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ROMAN ROOFING TILE PRODUCTION USING LABOUR INTENSIVE METHODS

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Abstract

This study uses local materials only, taking into consideration facilities prevailing in the locality where the project is to be sited and then makes use of rural labour transportation and marketing facilities available.

By this study it is now known that the Roman tile can be produced easily with wooden moulds and pallets. Also simple wood kilns could be constructed by communities or rural people without much problem.

Keywords: Tiles, clay, labour intensive, kiln

INTRODUCTION

Roofing tile is found the world over, and it is commonly used in developed countries rather than developing countries in Africa. In Britain it is produced on a mass scale and scarcely does one see a house roofed with any other material apart from the roofing tile.

In Ghana the situation is rather the opposite, that is, only very few buildings are roofed with tiles. Ghanaians use mainly iron sheets, asbestos sheets and aluminium sheets. In the farms, hamlets, cottages and villages thatch roofs are still common. Thatch roof which started long before colonization is still with the rural poor. Those who can afford go in for roofing sheets because they find them durable, lasting, easy to lay and readily available on the market.

In the southern parts of Ghana especially in Accra and its surrounding towns and villages, some buildings are roofed with tiles. Examples of these building can be found at the University of Ghana, Legon, State House Accra, and Akropong Teacher Training College. Some of these roofs have lasted for over forty years and the tiles are still in good condition.

The roofing tiles used at the Akropong Teacher Training College were moulded in clay, dried and fired at Akropong yet this has not made an impact on the populace. There is no other house in Akropong which has been roofed with roofing tiles apart from those of the college.

Clays abound in Ghana and roofing tiles could be made out of them at very cheap cost. Brown burning clays suitable for bricks and tiles occur in all regions of Ghana (1).

Brick and tile industries in Ghana produce roofing tiles but only few houses are roofed with tiles. Asbestos sheets continue to be used by individuals and state organizations despite being a health hazard. This project was undertaken to find cheaper, means of roofing houses to reduce building cost.

The Roman tile was produced easily without much machinery. Instead of a pug mill, the clay was pounded to break down the lumps. It was then kneaded and flattened by hand and it was either rolled with a simple locally made metal roller as shown in Figure 2 or rolled with a wooden roller as in Fig. I. It was then formed in a wooden mould and dried on a wooden pallet.

Mfensi tile had good green strength of 705 p.s.i. and so there were very few loses during handling in the green state. It had also adequate fired strength of 2,400 p.s.i. at 1100°C and although its apparent porosity was 17 per cent it did not leak at all when laid properly on roof. It did not warp nor crack easily during marking and firing process. It retained its shape without distorting which made laying on roofs easy.

LITERATURE REVIEW

The use of roofing tiles dates back to the Ancient Greek civilization where Greek temples were roofed with roofing tiles. The Greeks used two types of tiles together. First the roof surface was covered with tiles generally flat but with adjoining edges raised, laid in overlapping courses and all of equal sizes. Convex covering tiles, also overlapping, were then laid over the joints of the flat tiles below; in this manner an absolutely watertight roof was produced (2).

