Effect of Palm Oil Fiber on Laterized Concrete

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ABSTRACT

This paper aims at assessing the effect of incorporating Palm oil fiber on the structural behavior of laterized concrete cubes and beams. The experiments include compressive test for 7, 14, 28 days of 63 cube specimens (150 x 150 x 150mm) and flexural test for 7, 14, and 28 days of 63 Beam specimens (150 x 150 x 900mm) for flexural strength test, prepared and tested under standard specification. The specimen are prepared with palm oil fiber of length 20mm and 30mm. the percentage of palm oil fibers taken are 0%, 0.25%, 0.50% and 0.75% (for the cube strength test) and 0%, 1.25%, 1.50% and 1.75% (for the flexural strength test) by volume fraction. In all specimens, the mix proportion for this investigation is 1:2:4 (cement: Laterite/sand: Granite) with 0.5 water cement ratio. The test results showed that at 0.25% and 0.50% fiber content the optimum fiber length was 30mm and 20mm respectively can yield up to 39% of increase in strength development compared to the control specimen. The experiment results indicates that the compressive strengths of the palm oil fiber reinforced laterized concrete increases with the inclusion of palm oil fiber with curing age while the flexural was also improved significantly with the increase in volume of palm oil fiber content.

INTRODUCTION

Technology in concrete has been developing in many ways to enhance the quality and properties of concrete. One of the technological advances in improving the quality of concrete is by using additives. Additive is a substance added to fresh concrete in small quantities typically so as to upgrade its properties. The materials chosen for structural upgradation must, in addition to functional efficiency and increasing or improving the various properties of the structures, fulfill some criterion, for the cause of sustainability and a better quality. So far the work on retrofitting of structures is confined to the use of carbon, glass or aramid fibres etc, very little work is being imparted in improving structures using naturally available materials, or natural fibres. Development of plant fibre composites has only begun. Among the various natural fibres, Palm oil fibres is of particular interest for the purpose of this research as this composite have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibres. Hence encouragement should be given for the use of Palm oil fibres which are locally available materials, in the field of civil engineering. Considering the benefits accruable to the engineering field and to humanity in general, it demands that scientists and engineers apply appropriate technology to utilize these natural fibres as effectively and economically as possible for structural upgradation.

AIM AND OBJECTIVES

The Aim and objectives of this study are:

1. To study the Effect of Palm oil fibre on Laterized concrete (Compressive strength and flexural strength)
2. To determine the economic feasibility of using Palm oil fibre as reinforcement on Laterized concrete in contrast with normal Laterized concrete.

REVIEW

Palm oil fibres are prospective reinforcing materials and their use until now has been more traditional than technical. They have long served many useful purposes but the application of materials technology for the utilization of Palm oil fibres as the reinforcement in concrete has only taken place in comparatively recent
years. The distinctive properties of natural fibre reinforced concretes are to improved Compressive strength, tensile splitting strength, and high flexural strength (Choi Y. et al., 2005), greater ductility, greater resistance to cracking and hence improved impact strength and toughness. Besides its ability to sustain loads, natural fibre reinforced concrete is also required to be durable.

Salau (2015), studied the Effect of Different Coarse Aggregate Sizes on the Strength Characteristics of Laterized Concrete, the results of the tests showed that workability, density and compressive strength at constant water-cement ratio increase with the increase in the coarse aggregate particle size and also with curing age. As the percentage of laterite increases, there was a reduction in all these characteristics even with the particle size of coarse aggregate reduction due to loss from the aggregate-paste interface zone. The result further reveals that with replacement of sand by 25% of laterite, the 19.5mm and 12.5mm coarse aggregate particle sizes gave satisfactory results in terms of workability and compressive strength respectively at 28 days of curing age, compared to normal concrete. However, in case of 50% up to 100% laterite contents, the workability and compressive strength values were very low.

Godavarthyet al., (2015) reported on the strength and durability performance of laterized concrete subject to water and chemical solution curing for 7, 28, 60, and 90 days. With the percentage laterite content of 0%, 10%, 20%, 30%, 40% and 50% the effect of varying percentages of sulphuric acid (H2SO4) concentrations at 1%, 3% and 5% were investigated. The results revealed that the laterite fines used could satisfactorily replace the sand up to 30%.

