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ENGINEERING CHARACTERIZATION OF IMPROVED DOUBLE ROMAN ROOFING TILES (IDRT) – A SUSTAINABLE WASTE-TO-WEALTH TECHNOLOGY FOR NIGERIA

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ABSTRACT

Current Nigerian housing deficit is estimated at about 17 Million. With rapidly growing urban population in sprawling cities like Lagos, Abuja, Kano and Ibadan, the need to bridge this deficit cannot be more compelling than now. To achieve this, efforts must be directed towards development of alternative and cheaper building and construction materials as roof covering is a major high-cost component of total housing construction cost. This particular study therefore investigated the Engineering Characterization of the Improved Double Roman Tile (IDRT), to evaluate its compressive strength, fire resistance, durability, sound-proof resilience, water resistance and corrosion resistance attribute for possible recommendation for prospective clients and construction specifiers such as architects and building contractors. Prior to this, 18 Nos. of IDRTs (600mm X 600mm) of 4.2kg each were produced using a batch mix of 1 head-pan of Portland cement, 2 head-pans of sharp sand and 4kg of waste paper. The results presented in this paper showed that IDRTs achieved the aforementioned desirable engineering properties with strict adherence to standard operating procedures (SOP) for production. A generalized relationship between unit weight of constituents and product unit weight gave a value of about 1,600kg/m^3 compared to 1,700kg/m^3 obtained from direct measurements in displaced water volume set up. Taking an average of 1,650kg/m^3, the unit weight of IDRT came out lighter than that of standard concrete at 2,400kg/m^3. Average 14-day compressive cube strength of IDRT composite mix, came out to be about 1.0N/mm^2.The IDRT was also found to be strong enough to withstand a static pressure of 20.0 KN/m^2 arising from average static weight of an artisan, without being crushed.

Keywords: Engineering Characterization, Roof Covering, Improved Double Roman (IDRT) Tiles, Construction and Building Materials, Waste-to-Wealth Technology.

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1. INTRODUCTION

A roof is the covering on the uppermost part of a building. It protects the building and its inhabitants from the effects of weather and the invasion of animals [1]. In most countries roofs shelter buildings primarily against rain. Contingent upon the nature of the building, the roof may also protect against heat, sunlight, cold, snow and wind. The characteristics of a roof are dependent upon the purpose of the building that it covers. The available roofing materials and the local traditions of construction and wider concepts of architectural design and practice may also be governed by local or national legislation. The role of this component part of a building can be assessed from the standpoint of *function, strength* and *durability perspectives* [1]. These three points of view become necessary considerations for end users in utilizing it for their proposed buildings. From function perspective, a roof functions as cover that protects humans that reside in it. It keeps them from environmental hazards, such as the Sun's scorching heat and heavy rainfall. Residents in Tropical Climate tend to choose the type of roof covering that can protect them from sunlight, wind and water in the rainy season. The material chosen is different when it comes to subtropical and cool climates; hence climate has huge influence on the choice of roofing material. There are some kinds of roof design that can serve as alternatives such as gable, hip, and gambrel, mansard, flat and shed. The architectural design of these types is the most popular [2]. From the point of view of cost efficiency, gable roof is the most efficient amongst others. Therefore, the design also becomes a point of consideration for dwellers in choosing the type of cover for their houses. Concrete tiles, also known as existing Standard Double Roman Roofing Tiles (SDRT) are composite materials produced from a blend of Portland cement, smooth sand, sharp sand, and natural fibre [3]. It was established by Bolyn Industries that a mix ratio by volume of 1(cement): $1\frac{1}{2}$(sharp sand): $1\frac{1}{2}$ (smooth sand) with some fibre would make a good concrete tile product [4]. The sharp sand offers strength while smooth sand provides smoothness to the surface of the concrete. Generally, it is made from the mixture of cement, aggregates, water, and colourant. It is available in several different colours and a couple of textures. The surface texture of the tile can be smooth or rough. Cement has constantly featured in construction works in ancient times but was not used for making roof tiles until mass production of the materials started in the 19th century [5]. The first cement-based tiles were made in 1844 at the Kroher cement factory in Staudach, Bavaria. Until 1920 they were normally cast as square products, which were laid on the roof in a diamond pattern. In the early days, pigmented coatings were applied to the surface of the tiles, but efflorescence and poor colour durability rapidly spoiled the appearance. As a result, uncoated tiles of plain cement were preferred and quickly became popular. Over the years, concrete tiles and their production processes have evolved to give the products more aesthetic appeal. The major breakthrough came in 1919 when the first extruded tiles were made in the UK [6]. This new technology was soon commercialised in Australia, South Africa and the rest of Europe, allowing tiles to be mass-produced instead of being virtually hand-made. The new factories could make as many as 20 million tiles each year. In South Africa, the Standard Double Roman tile (SDRT) was the paramount roof tile to be produced massively. The shape of the Double Roman can be traced back to the principles of Roman engineering where it was discovered that arches have the capacity to resist greater pressures as they distribute the weight evenly down the base of a structure However, consequent upon the initial introduction of the concrete tile to the Nigerian roofing market, architects began to express discontentment with its unusually heavier weight than other competing roofing materials. Improvements on the product were suggested to original manufacturers for a reduction in the overall weight. In order to standardize and commercially accept paper as one of a composite material, it was found that smooth sand could be replaced with it, with 2kg of paper, 1 head-pan of sharp sand, ½ head-pan of Portland cement in a batch mix producing 8 pieces of stable and durable Improved Double Roman Tiles (IDRT) [7].Therefore, 16 Products will be achieved in a batch mix of 1 head-pan of Portland cement, 2 head-pans of sharp sand and 4kg of waste paper. Waste paper has therefore successfully replaced the smooth sand in the original SDRT mix. Since paper has a ductile and fibrous nature, it also eliminates the need to introduce a natural fiber in the mix. A more useful measure of paper properties is its stiffness - i.e. the extent to which it compresses under load. Its stiffness is many times less than that of concrete, but sufficient for the support of roof loads. The advantages of IDRT are numerous, but the major ones are outlined below:

