CONCRETE ROOFING TILES IN THE UNITED STATES

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This paper outlines the growth and development of concrete roofing tiles in the United States.

Ready and abundant sources of raw materials, coupled with increased concern for fire protection has accelerated the growth of the concrete roofing tile industry.

An overview of the U.S. concrete tile industry today is provided as is a summary of test standards and model code requirements.

In a country as large as the United States with widely differing climate zones, varying installation procedures are necessary. Conventional tile installation methods are included in an additional section.

HISTORY

The historical abundance of both wood and petroleum resources in North America is probably responsible for the lowest per capita use of roofing tiles of all industrialized countries. Diminishing supplies and rising costs of these resources have been responsible for the unparalleled growth of tile roofing, particularly concrete tile roofing, in America during the past 10 years.

Barrel-type clay tiles are the oldest type of manufactured roofing materials known to man. The Romans, Greeks, and the Chinese before them learned how to press wet clay into their thighs or into wooden molds and bake the clay under the sun or in ovens heated by steam or burning wood to form a hard, durable finish. Tile roofs installed centuries ago still protect ancient buildings standing today. In Europe, Asia, South America, Australia, New Zealand and Africa, pitched roofs are of either clay or concrete tiles.

In the early 1900s when Portland cement became commercially available, European farmers and builders began producing crude flat or rounded concrete tiles in wooden molds to replace the more expensive and traditional clay or natural slate roofing materials. The availability of electricity and improved production methods provided the opportunity to produce a better concrete tile in large quantities.

Probably the most important development in the concrete tile manufacturing process was the high-pressure extrusion process. This technique involves the continuous extrusion of concrete into steel or aluminum molds under high pressure. The resulting product is extremely dense, producing greater strength and minimizing water absorbency. This type of tile exhibits greater durability in both warm and cold climates. The development and use of concrete roofing tiles in America paralleled that of Europe until several independent factors combined to virtually stop its use. The primary factors were:

1. Introduction of economical plywood roof sheathing.
2. Development of low-cost asphalt shingle roofing which could be quickly installed with minimal labor.
3. A method of producing split-faced, taper-split shakes and sawn shingles made from virgin red cedar stumpage, formerly thought of as waste. Being light in weight, the shakes and shingles were easy to transport and install. Additionally, the wood shakes and shingles presented a rugged, attractive appearance.
4. Construction in America rose at a pace far greater than tile manufacturing facilities could handle.

A few concrete tile manufacturers continued to produce concrete tile in limited quantities. In 1962, a "state-of-the-art" high-pressure extrusion machine made in England was installed in Fremont, Calif. In 1966, faster equipment produced in Australia was placed in a factory located in Corona, Calif. The economical production of much higher quality concrete tiles at three to four times the speed formerly obtainable met the rapidly growing demand. Laws requiring fire-retardant roofs created a growing market for concrete tiles. Homeowners and developers found concrete tile roofs aesthetically pleasing, permanent and fire-safe.

Today, concrete roofing tiles are manufactured on improved equipment which can produce tiles at a rate exceeding two per second. Production facilities are scattered nationwide in more than 35 separate locations. Figure 1 shows the location of major manufacturing facilities.

MANUFACTURING METHODS

Concrete roofing tile is composed of Portland cement, sand, iron oxide pigments and water in designed proportions which are mixed and usually extruded or compacted in individual molds to form the tile. Tiles with surface-applied colors usually do not contain iron oxide in the body. Tiles are then cured, stripped from molds and packaged for shipment. Various color treatments are used, ranging from color throughout the entire tile to cementitious color surface coatings. Figure 2 shows a schematic layout of a modern concrete tile plant.

Concrete tiles may be classified in two major generic groups: interlocking and noninterlocking. Interlocking tiles, as the name implies, have an interlocking side lap which provides a channel for drainage from the side joint.

These two generic groups are further divided into two subgroups broadly described as barrel or roll tile, and flat or slate tile.

