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Polymer Reinforced Laterite for Building Materials

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ABSTRACT

This paper focuses on the potential in locally available materials to produce alternative building materials at low cost. Laterite was reinforced with plastic particulates obtained from plastic wastes, and vulcanized rubber to improve flexural and compressive strength respectively. It was found that 20% volume fraction of fine grain plastic particulates mixed with matrix (60% laterite + 20% cement) had a better flexural and compressive strength respectively compared to the other samples of various proportions. In comparison with the traditional building material (river sand), it showed a higher compressive strength and very close flexural strength, hence can be used as alternative building material.

Keywords: *Laterite, Plastic Wastes, Vulcanized Rubber.*

1. INTRODUCTION

The choice of building materials in the society has been influenced by availability and cost [1]. As such, in most developing countries, building or owning a house becomes relatively difficult. In other to mitigate this problem, there is, therefore, a need to explore new ways of producing building materials from locally available materials at low cost. These locally available materials such as clay, laterite, and plastic wastes can be processed into low cost building materials. This paper examines the effects of plastics and rubber as reinforcements on the strength of laterite based materials. These includes; processing of laterite based material with varying composition of reinforcements, characterization of samples using scanning electron microscope (SEM/EDS), and mechanical testing (compression and flexural test).

Several attempts have been made to provide local alternatives to the use of river sand as fine aggregate because of its high cost, which has made it difficult for a common man in most countries to have a house of his own [2-3]. Mustapha Kabiru [4] worked on natural fiber (straw) reinforced laterite and the result depicts improved mechanical properties such as compressive strength, flexural strength, and fracture toughness. The application of natural fibers as reinforcement in bricks has been widely used in cement concrete and earth blocks as construction materials for many years due to the availability and low cost of fiber [5-8]. This informs our research interest on composite building materials from the local available materials at low cost using laterite (as matrix), recycled pure water sachet and vulcanized rubber (as reinforcement).

Laterite is a soil type rich in iron and aluminum formed in the hot and wet areas. Almost all laterites are rusty-red because of iron oxide (which is one of the constituent compounds) [9]. In addition, laterite belongs to the class of Pedogenics (soil type that has an inherent binder). The cementing material in laterite is the sesquioxide (chemical substance with empirical formula M_2O_3, where M can be potassium (K), rubidium (Rb) or caesium (Cs). Sesquioxide is not the only compound in laterite; there are other minerals such as kaolinite, goethite, hematite and gibbsite. Goethite and hematite, which are iron oxides and aluminum oxides respectively, are compounds responsible for the red-rusty color for laterite [10].

Cement is a binder, a substance that sets and hardens independently and can bind other materials together. When Portland cement is mixed with fine aggregate (sand or laterite) together with enough water, it hardens the matrix and produces a good concrete [11].

Pure water sachet used as reinforcement in this work is made from low density polythene. Low density polythene (LDPE) is a thermoplastic which is produced through the polymerization of ethylene [12].

2. MATERIALS AND METHOD

2.1. Materials and Preparation

Pure water sachet bags were picked from Galadimawa junction in Abuja, FCT, Nigeria, then washed with detergent, rinsed with water and sun-dried. The dried sachets were melted in a proprietary solvent at temperature of 100-180^{o}C, after which they were sieved using a sieve of 10 microns diameter. The residue was dried in the sun and further sieved to obtain finer particulates (2 microns in size). The fine and coarse grains were put into various cans. The laterite was pounded into smaller grains with the aid of a mortar and pestle, sieved into fine grains and mixed with cement.

2.2. Composite Preparation

The composite was prepared by mixing various proportions of the grains with laterite (matrix) using a hand trowel. The composite prepared was then worked into a dimensioned mold with the aid of a hand trowel. Both the top and bottom surfaces of the mold were leveled and smoothened out to obtain uniform surfaces. In order to reduce friction between the wall of the mold and mixed concrete, lubricant (oil) was applied. This made the removal of the mold easy. For each sample, the volume of water used was 200 – 250ml. A total of 36 samples were molded for both compression and flexural tests. The dimensions for the compression samples were 25.4mm x 25.4mm, while that of the flexural samples were 12.7mm x 101.6mm x 12.7mm. The table below shows the varied volume fraction of laterite and reinforcements (recycled plastics and vulcanized rubber) used but the volume fraction of cement (20%) was kept constant throughout the test. Also, the mixture of the river sand and cement was used as the control sample.

