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Utilization of Palm Fruit Fibers as Constituent Materials for Hand Mould Clay Bricks

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Abstract

The production process of palm oil generates a huge amount of waste. As Nigeria is one of the largest producing countries, the fruit fiber wastes from palm oil processing have received a low level of waste management and have been a long-term environmental concern. This study is focused on recovery of the palm fruit fibers and its utilization as a constituent material for locally hand mold clay bricks. Varying percentages (1% to 3%) of palm fruit fiber was introduced into local hand mold clay. The bricks produced were tested for optimum moisture content and dry density. Some preliminary tests such as natural moisture content determination (wet and dry), Specific gravity test, Particle size distribution test (Sieve analysis), Atterberg limit test, Compaction test (Standard Proctor), Water absorption test, and Compressive strength test was carried out. The results show a decrease in optimum moisture content as the percentage of the palm fruit fibers increased from 1% to 3% in the soil sample while the maximum dry density increased. With the addition of 1% to 3% of the palm fruit fibers and the mix sun-dried, noticeable improvement in the compaction characteristics of the soil sample was observed. It can be deduced from the results that for a good construction clay soil, the lower the moisture content, the higher the dry density and the better the quality of bricks. Production of clay bricks with palm fruit fibers could serve as an economic substitute for the growing cost of sandcrete blocks.

Key words: Waste Management, Palm Fruit Fibres, Clay Bricks, Moisture Content

1. Introduction

Shelter is one of the basic amenities which many people wish to have but only a few get the opportunity to have a standard house built with conventional materials. Due to the high price of most of these conventional materials, many have resolved to improvise readily available materials such as clay and plant waste. Clay is one of the readily available materials used in time past, for the production of bricks which encouraged low-cost housing[1]. Clay is now widely used all over the world in restoring ancient buildings[2]. Plant waste like palm fruit fiber is also a readily available waste whose disposal has been either by burning or indiscriminate dumping on wasteland causing environmental issues. Some researchers in the course of their study have found clay as well as palm oil fruit fibers to be very useful[3]. Oil palm trunk and oil palm fruit bunch were used with clay for brick production and it was noted that for machine pressed bricks, oil palm fruit fiber gave low water absorption, better physical and mechanical properties[4]. An investigation on chemical treatment of fibers on acoustical, morphological, mechanical and spectra properties was carried out and it was found that there was improved sound absorption, increase in tensile and yield strength of the produced bricks.



The percentage increase of the oil palm fruit fiber content in clay bricks improves its thermal properties with appreciable mechanical strength [6]. These bricks are also eco-friendly due to their constituents and have good thermal conductivity (Raut & Gomez, (2017)). Fired clay bricks, when reinforced with natural fibers, improves both their compressive strength as well as tensile strength. According to [9], it has been recorded that there has been the successful utilization of palm oil fruit fiber and bunch in form of palm oil fuel ash as a supplementary cementitious material in concrete which improved both its fresh and hardened state properties. It was also discovered that at high temperature, the Palm Oil fruit Ash concrete had better performance when compared to that of ordinary Portland cement.

Other types of fibers have also been incorporated into brick production as an alternative for waste disposal so as to encourage low-cost housing and to strengthen its properties [10]. Introducing the use of zeolite [11], waste steel slag, and expanded perlite into the production of clay bricks to lessen energy loss during the operation phase. The hygrothermal performances of the clay bricks were also improved by using clay and olive tree pruning waste [3]. Sugarcane bagasse ash and rice husk ash were incorporated into the manufacturing of clay bricks at 5% to improve its compressive strength [12]. Lightweight and economical structures construction were encouraged by their research work. Rice husk and wood ash were used such that clay was partially replaced with these wastes [13]. It was discovered that the bricks produced from this mixture improved in thermal conductivity. New methods of reusing industrial wastes were also discovered by using residue [14]. The compressive strength of bricks after 28 days which was expected to be 2.0 MPa was exceeded denoting an excellent reason of waste utilization. The physical-mechanical properties of fired bricks were improved by using waste glass [15]. Waste marble powder was also adopted and recommended as pore maker which is important in the crystalline phase of brick production at a certain ratio [16]. A cigarette butt was added to clay at 2.5% to 10% in the manufacturing of bricks, and it was noted that energy for firing bricks could be reduced to about 58% [17]. This is a waste which is generally neglected and contributes to littering the environment and in return produces trillions of toxic substance [18][19]. Coir Fibre was used alongside with clay termite mound brick and it was discovered that for not more than 2% of coir fiber, both load bearing and non-load bearing structures can be built using produced bricks [20]

