DEVELOPMENT OF GROGGED CERAMIC CLAY ROOFING TILES FOR POULTRY HOUSING AS AN ALTERNATIVE TO ZINC SHEETS

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Abstract
Secondary clay obtained from Bomo, Zaria, Kaduna State was used for this research. Dry samples were fired to produce grog which was crushed and sieved to mesh 20(840microns). Body composition was formulated with 5, 10, 15, 20 and 25% additions of grog to the clay body with the different samples sintered to three varying temperature ranges of 900°C, 1000°C and 1150°C. Samples fired to the highest temperature of 1150°C sintered properly compared to others and thus had a low water absorption rate of 6%. Results of the Tensile strength and Cold crushing strength tests showed that samples with 5% grog addition fired to 1150°C had the highest values of 3736.82 N/mm^{2}and 285.45 kg/cm^2 respectively. These results revealed that samples with low percentages of grog resisted load better than samples with higher additions. This research indicates a huge prospect of developing grogged clay roofing tiles using locally available clay from the study area

Introduction

Industries have been looking for technical alternatives in order to optimize their processes, producing less waste materials in order to attain manufacturing efficiency. The ceramic industry, especially the sector devoted to the fabrication of building products is capable of incorporating and reusing different types of industrial waste materials (Ribeiro, *et al*., 2002).According to Vieira *et al*, (2007) grog waste could be used to improve the mechanical properties, workability, and chemical resistance of conventional ceramic bricks.

Clay materials used in the red brick ceramic industry show an extensive range of compositions, which permit the incorporation of a variety of industrial waste materials. Some wastes are very analogous in composition to the actual raw materials used, and often contain materials that can also be helpful in the fabrication of ceramic products. One such waste materials is the ceramic rejects, known as grog produced in growing amounts in the ceramic industry.

The earliest form of tiles historically dates back to pre- historic time when the use of clay as a building material was developed independently in several cultures. The first form of tiles was crude but 600 years ago, people started decorating them by adding pigment for colour and carving low relief designs into their surfaces (Kashim *et al*, 2013).

Poultry business is becoming increasingly important to the livelihood of Nigerians. Its housing and management plays a significant role in the profitability or the lack of it on the long haul. Awoniyi, (2003) documented that poultry egg production in poultry housed under asbestos roofing was higher than those housed under the metal roofing systems.
The focus of this research is to study the utilization of grog and clay as a medium for the production of roofing tiles as a suitable alternative to zinc sheets in poultry management.

Materials and Methods

The ball clay was sourced from Bomo in Zaria and grog was obtained from firing the same ball clay. These materials were chosen prior to their known physical, chemical and thermodynamic properties as obtained from available literature.

Clay and Grog processing

The clay was processed by manually crushing it into smaller particles after which it was soaked in water in a container for several days to disintegrate in readiness for sieving. After sieving to remove impurities, the clay was left to settle for 24 hours and dewatering was carried out to achieve the slurry. The slurry was then poured into plaster moulds meant for absorbing water from it and when the clay reached the right plastic consistency, it was demoulded and stored.

Dried bars of treated clay were fired up to a temperature of 1000°C, to obtain grog which was hand crushed with a hammer to reduce it to smaller grain sizes. The jaw crusher was used to further crush down the particles before being screened through 20 mesh sizes. This is approximately 840 microns as reported by Vieira, (2004).

Chemical Analysis

The clay was earlier analysed using the X-ray Fluorescence Spectrophotometer and it showed a large presence of silica and aluminum oxide in the sample which accounted for 67.336 and 19.569 wt% respectively. There is about 6.408 wt% of iron III oxide while other elements like potassium oxide, calcium oxide and titanium dioxide accounted for 2.241 wt%, 1.186 wt% and 1.750 wt% respectively. Other trace elements complete the composition of the clay sample as seen in Table 1(Opoku 2015).