Table 1: Sample Composition

Samples	Composition
A	100%M(L+C)
B	90%M(L+C) +10%FG
C	80%M(L+C) +20%FG
D	70%M(L+C) +30%FG
E	90%M(L+C)+10%CG
F	80%M(L+C) + 20%CG
G	70%M(L+C) + 30%CG
H	80%Sand + 20% C

M = Matrix **L**= Laterite **C** = Cement **FG** = Fine grain **CG** = Coarse grain, The control sample (CS) is sample H.

3. MECHANICAL PROPERTIES OF THE POLYMER REINFORCED LATERITE

3.1 Test Methods

The compression test and flexural test were carried out using a Tiratest-2810 Universal electromechanical testing machine. For the determination of the compressive strength of the reinforced laterite, the following equation was used [13]:

$$\sigma = F/A_o \qquad (1)$$

where, F is the load applied and A_o is the initial cross-sectional area.

A three point bend configuration was employed to determine the flexural strength of the reinforced laterite, using the equation [13]:

$$\sigma_f = 3F_fL/2bd^2 \qquad (2)$$

where, F_f is the load at fracture, L is the distance between support points, b and d are the width and height of the sample cross – section respectively.

The morphology of the different samples were observed using EVO MA 10 Scanning Electron Microscope(SEM). The energy dispersive spectroscopy of the samples were also determined from the SEM.

3.2 Analytical Method

The rule of mixtures equations can be used to estimate the analytical/theoretical strength of large particulate composites [13]. The theoretical strength of the plastic particulates reinforced laterite was determined using the upper bound rule of mixtures expression:

$$\sigma_{RL} = \sigma_M V_m + \sigma_p V_p \qquad (3)$$

where, σ_{RL} is the strength of reinforced laterite, σ_M and σ_p are the strengths of the matrix and polymer respectively while V_m and V_p are the volume fractions of the matrix and polymer respectively.

4. RESULT AND DISCUSSION

The experimental and theoretical strength results obtained from the experimental and analytical analyses are shown below.

Table 2: Experimental and Theoretical Compres-sive strength results for the different samples

Samples	Composition	Exp. Compressive Strength (MPa)	Theor. Compressive Strength (MPa)
A	100%M	1.41±0.03	-
B	90%M+10%FG	1.55±0.03	1.36±0.03
C	80%M+20%FG	2.47±0.05	2.54±0.04
D	70%M+30%FG	1.79±0.04	3.73±0.05
E	90%M+10%CG	1.02±0.02	1.36±0.03
F	80%M+20%CG	1.44±0.03	2.54±0.04
G	70%M+30%CG	0.78±0.02	3.73±0.05
H	80%Sand+20% C	1.05±0.02	-

Table 3: Experimental and Theoretical Flexural strength results for the different samples.

Samples	Composition	Exp. Flexural Strength (MPa)	Theor. Flexural Strength (MPa)
A	100%M	1.65±0.03	-
B	90%M+10%FG	2.31±0.05	1.6±0.03
C	80%M+20%FG	2.41±0.04	2.98±0.04
D	70%M+30%FG	1.68±0.03	4.35±0.05
E	90%M+10%CG	1.45±0.02	1.6±0.03
F	80%M+20%CG	1.17±0.03	2.98±0.04
G	70%M+30%CG	1.03±0.02	4.35±0.05
H	80%Sand+20% C	2.63±0.05	-

M = L+C **L** = Laterite **C** = Cement **FG** = Fine grain **CG** = Coarse Grain

The experimental results for the compressive and flexural strength were compared with the theoretical results obtained (see fig. 1 and 2 in appendix).

4.1. Compressive Strength

The optimum composition that had the highest experimental compressive strength was the 20% FG, while the 30% FG and 30% CG composition had the highest theoretical compressive strength. The linear progression observed from the theoretical result can be attributed to the rule of mixtures expression used for the strength estimation. As the volume fraction of the particulates increases, the strength increases. But we cannot just rely on that because this may not always be true in practical or real cases. Also, since the theoretical result did not show us any clear difference of using the CG or FG, it may be too unsafe to rely on it. Rather, we need to give more consideration to the experimental results, which clearly shows us some measure of distinction in using either the CG or the FG in the reinforced laterite.