Apart from plant wastes and industrial wastes, other forms of wastes from treatment plants were also used. The use of bio-solids which was gotten from wastewater sludge, a major component of wastewater treatment process was introduced [21]. It was partially replaced with clay for fired bricks and it was discovered that these bio-solids had the capacity of increasing the compressive strength of the fired bricks to an average of 16 MPa. Galvanized sludge waste, a product of physio-chemical treatment of wastewater generated by electroplating plants was found to be of great importance in the production of ceramic bricks. When mixed with clay in the brick production process, the valorization and inertization of this pollutant which contains heavy chemicals were achieved [22].

Considering the reduction in properties of oil palm fruit fibres which may occur due to overheating and burning while adopting firing method of production, solving environmental problems and providing an alternative for affordable shelter which low-income earner will embrace, this paper looks at Utilization Palm Oil Fruit Fibres as Constituent material for hand

mould bricks in order to strengthen its properties by adopting the natural method of sun drying.

2. Methodology

The earth bricks were produced in the laboratory of the department of civil engineering, OAU Ile-Ife. The following apparatus was used: weighing balance, mechanical sieve shaker, graduated cylinder, rammer, trowel, shovel, spade and a set of wooden brick mold. Sufficient volume of the lateritic soil obtained from three locations (A, B, C) was pulverized, weighed and poured on a flat surface. Then the palm fruit fibers were added to the soil in varying percentages of 0%, 1%, and 3% thoroughly mixed together after which a measured quantity of water was added. The mixing was done with shovel and hands while mixing and, the noticeable organic matter was removed. The mixing continued until a consistency is reached between the palm fruit fiber and the soil giving a homogenous color. The mixture was placed in wooden molds of dimension 230mm × 110mm × 80mm in three layers and properly compacted with the use of a wooden rammer to fill the mold. These molds were previously lubricated for easy removal of bricks.



Figure. 1 clay and palm fruit fiber waste

2.1 Curing of bricks

The bricks were removed from the mold and air dried in the laboratory for a period of 48 hours to avoid the immediate development of cracks that might result from the fast and high rate of dehydration. They were then placed under the sun and cured for 7, 14 and 28 with the bricks turned sideways after each day to ensure even distribution of sun drying on the bricks (Fig.2). Adequate care was taken to ensure that precipitation from dew or rainfall does not fall on the bricks by covering them up with the waterproof material during the nights. Some preliminary tests such as Natural moisture content determination (wet and dry), Specific gravity, Particle size distribution (Sieve analysis), Atterberg limit, Compaction (Standard Proctor), Water absorption, Compressive strength were carried out.



Figure 2: determination of natural moisture content

2.2 Determination of natural moisture content

The water content of the soil is an important soil parameter which influences the behavior, particularly of cohesive soil [23]. This parameter was determined in the laboratory by measuring the loss in weight of the soil sample oven-dried to a constant weight at 110°C . There are various methods to determine the moisture content of the soil sample, but for the purpose of this work, the oven-drying method was adopted

2.3 Specific gravity test

The specific gravity test was carried out as per ASTM D854.

2.4 Sieve Analysis of soil sample

The test was carried out in a mechanical sieve shaker using 500g of soil to determine particle-size distribution, fineness modulus, and average sample size.

2.5 Atterberg limit test

The physical properties of clays are considerably influenced by the amount of water present in them. The boundary water contents at which the soil undergoes a change from one state to another are called Consistency Limits. To determine the consistency of the soil the following tests were carried out; Determination of liquid limit, Determination of plastic limit, Determination of plasticity index.