BUILDING CODES AND STANDARDS

Most jurisdictions across the United States adopt the Building Code for regulating building construction, for greater public safety and for building uniformity. The code is founded on broad-based performance principles that organic nonperforated felts conforming to ASTM D 226 for use over solid sheathing. Other specially made reinforced underlayments are used for installation under spaced sheathing. Roof slopes exceeding 3:12 require either two layers of Type 15 felt laid up shingle fashion or one layer of Type 30 felt. The felts are secured to the decking by sprinkle nailing. In geographic locations defined by building officials as one with frequent roof-ice buildup, two layers of Type 15 felt are applied shingle fashion and solid-mopped together with an approved asphaltic cement. This treatment extends from the fascia up the plane of the roof to a point 24-inches inside the exterior wall line of the building. All head and side laps on the underlayment must be a minimum 6-inches. It is important at all valley locations to interlace the felts entering the valley from each side, creating a double layer of underlayment extending a minimum of 12-inches either side of the valley center line.

Size, Weight and Loading

Concrete roofing tiles generally provide about a 1-square-foot coverage per tile. The installed weight per 100 square feet varies from 800 to 1200 pounds depending on tile type, head lap and mode of installation.

Nails and Fasteners

Nails and fasteners used to secure tile must be of corrosion-resistant materials such as galvanized steel, stainless steel or copper. Chapter 32 of the Uniform Building Code requires No. 11 gauge corrosion-resistant nails for concrete tiles. Nails must be of sufficient length to penetrate ¾-inch into the sheathing or through the sheathing thickness, whichever is less. Special clips are available for securing the butt end of tiles when they are installed in high wind areas.

Battens

Battens, where required over solidly sheathed roofs, are a minimum 1-inch by 2-inch wood attached to the deck at not more than 24-inch centers using approved corrosion-resistant fasteners. Battens must be installed in a manner to provide roof drainage. This is usually accomplished with shims beneath battens, redwood counterbattens or ½-inch-wide spaces between the batten ends every 4 feet.

Ridge and Hip Nailers

The height of the ridge board and hip rafter may not be adequate to satisfactorily fix hip and ridge trim tile. Wood nailers of the correct thickness are used in these locations to achieve the proper height. Typical hip details are included in Figure 3.

Valleys

Extreme care must be exercised in the installation of valley metal. This is one of the most vulnerable areas for leakage. The Uniform Building Code requires a minimum valley metal to be No. 28 gauge corrosion-resistant metal. Two types of valley flashings are commonly used. The closed type has a splash diverter rib 1-inch high located along the valley center line. The open type has two such ribs 4 inches apart equally spaced and extending along the valley center line. In each case the metal extends at least 11 inches on each side of the center line. Longitudinal edges are turned in not less than 30 degrees and are of minimum ½-inch height to prevent water overflow. End laps are at least 6 inches. The open valley flashing is preferred where leaves or other vegetation may fall on the roof. Typical valley details appear in Figure 3.

Gutters

The simple eave drain is the most commonly used system. The tile must be installed with the correct eave edge overhang to drain into the gutter. Other gutters such as the hidden box are also available.

Flashing

It is important that roof projections such as vent stacks, etc. are properly flashed. Additional blocking or framing is usually required around these openings to adequately support the tiles. Closure of tile at wall abutments is usually achieved with pan flashing, counterflashing or a combination of both. The most common of these is the pan flashing, which is secured to the wall with a cap or Z-bar flashing. Flashing is usually made of lead, copper or other approved materials formed to match the contour of the tile.

Roof Layout

Care must be exercised in the initial layout of the battens, spaced sheathing or chalk lines to ensure proper alignment. Most manufacturers provide detailed instructions to assist in achieving proper layout.

Other Trades

Tile installation does not normally begin until other trades are made aware of the precautions required when walking on tile.

Cutting Tiles

When tiles are to be cut, the desired break line should be marked or scored on the tile with the tile in place. The tile can then be accurately cut to this line using tile saws or power saws. Several passes of the saw are preferred to prevent breakage and chipping.