- The raw materials used in its constructions are available locally;
- Higher sound proof resilience;
- It is strong and durable;
- It does not corrode compared to zinc roofing sheet;
- It doesn't contain asbestos which makes it non carcinogenic;
- The technology used for its production is easy to learn and environmentally-friendly;
- It possesses higher fire proof properties. It meets Class A provision;
- Simple and efficient installation for existing or new construction;
- Reduces maintenance costs.

Notwithstanding the anticipated outlook, the performance regarding function, IDRT is vital and must be sustained during its lifespan. Assurances of 20-30 years or more are frequently demanded, therefore improved double roman roof tiles must prevent ingress of water for many years while resisting a wide range of weather conditions. Any alternative system has to be lightweight and fireproof to fit with local construction methods. Interlocking concrete tiles have been made using an extruded lightweight mortar, which contains ingredients to copy the colour and texture of cedar shake [7]. The new material provides the additional benefits of being easier to lay and having better weather-tightness.

A previous study investigated the most economic mix ratio of the concrete tile constituents to achieve the desirable engineering properties of strength, light weight, water tightness, rust-proofness and durability [7–8]. Result with preliminary mix trials indicated that introduction of 0.2kg of paper or sawdust in the concrete batch may achieve the desired results, but paper produced a better ductile and more workable material while saw dust produced a brittle and more crack-prone product. Comparative market survey of existing roofing systems in Nigeria shows that there is a wide range in cost of N450 per m^2 for Galvanized Iron sheet, N1500.00 per m^2 for Aluminium Long span and N3, 500.00 per m^2 for Classic Stone-Coated roofing sheets respectively [9]. The improved double roman roofing tiles can trace its shape back to Roman engineering principles, where it was discovered that arches have an ability to withstand pressures as arches distributes the weight evenly down to the base. In the previous study an Improved Double Roman Roofing Tiles was successfully developed by optimal replacement of smooth sand with paper to achieve a lightly product weight of about 4.2kg compared to 5.0kg of the Standard Double Roman Roofing Tile (SDRT). Improved double roman roofing tiles is classic, clean and traditional making it ideal choice for homes. Perhaps, it is time for the development of an exciting new generation of double roman roofing materials that offer their own unique appearance, weight, as well as improved properties and roof structures [10]. With the development of this new product there is a need to test and validate whether or not the product exhibits the desirable engineering properties of strength, waterproof, fire resistance and durability which is the main objective of this study [11]. In addition to its strength, durability and appearance, improved double roman tiles are not prone to moisture penetration from wind driven rain, impervious to fire, insects, and rot, and it can be formulated to withstand cold climate. The Technical specifications of IDRT are tabulated below:

Table 1: IDRT SPECIFICATIONS

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	3.8 – 4.2kg
App. Weight per m^2 roof area	25-30kg
Purlins distance	500mm centers
Minimum roof pitch	25°
Rafter distance	1.2-1.5m
Colour	Grey, Red or Green
Fibre type	Natural plant fiber, and paper
Durability	30-40yrs
Fixing	with galvanized wire and nail hooks

More specifically, strength and durabilitya concrete tile roof will provide years of maintenance free service enhancing the aestheticappeal of the buildinga concrete tile roof will provide years of maintenance free service enhancing the aestheticappeal of the buildinga concrete tile roof will provide years of maintenance free service enhancing the aesthetica will be evaluated including possible effect that can hinder its functionalities and ways to improve its quality will be proffered.

