Development Of An Improved Concrete Roman Tile Alternative Roofing System Using Waste Raw Materials (Paper & Saw Dust) As Additives

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ABSTRACT: Since the early civilizations in China (Neolithic) and the Middle East, humans have recognized the dual desirable roles of clay tiles, as roofing material, which remain valid today - First, it was an effective means to shed water from buildings and secondly it reduced the spread of fire. The Standard Double Roman tile (SDRT) was the first roof tile to be mass produced in South Africa. The Double Roman can trace its shape back to Roman engineering principles where it was discovered that arches have an ability to withstand greater pressures as the arch distributes the weight more evenly down to the base of the structure. However, after the initial introduction of the concrete tile to Nigerian roofing market, architects began to express displeasure with its unusually heavier weight than other competing roofing materials. Suggestions were made to original manufacturers for product improvement by reducing the overall product weight. Concrete tiles are composite materials made from mixture of Portland cement, sharp sand, smooth sand and natural fibre. Bolyn Industries [7] has established that a mix ratio by volume of 1(cement):11/2(sharp sand):11/2(smooth sand) with some fibre makes a good concrete tile product. The sharp sand provides strength while smooth sand provides smoothness to the concrete surface. This study seeks to improve the current Double Roman product by reducing its overall product weight which is currently at about 5.0 kg to about 4.0 kg. Going by the previous experience with Polycrete invention [2], it is hereby conceived that replacement of smooth sand with lighter waste materials such as paper or saw dust in the concrete tile constituents may achieve the desired product weight reduction. The study investigates the most economic mix ratio of the concrete tile constituents to achieve the desirable engineering properties of light weight, strength, durability, water tightness and rust-proofness. Results with preliminary mix trials indicate that replacement of smooth sand with paper or sawdust in the concrete batch may achieve the desired results, but paper produces a better ductile and more workable material while saw dust produces a brittle and more crack-prone product. It is established in this study that 16-18 Products of Improved Double Roman Roofing Tiles (IDRT) of approximately 4.2kg each, are achieved in a batch mix of 1 head-pan of Portland cement, 2 head-pans of sharp sand and 4kg of waste paper compared to the average weight of 5.0kg achieved for the Standard Double Roman Tile (SDRT). Comparative market survey of existing roofing systems in Nigeria shows that there is a wide range in cost of N450.0 per m^2 for Galvanized Iron sheet, N1500.00 per m^2 for Aluminium Long span and N3,500.0 per m^2 for Classic Stone-Coated roofing sheets respectively compared to N1000.0 per m2 achieved for the IDRT; thus the second objective of this study to achieve a competitive product price in the median of the above-reported cost range has also been achieved.

Keywords: alternative building materials, roofing systems, concrete tiles, local raw materials, weight reduction.

1.0 AIM and OBJECTIVES of the STUDY

The aim and objective of this study is to develop an improved Double Roman roofing Tile (IDRT) such that a lighter weight per product and a lower cost per m^2 of roof coverage is achieved. By so doing, Double Roman Concrete Roofing tile can become more attractive to architects for specifying in future building constructions.

1.1 Existing Standard Double Roman Tiles (SDRT)

Concrete tiles are composite materials made from mixture of Portland cement, sharp sand, smooth sand, and natural fibre. Bolyn Industries [1] has established that a mix ratio by volume of 1(cement):11/2(sharp sand):11/2(smooth sand) with some fibre makes a good concrete tile product. The sharp sand provides strength while smooth sand provides smoothness to the concrete surface. This study seeks to improve the current Standard Double Roman product by reducing its overall product weight which is currently at about 5.0 kg to about 4.0 kg. It is conceived that if smooth sand is replaced with paper or sawdust which are much lighter materials than sand, a net reduction in overall weight of Double Roman tile will be achieved while the smoothness of surface will still be maintained [2].