Two other types of roof tile were common

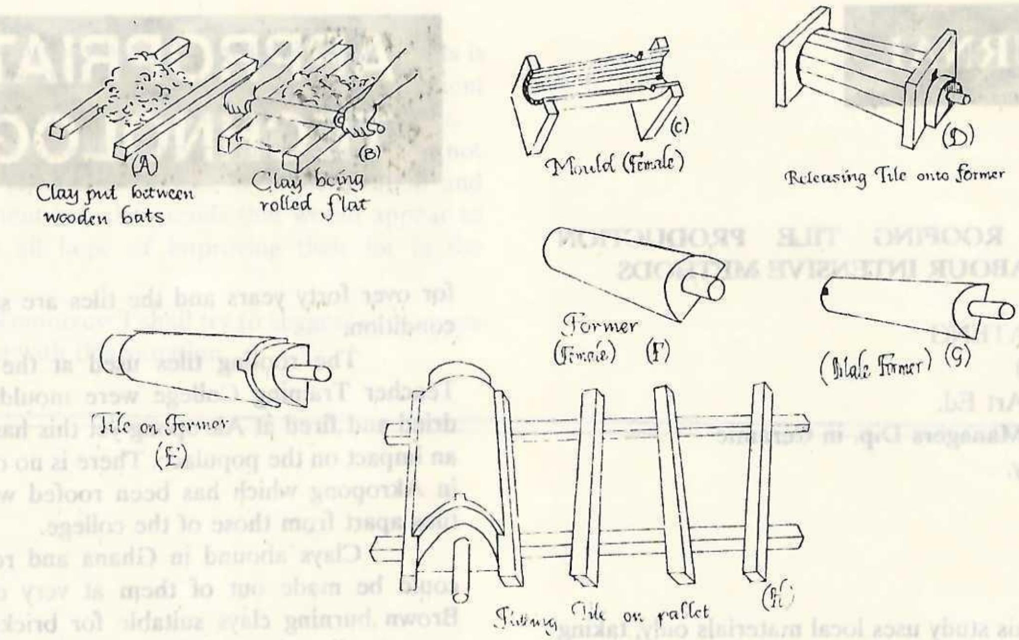

Fig. 1: Stages of Production

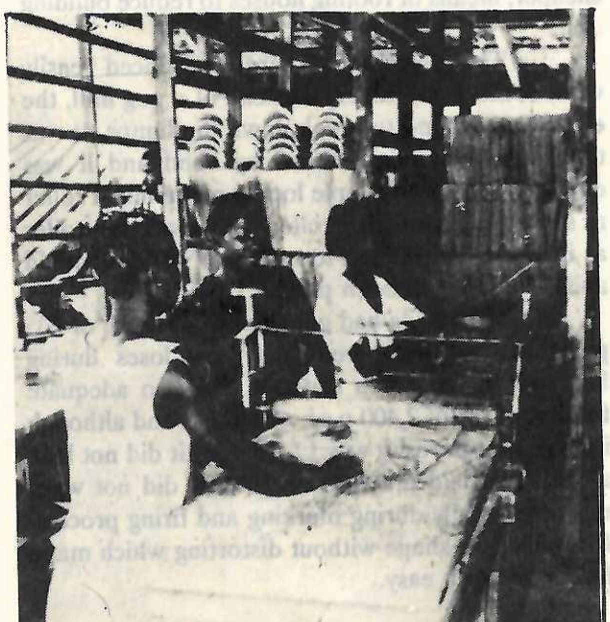

Fig.2: Pressing of Clay

in Roman architecture and probably represent common Mediterranean types of much earlier origin. One of these is the so-called "Spanish tile" also called "pantile" with the contour resembling the letter "S" in which the convex part of each tile fits over the edge of the concave portion of the next.(2) The Roman tile is similar but it is a "single-lap tiling (spanish pantiles)" (3) The other type is the single or flat tile found frequently in the Roman ruins of the northern provinces. The usual material of all of these tiles is burnt clay, varying in colour from orange-yellow to purple red (2).

The Chinese and the Japanese roofed their temples and palaces with roofing tiles. The principle of the roofing tiles is the same as the west but only slight differences in design (2).

Clay roof tiles remain substantially the same; improvements have been only in methods of manufacture and not in design. The flat tile designed to hook over roof battens or boards is perhaps most common type of small house-roof covering in England and parts of France and the combination of concave under tile over convex over tile is almost universal on pitched roofs in Italy, Spain, Greece and Turkey (4).

This paper is more concerned with the simple and easy method of production to facilitate the manufacture of roofing tiles by rural people, and in Fig.1 stages of production is shown clearly.
The Roman tile "Single lap tiling (Spanish pantiles)" is the simplest to make, especially for rural industry. It is of the shape and approximate dimensions of Fig.3.