2. EXPERIMENTAL MATERIALS AND METHOD

The content hereunder describes the methods and materials that were used in the construction and testing for strength and durability of the improved double roman tiles. Various tests were also carried out to ensure its strength and durability possesses the expected quality of a good roofing material. The materials used in the production of the roofing sheet are Portland cement, sharp sand, paper and water. The sharp sand, paper and water were obtained in Osun State University, Nigeria. Dry sieving was adopted for the sand obtained and made to pass through a sieve size of 2mm [12].Paper obtained is soaked in a measured amount of water, after adequate soaking; it is then pulverized to pulp in form of paper marsh. Water is obtained in soil laboratory, Osun State University and Portland cement is obtained in Oshogbo. The cement/aggregate ratio used in the improved double roman was 1:2.

- **Batching of Sample Materials**

The accurate measurement of all constituent materials to be used in the mixture is done. This is done by proper weighing of component materials to avoid variation and errors in the product. Batching by weight is done. This is done to have a significant amount of product with the same specific engineering properties. As mentioned previously, a batch mix ratio of 1 head-pan of Portland cement, 2 head-pan of sharp sand, 4kg of paper and 12-15 litres of water with a digital scale. [13]

- **Conceptual and Theoretical Framework**

Since IDRT is a composite product (i.e. consisting of two or more constituents). The final product unit weight will be a function of the unit weights of the constituents. It is therefore possible to model the final product unit weight of IDRT with a predictive equation.

In the case of concrete product,

$$\gamma p = f(\gamma c, \gamma s, \gamma g) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 1}$$

Where γp = unit weight of composite Product

γc = unit weight of Portland Cement

γs = unit weight of sand

γg = unit weight of gravel

- **Comparative Unit Weights of Material Constituents**

Unit weight of water = 1000.0 kg/m^3

Unit weight of portland cement = 1,500 kg/m^3

Unit weight of sharp sand = 1,600kg/m^3

Unit weight of paper = 929.0 kg/m^3

In the same vein, a functional relationship will exist between the final unit weight of Improved Double Roman Roofing Tile product and the constituent materials of Portland Cement, Sharp sand and Paper.

This can also be written as :

$$\gamma p = f(\gamma\, c, \gamma\, s, \gamma\, ppr) \ldots\ldots\ldots \ldots\ldots\ldots \text{Eqn. 2}$$

It is conceived in this study that a likely functional relationship will be a 'Weighted Average' relationship such that :

$$\gamma p = ((\gamma c.\, wc + \gamma s.\, ws + \gamma ppr.\, wppr) / (wc + ws + wppr) \quad \text{Eqn. 3}$$

Where wc = weight of portland cement in kg

ws = weight of Sharp sand in kg

wppr = weight of paper in kg

In general, we can say:

$$\gamma p = (\gamma 1.\, w1 + \gamma 2.\, w2 + \gamma 3.\, w3 + \ldots\ldots\ldots\ldots \gamma n\, wn)\ (w1 + w2 + w3 + \ \ldots\ldots wn\ ) \ldots\ldots\ldots\ldots\ldots \text{Eqn. 4}$$

Where: γp = unit weight of composite material.

w1, $\gamma 1$ = weight and unit weight of first constituent respectively.

w2, $\gamma 2$ = weight and unit weight of second constituent respectively.

w3, $\gamma 3$ = weight and unit weight of third constituent respectively.

- **Product Density**

The density of a material is its mass per unit volume. The symbol most often used is ρ.

The density of the product was obtained mathematically by equation 4 as:

$$\rho = \frac{M}{V} \text{...Eqn 5}$$

It can also be defined as its weight per unit volume. i.e.

$$\gamma = \frac{\rho.g}{V} = \frac{W}{V} = \frac{M.g}{V} \text{KN/m3} \text{...............Eqn. 6}$$

Where g = Acceleration due to gravity = 9.81m/sec^2

- **Production process**

Though, the existing standard double roman tile (SDRT) and improved double roman tiles (IDRT) have different mix ratio, with soft sand being replaced by paper in the latter, they both have the same moulding process.

