Journal of the Nigerian Association of Mathematical Physics
***Volume* 23 (March, 2013), pp 591 – 598**
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Ceramic As An Alternative Roofing Material In Nigeria

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Abstract

Shelter (housing) is the third most fundamental physical need of Mankind. In Nigeria, roofing constitutes about one third the entire cost of a building. Most Nigerian houses are presently being roofed with zinc and aluminum sheets. They are very good conductors of heat and thus make Nigerian houses very uncomfortable and with very high cooling costs as air conditioners are required. Clay roofing tiles made from clay deposits that are found almost in all states of Nigeria when commercially produced have many fundamental advantages of insulation (heat and sound), durability, aesthetics and economy over zinc, thatch and aluminum roofs. It also discourages pollution. Clay roofing titles when embedded with photovoltaic cells can generate enough electricity that can be used to run all utilities and amenities in a building. This would greatly reduce the pressure on PHCN and add to the energy mix available to the populace of Nigeria. A comparative analysis of present cost of purchase of zinc, aluminum and clay titles show that clay roofing titles material could be considerably cheaper and more affordable than zinc and aluminum.

Keywords: Cost, building, clay, roofing tile, aluminum, zinc photovoltaic cells, economy.

1.0 Introduction

Housing (shelter) is the third most fundamental need of man [1]. The future and wellbeing of mankind also depends on man's ability to design and construct suitable, affordable and safe housing units that are able to guarantee his safety from intruders and comfort within [2]. Due to the need to slow or reverse climate change, the UN HABITAT [3] and the technologically advanced countries like U.S.A., Britain, France, Germany, etc now also require that new buildings should also conserve energy. Nigeria with a rising population, and increasing poverty level should construct new housing estates or building that are safe, healthy and energy efficient. Presently in Nigeria, roofing cost represents about a third of the total cost of erecting a new building [4]. Investors and banks are no longer constructing enough houses to meet the rising population. This could pose a threat to social and political stability. The cost of new houses in Nigeria needs to be reduced. Conventionally, Nigerian houses are built with thatch and zinc roofs in the rural areas while, zinc, aluminum, concrete and baked zinc roofs predominate in the urban centres. These houses, however, are energy inefficient, do not protect from fire, and last for only a few years. Indeed the predominant use of zinc and aluminum roofs in most buildings contribute very significantly to the high heat content and thermal variations observed in Nigerian houses [5] because they are very good heat conductors. Clay roofing tiles are weather resistant, strong and stable, good heat insulators, fire proof, extremely durable, good sound insulators and absorbers, and are aesthetically very satisfying [6].

Essentially, a good roofing material must satisfy the following criteria:

a) Weather resistant - a properly classified roof must be able to protect itself and other things beneath it from the vagaries of the weather especially the heat of the sun, rainfall, air draughts and cold.
b) Strength and Stability — a good roof should be able to carry its own weight without fracture and also be able to sustain any superimposed load due to wind, rainfall and workmen. It should also be impact and static load resistant to a certain extent — at least enough to withstand the effect of pebbles and small stones falling on it.

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c) Thermal (heat) insulation — a good roof should be able to offer some degree of heat insulation to a building and thus help to keep to a minimum, the variation in temperature within the building. This helps to increase the conformability of the building and also residential appeal no matter the season of the year and the diurnal weather conditions

d) Fire resistant — a good roof ought to be able to help in protecting a building in such unfortunate circumstances like fire outbreaks. The extent to which a roof is able to contribute to the prevention of fire outbreak depends on the following: The nature of material and its structure, The temperature of the igniting agent and its nature, Proximity to other buildings, The area of the roof exposed to the fire.

e) Durability a good roof must also be durable or long lasting and require little or no maintenance. Thus, it must be able to withstand the effects of chemical weathering, corrosion, pollution, and attack by fungi, bacteria etc.

f) Aesthetically satisfying — a roof should also be able to add to the attraction which a building wields on its onlookers. This could be done through design geometry and natural colour.

g) Sound insulation - a good roof should contribute to sound insulation and isolation in buildings especially in those where musical concerts are held or recorded or in multiblock and large residential apartments and buildings

h) Affordability — a good roof satisfying all the above technical requirements must also be reasonably affordable. This is the only way in which it can gain buyers and sellers popularity.

