

# ROOFING TECHNOLOGY IN THE FAR EAST

MICHIO KOIKE

Research Laboratory of Engineering Materials  
Tokyo Institute of Technology  
Tokyo, Japan

## ABSTRACT

The paper deals with the present state-of-the-art of roofing technology, including a brief historical review and future trends, in the Far East.

In Japan, the market share of roof coverings for pitched roofs is as follows: clay and pressed cement tile, 55 percent; metal sheet, 25 percent and asbestos cement shingle and sheet, 20 percent. The market share for membrane systems for flat roofs is: built-up system using roofing felt of synthetic fiber base, 55-60 percent; sheet-applied, 20-25 percent which consists of rubber sheet, 75 percent, PVC sheet, 20 percent and modified bituminous sheet, 5 percent; liquid-applied system, mainly two-part polyurethane, 15-20 percent. Among these, architects and engineers have relied most on the built-up system.

In other countries, several types of sheet-applied systems have been introduced from the United States and Europe in recent years, in addition to the conventional built-up system used before. They are rubber and plastic sheets, polyethylene film laminated with a thick self-adhesive layer, and sheets of modified bitumen for the torch method. They might be used depending on the countries where architects or engineers studied or where the owners or contractors live.

The term "Far East" is rather vague. I will regard it as the whole area from India to Japan including Oceania, where the climate ranges from frigid to tropical. In the old days, people built their houses and roofed with readily available materials: wood, bark, grass or leaves in areas near the forest or wet plains; stone, brick, clay or mud in the dry plains; palm, or other leaves, in the tropics; and animal skins or textiles by nomadic people.

Contact between different cultures through trade, immigration, conquest and colonization gradually introduced building materials and systems from other areas. Industrialization during the 19th century also changed building materials and, consequently, building construction itself. Corrugated galvanized steel and asbestos cement sheets have been widely used for roofing on pitched roofs, and bituminous materials have covered flat or low pitched roofs constructed of reinforced concrete.

There is great variation in the development of these countries, from highly industrialized to under-developed. Economic conditions also differ greatly. Therefore, there is great variation in building materials and systems in the Far East.

## COUNTRIES IN THE NORTHERN AREA

### China

China is a very large country, extending from longitude 74-135 degrees east and latitude 18-53 degrees north, and nearly 1 billion people live there. Almost every type of traditional building material and system originated in China during its very long history. It is said that clay roof tiles were used in the 12th century B.C. They are still the most popular materials for pitched roofs. Wood shingles and thatch are still used in rural areas. Some 40 million people still enjoy life in cave dwellings, dug horizontally from rectangular pits in dry soil.

Roof waterproofing systems are usually used in the urban area. Built-up membrane systems consist of two layers of felts, either fully bonded or spot-bonded using perforated felt in the first layer. In the latter system, improved asphalt felt is used in the second layer. Both systems are expected to last 15 years if properly constructed. They also use rectangular concrete slabs with joints filled with bituminous sealant.

There is great demand for building materials in China, and the shortage of roof waterproofing materials is a major problem. New products made of modified asphalt and elastomeric materials for sheet and liquid application are greatly desired.

### Japan

The thatched roof is the oldest type in Japan, followed by wood shingles and bark. Clay roof tiles were introduced from Korea along with Buddhism in the sixth century. At first, their use was strictly limited to Buddhist temples and buildings and residences for the emperor and the highest aristocrats. Later, clay tiles were gradually permitted for houses. Finally, their use was required in the urban area of Edo, the former name of Tokyo, to reduce fire hazards.

Roof tiles, including pressed cement ones, have the highest market share, about 55 percent. They are used in the western area more than in the east and north. Initially they were placed on wood shingle substrates using bedding clay and lime mastic. But such roofs were so heavy that a strong earthquake often destroyed the houses. Now, they are placed on an underlayer of roofing felt with the projections behind the tiles hung on battens spaced at the working length of the tile. Roof tiles are nailed or fixed with wire at two courses and two rows along the perimeter of a roof, its ridge, and every three or four courses. Many people like Japanese-style smoked or glazed pantile, but some prefer the mission, or Spanish, style. Low-cost pressed cement tiles coated with acrylic paint replace clay tiles in houses for average- or low-income families.