The procedures in the production process are:

1. Mortar preparation
2. Placing on Vibrating Machine
3. Vibration
4. Placing of fixing device
5. Drawing onto Mould-(Moulding)
6. Positioning for air-drying
7. De-moulding

- **Experimental Study for the Engineering Characterization**

This specification deals with the improved double roman tiles intended for use as roof covering where function, strength, durability and appearance are required to provide a weather-resistant surface of specified design. The Impr tiles were manufactured from cement, water, fibre and mineral aggregates and shaped during manufacturing by moulding. [14] The samples were tested for the following requirements:

- **Strength test**

The strength of roof tiles is important, to ensure it can resist wind and other impact load exerted on it [15]. The dry and wet compressive tests of sample were determined by the formula:

$$\sigma \mathbf{c} = \frac{\mathbf{10 \ x \ L \ x \ D}}{\mathbf{W \ x \ h}} \text{................................Eqn 7}$$

Where

L: The load (weight of brick x number of brick) (kg)

D: The distance between the two woods (cm)

W: The width of brick (cm)

h: The average height of bricks (cm)

- **Static loading**

This was carried out on the cured roofing tiles by evaluating the amount of weight of object that the roof tiles could withstand without deformation. It was determined to know the maintenance procedure to be assigned should there be need for repair or replacement of the product. The compressive strength of individual roof tiles by impact loading was done with the aid of some apparatus which are given below:

- Two pieces of woods
- Bricks of known sizes and weight
- A plumb
- Aggregate
- Sample

- **Cube Strength determination**

This was achieved by casting a mortar cube of the mixed sample and compacted by hand to fill up the cube mould. The cube was then immersed in a curing water tank for specified number of days before the required test was carried out.

- **Constant Head Permeability Test**

Using falling head permeameter, this test was carried out to measure the possibility of easy movement of liquids, ions and gases into the roof membrane system. From Darcy's Law, the coefficient of permeability k was calculated directly as:

$$Q = \frac{k\,h\,At}{L} \; or \;\; k = \frac{QL}{hAt} \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn 8}$$

Where

$$i = \frac{H}{L}$$

$$Q = \text{Volume of water collected}$$

$$A = \text{Area of cross section of soil specimen}$$

$$t = \text{Duration of water collection}$$

$$k = \text{Hydraulic conductivity (co} - \text{efficient of permeability)}$$

$$i = \text{Hydraulic gradient}$$

3. RESULTS AND DISCUSSION

The following are results of extensive testing done on sample product for the expected engineering properties viz compressive strength, durability, water-tightness and fire resistivity.

3.1. Result of Unit Weight of IDRT

With the introduction of paper to replace smooth sand, several trial mixes were explored.

- **First trial**

The first mix trial was 25kg of cement, 4kg of papers; 64.2kg of sharp sand (2 head pans) with 18 litres of water gave optimum result. The trial mix produced 17 products of IDRT of average weight of 4.201kg. The results are presented on Table 2.

Table 2:

Sample	Weight (kg)
1	4.305
2	4.219
3	4.256
4	4.403
5	3.980
6	4.300
7	4.214
8	4.218
9	4.201
10	4.195
11	3.945
12	4.055
13	4.274
14	4.238
15	4.141
16	4.208
17	4.286
Total Weight (kg)	71.438kg

$$\textbf{Average Weight of Sample}(\text{kg}) = \frac{71.438}{17} = 4.201$$

- Second trial

Using 12.5kg of cement, 2kg of paper and 32.1kg of sharp sand (1 head pan) with 12.5 litres of water which gave optimal result, the second trial mix produced 8 pieces of Improved Double Roman Tiles (IDRT) of about 4.2kg each as shown on Table 3, and also, the average weight of the total product was:

$$\textbf{Average Weight of Sample}(\text{kg}) = \frac{33.595}{8} = 4.200$$

Table 3:

Sample	Weight (kg)
1	4.214
2	4.198
3	4.234
4	4.201
5	4.185
6	4.242
7	4.203
8	4.118
Total weight (kg)	33.595

3.3. Result of Products Densities

Table 5: Result of Products Densities

Weight (g)	Initial volume (cm^3)	Final volume (cm^3)	Volume displaced (cm^3)	Density (g/cm^3)
3945	8000	10200	2200	1.79
3980	8000	10246	2246	1.77
4256	8000	10520	2520	1.69
4286	8000	10540	2540	1.68
4300	8000	10634	2600	1.65

$$\text{Average Density } (g/cm3) = \frac{1.79 + 1.77 + 1.69 + 1.68 + 1.65}{5}$$

$$= \frac{8.58}{5} = 1.71\ g/cm3$$

$$= 1{,}710 kg/m^3$$

3.4. Compressive Strength Test Result

The result of compressive strength against static loading is presented on Table 6

Table 6: Compressive Strength Test Result

Sample	Weight of Bricks (Kg)	Load (Kg)	Width of Bricks (cm)	Dist.of Woods (cm)	Height (cm)	Compressive. Strength Qc (kg/cm^2)
A	24.35	194.8	29.5	50	76	43.44
B	24.35	170.45	29.5	50	66.5	43.44
C	24.35	146.10	29.5	50	57	43.44
D	24.35	194.8	29.5	50	76	43.44