2.6 Water absorption test

The aim of this test was to determine the percentage of water absorption of the lateritic hand mold bricks. The sun-dried bricks were weighed and initial weight recorded, then immersed completely in bowls containing clean water for 24hours. Bricks were then removed after 24hours and their final weights were recorded. Water absorption, % by mass, after 24 hours immersion in cold water was then calculated.

2.7 Compressive Strength of Lateritic Hand Mould Brick

This test was carried out to determine the compressive strength of the brick samples. This was done with the use of the compressive strength machine in the laboratory. The samples were cured for 7, 14, 21 and 28 days after which they were crushed.

3. Result and discussions

A summary of the preliminary test results conducted on the soil samples is as shown in the table .1 below. They show the summary of the properties of lateritic soils used in their natural states. Figures 3, 4 and 5 also show the sieve analysis for the three locations. It can be seen that the percentage of moisture content is higher in soil sample A (open site near the ETF hall, OAU, Ife) which is a result of larger pore space and presence of larger soil particles within its soil structure hence there is the higher absorption of moisture in its natural state.

3.1 Specific Gravity Determination and Sieve analysis

The specific gravity of the soil samples for all the locations fell between 2 and 3 hence corroborating [24] and conforming to the words of Adelu (2010) following her mapping of the University Community, indicating the soil samples to have formed from the disintegration and decomposition of Banded Gneiss mineral rocks, having the type of mineral in the soil to be Biotite (Mica group), Plagioclase Feldspar, Quartz (SiO_2) and Muscovite

Table .1 Summary of the properties of the lateritic soils used

Properties	Locations		
	A	B	C
Moisture Content	24.62	22.5	14.66
Specific Gravity	2.18	2.6	2.8
Liquid limit (%)	75.73	50.5	45.23
Plastic Limit (%)	51.61	35.62	27.52
Plasticity Index (%)	23.62	14.88	17.7
Maximum Dry Density(kgm^3)	14.06	15.78	14.18
Optimum Moisture Content (%)	28.6	24.5	32
Particle Size Distribution			
Coefficient of Uniformity, C_u	6.15	7.2	43.08
Coefficient of Curvature, C_c	4.31	1.61	0.49
Soil Classification	Well graded	Well graded	Well grade

For soil sample A (open site near the ETF hall, OAU, Ife), following AASHTO classification percentage passing $75\mu\text{m} = 1.8\%$ ($<35\%$), the soil fell within the silty or clayey materials (A-2-4 to A-2-7). Also, L.L = 75.23%, P.I = 39.66%, hence the soil falls in A-2-7 group. For soil sample B (burrowed site along OAUTHC link road), following AASHTO classification percentage passing $75\mu\text{m} = 1.4\%$ ($<35\%$), hence the soil falls within the silty or clayey sand materials (A-2-4 to A-2-7). Also, L.L = 50.50%, P.I = 14.87%, hence the soil falls in A-2-7 group.

For soil sample C (faculty of EDM temporary site), following AASHTO classification percentage passing $75\mu\text{m} = 18.8\%$ ($<35\%$), hence the soil falls within the silty or clayey materials (A-2-4 to A-2-7). Also, L.L = 45.23%, P.I = 17.70%, hence the soil falls in A-2-5 group. The Optimum Moisture Content (OMC) is highest in soil sample C compared to the other soil samples. It was observed that the lower the OMC, the higher the MDD and the better the soil for construction purposes.