CONCLUSION

Ready and abundant sources of raw materials, coupled with increased concern for fire protection has accelerated the growth of the concrete roofing tile industry. In new construction, the total share of the American steel roofing market enjoyed by concrete tile is estimated to be less than 7 percent. It is in excess of 50 percent of the market in southern California and approximately 30 percent of the market in the sun belt states. If the current acceptance of concrete tile continues, by the year 2000 it could account for more than 25 percent of all roofing material sold nationally for new construction.

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make possible the use of new materials and new construction systems. The Uniform Building Code is the most widely used of the model codes in the United States. It was first enacted by the International Conference of Building Officials at the sixth annual business meeting held in Phoenix, Ariz., in October 1927. Revised editions have been published at approximate three-year intervals. Changes to the code are proposed each year and published in supplements in a form permitting ready adoption by local communities. These changes are carefully reviewed in public hearings by experts in the fields of building construction and fire and human life safety. Changes recommended by the standing committees are voted on by members representing building jurisdictions at the annual meeting.

While new editions of the codes are published every three years, they are also amended annually by a code change process involving building officials and other interested parties, including representatives of the construction industry and the design profession. This truly is a sign of a performance-oriented code.

In 1931, the Conference recognized that it would be desirable to create a Research Committee to evaluate alternate products and methods of construction which are not fully provided for in the Uniform Building Code. Initially, the Conference actively participated in conducting tests on alternate materials and in the development of test programs for materials submitted for evaluation. In 1940, the bylaws of the Conference were revised and the Research Committee was charged with the responsibility of evaluating test reports submitted by recognized independent testing laboratories. Effective October 1984, the Research Committee has been renamed the Evaluation Committee and charged with the responsibility of monitoring evaluation reports and issuing acceptance criteria.

A recommended standard for concrete tiles was first adopted by the ICBO membership at its annual meeting in September 1963. Based on the membership action, U.B.C. Standard No. 32-12-64 was included in the book of standards. The 1964 edition of the Uniform Building Code included specific reference to concrete roof tiles and required that they be installed in a manner similar to clay tiles. The code required projected anchor lugs at the bottom of the tiles to be held in position by 1-inch by 2-inch decay-resistance-treated wood stripping. Two layers of 15-pound felt, or a single layer of 30-pound felt, were required to be installed over the sheathing. Although not specifically stated, it appears that the code envisaged installation of concrete tiles only on solid sheathing. Concrete tiles were required to be fastened to the decking with No. 14 gauge copper or No. 14 gauge corrosion-resistant nails long enough to penetrate ¾-inch into the sheathing or through the thickness of the sheathing, whichever was less. U.B.C. Standard No. 32-12-64 required that representative samples of the tile be subjected to a strength and water absorption test. This standard has remained virtually unchanged.

The 1970 edition of the Uniform Building Code required concrete tiles to be installed with No. 11 gauge corrosion-resistant nails instead of No. 14 gauge nails. Also, concrete tiles with projecting anchor lugs were allowed to be installed with untreated 1-inch by 2-inch wood battens. In the 1970 code, an Exception was also added to Section 3203(c)5 entitled "Nails." The Exception read: "Approved tiles of clay or concrete designed to be held in place by lugs engaging battens may be installed in accordance with their approvals."

Chapter 32 of the code was entirely revised in the 1976 edition. A table for roof covering application (Table No. 32-B) was added that specified that all tiles, flat or curved, were to be installed with a minimum of two fasteners per tile or in accordance with Section 3203(d) 3 F.

Further revisions were adopted and included in the 1979 edition of the code. They allowed interlocking tiles with projecting anchor lugs to be installed over spaced sheathing boards, or to be directly nailed to solid roof sheathing. Flashing, fastening and other requirements for tiles, however, remained unchanged. In the 1982 edition of the code, a revision to Table No. 32-B was included delineating separate fastening requirements for interlocking and noninterlocking tiles. The 1984 Accumulated Supplement to the Uniform Building Code and related standards contains a revised version of U.B.C. Standard No. 32-12, which includes amended test procedures and requires more detailed information in test reports.

Effective Aug. 1, 1977, the ICBO Research Committee adopted an Acceptance Criteria for Special Roofing Systems, dated January 1977. In addition to strength and water-absorption tests, the criteria require wind-resistance, wind-driven rain, uplift-bend, permeability and freeze-thaw tests for concrete tiles.