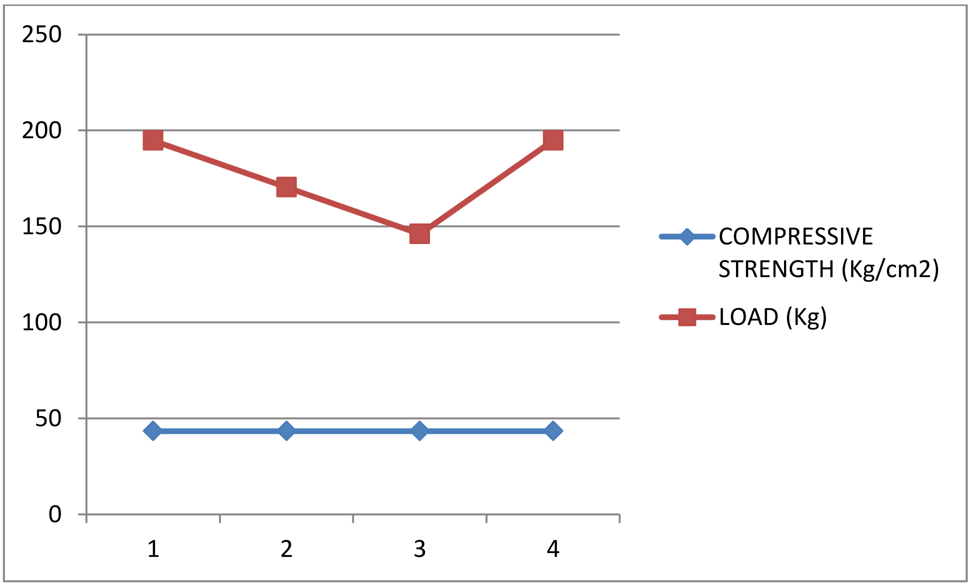

Figure 3 Compressive strength (kg/cm) of product under different load (kg) condition

- **Static Loading Resistance of Workman's Pressure**

Pressure = force ÷ area Force (N) = Mass (kg) x Acceleration (m/s2)

Mass = 80.0kg (assumed for a workman); Acceleration due to gravity = 9.8m/s2

Force = 80.0 x 9.8 = 800N Contact Area = 0.1m x 0.2m = 0.02m2

P = 800/0.02 therefore P = 40000N/m2 P = 40.0KN/m2 (Therefore average static weight of an artisan/foot print) = 20.0KN/m2

The product was able to withstand a total exerted pressure of 40.0KN/m2 which may be exerted by artisans (Workmen) stepping on the purlins during installation.

3.5. Cube Strength Determination

Presented on Table 7 are results of compressive strength of cubes for 14 and 28days period respectively:

Table 7: Compressive Strength of Cubes for 14days and 28days

S/N	Date Cast	Number of Days	Date of Test	Weight of Cube (Kg)	Area of Cube (m^2)	Compressive Load (KN)	Compressive Strength (N/mm^2)
1	22/04/2016	14	06/05/2016	5.366	22.5	23.0	1.02
2	22/04/2016	14	06/05/2016	5.392	22.5	21.6	0.96
3	22/04/2016	14	06/05/2016	5.422	22.5	30.1	1.33
4	22/04/2016	28	20/05/2016	5.742	22.5	39.3	1.74
5	22/04/2016	28	20/05/2016	5.556	22.5	34.2	1.52
6	22/04/2016	28	20/05/2016	5.447	22.5	32.2	1.43

3.6. Permeability Test Result

Measured parameters for the computation of permeability are as follows: $v = (ki) -$ Discharge velocity;Weight of can (kg) $= 3.476$; Weight of can $+$ sample (kg) $=$ 4.228; Weight of sample (kg) $=$ 0.752; Diameter of can (cm) $=$ 10; ;Height of can (cm) $= 13$. The results are as presented on Table 8.

Table 8: Permeability Test Result

S/N	H (cm)	L (cm)	A (cm^2)	t (secs)	Q (cm^3/sec)	i (H/L)	k (cm/sec)
1	60	13	78.55	54.20	1000	4.615	5.08×10^{-2}
2	70.1	13	78.55	45.33	1000	5.392	5.20×10^{-2}
3	74.2	13	78.55	43.74	1000	5.708	5.10×10^{-2}
4	80.2	13	78.55	42.33	1000	6.169	4.87×10^{-2}