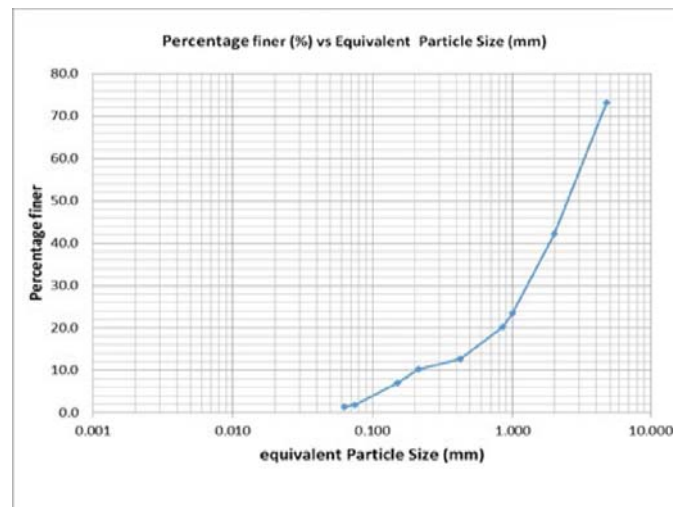


Figure. 3 sieve analysis for location A

From the graph, $D_{10} = 0.200\text{mm}$

$D_{30} = 1.030\text{mm}$

$D_{60} = 1.230\text{mm}$

$C_u = D_{60} / D_{10} = 1.230 / 0.200 = 6.15$

$C_c = D_{30}^2 / D_{10} \times D_{60} = 1.030^2 / 0.200 \times 1.230 = 4.31$ Since C_c is greater than 2, hence the soil is well graded.