Clay roofing tiles easily satisfy all the above criteria and their high density (71 00kg/rn3) ensures even heat distribution and low air circulation in buildings (thereby lowering cooling cost or reduces very significantly the need for air conditioning or fans) [7]. Moreover, due to significant energy shortfalls from PHCN, clay roofing tiles could be embedded with photovoltaic cells so that they produce their own electricity in a concept called building integrated photovoltaics (BIPV). Since 1990, BIPV products have become commercially available [8 -10].

Nigeria being in the tropics can embrace this technology on a large scale and construct buildings that are energy efficient and free from the unreliability and unpredictability of Power Holding Company of Nigeria (PHCN)

CLAY DEPOSITS IN NIGERIA

There is no state or local government area in Nigeria that does not have deposits of clay in various quantities [11]. The problem is that most of them have not been geologically surveyed and classified so that their types, quantities and quality are known with a degree of certainty. Thus, clay deposits are perhaps the greatest untapped natural mineral or resource in Nigeria. A few of the more famous ones which have been identified by various individuals, agencies and institutions together with their use by the local inhabitants of the area are listed in Table 1.

Table 1: Some known clay deposits in Nigeria *

S/No	Sample name	State	Uses
1	NSU	ABIA	Ceramics, chalk, medicines
2	ORLU	IMO	Pottery, bricks
3	UKPOR	ANAMBRA	Medicine, pottery
4	ENUGU	ENUGU	Pottery, bricks
5	ONIBODE	OGUN	Refractory
6	ORUN	OGUN	Refractory
7	OSHELE	OGUN	Refractory
8	IBAMAJE	OGUN	Refractory
9	OGBON	OYO	Pottery, brick
10	AKINLABI	OYO	Pottery, brick
11	ONIFO	LAGOS	Pottery, brick
12	WERROM I	PLATEAU	Refractory
13	WERROM II	PLATEAU	Refractory
14	ALKALERI	BAUCHI	Pottery, brick
15	KANKARA	KATSINA	Pottery, brick
16	GIRO	SOKOTO	Pottery, brick
17	SABON-GIDA	PLATEAU	Pottery, brick
18	IFON	ONDO	Refractory
19	OKPEKPE	EDO	Paints
20	AUCHI	EDO	Pottery, brick
21	IGBILE	OGUN	Refractory, pottery
22	ABAKALIKI	EBONYI	Pottery, brick
23	AFUZE	EDO	Brick
24	AWGBU	ANAMBRA	Pottery, brick
25	KANO	KANO	Pottery, brick
26	UGWU-OBA	ENUGU	Pottery, brick
27	WARRI	DELTA	Bricks

28	UBULU-UKU	DELTA	Paints, medicines, fertilizer
29	AMAI	DELTA	Pottery
30	ABRAKA	DELTA	Pottery
31	BENIN-OVIA	EDO	Bricks
32	OZA-NOGOGO	EDO	Chalk, pottery
33	BUAN	RIVERS	Chalk, refractory
34	UBIAJA	EDO	Pottery, bricks
35	AGULERI	ANAMBRA	Bricks, chalk
36	KAOJE	ZAMFARA	Bricks, pottery
37	ARGUNGUN	KEBBI	Bricks, pottery
38	SOKOTO	SOKOTO	Bricks, pottery
39	AMUKO	KOGI	Refractory
40	ISANLU	KWARA	Refractory
41	IGBADA	KWARA	Refractory
42	ZARIA	KADUNA	Pottery, bricks
43	SHOGBUN	ONDO	Refractory
44	IDAH	BENUE	Bricks, pottery

- Source [6]