INSTALLATION

General

To ensure proper fit and appearance, each tile is aligned so that horizontal joints are parallel to the eave and vertical joints are at right angles. Generally, a 2-inch head lap is permitted where the tile is installed over solid sheathing with an approved underlayment, and every tile is nailed. A minimum 3-inch head lap is required in all other installations. The side lap on most concrete tiles is only marginally adjustable, allowing a maximum ¹⁄₁₆-inch movement. Care is taken to remove all foreign material from the interlocking ribs and grooves to ensure correct clearance and adequate drainage. Tiles installed at hip and valley locations are cut to match the angle of the hip or valley and secured in a manner that will maintain the watertight integrity of the junction.

Roof Slope

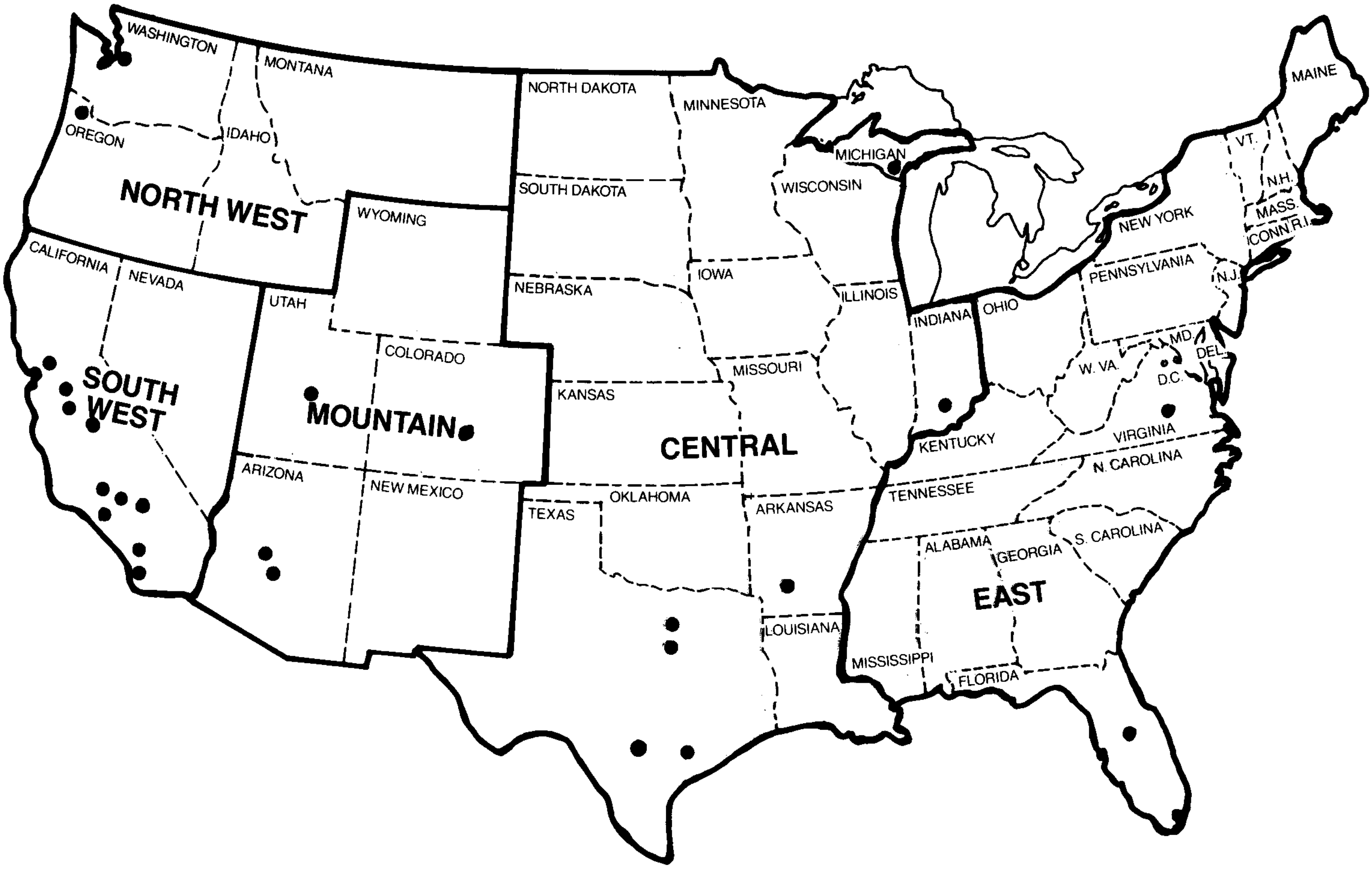
Concrete tiles are not designed for use in installations having a roof slope less than 3:12. If installed below this slope, the tiles are considered decorative and must be installed only with the approval of the building official having jurisdiction over an approved roofing.