2.0 METHODOLOGY

2.1 Conceptual Framework

Composite materials like concrete consist of two or more constituent materials. Concrete is made of three material components viz : i) Portland Cement, ii) Sand and iii) Gravel. When these constituent materials are mixed together in different proportions (batch mix ratios), concrete with differing desired engineering properties are produced [5,6]. The process of selecting different mix ratio to produce different concrete types with specified engineering properties is called 'Batching' [5,2]. The constituents can be mixed by volume or by weight proportions. It is more common to mix concrete in volume ratios of 1 : 2 : 4 (i.e. 1 part of Portland Cement to 2 parts of sand to 4 parts of gravel) to achieve a reasonably good compressive strength ; although it may be more desirable in certain situations to batch by weight (such as in a large construction batching plant).

2.2 Comparative Unit Weights of Material Constituents

The resulting Unit Weight of a composite mix $\gamma_{p,}$ depends on the individual unit weights of its constituents and the weight proportion of each constituent in the mix.

unit weight of water = 1000.0 kg/m^3
unit weight of portland cement = 1,470 kg/m^3
unit weight of sharp sand = 1,500 kg/m^3
unit weight of smooth sand = 1,500 kg/m^3
unit weight of paper = 89.0 kg/m^3 (its actual value varies and depends on state of compaction)

3.0 MATERIALS and METHODS

3.1 Materials

Besides the quality of the raw materials, a careful production procedure is the other important consideration for a product of high standard [1]. The materials required in the production of Improved Double Roman Tile (IDRT) are:

i) Bolyn Roman Tile Vibrating Table [1]
ii) 25 Bags (1^+ ton) of Portland cement
iii) 1 Tipper load (3.0 m^3) of Sharp Sand
iv) 50.0kg of waste paper
v) Headpans, Shovels and Accessories
vi) 250 liters of water

3.2 Production Process

The steps in the production process are:

1. Mortar preparation
2. Vibrating and Molding
3. Mold Curing
4. Demlding
5. Curing (in water tanks or vapour atmosphere) or Air curing/Hand Wetting

3.2.1 Mortar Preparation and Casting Procedure

The traditional mix ratio of Double Roman is 1 head pan of Cement: 11/2 head pan of Sharp Sand: 11/2 head pan of Soft Sand with 12.5 litres of water and some natural fibre. This batch will produce about 14 pieces of Standard Double Roman Tile (SDRT) each of 5.0kg product weight. With the introduction of paper to replace smooth sand, several trial mixes were explored but ultimately, a trial mix of 1 head pan of cement : 2 head pans of Sharp Sand: 4.0kg of paper and 15.0 liters of water gave optimal results. This trial mix produced 18 quality products of IDRT of about 4.2kg each per batch.

3.2.2 Mix Ratio by Volume or by Weight

Just as concrete mixes are prepared in ratios of volume, mix ratio by volume was initially adopted for this product development study. Thus a 1:2:4 concrete mix would contain one part of cement, two parts of sand and four parts of gravel by volume; but with introduction of paper as additive, measurement by weight was found to be more feasible (since paper has an unusually large volume-to-weight ratio and volume of paper is difficult to measure as it depends on its state of compaction). In order to avoid wastage of materials in the initial trial mixes, smaller batch weights were used in the investigative study; thus a mix ratio of (2 :1.73: 2.03) means 2.0kg cement: 1.73kg smooth sand: 2.03kg sharp sand.

First trial (2 :1.73: 2.03)

The first mix trial was 2kg of cement to 1.73kg of smooth sand to 2.03kg of sharp sand. The aggregates and cement with fibre were mixed together properly before adding water. Accurate quantity of mortar was placed on a clean plastic interface sheet on the vibrating table by the use of a measuring scoop, spreading the mortar roughly with hand trowel before vibrating. Vibration time should not be more than 50 seconds; after the vibration, the mortar was moved to the mold and de-molded after 24 hours. The resulting product did not form properly as all the surface of the product cracked.

Second trial (2 :2.03: 0.4)[paper]

Using 2kg of cement to 2.03kg of sharp sand to 0.4 kg of paper. The paper was soaked inside water for 48 hours. After the soaking, sharp sand and cement were mixed together then the soaked paper and water were added. The product did not form properly, as the product crashed because the paper content was too much.