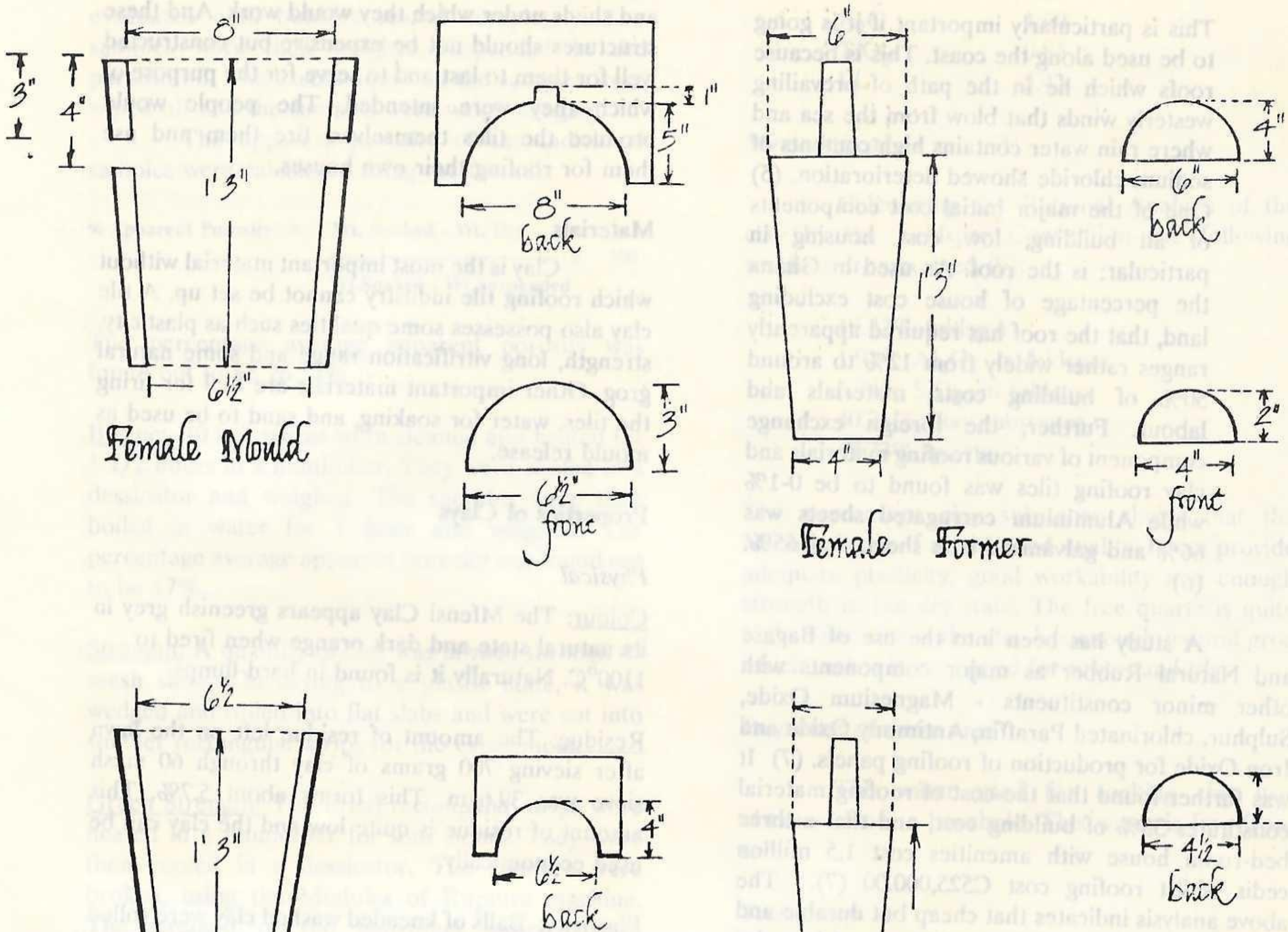

Fig. 3: Wooden Moulds and Formers

Its main, advantage is its flexibility on rough timbering; as a roof-cover it weighs about 10 lbs. per square foot (tiles alone). It may be laid to 260 slope (1 in 2) if torched. Torching is roughly plastering the underside of tiles in roof with mortar. Laid dry, without torching, the roof would not be tight against draining rain. For rougher work-out buildings, etc - the slope may be 1 in 5, without torching. Machinery has little function in forming the Roman tile, and the rural people can rely on their local resources to get roof covering which is not only cheap and durable but also more aesthetic also pleasant than roofing sheets.