Bijuet al., (2015) presented the experimental result of tensile strength and modulus of elasticity of M25 concrete with varying replacement of laterite as a fine aggregate. Flexural strength obtained for laterized concrete specimens was more or less same as that of normal concrete without laterite. As the percentage of laterite content increases, the modulus of elasticity is found to increase suddenly and remain the same after 10% of laterite content. Introduction of laterite into the concrete matrix is found to slight decrease its split tensile strength. Based on the outcome of the experimental study, they recommend the used of concrete with laterite for concrete work.

Joshua et al., (2014) presented a result of Sandcrete blocks, which were made with lateritic soil taken from different sources replacing the conventional fine aggregate (Local River Sand) in steps of 10% up to 60%. Their compressive strength results revealed that the lateritic soils are mostly sandy clay of high plasticity and may replace sand by up to 20%, though an approximate linear decrease in strength with increasing sand replacement with lateritic soil was observed. They opined that, this percentage replacement can be recommended to the block making industries within Ota (Ogun State) with a view to encouraging utilization, though it is encouraged to confirm the percentage before embarking on mass block production.

Shuaibuet al., (2014) present their findings on the strength and cost effects of using sugarcane bagasse ash and laterite soil to blend traditional concrete to produce sugarcane bagasse ash laterised concrete for building construction purposes. Sugarcane bagasse ash and lateritic soil were used as blenders and mixed with normal concrete ingredients by replacing partially (a) sand with laterites and (b) cement with sugarcane bagasse in proportions 0, 5, 10, 15, 20 and 25% and 0, 5, 10, 15 and 20% by mass respectively. Concrete mix of 1:1.5:3:0.55 (cement: sand: aggregate: water-cement ratio) was used in the tests to determine the effect of individual material on the properties of concrete while same mix but maintaining a constant slump of 30mm was used to determine the combine effect of the two materials on concrete properties. The results of the investigations showed that though sugarcane bagasse ash laterised concrete required higher water content to produce a workable concrete, replacement of 20% of cement and 25% of sand by sugarcane bagasse ash and laterite soil respectively, SB-LA-20-25C gave a little higher than the targeted strength of 20MPa at 28 days, a tensile strength of 2.15MPa and reduced the cost of constituent concrete material per m³ by 18%. They came up with observation that, the strength of sugarcane bagasse ash laterised concrete decreases as the replacement levels increased as compared with the control specimen. However, the replacement level of up to 20% of cement and 25% of sand (SB-LA-20-25C) yielded a compressive strength of 21.3MPa and a tensile strength of 2.15MPa, which gave targeted strength for 1:1.5:3 concrete mixes. It was also observed that sugarcane bagasse ash laterised concrete gained strength at a little lower rate than the control concrete as represented by the ratio of its 7 days to that of 28 days strength.
Based on the results obtained from the experiment conducted by Tsado (2013), on laterized concrete (LATCON), he concluded that: the workability of LATCON increases while the percentage of water absorption by the concrete decreases with increase in replacement level of sand by laterite; 40% of laterite and 60%, the strengths of laterite concrete generally increased with age but decreases with increase in the replacement level of sand by laterite; LATCON with maximum of 40% replacement levels of sand by laterite attained the design strength of 20.48 N/mm² for C20, but was 15.36% lower than the design of 25 N/mm² for C25 at 28-day hydration period; for class C20 he recommend that the mix proportion be modified to 1:0.8:1.2:4 (cement: daterite: sand: coarse aggregate) instead of the usual 1:2:4 (cement: sand: coarse aggregate) and correspondingly 1:0.8:1.2:2 instead of 1:2:2 for C25; and for C20 and C25 LATCON.

Chakraborty (2013) also reported the use of natural fibres in fibre reinforced concrete composite (FRCC) that agglomeration could not be avoided. On the other hand, palm oil fibre processing covers a long process line during its manufacturing along with fibre opening, cleaning, faults removing and parallelizing, Muttaki (2013).

Olubisi (2013), ascertained the suitability of laterite as aggregate substitutes at 0, 10, 20, 30 and 40% of fine aggregate used in the construction industry. The results showed that the compressive strength of laterized concrete with laterite-fine aggregate ratio variation decreases when subjected to alternate wetting and drying and increases when subjected to magnesium sulphate (MgSO₄). It was also observed that a laterized concrete with a laterite-fine aggregate ratio of 20% conditioned to a temperature range of 100°C attained optimum compressive strength of 12.9N/mm².