Roof Deck

Concrete roof tiles are installed over either solid or spaced sheathing of sufficient thickness to carry the applied roof loads. Solid sheathing usually consists of plywood or tongue-and-groove decking. Spaced sheathing consists of 1-inch by 6-inch boards, spaced to support roof design loads and to provide the specified head lap of the tile, but not exceeding 13 inches on center. The roof deck in all instances must conform with the appropriate model building code.

Underlayment

Underlayments may be either rigid or rolled type installed in accordance with the manufacturer's instructions and the code. Roll underlayments are usually asphalt-saturated



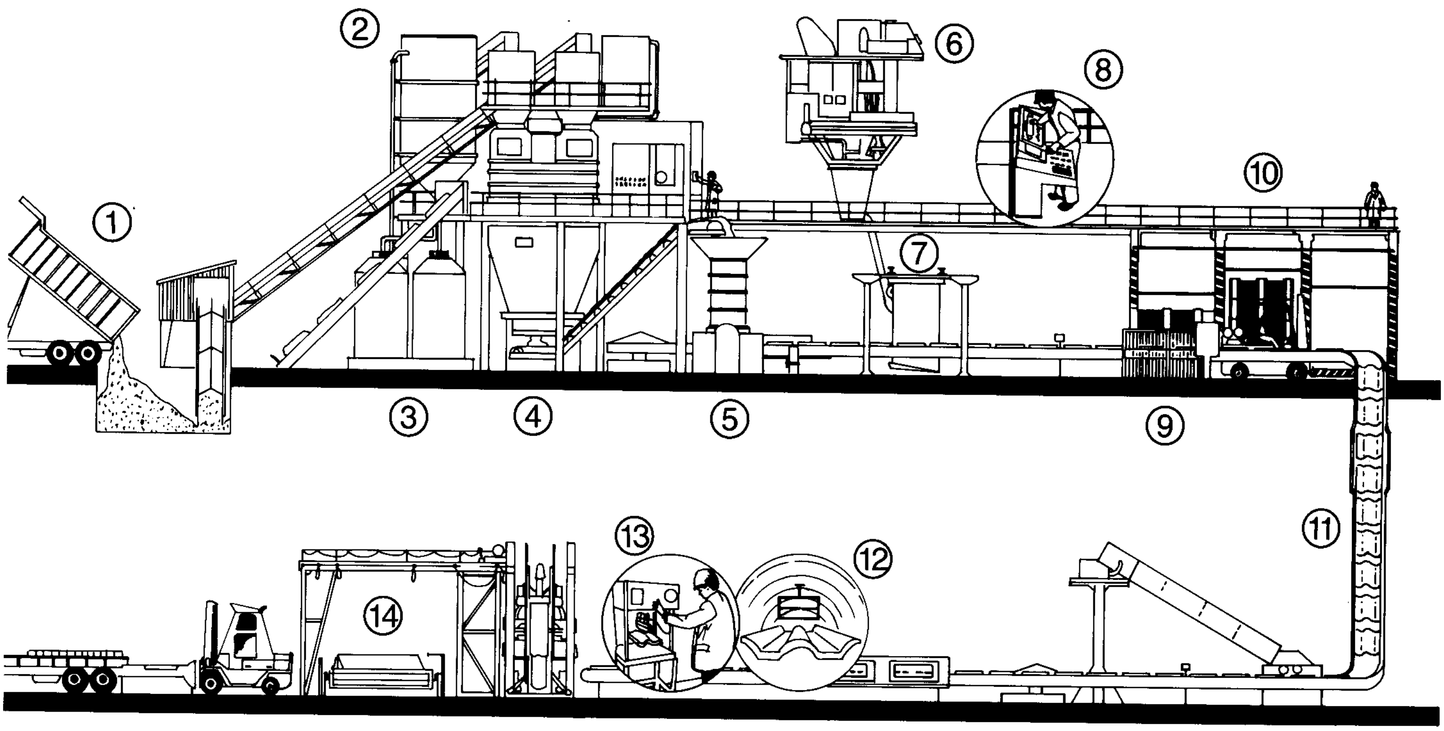
U.S. CONCRETE TILE PRODUCTION AREAS

• MANUFACTURING LOCATIONS.

TILE PRODUCTION BY REGION

AREA	PLANT DESCRIPTION
NORTHWEST REGION	2 MAJOR PLANTS
SOUTHWEST REGION	12 MAJOR 3 MINOR PLANTS
MOUNTAIN REGION	4 MAJOR
CENTRAL REGION	4 MAJOR 1 MINOR PLANT
EASTERN REGION	4 MAJOR 10 MINOR PLANTS

Figure 1



THE MODERN CONCRETE TILE MANUFACTURING PLANT.

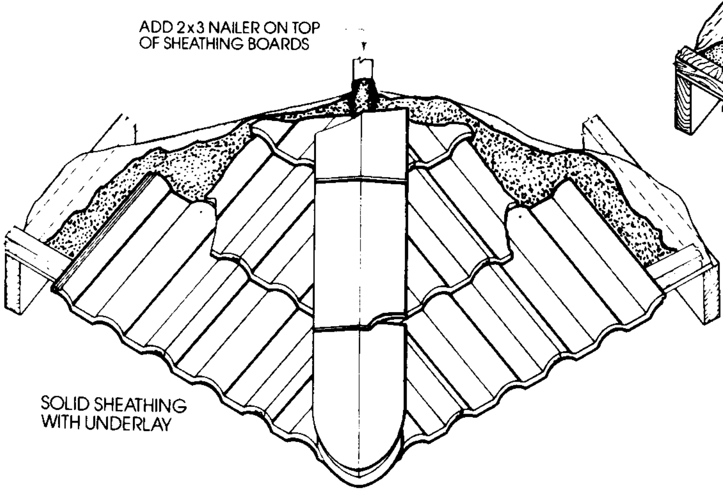
1. AGGREGATE STORE	Sand is received, processed and fed to the weigh batchers at the mixing area.
2. CEMENT STORE	Portland Cement is received, stored and fed to the weigh batchers at the mixing area.
3. OXIDE MIXING	Coloring oxides are mixed in slurry form for coloring tile.
4. MIXING PLANT	Cement, aggregates, water, additives and oxide are mixed in accurate proportions.
5. EXTRUSION MACHINE	The extrusion machine extrudes the mixture onto the mold, using high pressure.
6. SLURRY MIXER	Coatings are prepared for coloring the tile.
7. SLURRY APPLICATOR	Applies prepared slurry coating to the tile.
8. CONTROL STATION	Functions of the plant and process are monitored and controlled centrally.
9. TILE RACKING	Finished, uncured tile and molds are assembled in racks for transport to the cure area. At the same time cured tile is taken from racks and returned to the circuit.
10. CURING AREA	Tile is cured under controlled conditions to ensure maximum strength.
11. SEPARATING AREA	Tile is removed from molds. The molds returns to receive new tile and tile proceeds to finishing area.
12. FINISH AREA	Tile is coated to minimize efflorescence.
13. QUALITY CONTROL	All facets of production are monitored through quality control.
14. PACKAGING	Finished tile is packaged for shipment.