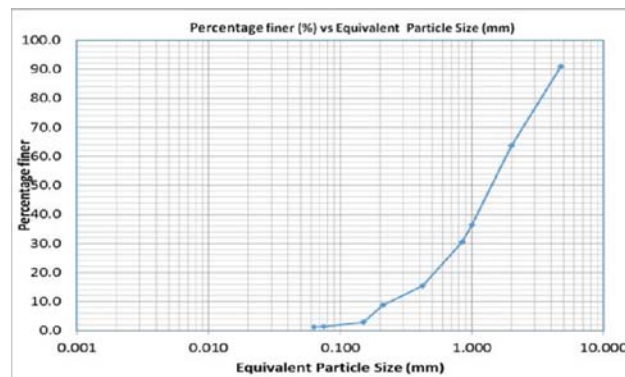


Figure. 4 Sieve analysis for Location B

From the graph, $D_{10} = 0.250\text{mm}$

$D_{30} = 0.850\text{mm}$

$D_{60} = 1.800\text{mm}$

$C_u = D_{60} / D_{10} = 1.800 / 0.250 = 7.20$

$C_c = D_{30}^2 / D_{10} \times D_{60} = 0.850^2 / 0.250 \times 1.800 = 1.61$

Since C_c is between 1 and 3, hence the soil is well graded

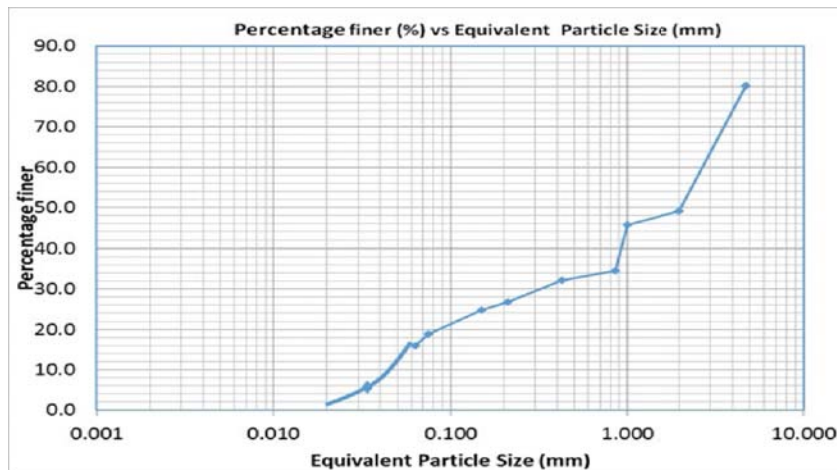


Figure. 5 Sieve analysis for Location C

From the graph, $D_{10} = 0.045\text{mm}$

$D_{30} = 0.300\text{mm}$

$D_{60} = 2.800\text{mm}$

$C_u = D_{60} / D_{10} = 2.800 / 0.045 = 6.22$

$C_c = D_{30}^2 / D_{10} \times D_{60} = 0.850^2 / 0.250 \times 1.800 = 0.49$

3.2 Effect of varying percentage of Fibre on the Water Absorption property of the Bricks at 28days Curing ages

Lateritic bricks with 0% and 1% palm fruit fibre at 7 and 14days curing ages for all locations were found to collapse after immersion in water for 24hours. Bricks with 1% fibre contents were observed to absorb more water than those with 3% fibre content due to the presence of a larger quantity of the fibers in those containing 3% fiber content which enhances the binding tendency of the bricks. The fibers tend to bind the soil particles together and as such reduce the pores within the soil structure hence reducing the percentage of water absorption property of the bricks. It was discovered that the rate of water absorption was greater in bricks containing 0% and 1% fiber contents compared with those with 3% fiber content. The result is as shown in figure .6 below

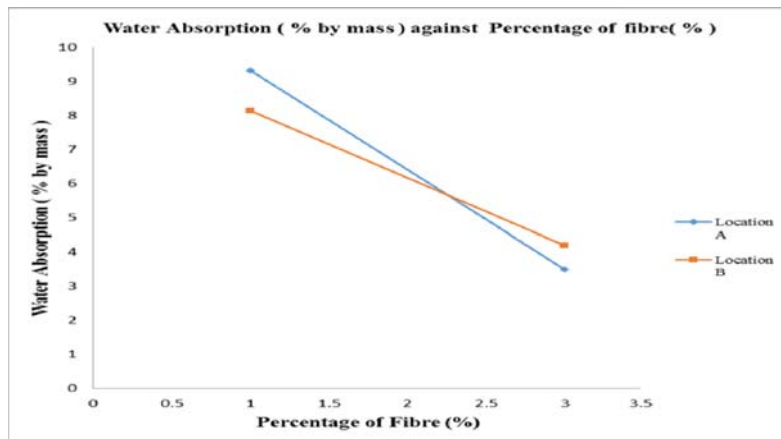


Figure. 6 The effect of varying percentages of fiber contents on the water absorption property of the

3.3 Effects of Varying Percentages of Palm Fruit Fibre on Optimum Moisture Content

The effects of varying percentage of palm fruit fiber at 0%, 1% and 3% on the optimum moisture content and maximum dry density during the compaction test are shown in fig.7 below. It was observed that OMC decreases as the percentage of the palm fruit fiber are increased from 0% to 3% in soil sample A. This is a result of the presence of fibers in the soil which will require a lower moisture content in order to attain a Maximum Dry Density (MDD).

In soil sample B, it was observed that an increase in the percentage of palm fruit fiber results in an increase in moisture content which is due to the presence of a low percentage of natural moisture content in the soil sample which will require more moisture in order to attain its maximum dry density. It was also observed that an increase in the Optimum Moisture Content (OMC) results in an appreciable increase in the Maximum Dry Density (MDD).

In soil sample C, there was an initial decrease in the OMC at 0% to 1% palm fruit fiber content then an increase was observed when the palm fruit fiber content was increased to 3%. It was observed that OMC is highest in soil with 0% palm fruit fiber and lowest in soil with 1% palm fruit fiber content. It can be deduced from the above that for a good construction soil, the lower the OMC, the higher the MDD and the better the quality of the brick. Hence there is an improvement in the compaction characteristics of the soil samples at 1% and 3% for soil sample A and C.

