# Review of Residential Roofing Materials, Part I

## *A Review of Methods for the Manufacture of Residential Roofing Materials*

*by Hashem Akbari, Ronnen Levinson, and Paul Berdahl, Heat Island Group, Lawrence Berkeley National Laboratory*

According to *Western Roofing Insulation and Siding* magazine (2002), the total value of the 2002, residential roofing market in 14 western U.S. states (Alaska, Ariz., Calif., Colo., Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Wash., and Wyoming) was about $3.6 billion. We estimate that 40% ($1.4 billion) of that amount was spent in California. The lion's share of residential roofing expenditure was for fiberglass shingle, which accounted for $1.7 billion, or 47% of sales. Concrete and clay roof tile made up $0.95 billion (27%), while wood, metal, and slate roofing collectively represented another $0.55 billion (15%). The value of all other roofing projects was about $0.41 billion (11%).

We estimated roofing area market shares by assuming that roofing projects involving concrete tile, clay tile, wood shingle/shake, or slate were 50% to 100% more expensive than those using other roofing materials, such as shingle, metal, or membrane. This suggests that the roofing market area distribution is 54-58% fiberglass shingle, 8-10% concrete tile, 8-10% clay tile, 7% metal, 3% wood shake, and 3% slate.

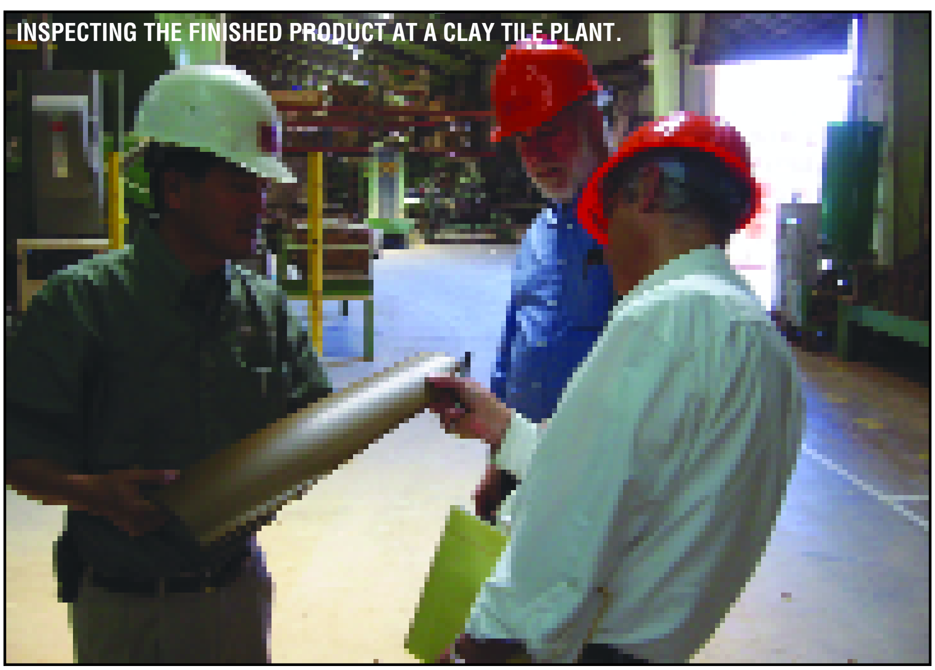
2002 Project residential roofing market in the U.S. western region[a] surveyed by *Western Roofing* (2002).

| Roofing Type | Market share by $ | | Market share by roofing area (%) | |
|---|---|---|---|---|
| | $B | % | Estimate 1 | Estimate 2 |
| Fiberglass Shingle | 1.70 | 47.2 | 53.6 | 57.5 |
| Concrete Tile | 0.50 | 13.8 | 10.4 | 8.4 |
| Clay Tile | 0.45 | 12.6 | 9.5 | 7.7 |
| Wood Shingle/Shake | 0.17 | 4.7 | 3.6 | 2.9 |
| Metal/Architectural | 0.21 | 5.9 | 6.7 | 7.2 |
| Slate | 0.17 | 4.7 | 3.6 | 2.9 |
| Other | 0.13 | 3.6 | 4.1 | 4.4 |
| SBC Modified | 0.08 | 2.1 | 2.4 | 2.6 |
| APP Modified | 0.07 | 1.9 | 2.2 | 2.3 |
| Metal/Structural | 0.07 | 1.9 | 2.2 | 2.3 |
| Cementitious | 0.04 | 1.1 | 1.2 | 1.3 |
| Organic Shingles | 0.02 | 0.5 | 0.6 | 0.6 |
| **Total** | **3.6** | **100** | **100** | **100** |

