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Effects of Untreated Oil-Palm Fruit Fibre Reinforcements on the Strength and Durability Properties of Non-Fired Pressed Mud Blocks

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Abstract

This study investigated the effects of untreated oil palm-nut fibre reinforcements on the strength and durability properties of non-fired pressed mud blocks. Different proportions of untreated oil palm-nut fibre from 1% to 5% by weight of the blocks were incorporated into already characterized soil samples and used to produce blocks. Blocks containing 0% fibre were used as the control. The effects of the incorporated fibres were examined in terms of density, water absorption ratio, and compressive strength of the produced blocks. The water absorption of the blocks increased linearly with an increase in fibre content as the control exhibited the least water absorption of 7.9%. The density of the blocks decreased with an increase in fibre content. Block sample containing 5% fibre had the least density of 1644.44kg/m^3 as compared to the control with density of 1866.66 kg/m^3. The addition of untreated oil palm-nut fibre reinforcements to the block increased its compressive strength up to 3% fibre addition where the maximum strength (1.91N/mm^2) was observed. Beyond 3% fibre addition, the compressive strength decreased. Results obtained indicate that untreated oil palm-nut fibre reinforced earth block is a sustainable building material. This study recommends 3% fibre addition to attain optimum strength results and dissuades the use of fibres to reinforce mud blocks in high humidity environments.

Keywords: Oil-palm nut fibre, untreated, reinforcement, strength and durability, mud block.

1.0 INTRODUCTION

The use of mud blocks for construction has been an age-long practice. Earthen buildings have existed as one of the methods used by humans to cater for shelter. According to [1], the use of earth as a building material dates as far back as 2500 BC.

Mud blocks consist of clay, water, and sometimes natural and/or artificial fibres that are mixed and compacted manually. The blocks are moulded into different dimensions as required. The use of mud blocks in building construction can be attributed to their low cost, easy production method, ability to be formed into different forms, availability, acceptable physical, mechanical and thermal properties. However, their brittle behavior, low compressive and tensile strength and affinity for water makes them undesirable as compared to other materials used in building construction [2], [3]. Such undesirable properties of mud blocks can be controlled by reinforcing the blocks with additives. Sharma [4], in his study showed that the compressive strength of soil is increased with the addition of fibers. These additives can help to reduce shrinkage cracks by creating a network of fibres [5], increasing ductility and tensile strength. According to Guettala [6], durability tests that can be carried out on earth blocks include capillary water absorption test, total water absorption test, and freezing and thawing test.

The practice of adding natural fibres to mud blocks dates back to many centuries ago. Some of these natural fibres include palm, straw, jute, cane, sisal, and bamboo [7]. In early building construction using mud blocks, Egyptians added horsehairs or straws as reinforcement, while the Japanese and Chinese used straw mats [8]. Several studies have been carried out by researchers to investigate the effects of natural and industrial fibres on the performance of mud blocks.

Lamrani [9], investigated the thermal properties of clay mixed with date palm fibers, olive waste, and straw. They observed that the diffusivity and thermal conductivity decreased according to the variation of the volume fraction of additive materials varying from 0 to 30%. Similarly, in their study to investigate the mechanical properties of fibre reinforced mud blocks, Salih [10], used chicken feathers and sugarcane bagasse as fibre reinforcements. They carried out extensive compressive tests on the specimens and developed a third-order polynomial empirical correlation between the strength,

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density, and fibre content of the bricks produced using regression analysis ($R^2 = 0.99$). They concluded that the use of reinforcements in mud blocks reduces brick density and improves its strength which is consistent with the conclusions of [11] and [12]. On the other hand, Aouba [13], studied the effect of incorporated biomass (olive stone flour and wheat straw residue) on the properties of fired clay and proposed the inclusion of wheat straw residues in clay as it results in improved strength of the produced brick samples.

Taallah [14], noted that the addition of 0.05% date palm fibre and 8% cement to earth blocks when compacted at 10Mpa yielded maximum compressive strength. In addition, they stated that a further decrease in water absorption could be achieved by increasing the cement content and decreasing the date palm fibre content. The influence of straw fiber on the mechanical properties of Roman bricks was investigated by [15]. They observed that the straw fiber did not have any effect on the compressive strength of the Roman bricks but had a control on the plastic behavior. Donkor [16], noted that adding 0.4% weight Polypropylene in compressed earth block increased the compressive strength significantly. However, above 0.4% weight, the compressive strength reduces.

Mahat [17], compared the effect of oil palm trunk fibre and oil palm fruit fibre as reinforcement in clay blocks and noted that oil palm fruit fibre resulted in low water absorption, improved mechanical and physical properties of machine pressed clay bricks. Also, palm fruit fibre in clay bricks improves the thermal characteristics of the bricks [18, 19]. The resulting bricks are also eco-friendly [19].

Nigeria is the largest consumer of palm oil in Africa with a population of 197 million people [20] and oil palm production is a prime industry in Nigeria. Large amounts of waste amounts during the processing of oil palm to obtain palm oil including palm kernel fiber. This results in environmental waste issues. However, the re-use of these wastes will play an important role in waste minimization and propagate cost-effective and durable housing alternatives. In this regard, this research investigates the re-use of oil palm fibre as a means of effectively managing waste with a primary aim to determine the effects of untreated oil palm-nut fibre reinforcements on the properties of pressed mud blocks.