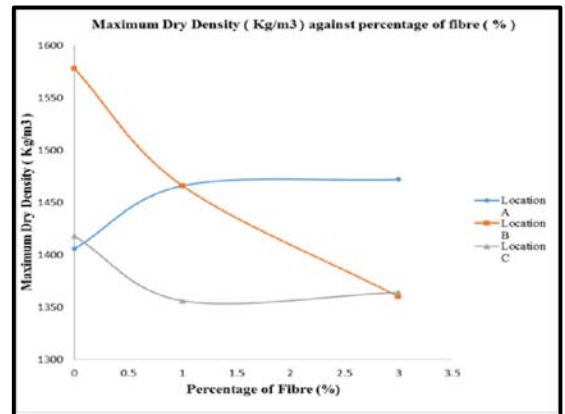
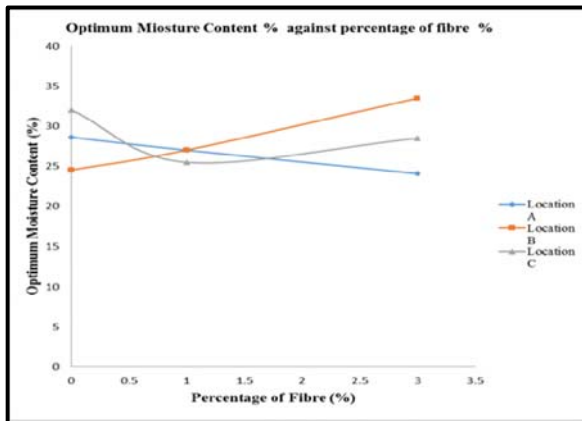
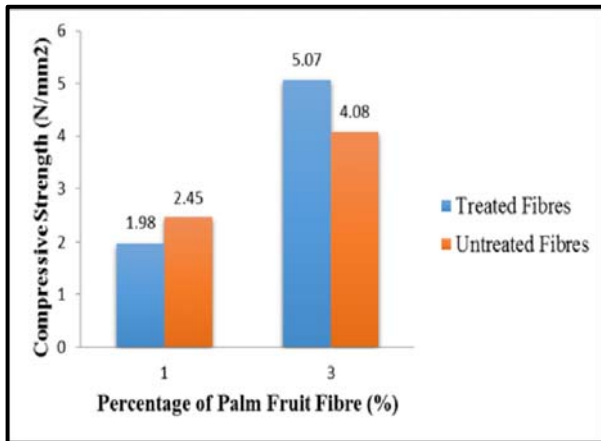
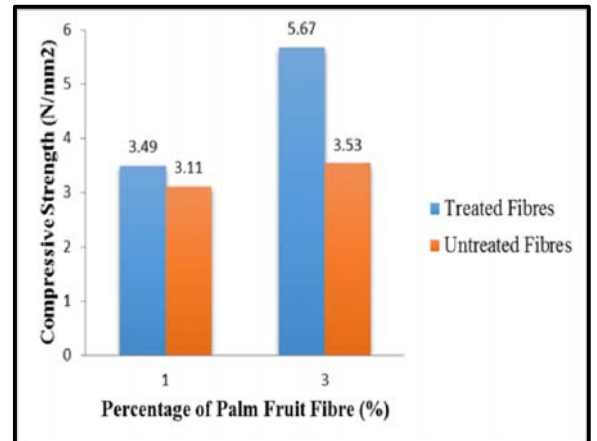


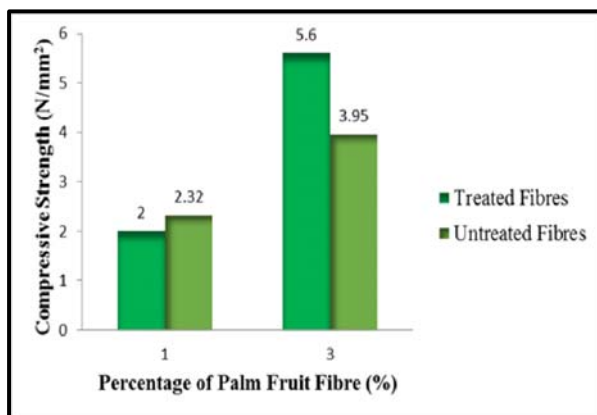
Figure.7 (a) Optimum Moisture Content (%) against Percentage of fiber (%)
 (b) Maximum Dry Density (Kg/m³) against Percentage of fiber (%)