*a. The 14 states included in the U.S. western region are Alaska, Ariz., Calif., Colo., Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Wash., and Wyoming.*

The functional distribution of the steep-slope roofing market (including both residential and small-commercial buildings) was about 60% replacement, 25% new construction, and 15% repair and maintenance.

This paper examines methods for manufacturing fiberglass shingles, concrete tiles, clay tiles, and metal roofing that constitute over 80% of all roofing materials, by both expenditure and area. We have focused on these four roofing products because they are typically colored with pigmented coatings or additives. We do not discuss production of wood and slate roofing. A better understanding of the current practices for manufacturing colored roofing materials would allow us to develop cool colored materials creatively and more effectively. The paper also discusses innovative methods for increasing the solar reflectance of these roofing materials.



INSPECTING THE FINISHED PRODUCT AT A CLAY TILE PLANT.

### Methodology

We reviewed the pertinent literature for production of roofing materials and visited several roofing material manufacturing plants.

### Literature Review

The following briefly summarizes several pertinent sources of information about roofing manufacturing methods available from websites, articles, papers, patents, and books. In *The Science and Technology of Traditional and Modern Roofing Systems*, Laaly (1992) provides an overview of the production and application of various roofing materials. A website of the National Park Services (NPS 2003) also provides the historical backgrounds of several roofing materials, including asbestos-cement shingle, asphalt shingle, clay tile, composition (built-up roofing), metal, slate, and wood shingle.

The Department of Health and Human Services (DHHS 2001) and the Environmental Protection Agency


CLAY TILES ARE KILN FIRED.

(EPA 1995) have each prepared extensive documents discussing various manufacturing methods for asphalt roofing products. These focus on environmental pollution, and do not address the effects of roof reflectivity and its effects on heating-and-cooling energy use and on roof durability.

Brown (1960) and Jewett et al. (1994) detail the manufacture of colored roofing granules in chapters of 1960 and 1994 editions of *Industrial Mineral and Rocks*. Though these texts cover a wide range of technical and marketing issues related to the manufacture and production of colored granules, they provide limited information on granule coloring techniques. Joedicke (1997 and 2002) discusses this topic in greater detail.

Finally, Paris and Chusid (1997, 1999) briefly describe methods for coloring concrete products using powder, liquid, and granulated pigments. They also discuss issues related to the durability of colored concrete.

## Plant Visits

We visited a shingle plant, a metal roofing plant, and a clay tile plant in southern California; and a granule production plant and a concrete tile plant in northern California.

☗ ***Asphalt Shingle:*** Asphalt is a dark-brown-to-black cementitious material, solid or semisolid, in which the predominant constituents are naturally-occurring or petroleum-derived bitumens. It is used as a weatherproofing agent. The term asphalt shingle is generically used for both fiberglass and organic shingles. There are two grades of asphalt shingles: (1) standard, a.k.a. 3-tab; and (2) architectural, a.k.a. laminated or

(Continued on Page 56)

# Review of Residential Roofing Material, Part I

(Continued from Page 55)

dimensional. Asphalt shingles come in various colors.

*Examples:* Fiberglass shingles, commonly known as "asphalt shingles," consist of fiber mats that are coated with asphalt and then covered with granules. Granules, a.k.a. mineral granules or ceramic granules, are opaque naturally- or synthetically-colored aggregates commonly used to surface-cap sheets and shingles.

Organic shingles have a thick cellulose base that is saturated in soft asphalt. This saturation makes them heavier than fiberglass shingles, and less resistant to heat and humidity, but more durable in freezing conditions.