Third trial (2 :3.04: 0.2)[paper]

Using 2kg of cement to 3.04kg of sharp sand to 0.2kg of paper. The paper was soaked for 24 hours. After the soaking, sharp sand and cement were mixed together then the soaked paper and water were added. In fact, the product formed properly with a smooth surface.

Fourth trial (2 :2.03: 0.2) [sawdust]

2kg of cement to 2.03kg of sharp sand to 0.2kg of sawdust. Sharp sand, sawdust and cement were mixed together then water was added to it. The product did not form properly. Since the Third Trial mix of (2 :3.04: 0.2) i.e. 2kg of cement to 3.04kg of sharp sand to 0.2kg of paper gave the most optimal result, it was adopted for further development in this study.

4.0 RESULTS and DISCUSSION

4.1 Result of Compressive Strength Test on IDRT Mix Cubes

The result of the compressive strength for 7days and 14days are as shown in Table 1. It can be seen that the maximum compressive strength of 4.22N/mm^2 was achieved for the ratio of the Third Trial mix of 2 :3.04: 0.2. This value is expectedly much lower than the value of 20.0N/mm^2 expected for 1:2:4 mix normal concrete[6]. The compressive strengths showed reduction with the reduction of cement content in the mix.. A unit weight of 1,800kg/m^3 was also recorded for the IDRT mix which is expectedly lower than the unit weight of normal concrete of about 2,400kg/m^3.

TABLE I: Compressive Strength Test on IDRT Mix Cubes

MIX RATIO	DATE CAST	AGE OF TESTING	DATE TESTED	WEIGHT OF CUBE (g)	AREA OF CUBE (mm^2)	VOLUME OF CUBE (cm^3)	Density of Cube (g/cm^3)	CRUSHING LOAD (kN)	CRUSHING Strength (N/mm^2)
2:3.04:0.2	03\04\2012	7DAYS	10\04\2012	6156	22500	3375	1.824	95	4.22
2:3.04:0.2	03\04\2012	14DAYS	17\04\2012	6250	22500	3375	1.85	96	4.27
1.75:3.04:0.2	03\04\2012	7DAYS	10\04\2012	6280	22500	3375	1.86	70	3.11
1.75:3.04:0.2	03\04\2012	14DAYS	17\04\2012	4600	22500	3375	1.36	76	3.38
1.5:3.04: 0.2	03\04\2012	7DAYS	10\04\2012	6180	22500	3375	1.83	60	2.67
1.5:3.04:0.2	03\04\2012	14DAYS	17\04\2012	6102	22500	3375	1.81	53	2.35

5.0 PRODUCTION ECONOMICS (1000 tiles @ 100 pieces per day)

Materials needed:

1. 4.5 Tonnes of Sharp Sand = ₦6,000
2. 25 Bags of Cement = ₦1,900 X 25 =₦47,500
3. Waste paper=₦125.00
4. One Roll Galvanized Steel Wire = ₦1,000
5. 12,500 Litres of Water = ₦1,000 X 5 = ₦5,000
6. 2 Labours =₦1,500 X 2x10 =₦30,000

Table II: Production Cost of 1000 tiles

S/N	DESCRIPTION	QTY	UNIT	RATE ₦: K	AMOUNT ₦ : K
1	Sharp sand	4.5	Tonnes	1,333.00	6,000 00
2	Cement	25	Bags	1,900.00	47,500 00
3	Waste paper	125	Kg	1.00	125 00
4	Galvanized steel wire	1	Roll	1,000.00	1,000 00
5	Water	12,500	Litres	0.4	5,000 00
6	Labour for (ten working days)	2	Labours	1,500x2x10days 00	30,000 00
	Total				**89,625 00**

₦89, 625.00 for 1,000 tiles

₦ 90.00(Input cost) + Profit (at ₦50.00) = ₦140.00 per Tile

6 Double Roman Tiles make 1 square metre = ₦140.00 X 6 **= ₦840.00 per m^2**

Price per metre square of Double Roman Tile Roofing Sheet =N840.00 per m^2 (Approximately N1,000.00 per m^2) (Inclusive of a modest margin of profit.)

