com
Modular metal roof-tile panels

Atas International
www.atas.com
Modular metal shingle, tile, and standing-seam panels

Custom-Bilt Metals
www.custombiltmetals.com
Modular metal shakes and standing seam panels

Low-Slope Roofing Membranes

Duradek
www.duradek.com
Vinyl roofing and walkable deck membrane

Firestone
www.firestonebpe.com
RubberGard EPDM residential roofing system

GenFlex Roofing Systems
www.genflex.com
Peel-and-stick TPO membrane

Hyload, Inc.
www.hyload.com
Kwik-Ply self-adhering polyester and coal-tar roofing membrane

Ridge Vents

Air Vent/A Gibraltar Company
www.airvent.com
A complete line of roof ventilation products, including shingle-over and exposed-ridge vents with exterior wind baffles and internal weather filters. Also soffit and drip edge vents and passive and powered attic turbine-type vents.

Benjamin Obdyke
www.benjaminobdyke.com
Shingle-over ridge vents. Low-profile Roll Vent uses nylon-matrix. Extractor vent is molded polypropylene with internal and external baffles.

Cor-A-Vent
www.cor-a-vent.com
Shingle-over low-profile ridge vents, including Cor-a-vent, Fold-a-vent, and X-5 ridge vent, designed for extreme weather. Corrugated core.

GAF Materials Corp.
www.gaf.com
Cobra vent: roll-out shingle-over ridge vent with a polyester-matrix core

Mid-America Building Products
www.midamericabuilding.com
Ridge Master and Hip Master shingle-over molded plastic ridge vents with internal baffles and foam filter

Owens Corning
www.owenscorning.com
VentSure corrugated polypropylene ridge vents; also passive roof vents and soffit vents

Trimline Building Products
www.trimline-products.com
Shingle-over low-profile ridge vents, Flow-Thru battens for tile roofs

Elk Premium Building Products
www.elkcorp.com
Highpoint polypropylene shingle-over ridge vents

Tamko Roofing Products
www.tamko.com
Shingle-over ridge matrix–type Roll Vent and Rapid Ridge (nail gun version) and Coolridge, which is molded polypropylene with external and internal baffles

Venting Underlayments

Benjamin Obdyke
www.benjaminobdyke.com
Cedar Breather, a $\frac{3}{8}$-in.-thick matrix-type underlayment designed to provide ventilation and drainage space under wood roofing

For More Information

Asphalt Roofing Manufacturers Association (ARMA)
www.asphaltroofing.org

Cedar Shake and Shingle Bureau
www.cedarbureau.org

Metal Roofing Alliance
www.metalroofing.com

Tile Roofing Institute
www.tileroofing.org