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Corrugated Laterite Based Ceramic Roof Tile Stabilized with Cement

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ABSTRACT

The use of laterite based material as ceramic roof tile contributes to the innovation and application of local materials within our immediate environment. In this study the aim is to design and produce corrugated laterite based roof tile and investigate its water absorption and penetration. Paste of laterite-cement mix was formed with water to cement ratio of 3:1. The percentage composition of the cement used was 15% and 20%. The paste was poured into a wooden frame (dimension of 200mm x 300mm x 20mm) with an underlying corrugated metal sheet, while another corrugated metal sheet was placed on the paste to ensure formation of the corrugated shape on both sides. Water analysis carried out on the cast samples showed that the sample with 20% cement composition had a better resistance to water absorption and penetration. The result of this study indicates that the formation of corrugated roofing tile using laterite material is feasible and it is possible to have good water resistant property if fully optimized.

Keywords: *Cement, ceramic, corrugated, laterite, roof tile.*

1. INTRODUCTION

Building materials has undergone a lot of modification from accident times till this present technology era. With everyone seeking for affordable and confortable houses to live in, every scientist and engineer is working hard to develop and optimize new building materials that would be durable and cost effective. Building materials range from roofing sheet, block, concrete, gravel, sand, clay, stone, cement, roofing tiles, steel, fine aggregate, coarse aggregate, laterite among others.

Materials used for roofing in building have evolved over time. A number of them have been deployed for specific reasons such as: building, weather condition, availability, cost, durability, weight, among others. Common ones in use are: metal, asphalt, wood, ceramic, and polymers. Ceramic roof tiles are resistant to corrosion; which is common in iron based roofing sheet, as well as high durability. Common ceramic roof tiles are either clay or concrete based. Laterite has been used for wall construction around the world; it is cheap, environmental friendly and abundantly available building material in the tropical region [1]. There are large deposits of laterite in the six geopolitical zones of Nigeria like most tropical regions of the world [1]. Laterite is used extensively in road and earth dam construction [1]. Lateritic soils are widely used as construction material in Nigeria and other under-developed and developing countries of the world [1-3]. Laterite a natural material has continuously been put to use in building walls which are vertical members forming an enclosure or defining a space to or boundary and are usually required in a building to hold the roof to keep out rain [3], resist the transmission of heat and sound [3], resist fire to a reasonable extent [3], and give protection to the users of such structures [3]. Despite the availability and cheapness of laterite as a building material [2, 3], the use of the material is gradually fading away due to problems such as shrinkage cracking when trying to pour laterite walls as water slurry [3], intensive labour involved in ramming laterite and joining blocks together among others [3].

Despite its wide use there is still much to be explored of its functional properties. This work examines the viability of laterite as material for corrugated roofing tile as nothing has been reported of laterite in this regard. The approach of this work is to achieve the desired properties in the roof tile via processing and proper combination of materials. The samples to be produced are to be tested based on the acceptable standards for ceramic roof tiles, to properly characterize it, hence ensuring that its choice as a roofing tile is properly guided.

The use of laterite stabilized with cement, combined with appropriate processing to achieve application properties will impact significantly in the reduction of building construction cost, while still mobilizing the country's deposits for economic purposes towards national development. The main aims and objectives of this work are to produce corrugated laterite based roof tile, test the produced sample for water penetration, compare the obtained result with standard for roof tiles, and provide alternative ceramic roof tile other than clay based ones.

2. MATERIALS AND METHOD

2.1. Laterite

The laterite sample used in this work was collected from a deposit site at Galadimawa village in the Federal Capital Territory, Abuja, Nigeria. The collected laterite sample was prepared with a 1000 microns sieve. Laterite is a highly weathered material rich in secondary oxides of iron, aluminum or both [4]. It is nearly devoid of base and primary silicates but may contain large amount of quarts, and kaolinite. The presence of iron can be noticed by the characteristic colour produced by iron in the soils. The aluminum is generally in the form $Al_2O_3.nH_2O$, which is called bauxite, an ore of aluminum [5]. Although laterite physically has element of red colour, it should not be mistaken for red sandy-clay soil.