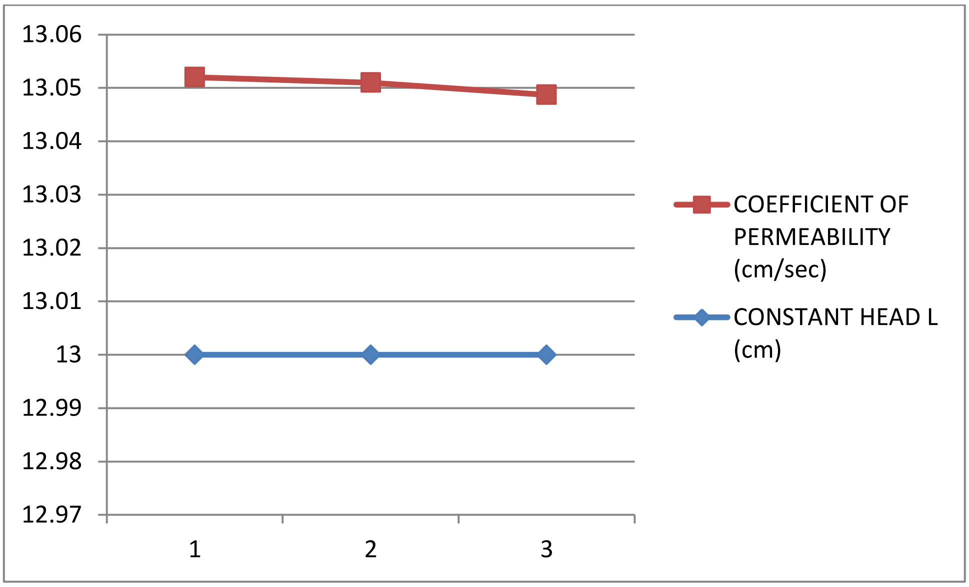

Figure 4 The coefficient of permeability k (cm/sec) and the constant Head (cm)

3.7. Ageing by moisture

Table 9a: Full Immersion

Sample	Weight (kg)	Water Absorption (%)		
		2weeks	4weeks	8weeks
A	4.300	0.010	0.013	0.013
B	4.203	0.013	0.013	0.014
C	4.201	0.016	0.017	0.017
D	4.242	0.010	0.011	0.011

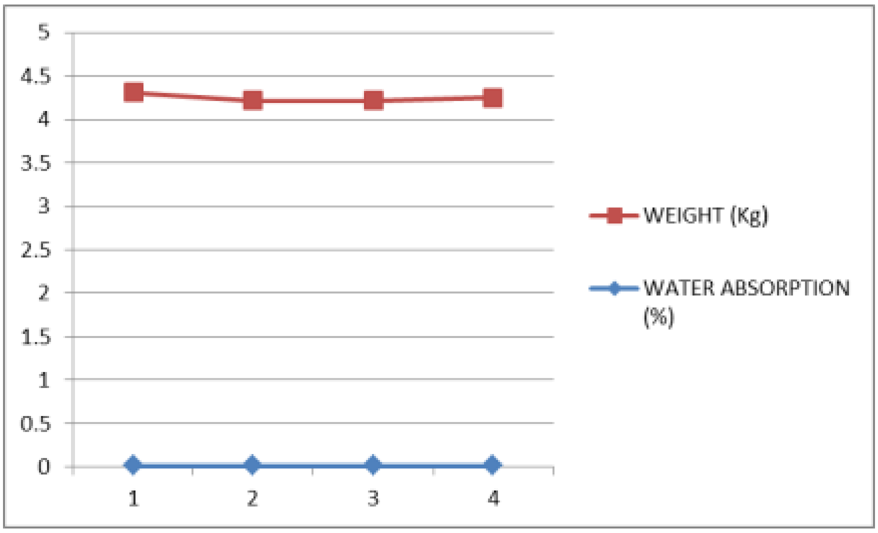

Figure 5 Water absorption (%) and the number of weeks fully immersed in water

Table 9b: Partial Immersion:

Sample	Weight (kg)	Water Absorption (%)		
		2weeks	4weeks	8weeks
1	4.274	0.13	0.13	0.14
2	4.055	0.00	0.01	0.01
3	4.238	0.00	0.00	0.00
4	4.214	0.01	0.01	0.02