Design Consideration In The Selection Of Roofing Tile

The most important design factors considered for the selection of the specific types of clay roofing tiles to be produced in accordance with engineering and marketing requirements are as follows:

(i) Shape (ii) flexural rigidity (iii) producibility (iv) aesthetics (v) simplicity (vi) weight (vii) cost of formwork (viii) ease of assembly

i. Shape since all the properties of the roofing tile are standard, the shape i the most important factor that determines all its geometric characteristics like levelness, straightness, flatness and concentricity (roundness). It is also very important in its load bearing or carrying ability. Thus, the shape is what makes the roofing tile functional.

ii. Flexural rigidity — this is the roofing tile ability to resist torsion and distortion under load. This is very important as clay roofing tiles are not elastic and have very little plastic properties. They are brittle and thus allow for very little elastic deformation. However, this is also dependent on the shape of the chosen tile.

iii. Producibility — clay roofing tiles are cast in or produced with wooden patterns and metallic moulds. Any chosen tile shape and structure must not be too complex so that the wooden patterns and metallic moulds required for its production can be fabricated or produced by local artisans, technicians and technologists. Also, the shape must not be so complex that it may suffer undue distortion when fired at elevated temperatures in the production kiln.

iv. Aesthetics — this refers to how pleasant and beautiful the assembled tiles are to the eye. Clay roofing tiles usually become more beautiful as they age since that is when all their contrasting colours usually blossom. It is also very important for the commercial marketing of the tiles as clay roofing tiles because of their beauty are treated as ornaments.

v. Simplicity — this refers to the ease with which the chosen roofing tile is produced, handled and recognized. Thus, simplicity is a function of the shape chosen and the overall geometrical characteristics of the tile.

vi. Weight — this refers to the “dead load” on the supporting roof trusses it he absence of wind, rain and structural vibrations. Clay is a very dense material. Therefore, clay roofing tiles are naturally heavy. The high density of clay roofing tiles is responsible for its excellent heat insulating property but also responsible for the high cost and quantity of the wooden trusses required to support it.

vii. Cost of formwork — this refers to the cost of preparatory woodwork required at ridges, garble verges, bonnet hips and valleys. These are extremely important to prevent water leakage and ensure good aesthetics. They usually require highly skilled, technical and experienced manpower to produce.

viii. Ease of assembly — this refers to the difficulty or otherwise encountered by the workmen while laying or installing the roofing tiles. It is affected by the weight, span, geometry or shape of the roofing tiles. It is not the ease with which one single tile is laid, rather, it is the ease with which a set of tiles are laid.

Composition Of Clay Roofing Tiles

Clay roofing title comprises of primarily of kaolinites, sand (silica quartz), and desirable impurities of iron, titanium, magnesium, etc. The methods, for analyzing and quantification of the size and range of these materials must conform to B.S. 1377 [12] requirements. The functions of the constituents of the clay roofing tiles are itemized in Table 2.

Table 2: Roofing Tile Constituents and their Function*

Material (oxide)	Name	Function
$Si0_2$	Silica	Stabilizer
$A1_20_3$	Alumina	Heat resistance

TiO_2	Titanium oxide	Flux
Fe_2O_3	Iron oxide	Flux
MnO	Manganese oxide	Flux
MgO	Magnesium oxide	Flux
CaO	Calcium oxide	Flux
Na_2O	Sodium oxide	Flux
K_2O	Potassium oxide	Flux
H_2O^+	Water (LOI)	Dimension control
H_2O	Water (adsorbed water)	Drying shrinkage

* Source [6]

Various types of different design shapes were considered and analyzed. The result of the analysis are shown in Table 3

Table 3: Preferred Tile as Selected by Ranking

Property and characteristic / Titles	Shape	Flexural rigidity	Producibility	Aesthetics	Simplicity	Weight	Cost of form	Ease of assembly,	Total
Pan tiling	6	9	9	5	6	7	7	8	57
Plain tiles	7	9	6	5	4	7	5	5	48
Double roman	7	9	8	5	7	9	8	5	58
Single roman	2	6	4	4	4	7	5	4	36
Spanish	6	6	5	5	6	7	7	8	50
Flat interlocking tiles	3	6	7	6	7	7	3	8	47

Score 1-2 very good, 3-4good, 5-6 poor, 7-10 very poor

Auchi clay deposit was used after suitable beneficiation to produce clay roofing tiles conforming to B.S. 402 [13]. The produced tiles are shown in fig la & b.