Laterite also contain sesquioxides which are chemical substances with empirical formula M_2O_3 where M = potassium (K), rubidium (Rb) or cesium (Cs) [6]. At ordinary temperatures and pressure below 100 mm mercury, potassium peroxide combines with oxygen to give the sesquioxides, K_2O_3 [6]. The laterite sample used in this work was stabilized with Portland cement used as a binder. Laterite stabilization is any treatment applied to it to render it suitable and strong [7].

2.2. Cement

Cement is a binder that sets and hardens independently and binds other materials together. It is made by heating limestone with small quantities of other materials such as clay. The type used for this work is Portland cement purchased at a store in Abuja, Nigeria.

2.3. Corrugated ceramic roof tile preparation

Two samples A and B of laterite based corrugated ceramic roof tile were prepared, varying the cement and laterite compositions. The size of the samples was 200 mm x 300 mm x 20 mm. Paste of laterite-cement mix was formed with water to cement ratio of 3:1. The paste was poured into a wooden frame with underlying corrugated metal sheet. Another corrugated metal sheet was placed on the paste to form the corrugated shape. The samples were air dried for 14 days.

Figure 1: Freshly prepared sample

Figure 2: Dried sample

2.4. Scanning electron microscopy (SEM) / energy dispersive x-ray spectroscopy (EDS)

SEM/EDS were carried out at the Sheda Science Complex (SHESTCO) in Gwagwalada, Abuja, Nigeria. The SEM analysis was carried out in a Zeiss Evo 60 Environmental Scanning Electron Microscope (Carl Zeiss Canada Ltd., Canada) equipped with a Bruker AXS Quantax 4010 Energy dispersive X-ray Spectrometer (EDS). The SEM provides a highly magnified image of the surface of materials that are similar to what one would expect if one could actually see the surface visually. This tends to simplify image interpretations considerably. The resolution of the SEM can approach a few nm and it can operate at magnifications that are easily adjusted from about 10x – 300,000x. Images of samples A and B matrices were taken with SEM machine to observe their surfaces.

EDS is an acronym describing a technique of X-ray spectroscopy that is based on the collection and energy dispersion of characteristic X-rays. An EDS system consists of a source of high-energy radiation, usually electrons; a sample; a solid state detector, made from lithium-drifted silicon, Si (Li); and signal processing electronics. EDS spectrometers are most frequently attached to electron column instruments. X rays that enter the Si (Li) detector are converted into signals which can be processed by the electronics into an X-ray energy histogram.

This X-ray spectrum consists of a series of peaks representative of the type and relative amount of each element in the sample. With modern detectors and electronics most Energy Dispersive X-ray Spectroscopy (EDS) systems can detect X-rays from all the elements in the periodic table above beryllium, Z = 4, if present in sufficient quantity. The minimum detection limit (MDL) for elements with atomic number greater than Z=11 is as low as 0.02% wt., if the peaks are isolated and the spectrum has a total of at least 2.5×10^5 counts. Quantitative analysis (determination of the concentrations of the elements present) entails measuring line intensities for each element in the sample and for same elements in calibration standards of known composition. EDS analysis of samples A and B matrices was done to ascertain the constituent elements of the matrix materials.

2.5. Water absorption

Water absorption test was carried out on samples A and B matrices. Dry mass (W_d) of the samples were weighed. The samples were then soaked in water until no bubble was observed. Excess water was removed from the samples using tissue paper and the wet mass (W_w) was also weighed.

Figure 3: Samples soaked in water

The water absorption was calculated from:

$$W_A = \frac{W_w - W_d}{W_d} \times 100$$

As given by Olokode (2011).

2.6. Water Penetration

The cast samples A and B of the corrugated ceramic roof tile were placed in the wooden frames used in their casting. The clearance between the casts and the frame was filled with RTV Silicone Sealant to prevent water leakage. Measured amount of water was poured into the set-up and the time taken for the first drop of water from below the set-ups was recorded.