According to Joseph et al., (2012) study on the flexural and tensile characteristics of concrete using combinations of lateritic sand and quarry dust as complete replacement for conventional river sand fine aggregate. Samples of concrete (e.g. cylinders, beams) were made using varying contents of lateritic sand and quarry dust as fine aggregate. The proportion of lateritic sand was varied from 0% to 100% against quarry dust at intervals of 25%, using concrete mix of 1:1.5:3 and water/cement ratio of 0.5. Concrete samples were prepared, cured for 28 days, from the results obtained they concluded that concrete containing mixtures of lateritic sand and quarry dust can be reasonably used in structural elements as for normal concrete (concrete with river sand as fine aggregate).

According to Muthusamy and Kamaruzaman (2012), there was a fall in the slump as the proportion of laterite as coarse aggregate rises. This finding shows a continuous decline in slump as the proportion of laterite increased. They opined that 10 percent laterite aggregate replacement of coarse aggregate can yield a comparable with that of normal concrete. They also added that 30% replacement exhibited the targeted strength of 30Mpa.

Kim et al (2012) studied the Mechanical properties of palm oil fiber reinforced concrete (PFRC) for making a suitable building material in terms of reinforcement. Two palm oil fiber reinforced concretes, so called palm oil fiber reinforced normal strength concrete (PFRNSC) and palm oil fiber reinforced high fluidity concrete (PFRHFC), were tested in axial compression, flexure and splitting tensile strength. Palm oil fiber is economic and environmental-friendly fiber because it can be cultivated in nature. The slump value, compressive, flexural and splitting tensile strengths of specimens were investigated to four levels of palm oil fiber contents by volume fraction. The results showed that the slump value of PFRHFC decreased sharply as the increase of fiber content, which indicated the palm fiber in HFC should limited to maintain the HFC characteristics.

Olawuyi et al (2012), investigated the influence of curing age and mix proportions on the compressive strength of volcanic ash (VA) blended cement laterized concrete. The results show that the compressive strength of the VA-blended cement laterized concrete increased with the increase in curing age but decreased as the VA and laterite (LAT) contents increased. The optimum replacement level was 20%LAT/20%VA. At this level the compressive strength increased with curing age at a decreasing rate beyond 28 days. The target compressive strength of 25N/mm2 was achieved for this mixture at 90 days of curing. VA content and curing age was noted to have significant effect (α ≤ 0.5) on the compressive strength of the VA-blended cement laterized concrete.
MATERIALS AND METHOD

Cement.
Ordinary Portland cement manufactured by Dangote cement plc. was used. It was obtained at Yaba, lagos. The cement was well protected from dampness to avoid lumps. Conventionally, cement is a powdered material that serves as a binder in mortar or concrete after reactions of lime or lime compounds have taken place with appropriate medium-usually water.

Coarse Aggregate.
The coarse aggregate used was crushed granite chippings of 12mm maximum diameter and density of 2690kg/m$^3$ produced at Ojodu-Berger in Lagos state. Aggregate is one component of Palm oil fibre reinforced laterized concrete, which is connected into a cohesive whole by means of binding materials-the cement paste.

Fine Aggregate.
The fine aggregate used in this research composed of laterite and sand with density of 2630 kg/m$^3$ and 2600kg/m$^3$ respectively. Laterite (reddish brown), one of the two fine aggregates used for this research work was obtained from a borrow pit site in Bauchi state. Sand the second fine aggregate used in this study was taken from Dindima River bed in Bauchi state.

Water.
Portable tap water supplied by the Bauchi State Water Board in Gubi Dam for domestic consumption was used throughout the research experiments.

Palm Oil Fiber
The palm oil fiber used in this research is obtained from KotonKarfe in Kogi State of Nigeria. Palm oil fibre is a natural fibre that posses several advantages such as; low cost, easily available and eco friendly and they also offer high strength and toughness when mix in cement composite, kumar (2015). Palm oil fibre being cheap, strong and durable will serve as a prospective reinforcing material for cement based matrices, this suggestion was according to mohammed et al., (2015). The fiber content chosen was 0.25%, 0.5% and 0.50% of cement weight.