Body Formulation

Jaw crushed grog materials that have been screened through 20 mesh size which is approximately 840 microns as reported by Vieira, (2004), were made in additions of 5, 10, 15, 20 and 25 wt.% (see table 2 for the composition of materials in the blend.) to the plastic clay body. Samples were mixed and kneaded for proper homogeneity. It was allowed to age for a period of seven days to help in the production, drying and handling to reduce or prevent cracks during firing (Opoku, 2015).

Production of Test Specimens

The test specimens were produced according to test requirements. Example, the test slabs for the determination of tensile strength of the tiles were required to be in a dumbbell or dog bone shape to effectively fit into the Tensometer before load application while test samples for the determination of the cold crushing strengths were produced and cut into a rectangular bar of area $5.5cm^3$.

Drying and Sintering of Test Tiles

The tiles were placed on a rack to dry at room temperature. This process allowed air to circulate on all sides of the tiles and as such they dried evenly without warping. A digital electric kiln was used for the sintering of the tiles to the varying temperatures of 900^oC, 1000^oC and 1150^oC. Sintered test samples are shown in Plate I.

Results and Discussion

Tensile Strength Analysis of the Tile

Tensile properties are measured in order to predict the behaviour of a material under forms of loading, ASM International, (2004).Three test tiles each of every single composition and temperature range were tested and the average result was taken (see Table 3).

The following formula was employed: Tensile Strength (N/mm) = Force (kN) / Area (mm^2)

These results as obtained from the strength of materials laboratory showed that the samples fired up to 1150^oC are the samples that performed best. The strongest sample was sample T1, which registered 3736.82 N/mm^2 as its tensile strength. This sample contained 5% grog addition to the clay body. It was equally observed that tensile strength increased with a reduction in grog application. These results appear to agree with RipoliFilho, (1997) who asserts that grog is generally detrimental to the mechanical strength of pieces but rather optimizes the workability of highly plastic bodies.

Cold Crushing Strength (CCS) Analysis

Cold Crushing Strength (CCS) is the product's ability to resist failure under a compressive load, until the sample fractures (or fails) ASTM, (1985).All the tiles were tested using the Form + Test Seidner Machine. The Cold Crushing Strength was calculated using the following formula and the results are as presented in Table 4:

$$\text{CCS (kg/cm}^2\text{)} = \frac{\text{Mass (kg)}}{\text{Area (cm}^2\text{)}}$$

The highest cold crushing strength was accounted for by the samples containing 5% grog addition fired up to 1150^{o}C. This sample was able to resist failure under compressive load of 285.45 kg/cm^2. These results appeared to be consistent with the previous results which showed a drop in mechanical strength with increased grog percentages.

Water Absorption Test Results

The less water infiltrates into a ceramic tile sample, the more durable the tile is and the better its resistance to the natural environment (Rajamannan, *et al*, (2013). The test specimens were dry weighed and submerged in water for 24 hours, after which they were removed and excess water cleaned off with a piece of dry cloth. The tile specimens were then weighed again to determine the rate of water absorption where,

W1 – Weight of the dry specimen and

W2 = Weight of the specimen after 24 hours immersion into water.

The following formula was employed to calculate the water absorption rate and the results obtained are as presented in table 5.

$$\text{Water absorption} = \frac{\text{Saturated weight} - \text{Dry weight}}{\text{Dry Weight}} \times \frac{100}{1}$$

Samples T1, T2, T3 and T4 fired to the temperature of 1150^{O}C had the lowest water absorption percentage of 6%. Roundhay Roofing and UK Federation of Roofing Contractors, (2016) recommended a 6% water absorption rate for clay roofing tiles.

Mould Making

Following the specifications of the two roofing tiles considered for the research, moulds were fabricated using mild steel sheets of 2.5mm and 3mm. Arc welding machine and electrodes of gauge twelve (12) were used. This was first done by outlining the various shapes of the proposed moulds on the metal sheet and using a Jigsaw machine to cut them out. A Welding machine was then employed to weld the different pieces together to form both negative and positive moulds of both tiles. Care was taken to ensure that the metal sheets were welded without any signs of giving way due to production pressure as suggested by Sullayman, (2006).