It is interesting to note from the results obtained that the samples with fine grains reinforcement had higher experimental strengths compared to the coarse grains. It was also observed that the effect of the coarse grains on the experimental compressive strength was negligible because the difference in strength between the 20% coarse grains composites and the matrix materials was quite small (about 2.08%). Also, the river sand material (CS) did not give a good compressive strength (1.05 MPa). Hence, from all these, it can be seen that the 20% fine grains reinforced composites has the potential of serving as a better alternative for the traditional building materials (river sand bricks and pure laterite non fired bricks).

4.2 Flexural Strength

As observed for the compressive strength, the theoretical flexural strength of the composites increased linearly with the volume fractions of the particulates. But this again cannot be relied on as it still fails to clearly show us any distinction in using either the CG or FG within the composites. In order to arrive at more real conclusions, we would need to focus on the experimental result, which clearly shows us the effects of the grain size in the composites. Based on these results, the river sand material had the highest flexural strength followed closely by the 20% FG reinforced composite (difference of 7.5%). This can be attributed to the shrinkage of the cross sectional area of the laterite based materials during curing. This variation in cross section can be corrected by optimizing the process.

The effect of fine grains reinforcements is such that the flexural strength increases with increasing volume fraction up to the content of 20%, where a peak flexural strength of 2.41MPa was observed. Above this volume, the flexural strength decreases as the volume of reinforcement increases. The coarse grains reinforced laterite exhibit a peak flexural strength (1.45MPa) at 10% reinforcement. Above 10%, the results showed that the strength decreases as the volume fraction of reinforcement increases. The unreinforced laterite had a higher strength compared to that of coarse grains reinforced composites, but lower than the flexural strength of the FG reinforced laterite. Therefore, based on the relatively high flexural strength of the 20% FG reinforced laterite, it shows a strong potential of being used as a suitable material for building purposes.

4.3. SEM Results

The morphology of the different samples observed using EVO MA 10 scanning electron microscope are shown at the end of this paper. Figures 3 to 9 show the morphology of the fractured surface of the specimen, the plastic grains were firmly bonded to the matrix materials. This is evident in the test sample with 20% plastic reinforcement (fine grains). The arrows on the micrographs Fig. 7 shows the direction of cracks propagation.

4.4. EDS Results

Energy dispersive spectroscopy (EDS) technique was used for the elemental analysis of the various testing samples. For the matrix sample (laterite + cement), the different peaks on the spectrum show the chemical elements presents such as calcium (Ca), oxygen (O), aluminum (Al), silicon (Si) and traces of potassium (K), titanium (Ti) and iron (Fe) (see Fig. 10). In comparison, laterite based specimen have more elements than the river sand based sample such as titanium (Ti), iron (Fe), potassium (K) and carbon. Fig. 11 ascertains the presence of Silicon (Si), aluminium (Al), and calcium (Ca) as major elements. Please see figures 10-14.

5. CONCLUSION

Results obtained from the experiments show that polymer reinforced laterite composite is a potential alternative to conventional building materials. This is evident from the improved mechanical properties especially the compressive strength of the 20% volume fraction of fine grain plastic particulates in comparison to river sands that are used for making conventional building blocks. The reinforced laterite also shows the ability to sustain crack propagation. (See Fig. 7 in appendix).