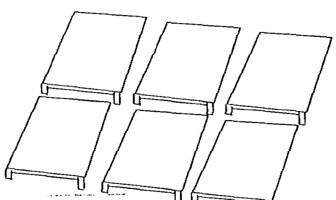


Fig 1a: A Collection of Unders

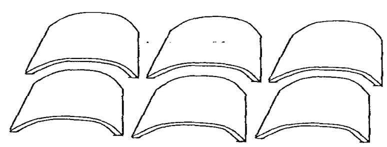


Fig 1b: A Collection of Overs

Force Analysis

To compare their suitability using force analysis, two important physical criteria will be considered.

i. Shear force (S.F)

ii. Bending moment (B.M)

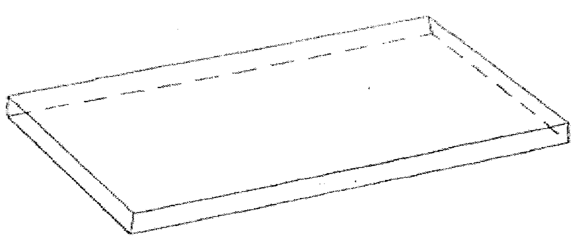


Fig 2: Flat tile

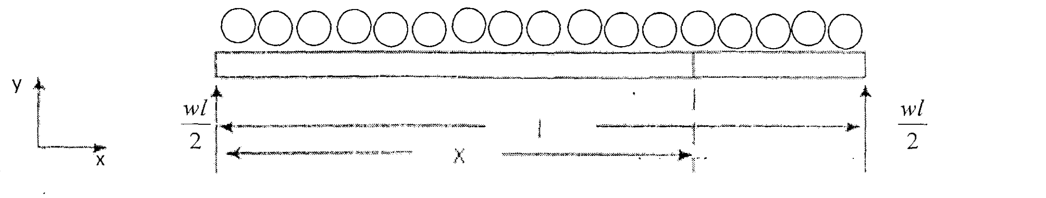


Fig 3: Load diagram

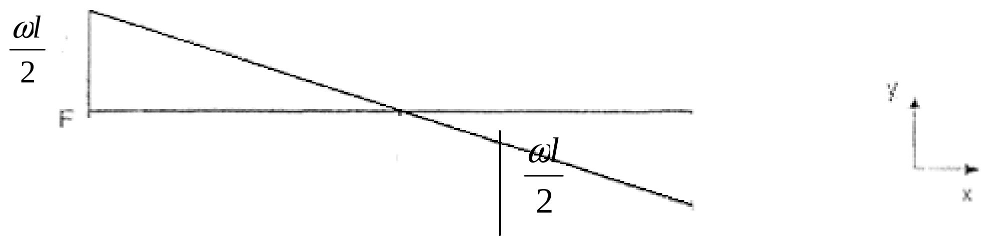


Fig 4: Shear Force Diagram

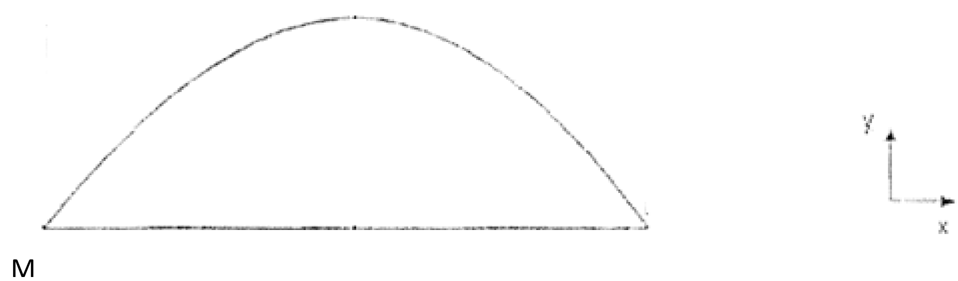


Fig 5: Bending moment Diagram

Since the flat tiles are produced using a mould, they would be of uniform density and can be represented as a uniformly distributed load (U.D.L). Then, the shear force equation can be written after examining, Figures 4 and 5 [14] as:

$$S.F. = \frac{wl}{2} - wx$$

w = uniform load per unit length

i.e. $$S.F = w\left(\frac{1}{2} - x\right) \qquad (1)$$

This gives a straight line of slope equal to the rate of loading. The bending moment equation can be written after considering Fig 5 as

$$B.M = \left(\frac{wl}{2}\right)x - (wx)\,{}^{x}\!/_{2}$$

$$= \left(\frac{wx}{2}\right)(l - x) \qquad (2)$$

This is a parabolic curve, having zero values at each end and a maximum value at the centre where S.F. = 0