In Australia attempts have been made to glaze roofing tiles. Later, it was observed that salt-glazed tiles and englobe-covered tiles showed deterioration. A solution of this problem was found to be:

1. both glazed and unglazed tiles should have low water absorption, that is, less than 9 percent. The corresponding figure for glazed tiles is 6 per cent.

2. tiles should be fired at 1100 C or higher.

This is particularly important if it is going to be used along the coast. This is because roofs which lie in the path of prevailing westerly winds that blow from the sea and where rain water contains high contents of sodium chloride showed deterioration. (5) One of the major initial cost components of all building, low cost housing in particular; is the roof. As used in Ghana the percentage of house cost excluding land, that the roof has required apparently ranges rather widely from 12% to around 50% of building costs, materials and labour. Further, the foreign exchange component of various roofing materials and clay roofing tiles was found to be 0-1% while Aluminium corrugated sheets was 66% and galvanized iron sheets was 65%. (6)

A study has been into the use of Bagase and Natural Rubber as major components with other minor constituents - Magnesium Oxide, Sulphur, chlorinated Paraffin, Antimony Oxide and Iron Oxide for production of roofing panels. (7) It was further found that the cost of roofing material constitutes 35% of building cost, and that a three bed-room house with amenities cost 1.5 million cedis whilst roofing cost C525,000.00 (7). The above analysis indicates that cheap but durable and locally available materials should be used in order to bring down the cost of building.

It has also been stated elsewhere that one of the cheapest building materials commonly used in India for both rural and urban housing and for light duty floor in industrial buildings, schools and health buildings is the clay tiles. Physical analysis of the tiles produced were given as:

(1) adequate strength the breaking load should be between 120 and 160 kg.

(2) low porosity with water absorption of 10 to 15 per cent and

(3) Plastic and easily workable.

The tiles produced were hand moulded after extrusion from pug mills, dried on wooden pallets and fired in a down draft kiln at a firing temperature of 850°C - 950°C (8).

METHODOLOGY

The study was conducted on how roofing tiles could be made by the rural poor who had no access to machinery but would depend on their own effort through the utilization of manpower resources and labour intensive methods. Simple hand tools were to be used in the manufacturing processes. The rural people would be helped to construct wooden moulds, pallets etc., build their own kilns and sheds under which they would work. And these structures should not be expensive but constructed well for them to last and to serve for the purpose of which they were intended. The people would produce the tiles themselves, fire them and use them for roofing their own houses.

Materials

Clay is the most important material without which roofing tile industry cannot be set up. A tile clay also possesses some qualities such as plasticity, strength, long vitrification range and some natural grog. Other important materials are fuel for firing the tiles, water for soaking, and sand to be used as mould release.

Properties of Clays

Physical

Colour: The Mfensi Clay appears greenish grey in its natural state and dark orange when fired to 1100°C. Naturally it is found in hard lumps.

Residue: The amount of residue left on the lawn after sieving 700 grams of clay through 60 mesh sieve was 39.6gm. This forms about 5.7%. This amount of residue is quite low and the clay can be used economically.

Plasticity: Balls of kneaded washed clay were rolled into pencil shapes and coiled into hoops but no cracks developed at the edges of the coils. This is an indication that the clay is of plastic nature. This plasticity is further proved by its green strength as shown by the Modules of Rupture test conducted in the green state. The clay can be used solely as a raw material for structural clay products or it can serve as a binder in other bodies.

Shrinkage: 10 slabs of clay were made out of plaster mould for the shrinkage test. Two fine lines, 5cm apart were marked on each slab immediately the clay was pressed in the mould. On drying, the wet-to-dry shrinkage was taken on each sample from which the average wet-to-dry shrinkage was taken. And the average wet-to-dry shrinkage was 7. 6%. The slabs were fired at 1100°C and the average wet to fired shrinkage was 9.6%.

Warpage: Of the 10 slabs made five of them showed signs of warpage though the warpage was slight. There were no cracks on any of them.

Apparent Porosity:

Green state: 10 dried test pieces about 100 grams each were heated in a humidifier for 1 1/2 hours. They were cooled in a dessicator and weighed on cooling. The pieces were placed in a beaker and covered with paraffin oil. The beaker was placed in a vacuum dissicator and was evacuated until bubbles ceased completely. The samples were then weighed suspended in the paraffin oil. The excess liquid on the samples were wiped off and the samples were weighed again.