Tile Production

A hydraulic press machine was employed as adopted by Achilam, (2010) to press the tiles to about 15.45MPa pressure as suggested by Sullayman (2006) and also, Opoku (2015). This method proved effective in the pressing of both tiles. Dried tiles were fired using a digital electric kiln to a temperature of 1150^{o}C and properly sintered to a reddish color.

Conclusion

There exists in great abundance, local raw materials that can be used for the development and manufacturing of durable ceramic roofing tiles. Thick metal sheets can be designed, measured, cut, and fabricated into viable moulds for the pressing of clay roofing tiles. Tiles fired to 1150^{o}C revealed increases in both tensile and cold crushing strengths with reduced grog additions to the clay body, revealing 5% grog to clay body composition as most appropriate. Also, results of water absorption indicate this sample to be the best for the production of this tile since it conforms to industry standards.

This research proves the prospects of developing grogged clay roofing tiles, using local raw materials is possible and that this can meet the local roofing demands in the poultry industry.

Plate I: Sintered Test samples

Plate III: Materials used in mould production

Plate IV: Welding and reinforcement of mould

Plate V: Finished (negative & positive) tile mould

Plate VI: Loaded Hydraulic Machine

Plate VII: Pressed roofing tiles ready for drying

Plate VIII: Fired roofing tiles

Plate IX: Other samples of fired roofing tiles

Table 1: Results of chemical analysis of Bomo clay

Oxides	Concentration
Na_2O	0.090Wt%
MgO	0.866 Wt%
Al_2O_3	19.569 Wt%
SiO_2	67.336 Wt%
P_2O_5	0.000 Wt%
SO_3	0.411 Wt%
Cl	0.017 Wt%
K_2O	2.241 Wt%
CaO	1.186 Wt%
TiO_2	1.750 Wt%
Cr_2O_3	0.011 Wt%
Mn_2O_3	0.060 Wt%
Fe_2O_3	6.408 Wt%
ZnO	0.025 Wt%
SrO	0.028 Wt%

Source: Nigerian Geological Survey Agency, National Geosciences Research Laboratory (NGRL), Kaduna, Nigeria. (2015)

Table 2: Blends of Grog and Ball Clay in Percentages

Body Composition	Clay Body T1 (5%grog)	Clay Body T2 (10%grog)	Clay Body T3 (15%grog)	Clay Body T4 (20%grog)	Clay Body T5 (25%grog)
Ball Clay	950g	900g	850g	800g	750g
Grog	50g	100g	150g	200g	250g
TOTAL	1kg	1kg	1kg	1kg	1kg

Table 3: Results of Tensile Strength of Samples

Sample	Average Tensile Strength of Tiles Sintered to 900°C (N/mm^2)	Average Tensile Strength of Tiles Sintered to 1000°C (N/mm^2)	Average Tensile Strength of Tiles Sintered to 1150°C (N/mm^2)
T1	1002.32	729.34	3736.82
T2	902.68	1003.31	2461.87
T3	739.81	1143.51	2251.69
T4	688.42	1261.97	1978.44
T5	1089.07	1578.95	1699.63

Table 4: Results of Cold Crushing Strength Tests

Sample	Cold Crushing Strength of Tiles Sintered to 900°C (kg/cm^2)	Cold Crushing Strength of Tiles Sintered to 1000°C (kg/cm^2)	Cold Crushing Strength of Tiles Sintered to 1150°C (kg/cm^2)
T1	227.27	243.63	285.45
T2	229.09	241.81	283.63
T3	227.81	245.45	281.81
T4	230.90	247.27	280
T5	225.45	249.09	278.18

Table 5: Results of Water Absorption Tests

SAMPLE	900°	1000°	1150°
T1 (5%)	16%	8%	6%
T2 (10%)	16%	8%	6%
T3 (15%)	16%	8%	6%
T4 (20%)	16%	8%	6%
T5 (25%)	16%	8%	7%

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