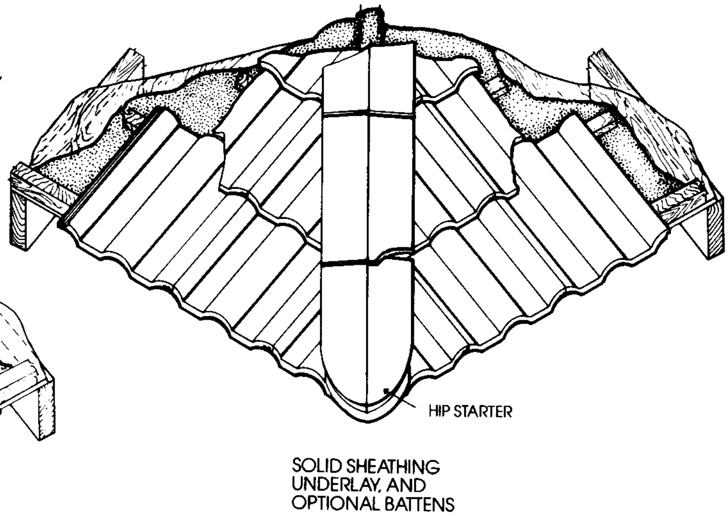
Figure 2

HIPS

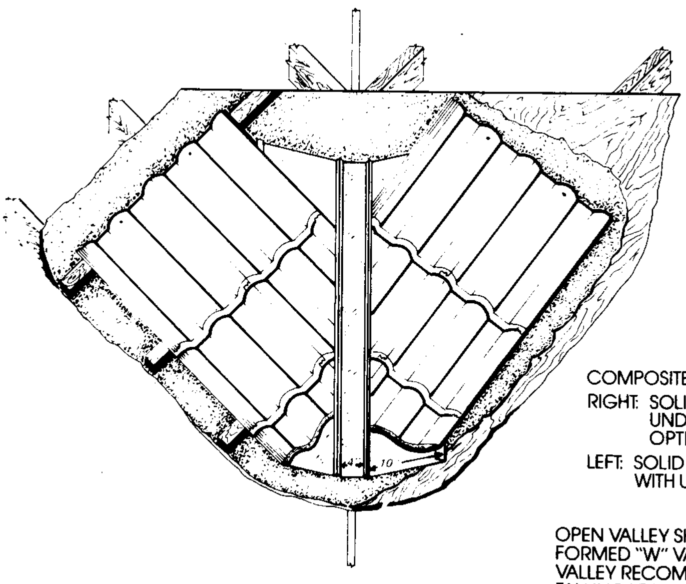
HIP ON SOLID SHEATHING

Hips are formed by cut field tiles brought close to each other and capped with hip tiles. The hip tiles are bedded in mortar, but no mortar is to be used in the overlapping joints of the hip tiles. At the foot or base of the hip a special shape "Hip Starter" is used.





VALLEYS



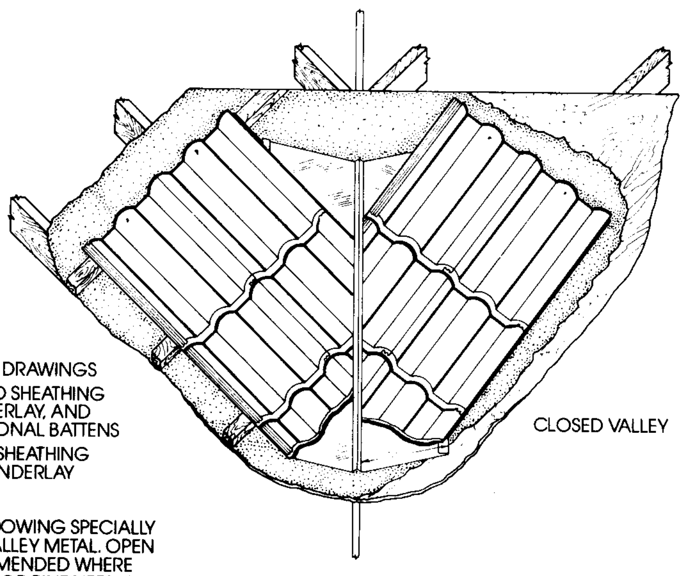


Figure 3