PRELIMINARY TEST ON AGGREGATES
The results of particle size distribution for the aggregates are shown in figure 1. The coefficients of uniformity of the laterite, sand and granite are respectively, 2.06, 2.32 and 2.25 while those of curvature are 0.94, 1.22 and 1.56, with specific gravity of 2.61, 2.63 and 2.71. In view of these, the aggregates are classified as well graded and suitable for concrete production according to ASTM C33.
BATCHING AND MIXING OF MATERIAL
The concrete for this investigation is produced from cement, sand/laterite and granite mixed in the ratio of 1:1.5:3 with water/cement ratio of 0.5. The ratio of laterite to sand was 1:3 (25% laterite and 75% sand) in the fine aggregate, according to Olugbenga (2007), quoted that, “the most suitable mix of laterized concrete for structural purposes is 1:1.5:3, using batching by weight with a water/cement ratio of 0.5, provided that the laterite content is kept below 50% of the fine aggregate content.”

CASTING OF SPECIMENS
A total of 126 specimens were casted for the entire test regimes in this research work. The cube size of 150 x 150 x 150 mm is used to conduct the compressive test. On the other hand a beam size of 150 mm x 150 mm x 900 mm is used to conduct the flexural test. The specimens are differentiate with respect to aspect such as the fiber length and the fiber content by weight of cement. A specimen which contains zero percentage of fiber is also used as control specimen.

The fine aggregate portion of the mix was achieved by combining laterite and river sand in ratio of 25% laterite to 75% sharp sand; the materials were then mixed thoroughly. The required proportions of mix ingredients obtained were weighed for each batch separately. Then, gravel was spread in an even layer in the mixing pan followed by cement. Relative amount of fibre was added on each top of ingredient. After 1 minute dry mixing, water and the remaining fibre were added and the mixing operation continued for more than 3 minutes (since Fibre Reinforced Concrete requires more mixing period than ordinary concrete) to produce fresh concrete.

TESTS ON FRESH CONCRETE
Workability test i.e slump test was carried out on fresh concrete to determine and ascertain the workability of variousw mixes used in this research.

WORKABILITY
Shear slump was observed for unreinforced laterized concrete mix, this indicates that the unreinforced laterized concrete mix lacks adequate cohesion, which might result into segregation and bleeding. However, after mixing the laterized concrete with palm oil fibre, decrease in slump was observed as the fibre content increases. The drop in slump given in Table 1 was attributed to increase in water absorption capacity of the fibre which is within the range of 25%-40% as reported by Aziz and Mansur (1982), more water is needed for the reinforced laterized concrete mix to effectively workable. True slump was observed on all the reinforced laterized concrete mixes, this indicates that a general drop of concrete mass will be expected.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Average slump value (mm)</th>
<th>Type of slump</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>75</td>
<td>Shear slump</td>
</tr>
<tr>
<td>0.25%</td>
<td>60</td>
<td>True slump</td>
</tr>
<tr>
<td>0.50%</td>
<td>55</td>
<td>True slump</td>
</tr>
<tr>
<td>0.75%</td>
<td>50</td>
<td>True slump</td>
</tr>
<tr>
<td>1.25%</td>
<td>68</td>
<td>True slump</td>
</tr>
<tr>
<td>1.50%</td>
<td>65</td>
<td>True slump</td>
</tr>
<tr>
<td>1.75%</td>
<td>66</td>
<td>True slump</td>
</tr>
</tbody>
</table>

Table 1: Average slump value for fibrelaterized concrete.
TESTS ON HARDENED CONCRETE

Compressive strength test and flexural test were carried out on hardened concrete. These tests were carried out to determine the mechanical properties of concrete up to 7, 14 and 28 days for compressive and flexural strength. M20 concrete mix was used with coarse aggregates of size 20mm. mix design was carried out as per Indian Standard IS guidelines. After mix design it was found that the final mix proportion were 1:1.5:3.3 (Cement:Fineaggregates:Coarse aggregates), water/cement ratio was 0.5. Hand mixing was used throughout the experiment.

TEST RESULTS

Table 2: Average compressive strength of palm fibre reinforced laterized concrete.

<table>
<thead>
<tr>
<th>Days</th>
<th>20mm length</th>
<th>30mm length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>0.25%</td>
</tr>
<tr>
<td>7</td>
<td>14.22</td>
<td>15.11</td>
</tr>
<tr>
<td>14</td>
<td>18.67</td>
<td>18.37</td>
</tr>
<tr>
<td>28</td>
<td>21.13</td>
<td>21.69</td>
</tr>
</tbody>
</table>

Figure 3: Variation of compressive strength with curing Age for unreinforced and palm fibre reinforced laterized concrete
Results from Table 2 and figure 3 indicate that compressive strength increases with increase in fiber concentration and fibre length across all ages and various mixes. Results also showed that at 0.25% and 0.50% fiber content the optimum fiber length was 30mm and 20mm respectively which can yield up to 39% increase in strength gain compared to the control specimen as reflected in figure 4.