The apparent porosity of the individual samples were calculated using the formula

$$\text{\% Apparent Porosity} = \frac{\text{Wt. Soaked - Wt. Dry}}{\text{Wt.Soaked - Wt.Suspended}} \times 100$$

The percentage average apparent porosity was found out to be 26.54%

Bisque: 10 test pieces were cleaned and heated for 1 1/2 hours in a humidifier. They were cooled in a dessicator and weighed. The samples were then boiled in water for 1 hour and weighed. The percentage average apparent porosity was found out to be 17%.

Strength: A quantity of clay was lawned through 60 mesh sieve. On drying to a plastic state, it was wedged and rolled into flat slabs and were cut into smaller rectangular strips for the experiment.

Green Strength: The dried rectangular strips were heated in a humidifier for four hours. They were then cooled in a dessicator. The samples were broken, using the Modules of Rupture machine. The strength of the individual samples were calculated from:

$$\text{Modules of Rupture} = \frac{3}{2}\ \frac{W.L}{bh\ 2}$$

where W is the breaking load
L is length between points
b is breadth
h is height

The average green strength was 705.5 p.s.i. This is an indication that the clay has good green strength.

Fired strength: The average fired strength was 2,401.7 p.s.i. at 1100°C

Chemical

Chemical Analysis of Mfensi clay was done at the Geological Survey Department in Accra and gave the following results:

SiO_2	72.9
Al_2O_3	18.0
Fe_2O_3	0.49
CaO	0.23
MgO	0.34
Ma_2O	0.60
K_2O	1.60
TiO_2	0.85
I.L.	5.43

Mineralogical

Calculating the Rational Analysis of the clay by the Feldspar Convention the following results were obtained (9):

10.42% feldspar
1.91% Al_2O_3 in feldspar
6.74% SiO_2 in feldspar
40.71% Clay substance
47.23% quartz

The percentage clay substance shows that the Mfensi clay is of a very good quality. It can provide adequate plasticity, good workability and enough strength in the dry state. The free quartz is quite high. That means the clay has enough natural grog which makes it very good for bricks and tiles.

Properties of water used

The water used for soaking clay was obtained from a borehole. This water is free from salt.

Technology

The method adopted for the production of the roofing tiles did not demand any high technology. Simple tools were used for winning clay and clays were carried into tipper trucks, dumpers or tractors and unloaded at production site. The clay was soaked in two pits 10 x 9 x 3" each for about three days. It was removed from the pits and pounded on wooden floors. It was wedged and flattened by hand before it was rolled either with a wooden roller Figure 1 or by a simple rolling machine Figure 2. Clays which had been rolled flat were lifted and placed in wooden moulds, trimmed and placed on drying racks during humid weather conditions. Firing was done in a fire wood kiln without thermocouples, pyrometers, or cones.

Machine and Equipment

Clay Winning

Cutlasses were used for weeding the clay site, and by means of pickaxes, shovels and mattocks the top humus soil was removed and dumped away. With the same equipment as above, the clay was dug and heaped ready for carting.

Carting of Clay

Tractors for farm work were very common in the rural area. They were used for carting food stuffs etc. and they provided alternative method of transporting clay from the quarry to the factory site.

Tile Manufacture

The clay was soaked in soaking tanks for about three days. It was then removed and pounded on wooden floor to break down the lumps (Figure 4)

Fig. 4

The flattened clay was pressed by rollers, locally manufactured, for even thickness (Figure 2). The stages of tile manufacture are illustrated in Figure 1.

APPLIED PRODUCTION PROCESS

The sequence of manufacture is as follows:-

* Remove top soil and vegetable loam from tile clay
* Dig out the clay
* Cart the clay tow weathering pits and soaking tanks.
* Prepare clay by addition of water and break up if dry.
* Pound to make it thoroughly homogeneous and storage in polytene for a few days.