In addition to corrugated asbestos cement sheets introduced about a century ago, American colonial shingles were introduced about two decades ago and have been used mostly for houses in the metropolitan areas. Corrugated sheets are still used on factories, warehouses, roofs of railway platforms and so on. Asbestos cement roofing materials have a market share of about 20 percent.

Galvanized steel has been supplied in either corrugated or flat sheets since it appeared in the market. Flat sheets were usually applied with a Dutch-lap for long time. The use of galvanized steel has expanded greatly since the appearance of products that are pre-painted and supplied in long rolls. Now they are applied mainly with several types of batten or standing seams. Ninety percent of houses in Hokkaido, the northernmost area in Japan which is very cold and snowy, are covered with standing seam galvanized steel. Steel roof decks with various profiles are used in houses or commercial buildings because they don't need short-spaced purlins or supporting beams, and because they can be used on flat or low pitched roofs.

The membrane waterproofing system was imported from the United States at the beginning of the 20th century. The first modern manufacturer started producing roll roofing felts in 1913. In the 70 years that have passed, many types of membrane systems have been used in Japan: hot-applied and cold-applied built-up, sheet-applied and liquid-applied. The materials for membranes on flat or pitched roofs are prescribed in the Japanese Industrial Standards. The Japanese Architectural Standard Specifications (JASS) has established a Code of Practices with specifications for construction.

The JASS shows about 40 kinds of specifications for roof membranes classified by systems: built-up, sheet-applied, liquid-applied; types of roof decks; and kinds of materials and grades. But an astonishing number of membrane systems are listed in cost pages of a magazine for specialists by company, substrate and grade, with or without insulation and their type, thickness and position in the system. Besides manufacturers' brands, a large number of products are supplied by corporations, suppliers, and waterproofing contractors as their own brands. The result is a flood of systems on the market.

Built-up membrane systems with improved roofing felts of non-woven synthetic fiber base are the most used by architects and engineers, regardless of the type of substrate and with or without protective toppings. Systems with vulcanized rubber sheet are used without toppings regardless of the type of substrate. PVC sheet is applied only on poured concrete and without toppings. Liquid-applied two-part polyurethane is used mainly for repairing membranes. The market share of membrane systems is roughly estimated as follows: built-up, 55-60 percent; sheet-applied, 20-25 percent (rubber sheets, 75 percent, PVC, 20 percent and modified asphalt sheets, 5 percent; and liquid-applied polyurethane, 15-20 percent. In addition, polyethylene, EVA or CSPE sheets have been introduced, but are little used.

To help architects and engineers select membrane systems, the systems should be ranked based on performance requirements and criteria such as the assessment method of the UEAtc. A sub-committee of the Architectural Institute of Japan is now developing assessment methods.

It is noteworthy that rainwater leaks in roof waterproofing systems have gradually been reduced to about 20

percent of all leak problems. The other 80 percent occur in external walls including around windows. Based on field experience with many kinds of buildings over the years, it might be possible in 10 years or so to guarantee membrane systems.

### South Korea

South Korea has rapidly industrialized within the last decade and produces almost all fundamental materials, machines and equipment. Construction is very active in preparation for the Olympics in 1988.

In addition to traditional clay roofing tiles, new roofing materials such as galvanized steel, asbestos cement sheet, coated pressed cement tiles and so on are produced and widely used in both urban and rural areas. The manner of their use is similar to Japan's.

Asphaltic built-up membrane roof waterproofing systems are very popular and widely used. Self-adhesive polyethylene sheet is produced in Korea by a licensee. Other elastomeric sheet- and liquid-applied systems are in limited use. These new systems are not necessarily satisfactory. In concrete houses, there is a recent trend to construct pitched, reinforced concrete roof slabs waterproofed with liquid-applied membranes or waterproofing mortar and traditional Korean or Spanish roof tiles placed with bedding mortar.

## COUNTRIES IN THE TROPICAL ZONE

### Singapore

Singapore is the most prominent city in the tropical zone. Almost all roofing materials in the world are available here because Singapore is a free port, as is Hong Kong.