![Figure 4: Compressive strength for unreinforced and palm fibre reinforced laterized concrete for optimum fibre content and fibre length](image)

CRACK FORMATION ON PALMOIL FIBRE REINFORCED LATERIZED CONCRETE

Table 4.4 show the response of palm fibre reinforced laterized concrete beam test specimens to loading as fibre content increase from 0% to 1.75%. It is observed that in all the plain/unreinforced laterized concrete beams, the appearance of cracks was not noticed before failure occurred. Failures were quite sudden and occur at the middle third span of the test specimens on the tension surface. However, failure of reinforced laterized concrete beams specimens were not quite sudden, flexural crack was observed on the middle third span of the beam specimens on the tension surface before rupture. Once cracking occurs, the palm fibre acts as crack arresters and absorb a significant amount of energy as they are pulled out from the matrix without breaking.
The contribution of the palm fibre was attributed to the ability of palm fibre reinforced laterized concrete to maintain the ultimate load through further deflection without sudden collapse. The crack patterns are shown in figures 7 (a), (b) and figure 8. The ultimate failure load was used to compute the modulus of rupture, which is the ratio of the highest load and span length to the width and square of the overall depth of the sample expressed in Mpa, and the average results adopted as the modulus of rupture.

The mathematical expression of modulus of rupture, can be expressed by: 

\[ f_r = \frac{P L}{b h^2} \]

Where \( P \) is the failure load, \( L \) is span length, \( b \) is the width of the beam, and \( h \) is the overall depth of the beam.

DEFLECTION AND FAILURE IN BEAMS

The vertical deflections of mid-span of beam specimens are observed on the dial gauges position as indicated in Figures 9.

Figure 10 (a) and (b) present the load-deflection behaviour of palm fibre reinforced laterized concrete beams, for all the unreinforced beams relative to fibre length, the range of maximum central deflection at the point of failure is between 4.68mm to 6.58mm. The maximum central deflection at the point of failure for palm oil fibre reinforced laterized concrete values of 10.17 mm and 10.25 mm corresponding to the fibre lengths of 20mm and 30mm were observed in beam specimen with 1.75% fibre content in the laterized concrete mix. Generally, in test specimens with palm fibre content increases from 0% to 1.75% central deflection also increases in all test specimens. This suggests that palm oil fibre reinforcement in laterized concrete beams helps to improve the ductility of the specimens apart from the contribution of the laterite.

Figure 7 (a)& (b): Crack pattern of palm fibre reinforced laterized concrete beam specimens at 7 & 28 days curing age respectively

Figure 8: Flexural crack of the beam specimen
CONCLUSION AND RECOMMENDATIONS
In this work, the effect of palm oil fibre on the characteristics of laterized concrete specimens (cubes and beams) was investigated. The findings show:

i. Effect of palm oil fibre on workability of concrete.
Palm oil fibers do affect the workability of laterized concrete mix significantly by decreasing the slump values due to high water absorption capacity of the fiber. More water is needed for the reinforced laterized concrete mix to effectively workable.

ii. Effect of palm oil fibre on compressive strength of concrete:
Inclusion of palm oil fibre on laterized concrete contributes in improving the compressive strength of laterized concrete composite with age relative to the fibre length (20mm and 30mm).

iii. Flexural Characteristics:
- Flexural strength were found to be improved significantly with the increased in volume content of palm oil fibre from 1.25% to 1.75% simultaneously relative to palm oil fibre cut length of 20mm and 30mm.

iv. Deflection Characteristics:
- On all the Beam specimens (Reinforced/palm oil fibre reinforced laterized concrete), Central deflection increases with increased in fibre volume content, and this suggests that palm oil fibre reinforcement in laterized concrete beams helps to improve the ductility of the specimens apart from the contribution of the laterite.

The results of the work showed that use of alternative reinforcing materials such as palm oil fibre and laterite may be ideal for non-critical structural members including: Low cost housing and Temporary structures such as refugee camp. It is therefore recommended that low volume fraction of fibre (< 1%) can also be used to reduce shrinkage cracking mostly in slabs, lintel and pavements that have large exposure. Moderate volume fractions of fibre (between 1% to 2%) can be employed in structures that require energy absorption capability, improved capacity against delamination, spalling, and fatigue.
REFERENCE