Equation (1) and (2) show that Share Force occurs at the edges with values max of $\pm\, {}^{wl}\!/_{2}$ and B.M ($m_{ax)}$) occurs at the center where it is $\frac{wl^2}{\sigma}$ … σ = deflection (mm)

Deflection of support relative to center, is given by [15]

$$\sigma = \frac{5wl^4}{384EI} \qquad (3)$$

….E = modulus of elasticity (N/mm^2)
I = second moment of area (mm^4)

For half round tiles (either Unders or Overs and whether, Italian, Spanish or Sicilian or Roman tiles) as shown in figure (6), the load diagram is as shown in Figure (7)

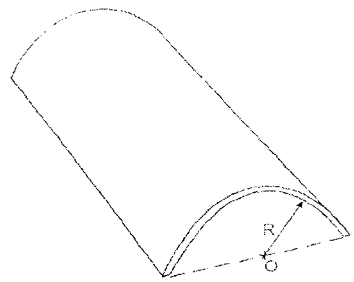
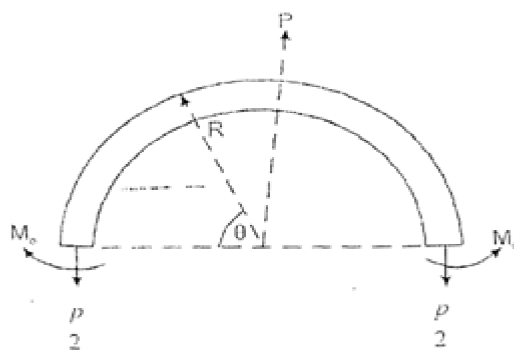


Fig 6: Half round tile (over)



P=Load
M_o = Bending Moment
R = radius

Fig 7: Load and Bending moment diagram

By symmetry let M_o be the bending moment on cross-sections perpendicular to P (Figure 7).
At angle θ,

$$B.M.(M) = \left(\frac{PR}{2}\right)(1-\cos\theta) - M_o \qquad (4)$$

Using Castigliano's theory [15],
U (the shear energy due to the application of load P)

$$= 4\int_o^{\Pi/2} \frac{[PR(1\cos\theta) - 2M_o]^2 Rd\theta}{4\times 2El} \qquad (5)$$

i.e. $$\frac{\partial u}{\partial M_o} = \left[\frac{R}{2El}\right]\int_o^{\frac{\Pi}{2}} 2[PR(1-\cos\theta) - 2M_o](-2)d\theta \qquad (6)$$

= rotation of M_o
= θ by symmetry

$$\therefore \int_o^{\Pi/2} \left(PR - PR\cos\theta - 2M_o\right)d\theta = 0 \qquad (7)$$

i.e. $PR\frac{\Pi}{2}PR - 2M_o \Pi/2 = 0$

thus $M_o = PR\left(\frac{1}{2} - \frac{1}{\Pi}\right)$ (8)