6.0 CONCLUSION

This research effort has produced the expected outcome of weight reduction of Standard Double Roman Tile (SDRT). An Improved Double Roman Tile (IDRT) was successfully developed at a reduced net Product weight of 4.2kg compared to the standard weight of 5.0kg. This lighter weight of product will make the use of Concrete Roofing Tiles more attractive to architects and other Building Materials Specifiers. With an allowance of a modest profit per tile, a product market price of N1000.00 per m^2 was achieved with 6 pieces of IDRT covering 1.0m^2 of roof area. A graphical presentation of range of roofing materials cost at Osogbo, Fig.1 shows that a median cost price has been achieved for the Improved Double Roman Tile (IDRT) compared to other roofing materials such as Classic Stone Coated, Galvanized Iron Sheet, Aluzinc, Nigerite Super 7 and Nigerite Litespan. A competing Micro Fiber Concrete (MFC) roofing tile product being produced by Nigerite currently sells at N1,850.0 per m^2. There is therefore a comparative cost advantage in the production and use of IDRT recently developed in this study. Moreover, the production of IDRT involves the use of local raw materials which are asbestos-free, local labour, simple tools and is therefore more eco-friendly, more sustainable and will enhance employment generation especially among the youth. This will therefore, make it a more attractive roofing choice for most medium income home owners. It is planned to engage in further research work on this study by carrying out extensive testing and engineering characterization of the newly developed (IDRT) product for strength, durability and water-tightness and to compare results with those of competing materials and existing established standards.