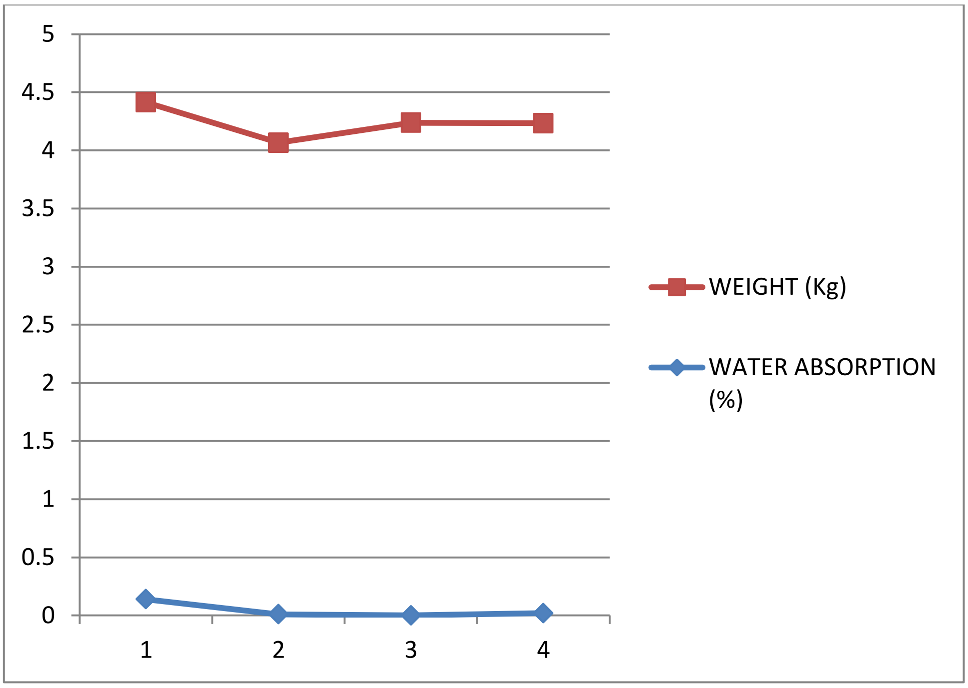

Figure 6 Water absorption (%) and the number of weeks partially immersed in water

3.8. Long term exposure to weathering results

Result of the effect of natural weathering on the roofing sheet and others stored outdoor as shown on Table 10:

Table 10: Result of Long Term Exposure to Weathering

Observation	Week 1	Week 4	Week 8	Week 12	Remarks
Weight	☆	☆			Good
Strength			☆	☆	Good
Durability	☆	☆	☆	☆	Good
	☆	☆	☆	☆	
Appearance	☆	☆	☐	☐	Good

Legend: ☆ - **No changes** ☐ - **Slight changes**

3.9. Fire Resistance Test Result

The heat penetration through the roof covering and effect of fire on the specimen was represented as the time it took a candle wax to melt at a certain temperature.

Table 11:

Temperature (°C)	Time (mins)	Observation on specimen
100	4.72	No changes
150	5.84	No changes
220	4.50	No changes
320	3.24	No changes

Observation

The fire flame and heat has no effect on the specimen weight and dimension but the appearance of specimen change due to the effect of flame resulting to occurrence of black colour on the specimen surface receiving the heat and flames.

3.10. Production of 1000 IDRT at 100 Tiles per day

Standard Mix Ratio

½ Head-pan of Portland cement (12.5kg)

1 Head-pan of Sharp sand

2kg of Paper

7.5 – 8 Litres of Water

Outcome= **8 pieces/products of IDRT**

For A bag of Portland cement

4 Head-pans of Sharp sand

8kg of Paper

Outcome = 32-35 pieces/products of IDRT

Materials needed

- 5 tonnes of sharp sand = ₦7,500.00
- 45 bags of Portland cement; ₦2,300 per bag = ₦103,500.00
- 240kg of Waste Paper at ₦10/kg = ₦2,400.00
- 2 rolls of Galvanized wire at ₦1,200 per roll = ₦2,400.00
- 12,500 litres of Water = ₦2,000.00