ACKNOWLEDGEMENT

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Appendix: Figures

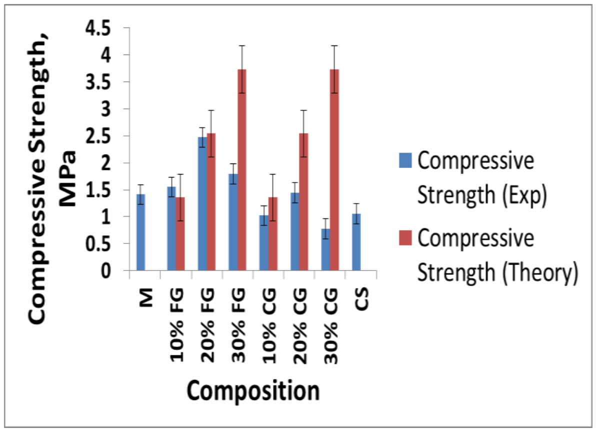

Fig. 1: Variation in Compressive Strength with different matrix compositions

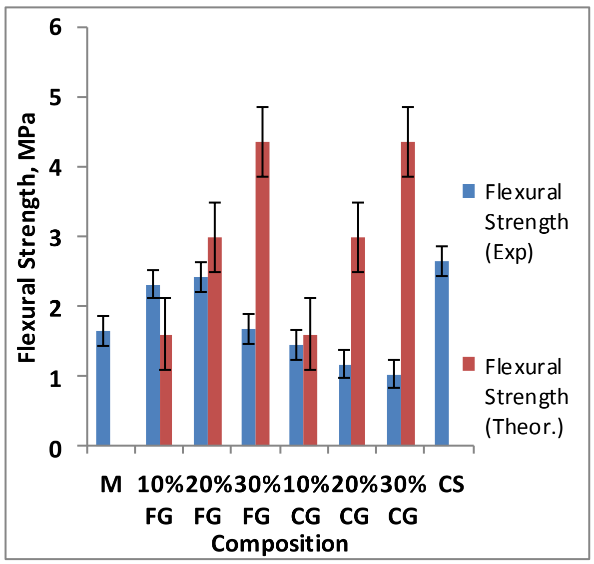

Fig. 2: Variation in Flexural Strength with different matrix compositions.

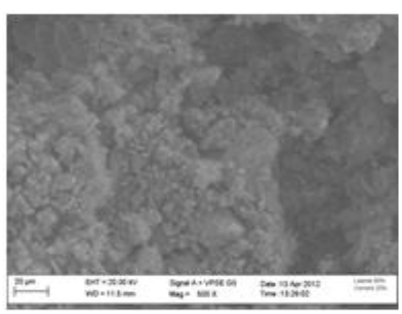

Fig. 3 SEM Micrograph of 80% laterite + 20%Cement

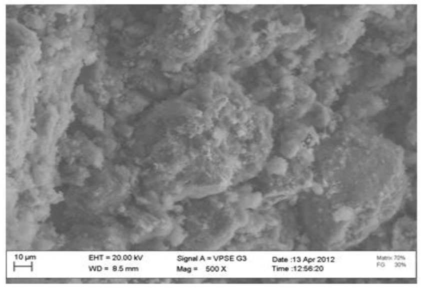

Fig. 4: SEM Micrograph of 80% River sand + 20% Cement

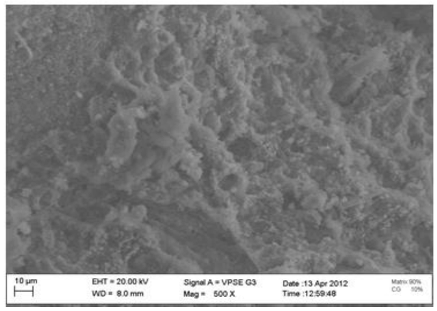

Fig. 5: SEM Micrograph of 90%Matrix + 10% coarse grains

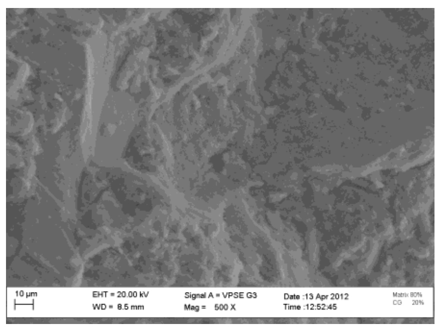

Fig. 6: SEM Micrograph of 80% Matrix+ 20% coarse grains

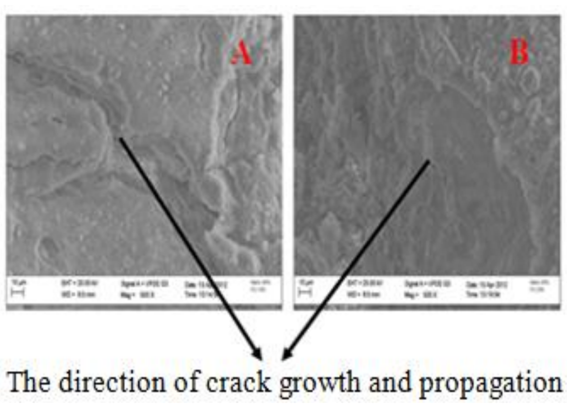

Fig. 7: SEM Micrograph (A) 90% Matrix + 10% fine grains (B) 80% Matrix+ 20% fine grains