Moulding

* The weathered clay which had been stored in polytene was given final pugging by wedging and flatening by hand
* The clay was made evenly thick by a roller after a jute sack or canvas had been spread over it. A jute sack also covered the top of the table to prevent the clay from sticking.
* The moulder worked a table fitted with a sand box. The sand was used as mould release for the wooden moulds.

The rolled clay was lifted and placed into the mould. The edges of the excess clay were trimmed, the nib was pressed and trimmed as well. The former was placed on the clay inside the mould and the tile just formed released onto the former.

* The former with the tile on it was lifted and placed on a pallet and the former pulled out gently without distorting the shape of the tile. A palette was made to carry about four or five tiles.

Drying

Drying was done either in the open, directly under the tropical sunshine or in the drying shed. If tiles were being dried in the open, they were removed and placed on drying racks under the shed before workers left for their homes after the days work. On the other hand tiles were dried on drying racks under the shed as soon as they are made during rainy seasons. The palette Fig. 1 allowed circulation of air around tile. After a period of about 3 days, depending on the rate of drying, the tiles were moved into the kiln and stacked on edge for firing. The tiles were stacked as upright as possible to prevent warping in the drying and firing.

Stacking in the Oven

This operation is very important and was supervised by an experienced fireman. Tiles were stacked as upright as possible and no more than 5 rows of tiles were stacked upon the other. As soon as the oven was full the loading aperture was bricked up and mud plastered.

Firing

Fire was lighted and allowed to burn slowly for about 24 hours. It was then increased to burn fiercely for a further 24 to 48 hours. The firewood used did not give equal heat. The fire boxes were bricked up and plastered with mud and the damper lowered completely to allow soaking and cooling. The cooling of the kiln took about 48 hours. The tiles could then be removed from the kiln.

Method for the Ridge Cap Production

The same clay used for making tiles was also used for the manufacture of the ridge cap. The thickness of the ridge cap was 5/8 inch which was thicker than the roofing tiles. After pounding, kneading and flattening by hand the clay was made evenly thick by a roller after a jute sack or canvas had been spread over it. A jute sack also covered the top of the table on which the clay was rolled to prevent the clay from sticking. Details of mould for forming ridge cap are shown in Figure 5.

The Kiln Used

Bricks sufficient for kiln construction were made in wooden moulds at the project site. These bricks were fired by the clamp firing method and were used for the construction of a small down-draft kiln of 2,000 roofing tiles capacity. The kiln was made to be fired with firewood. (Figure 6).

Fig. 6 Kiln Used

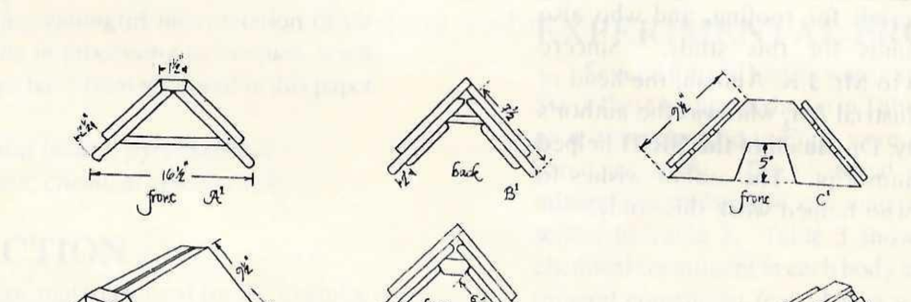

Fig. 5: The Relation between Water Absorption and Firing Temperature

DISCUSSIONS AND CONCLUSIONS

Clay is the most important material when considering the setting up of a roofing tile industry, and so when the Mfensi clay was discovered, it was examined chemically, physically and quantitatively.

The clay had almost 41 percent clay substance and contained 47 percent free quartz. It therefore possessed adequate plasticity, good workability and enough strength in the dry state.

The clay had green strength of 705 p.s.i. and an average firing strength of 2,400 p.s.i. at 1100 C. Although the clay had porosity of 17 per cent at 1100°C it did not leak at all when laid properly on roof.

After production, Mfensi tiles could be easily dried within six hours on hot days without cracking.

By labour intensive method, the clay was prepared for moulding by pounding, kneading, flattening, and rolling. The tile's manufacture did not require machinery and expensive infrastructure.

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