Figure 4: Sample tested for water penetration

3. RESULTS

3.1. Scanning electron microscopy (SEM)

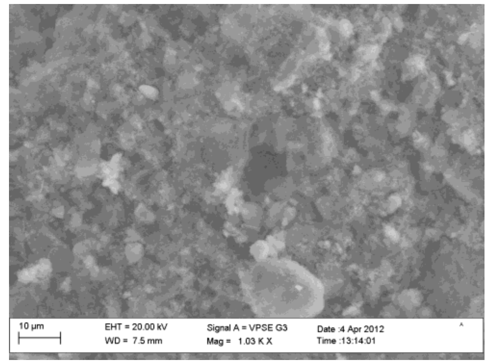

Figure 5: SEM for sample A

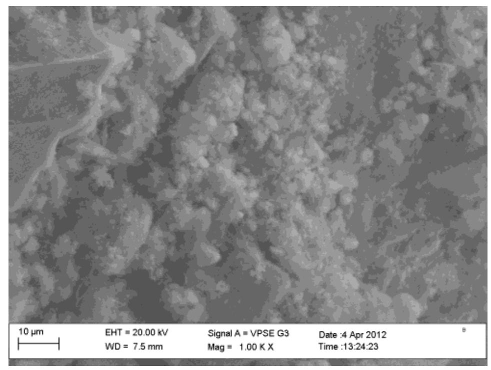

Figure 6: SEM for sample B

3.2. Energy dispersive x-ray spectroscopy (EDS)

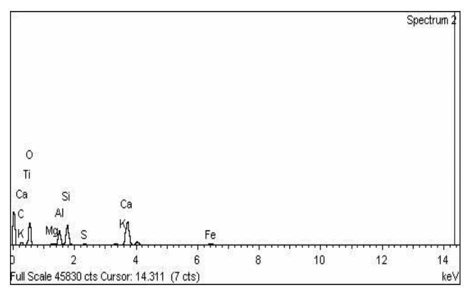

Figure 7: EDS result for sample A

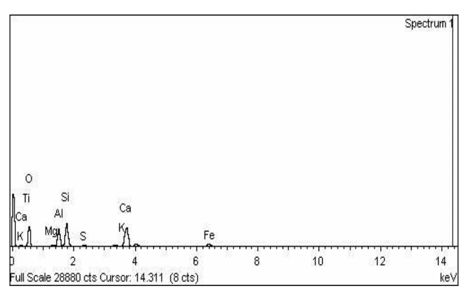

Figure 8: EDS result for sample B

3.3. Water absorption

Table 1: Water absorption result for samples A and B

Samples	Percentage of Cement	Percentage of Laterite	W_d (g)	W_w(g)	Time Taken (sec)	Water absorption (W_A) %
A	15.0	85.0	67.2	87.8	613.0	30.5
B	20.0	80.0	62.7	79.0	613.0	26.0

3.4. Water penetration

Table 2: Water penetration result for samples A and B

Sample	Volume of Water (ml)	Penetration time (s)
A	1000.0	9.0
B	1200.0	52.0

4. DISCUSSION

The results obtained from the Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), Water absorption test and Water penetration test indicates the microstructure, element present and properties of the corrugated ceramic roof tile. Figure 5 and 6, shows the SEM results from sample A and B, which indicates the level of pores present in the both samples, it shows a decreasing level of pores as the percentage of cement is increased from 15% to 20%, which indicates that the cement serves as a binding agent for the corrugated laterite ceramic roof tile. Sample A has very little pores, while sample B has fewer pores and is more compacted than sample A, this is as a result of the cement being a good binder, it tends to occupy interstitial positions in the laterite structure, thereby reducing the atomic separation distance and having a more closed packed structure. Finer grains tends to bind together better than larger grains, and since the laterite has fine grain and the cement is much finer, it makes them bind together properly, which reduces the level of pores present.