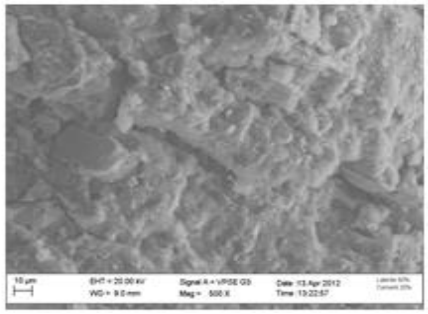

Fig. 8: SEM Micrograph of 70% Matrix + 30% fine grains

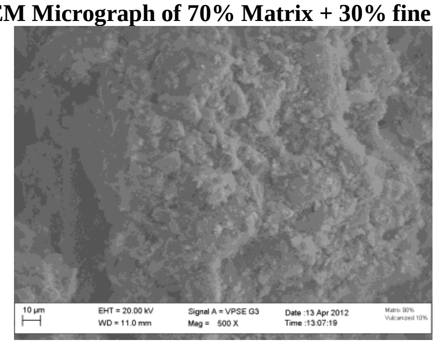

Fig. 9: SEM Micrograph of 90% Matrix + 10% rubber

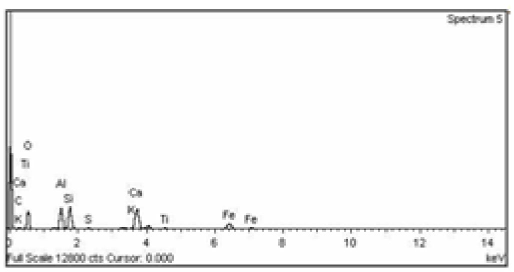

Fig. 10: EDS result for Laterite and Cement

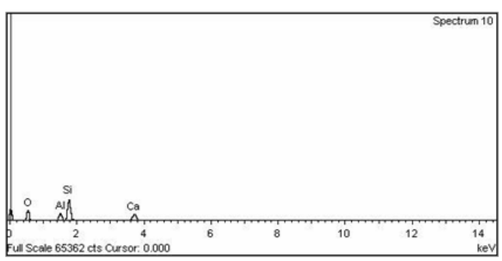

Fig. 11: EDS result for River sand and Cement

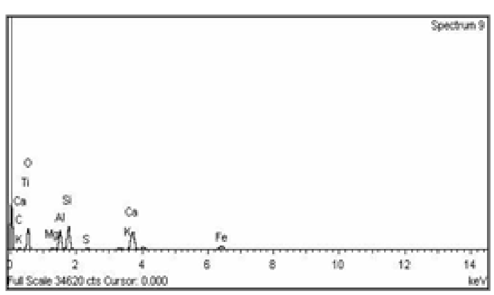

Fig. 12: EDS result for composite matrix and coarse grains

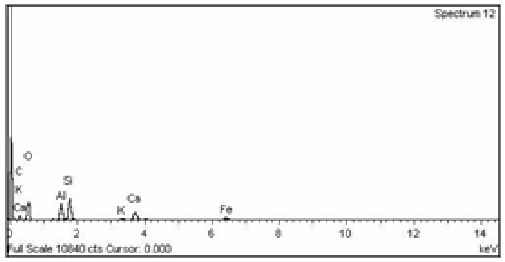

Fig. 13: EDS result for composite matrix and vulcanized rubber

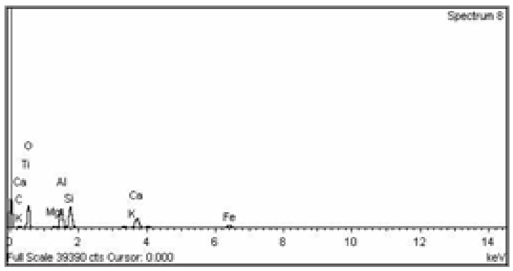

Fig. 14: EDS result for composite matrix and fine grains