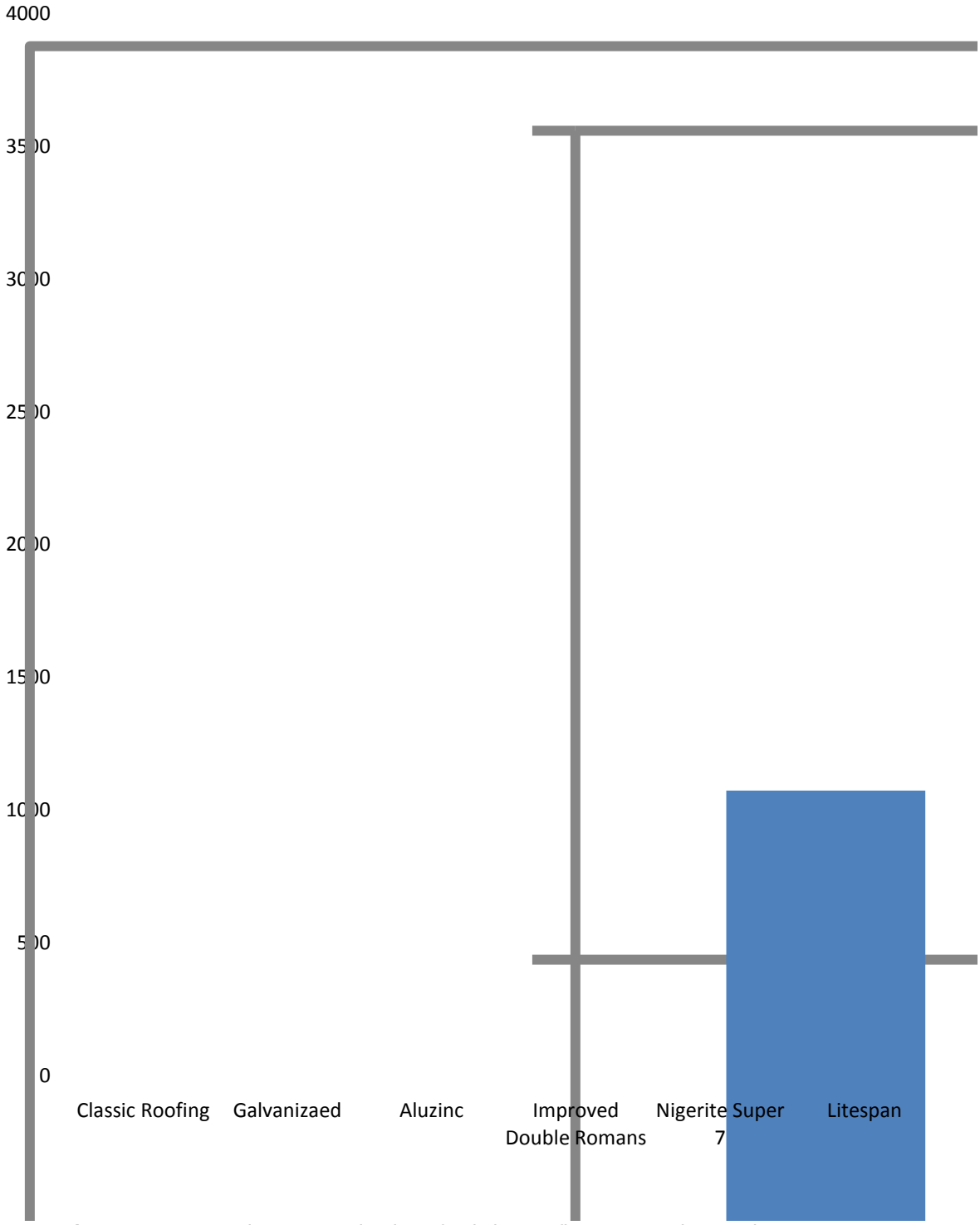

***Figure 1**: Comparative cost evaluation of existing roofing systems in Osogbo, Osun State*

Table III, below shows the product data and Nominal Dimensions of the IDRT produced in this study.

Table III - Product Data and Technical specifications of Improved Double Roman Roofing Tiles (IDRT)

Standard length	600mm
Overall width	400mm
Net covering width	325mm
Side lap	75mm
Nominal thickness	6-8mm
No of Tiles per m^2	6 pieces
App. Weight per tile	4-4.5kg

App. Weight per m^2 roof area	25-27kg
Purlins distance	500mm centers
Minimum roof pitch	25^o
Rafter distance	1.2-1.5m
Colour	Grey and Red
Fibre type	Natural, and paper
Durability	30-40yrs
Fixing	with galvanized wire and nail

IMPROVED DOUBLE ROMAN TILE (IDRT)

PHOTOSPEAK

Picture illustrating actual field Application of Concrete Roman Tiles Technology

6No IDRT = One Square Metre of Roofing Area

Casting the IDRT Mix Cubes

De-molding of IDRT Mix cubes after 24hours

Operating the Universal Testing Machine

The total failure of the IDRT cube test

Measuring of paper

Measuring of Sawdust

Soaking of paper in water for 24hours

Mixing of sharpsand, with cement

Dressing of the motar on Vibrating Table

Moving of the vibrated motar to mold

Dressing of the motar on the mold

Improved Double Roman Roofing Tiles (IDRT) Sheet

6.0 REFERENCES

[1] Bolyn Industries Mushin Lagos,2005: Several Technical Publications (Brochures, Manuals etc. on low-cost Building Technology)

[2] Adegoke C.W. "Weight Reduction Studies of Polycrete – An Asbestos-free Alternative Building Material Product" International Journal of Science and Technology Research (IJSTR), November 2013 Vol2 Issue 11, pp 92-95

[3] Adegoke, C.W., Gasu ,M.B., and Abiona," Waste-to-Wealth Technology in Conversion of Polyethylene pure Water Sachets Waste to an Alternative Building Materials Product" – RETAV 2009, Faculty of Technology, Obafemi Awolowo University, November, 2009.

[4] Fulmer Robert L. "Analysis and Inspection Techniques for Roof Consultants"

[5] Aitcin, Pierre- Claude (2000) `Cement of yesterday and today concrete of tomorrow`. Cement and Concrete RESEARCH 30(9): 1349-1359.

[6] St. John D. A. et al "Concrete Petrography"- A Handbook of Investigative Techniques, London Arnold Publishers,1998.

[7] Alloway, B. J. and Ayres, D.C. (1997): Chemical Principles of Environmental pollution, Blackie Academic and Professional.

[8] Anyakoha, E. U. (1994): Towards achieving effective waste generation and Disposal practices in private premises in Nigeria International Standard ISO 536: Paper ands board-Determination of grammage. International organization for standardization,

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