Figure 7 and 8, shows the EDS result for sample A and B, this indicates elements present in the corrugated ceramic roof tile and since the both samples A and B where both from the same source they both have similar EDS result, which confirms that they are from the same source. The EDS result indicates the present of K, C, Ca, Ti, O, Mg, Al, Si, S and Fe, these elements are usually obtained from laterite ceramic, the light reddish colour is as a result of the low level of Fe present as shown by the EDS result and sample B tends to have more Ca than sample A, this indicates an increase in cement for sample B. Table 1, shows the water absorption result for sample A and B, which indicates that it takes the same time to absorb water when soaked in water, but the percentage of water absorbed decreases as the percentage of cement increases, this is due to increase in the content of cement, which reduces the amount of pores present and provide better binding properties, the results obtained shows that the amount of pores decreases as the amount of cement is increased, hence a decrease in the amount of water absorbed. This shows a relationship between the SEM and the water absorption result, since the interstitial position has been occupied by the cement, the amount of pores will be reduced.

Table 2, shows the water penetration results for sample A and B, which indicates an increase in the penetration time as the percentage of cement increases, this is because of the increase in binding properties between the laterite and cement content when increased from 15% to 20%, which reduces the amount of pores present, hence an increase in the water penetration time. This shows a relationship between the SEM and the water penetration results, since the cement fill up the interstitial position in the laterite, which reduces the amount of pores, makes it difficult for water to penetrate; hence it takes a longer time for water to penetrate through.

5. CONCLUSION

In this study, it can be concluded that the corrugated shape can be formed and the amount of water absorbed by the corrugated ceramic roofing tile decreases as the percentage of cement was increased from 15% to 20% and the time taken for water to penetrate through the corrugated ceramic roofing tile increased as the percentage of cement was increased from 15% to 20%.

So we can also conclude that the amount of pores decreases as the percentage of cement was increased from 15% to 20%. It can be concluded that increasing the percentage of cement to a certain percentage and the use of quarry dust and water sealer will provides better resistance to water absorption and water penetration properties and also improves the mechanical properties of the corrugated ceramic roofing tile material and also provide economical building roofing tile materials since the cost is low compared to the corrugated roofing sheet.

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REFERENCES

[1]. Olugbenga A., Kolapo O., Oludare O. and Abiodun O. 2007. A study of compressive strength characteristics of laterite/sand hollow blocks. Civil Engineering Dimension. 9(1): 26-29.

[2]. Osadebe N. N. and Nwakonobi T. U. 2007. Structural Characteristics of Laterized Concrete at Optimum Mix Proportion. Nigerian Journal of Technology, Nsukka, Nigeria. 26(1): 12-17.

[3]. A. Adedeji, "Assessing the Bearing Capacity of Cast Laterite in Compression and Flexure" The Open Civil Engineering Journal, 2009, 3, 41-47.

[4]. J. O. Ukpata, M. E. Ephraim And G. A. Akeke, "Compressive Strength of Concrete using Lateritic Sand and Quarry Dust as Fine Aggregate", ARPN Journal of Engineering and Applied Sciences, Vol. 7 No. 1, January, 2012, ISSN 1819-6608.

[5]. Gidigasu, M.D. 1971. The importance of soil genesis in the engineering classification of Ghana soils. Eng. Geol. 5(2): 117-61.

[6]. Madu, R.M. 1977. An investigation into the geotechnical and engineering properties of some laterites of Eastern Nigeria. Eng. Geol. 11(2): 101-25.

[7]. Kamang E.E. 1998. Effect of Water-Cement Ratio on the Strength Properties of Stabilized Laterite Soils. Nigerian Journal Of Construction Technology and Management.1(1): 58-62

[8]. C. Richard Brundle, Charles A. Evans,Jr., Sham Wilson. 1992. Encyclopedia of materials characterization Series: surfaces, interfaces, thin films. Butxetworch-Heinemann, a division of Reed Publishing (USA) Inc. pp. 11,70-71,120

[9]. Madu, R.M. 1984. The influence of soil chemical composition on cement treated laterites. Proc. 8th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Harare, Zimbabwe, 4-7 June 1984, pp. 391-402.

[10]. Olokode, O.S. 2011. Empirical Model for Estimating the Physical/Mechanical Properties of Clay/Cement Tiles. The Pacific Journal of Science and Technology. 12(1): 81-88.