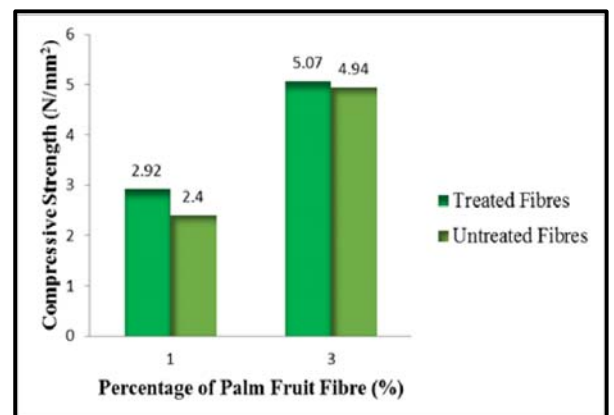
(a)



(b)



(b)



(d)

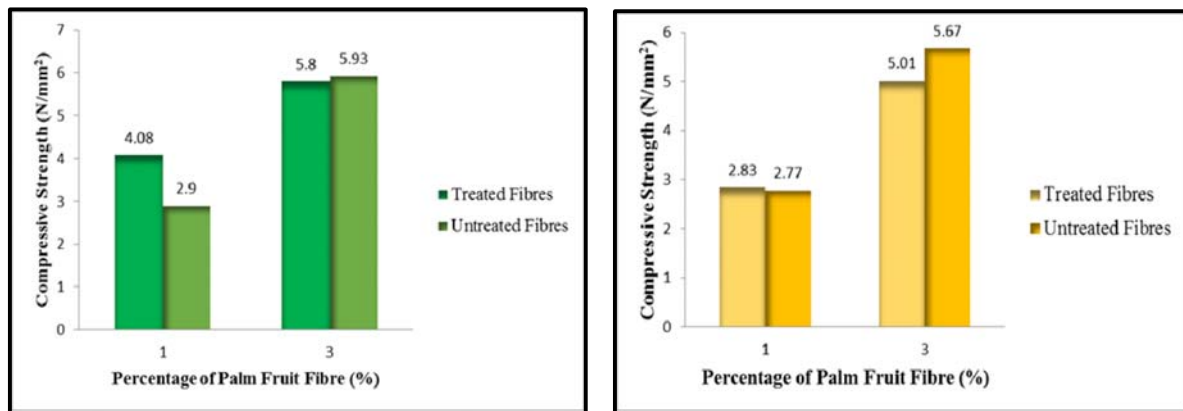


Fig. 8 (a) 7-day Compressive Strength of Bricks containing Treated and Untreated Fibre for Location A (b) 7-day Compressive Strength of Bricks containing Treated and Untreated (c) 14-day Compressive Strength of Bricks containing Treated and Untreated Fibre for Location A (d) 14-day Compressive Strength of Bricks containing Treated and Untreated Fibre for Location B (e) 14-day Compressive Strength of Bricks containing Treated and Untreated Fibre for Location C (f) 28-day Compressive Strength of Bricks containing Treated and Untreated Fibre for Location A

4. Conclusion

Based on the research work carried out on the effects of palm fruit fibers on the compressive strength of lateritic earth bricks, and the discussions of the results obtained from the tests carried out, the following conclusions were drawn:

- The compressive strength of the lateritic earth bricks increases with increase in curing ages with the 28-day bricks having the maximum compressive strength at 3% fiber contents.
- As the percentage of fibers increases from 1% to 3%, the compressive strength also increases giving optimum compressive strength at 3% fiber content.
- Presence of oil in the fibers reduces the compressive strength of bricks.
- Increase in fiber content decreases the water absorption since maximum water absorption was obtained.
- The larger the palm fruit fiber contents, the lower the percentage and rate of water absorption and vice versa. The weight of the bricks after sun drying was found to be similar to the initial weight of the bricks before immersion in water hence the bricks can be said to be recoverable and the difference in weight is as a result of dissolved parts of the bricks.

5. Recommendation

The hand mould bricks is recommended for partitioning walls due to its low compressive strength. Ways to improve the compressive strength of hand mould clay bricks made with palm fruit fibres can be looked into for further studies.

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