B.M.$_{max}$ occurs when $\theta = \Pi/2$

And M_{mean} =PR/2-M_o

$$\frac{PR}{\Pi} \qquad (9)$$

And the deflection caused by load

$$\sigma = \frac{PR^3}{4El}\left(\frac{\Pi^2 - 8}{\Pi}\right)$$

By comparing equation (3) and (4), it can be seen that the moment of resistance for half-rounded tiles is greater than that of flat tiles. Thus half-rounded tiles are better than flat ones for supporting loads.

Comparison of Purchase Cost of Different Roofing Materials

A market survey was conducted in Benin City to ascertain he present cost of some familiar roofing materials. The results obtained are as follows:

1	Aluminum roofing sheets	N2400/m2
2	Concrete tiles	N1300/m2
3	Corrugated (coolite) NT sheets	N950/m2
4	Corrugate zinc sheets	N55/rn2
5	Asbestos roofing sheets	N800/m2

Estimated Cost of Clay Roofing Tile

1	A truck load of clay (8 tonnes)	N30,000
2	A truck of Sand (5 tones)	N8,000.00
	For each firing:	
	Half bottle of gas	N1,200.00
	50 litres of kerosene N2,500.00	N2,500.00
	No of tiles fired per firing	30 tiles
	(15 unders and 15 overs)	

After firing:
No of good tiles

a) Unders approx. 10 per firing
b) Overs approx. 19 per firing

Cost of labour N500.00 per firing
Neglecting cost of clay and sand, as the quantity used is very small per firing, then estimated total cost is
N1 ,200+N2,500+N500=N4,200.00
Cost per tile = N4200/20 = N210.00 per tile
Maximum number of estimated number of tile per m^2 = 12 unders and 12 overs
:. Cost per m^2 = 24 x N 210 = N5040.00

This is for a very small scale, totally manual and experimental firing. It is hoped that with machine moulding and improvement, mechanized firing process or by substituting use engine oil for kerosene, the cost of production can easily be reduced to about one tenth of the above cost i.e. N504.00/m^2.
An envisaged production layout suitable for small scale, medium scale and large scale production is shown

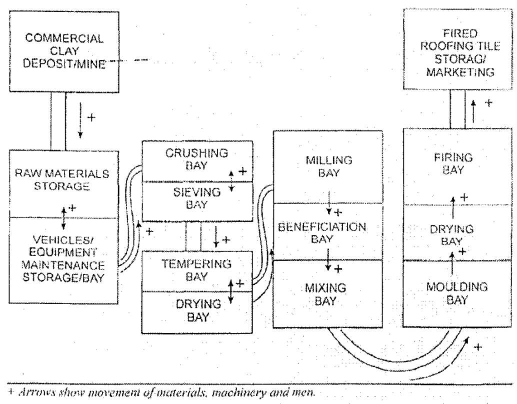


Fig 8: Flow diagram depicting movement of material

Conclusion

Vast clay deposits exist naturally in our various localities. In fact, clay deposits could be said to be available in every state in Nigeria in commercial quantities. Local expertise and knowledge already exist and have been handed down by our ancestors as can be seen in the various ways they have been making use of local clay deposits for pottery, bricks, chalk, refractory and medicine. Thus, commercial exploitation of suitable kaolinitic clay deposits for the manufacture of roofing tiles is a sustainable development that needs urgent attention by all. Clay roofing tiles when embedded with photovoltaic cells provide electricity and therefore act in double capacity as both roof and electric generator. Solar power is a renewable resource and solar powered buildings are highly economical and much sought after. Clay roofing tile production and use, is therefore, a viable way for the Federal, State or Local Government to create employment, generate. wealth and promote technology transfer in order to engineer sustainable development and a healthy socio-economic and political environment in Nigeria.

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