Total Amount = **₦117,800.00**

Using 2 labourers for 10 working days

@ 3,000/day; = **₦30,000.00**

Grand Total = ₦147,800.00

Input cost; ₦147,800/1000 = 147.8 ≈ ₦150

Profit cost per product; ₦50

Total cost of sale = Input cost + Profit cost

: ₦150 (Input cost) + ₦50 (Profit cost) = ₦200 per tile

6 pieces of Improved Double Roman Roofing Tile = 1 square metre

Price per square metre = ₦200 x 6 = **₦1,200.00**/m^2**-**

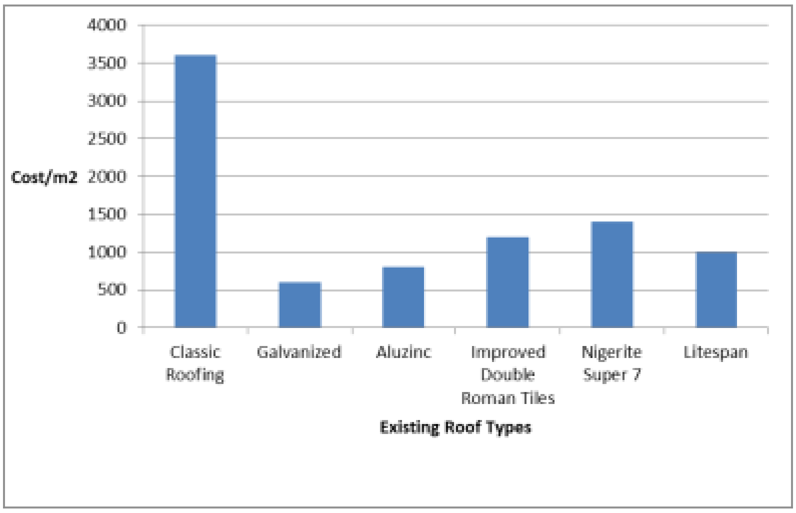

Figure 1 Comparative cost evaluation of existing roofing system in Osogbo, Nigeria Source: [7]

4. CONCLUSION

This experimental study of engineering characteristics of IDRT has shown that the Improved Double Roman Roofing Tile possesses all the desirable engineering characteristics of strength, water-tightness, sound-proof resilience, rust-proofness and durability to withstand weathering effect. The static loading tests have shown that the product can withstand artisans' exerted pressure during installation and after-installation maintenance. Also, as the age of product casting increases the compressive strength of the cubes continues to increase. The durability test on the product showed that the absorption rate of water when immersed in water for 8 weeks was minimal such that when exposed to atmosphere it evaporated quickly without moisture retention. The investigation showed that regardless of the production method used, improved double roman roofing tiles can achieve the aforementioned properties. This research has also shown that it is feasible to produce a light weight Improved Double Roman Roofing Tiles of 3.8 – 4.2kg at a cost of ₦200 per IDRT and ₦1,200 per m^2 of product roof coverage. From the outcome of this investigation, IDRT is hereby recommended to prospective clients and contractors.

REFERENCES

[1] Akinyemi, B. A. (2012). Durability based suitability of bagasse-cement composite for roofing sheets. Journal of Civil Engineering and Construction Technology, 3(11), 280-290.

[2] Adegoke C.W. (2013) ―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] Anyakoha, E. U. (1994): Towards achieving effective waste generation and Disposal practices in private premises in Nigeria International Standard ISO 536: Paper and board-Determination of grammage. International organization for standardization.

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

[5] Aïtcin, P. C. (2000). Cements of yesterday and today: concrete of tomorrow. Cement and Concrete research, 30(9), 1349-1359.

[6] Bender, W., & Böger, H. H. (2009). A short history of the extruder in ceramics. In Extrusion in Ceramics (pp. 85-128). Springer, Berlin, Heidelberg.

[7] Adegoke C.W. Funmi, A. (2015). Development of An Improved Concrete Roman Tile Alternative Roofing System Using Waste Raw Materials Paper and Saw Dust as Additives. International Journal of Scientific & Technology Research, 4(5), 1-7.

[8] Omoniyi, T.E. and Akinyemi B.A, "Durability based suitability of bagasse-cement composite for roofing sheets".

[9] Kyoji TANAKA, Ichiro SHIMZU and Michio KOIKE: Performance Test Results of Roof Waterproofing Systems; 269-278, Proceedings of IX International Congress, IWA, 1995.
[10] Standard Methods of Fire Tests of Building Construction and Materials, Designation E119-73, Part 18, 1974, pp.610-628.
[11] St. John D. A. et al ―Concrete Petrography‖- A Handbook of Investigative Techniques, London Arnold Publishers, 1998.
[12] Professor & Former Director, Centre for Alternative Energy Research & Rural Environmental Technologies (CAERRET), Osun State University, Osogbo, Nigeria.
[13] RILEM 5-SLR/CIB W.83 Joint Committee: Performance Testing of Roofing Membrane Materials, 1988.
[14] Analysis of an Inspection Technique for Roof Consultants by Robert L. Fulmer.
[15] American Society for Testing and Materials (ASTM) (1991).C1185-1991 Standard Test Methods for Sampling and Accelerated Testimg, Annual book of ASTM Standards, 04.09 Wood, Philadelphia, PA pp. 1-84.

PHOTO SPEAK

Display of Improved Double Roman Roofing Tile

Cleaning of the Vibrating moulding machine before casting

One square metre of fixed Improved Double Roman Roofing Tiles

Smoothening the surface of IDRT during casting

Mixing of paper, cement and sharp sand

Mixing for workability and uniformity

Uniform mixture after addition of colourant

IDRT positioned after casting

IDRT cube cast

Curing of the cube in the curing tank

Artisan's pressure static load testing

Static load testing

Full immersion of samples in water

Fire resistance test on sample

Fire resistance test on sample