Most pitched roofs of houses are covered with clay or cement roof tiles, which usually withstand tropical weather conditions well. But fading and erosion of the glazed tile coating are experienced within 10 years. This problem is also reported in coastal areas of Australia. Corrugated galvanized steel and asbestos cement sheets have been used in houses in the outer urban area for generations. These houses are now being replaced rapidly with high rise apartments and condominiums because of the country's development.

For the past two decades, since metal cladding was introduced, most pitched roofs on industrial, warehouse and storage buildings have been covered with long-run metal cladding. Galvanized steel cladding stands up well for 10 to 15 years.

Most of the traditional asphaltic membranes, with or without toppings, often leaked before the 10-year guarantee expired. Sheet- and liquid-applied membrane systems have been imported since 1970. These include elastomeric sheets, polyethylene sheets, and rubberized asphalt sheets reinforced with either glass or polyester fabric. They feature easy installation and durable performance. A liquid-applied, low-cost system is used mostly on public housing projects. It consists of an asphaltic membrane made from asphalt emulsion with a layer of fabric, and precast concrete slabs (600 × 1200mm) placed above the membranes with a gap of about 23cm between them.

The usual cement toppings are mortar slabs, often cast in-situ, 300-750mm square, 25-38mm thick. V-joints are filled with hot poured rubberized asphalt or sealant. These toppings are called panel toppings, and roof systems with panel toppings are called panel roofings. In many cases, except for the low-cost system mentioned above, insulation, such as ex-

truded polystyrene or lightweight concrete, is combined in the system, usually between the membrane and the topping.

Roof waterproofing systems are obliged to offer a 10-year guarantee or more, which includes both roof leaks and any losses directly attributable to leaks.

### **Philippines**

Because of the weather and climate in the Philippines, pitched roofs are very popular as in other tropical countries. Thatched roofs were widely used and still are in rural areas. They are not only affordable but also appropriate in the hot climate. In urban areas, the use of galvanized steel sheets has increased because of fire safety, technological image, availability and easy installation. Glazed roof tiles are used less often but much desired, as are cement or concrete tiles and vinyl and wood shingles. The use of these materials is limited to the houses of the more well-off members of society. Aluminum sheets and asbestos cement roofing materials are used a little for pitched roofs in industrial buildings and houses of middle-income families.

The use of the roof waterproofing systems is limited because of cost and climate conditions. Their use was once limited to a few special buildings, such as churches, landmarks or the like. They are now used on office buildings, condominiums, hotels and government institutions whenever the budget allows. Almost every type of membrane available in Singapore could be imported in the Philippines.

Several years ago, when the membrane quality was unreliable, their popularity was very low. Thus, pitched roofs were employed even behind parapets, giving the impression of a flat roof.

### **Thailand**

Roof tiles and palm leaves are traditional roofing materials for pitched roofs here. Recently clay or pressed cement tiles have been replacing palm leaves. Corrugated galvanized steel has been used, but is not as popular because it is noisy in the rain and produces a very hot building interior. It is popular in places where transportation is difficult, and shared the highest percentage of the market until corrugated asbestos cement sheets were introduced.

The most reliable membrane system here is a built-up roof using glass fiber layers and asphaltic material. Hard vinyl sheets are used for heavy duty roofs. Roofs of four to five story housing, called row-tenements, are covered with waterproofing mortar. The waterproofing mortar system is very simple, but there are very few failures. Failures occur only because of poor workmanship or too-thick application which causes the mortar to crack because of temperature changes.

### **Burma**

Except for the very few government buildings with flat roofs, almost all buildings in Burma have pitched roofs. Imported corrugated steel sheets are widely used in urban areas, and to some extent in rural areas. Corrugated asbestos cement sheets, manufactured in Burma with locally available materials, are gaining popularity over galvanized steel. Clay roof tiles were widely used in government buildings and some private houses before World War II. Their use has declined, but they are still used in some rural areas. Pressed cement tiles are used in some government buildings, but are not popular. Corrugated aluminum sheets were used at one time but not now. The use of teak shingles has been

almost discontinued. Wagot (woven bamboo sheet), thatch and dhani (woven palm leaf sheet) have been used in rural areas, and this is not likely to change in the near future.