- ***Tile:*** Usually made of concrete or clay. Concrete tile is a combination of sand, cement, and water; the water fraction depends on the manufacturing process. Concrete tiles are either air-cured or auto-claved. Color is added to the surface of the tile with a slurry coating process, or added to the mixture during the manufacturing process.

Clay tile is a combination of various clays and water. Color is added to the surface of the tile with a slurry coating process before the tile is kiln-fired.

- ***Metal:*** Metal roofs can be classified as architectural or structural.

*Examples:* Architectural (hydrokinetic-watershedding) standing-seam roof systems are typically used on steep slopes with relatively short panel lengths. They usually do not

FIBERGLASS ENTERING THE SHINGLE PRODUCTION MACHINERY.

have sealant in the seam because they are designed to shed water rapidly. They do not provide structural capacity or load resistance, and their installation is less labor-intensive because they have a solid substrate platform that makes installation easier..

Structural (hydrostatic-watershedding) standing-seam roof systems are versatile metal panel systems that can be used on both steep- and low-slope roofs and are designed to be water-resistant. Most structural standing-seam systems include a factory-applied sealant in the standing seams to help ensure water tightness. These panel systems provide structural capacity and load resistance.

## Manufacturing Methods - Shingles

- *Production of colored granules.* Granules cover over 97% of the surface of a typical asphalt-soaked fiberglass shingle. Granules are applied to asphalt shingles for several reasons, including UV protection, coloration, ballasting, impact resistance, and fire resistance.

Granule manufacturing plants are typically sited near a quarry of suitable base rocks, including andesite, coal slag, diabase, metabasalt, nephaline syenite, quartzite, rhyodacite, rhyolite, and/or river gravel. The essential characteristics of the base rock include: opacity to ultraviolet light, to protect the asphalt from ultraviolet damage; chemical and physical inertness, to provide resistance to acid rain, leaching, freeze/thaw, wet/dry cycling, oxidation and rusting; low porosity, to improve physical strength, binding between coating and rock, and efficiency with which the pigment coating covers the surface; and resistance to high firing temperatures. Other necessary characteristics include moderate hardness, to remain intact during the granule coloring process; moderate density (to weight the shingle against wind lift); uniformity, and crush equidimensionality (to prevent directional embedment in the shingle manufacturing process, which changes shingle appearance).

In a roofing-granule manufacturing plant, rocks blasted from quarries are crushed in several stages to reduce the rock to granule-size aggregate (0.5 to 2 mm). In this process, the larger aggregates are recycled to the crushing system and the smaller debris is separated for other usage.

Once the granules are milled to the right size, they are transferred to the coloring plant. In the coloring plant, in a continuous process they are mixed with a semi-ceramic color coating. The coating is a mix of color pigments in a sodium silicate, hydrated kaolin clay, and water. The preheated granules are mixed and tumbled with coating sufficient to cover the surface. The wet coated granules are then transferred to a rotary kiln where they are gradually heated to 250-550°C (500-1,000°F). This dehydrates and polymerizes the coating, forming an insoluble pigmented ceramic layer. The granule is then gradually cooled in a rotary cooler by sprayed water and circulated air. Finally, the pigmented granules are coated with mineral oil to control dust and to improve asphalt adhesion. The mineral oil typically evaporates within a few months.

The pigments used for colored granules must have certain properties, including stability at high temperature, chemical inertness, ease of dispersion, color consistency, weather stability, non-toxicity, and low cost. Common pigments used in roofing granules include titanium dioxide (white), zinc ferrite (yellow), red iron oxides, carbon black, chrome oxide (green), and ultramarine (blue). Typically, 2.3-2.7 kg (5-6 lb.) of pigment per ton of granules are required to create a single-layer coating. Multiple coatings are needed to increase pigment loading. Some granule manufacturing plants have parallel coloring lines that can be used in series to apply multiple layers of coatings on granules. The granules (both colored and uncolored) are transported to shingle manufacturing companies by road and rail.

*(Editor's Note: Next issue, we'll present Part II of this article.)*