Built-up membranes and mastic asphalt with toppings are used on flat roofs, but are not popular because of the heavy rainfall, wide temperature changes and high initial and maintenance costs.

### **India**

Pitched roofs here were covered mostly with wood or slate shingles in the past, but a shortage of resources has resulted in an effort to replace them with other materials, especially low-cost ones. Corrugated asbestos cement sheets also have been used, but are not economical. Metal and polymeric shingles are very expensive. In these circumstances, the India Central Building Research Institute for 10 years has tried to produce low-cost roofing materials from waste. Some examples include: corrugated roofing sheets from coir, waste paper and other agro-based wastes; and, roofing shingles from pine needles processed by chemical and mechanical pulping, saturated with asphalt emulsion and finished with a weather-resistant coating.

Economical systems for constructing roofs with prefabricated reinforced concrete units have been also developed. Among them are channel units, hollow slabs, planks, brick panels and waffles for flat roofs, and L-shaped units for pitched roofs. The surface of flat roofs is coated with hot asphalt and covered with lime concrete or clay mastic mixed with chopped straw, and roof tiles. Pitched roofs with L-shaped units are not provided with any weather-resistant treatment.

### **Sri Lanka**

Roof tiles are also traditional materials here, and houses of high-income families except in the hill zone are roofed with them. Those of average- and lower-income families are covered with asbestos cement or galvanized steel sheets for low cost and easy installation. Asbestos cement sheets have replaced other materials in the last two or three decades. Almost all houses in the hill zone are roofed with galvanized steel or aluminum sheets, regardless of family income. Zinc-aluminum roofs have been introduced in the last five years, and are being used on high-rise buildings. Copper sheets were used in the New Parliament, but are very expensive.

Thatched roofs were commonly used in rural areas by lower-income families. Thatched roofs give a better cooling effect than other types, but their use has declined because they require maintenance every two years. Flat roofs are used very little. High-income families use flat slabs as roof gardens, but they have not been successful because of poor waterproofing technology and materials.

### **The Other Countries**

I do not have enough information on Indonesia, Malaysia, Brunei, Hong Kong and Taiwan. However, it can be assumed that both traditional and industrial roofing materials and practices are common. The difference comes from the economic situations of countries and families.

## **COUNTRIES IN THE SOUTHERN AREA**

### **Australia**

Corrugated galvanized steel sheets were once the most common traditional materials for pitched roofs. Slates imported

from the U.K. were also used in the early days on government buildings, but their use has declined. Now, terra cotta and concrete tiles are commonly used. About 80 percent of dwellings are roofed with one or the other. Asbestos cement sheets, galvanized and painted steel sheets and pressed metal tiles surfaced with acrylic-resin-bonded aggregate are preferred on light timber framing in order to avoid creep problems.

Since the 1960s, metal decks have predominated as coverings for low-pitch roofs. They are available in long lengths of steel, aluminum, copper and stainless steel. The first two are available in a range of prepainted colors and with various profiles.

Asphaltic membranes have been used here since the turn of the century, but their use has markedly declined with the development of the long-length metal systems. Good performing membranes can be constructed with three layers of felt. The first layer is perforated for spot-bonding on the substrate. The second has high strength to minimize problems of rupture over joints or cracks, and the third layer has good weatherability and low moisture sorption.

Early liquid-applied vinyl coatings performed very badly, making the introduction of these new liquid- or sheet-applied synthetic membranes difficult. Now, both polyurethane and CSPE types have had some success. Butyl rubber sheets are the most common, and vinyl and thick polyethylene sheets are also available.

#### **New Zealand**

Clay or terra cotta tiles and corrugated galvanized steel are traditional materials for pitched roofs. Concrete tiles have replaced clay tiles, and a substantial part of the roofing market has been captured by pressed metal tiles. They are made from galvanized steel, pressed into the desired shape. After forming, the tile surface is covered with colored stone chips embedded in acrylic resin or modified asphalt.

Galvanized steel sheets of various profiles are widely used, and aluminum or galvanized steel decks are used on flat or low pitched roofs.

Asphalt waterproofing membranes have been largely replaced by butyl rubber and asbestos-asphalt semi-rigid sheets. They appear to be more durable here.

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