2.0 MATERIALS AND METHODS

2.1 Soil

The mud soil used in this research was obtained from Ufuma, Orumba North Local Government Area, Anambra State, Nigeria. Ufuma's geographical coordinates are 6° 5' 0'' N, 7° 11' 0'' E. The mud sample was dried under sunlight for 7 days, taking the samples into shelter after each day. The moisture content of the soil was obtained to be 19.3%. After drying of the soil sample, its lumps were crushed to powder with the aid of a mortar and pistol. Standard soil classification tests were carried out according to BS 1377-2: 1990. However, to ensure adequate plasticity, uniformity and maintain same water content amongst the test specimens, only soil fraction finer than 2.00 mm sieve were used for moulding the blocks.

2.2 Fibre

Oil palm nut fibre used in this study was obtained from Akpo town situated in Aguata, Anambra, Nigeria. The geographical coordinates are 5° 57' 0'' N, 7° 6' 0'' E. The palm nuts were sorted from the fibres and set aside as in Figure 2. The fibres were washed with warm water to extract most of its oil and then dried for 7 days under the sunlight.

Figure 1: Oil palm fibres

2.3 Preparations of specimen

Mud blocks of 150×150×150mm containing different proportions of fibre were produced from the already sundried and screened mud soil. The fibres were used as additives, whereby they were added at weight fractions of 0%, 1%, 2%, 3%, 4% and 5%. The mud blocks were moulded in layers and pressure was applied with the aid of a locally manufactured rammer. The blocks were air-dried for 28 days prior to testing.

2.4 Laboratory tests

Basic preliminary tests to characterize and determine the suitability of the soil for producing rammed earth blocks including specific gravity and particle size distribution were carried out in accordance with procedures and methods described in [21]. The soil was then classified using the Unified Soil Classification System (USCS).

The densities were also obtained from the mass (kg) and the volume (m^3) of each produced block. The mass was obtained with the aid of an electronic weighing scale with an accuracy of 0.01kg while the principal dimensions i.e. length, width and height of the blocks were measured with the aid of a digital vernier caliper, having accuracy of 0.01 mm.

The water absorption test (WA test) was carried out to determine the amount of water that the rammed earth block can absorb after 24 hours immersion in water. This test was carried out in accordance to procedures suggested by [8]. The water absorption was calculated using equation (1).

$$M = \frac{m - m_o}{m_o} \qquad (1)$$

Where m_0 denote the oven dry weight and m denote the wet weight after 24hrs in water.

The compressive strength test on the fibre reinforced pressed blocks was carried out with a Universal Testing Machine with frame capacity to deliver a maximum load of 1000KN in accordance with procedures and methods described in [21]. Force loading speed was set from 0.5-10mm/sec.

3.0 RESULTS AND DISCUSSIONS

3.1 Particle size distribution

The particle size distribution curve for the soil sample is shown in Figure 2.

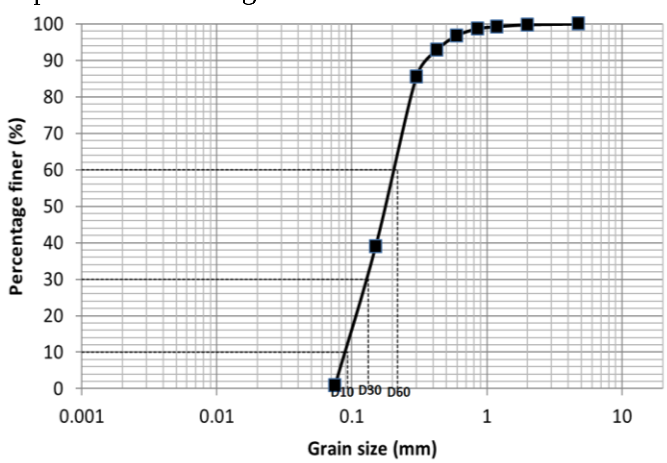

Figure 2: Particle size distribution curve

From the curve of the soil distribution, the uniformity coefficient, C_u and the coefficient of gradation, C_c can be obtained thus.

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.217794}{0.092913} = 2.344 \qquad (2)$$

$$C_c = \frac{D^2{}_{30}}{D_{60}D_{10}} = \frac{[0.132283]^2}{0.217794\ x\ 0.092913} = 0.865 \qquad (3)$$

From Equations (2) and (3), the soil sample used in this study can be classified as poorly graded in terms of soil gradation.

3.2 Characteristic properties

The physical properties of the soil used are shown in Table 1.

Table 1: Physical properties of the soil sample used in this study

Physical properties	
Specific gravity	2.52
Liquid limit	42.7%
Plastic limit	21.1%
Plasticity index	21.6%
Soil description	Clay with medium plasticity

3.3 Density

From Figure 3, it can be deduced that addition of fibre leads to decrease in the density of the blocks produced. The control containing 0% fibre had a density of 1866.66kg/m^3 as compared to a density of 1644.44 kg/m^3 of sample containing 5% fibre. This is in agreement with [22] who concluded that addition of fibers increases the density of composite materials, which is an advantage for building structures.

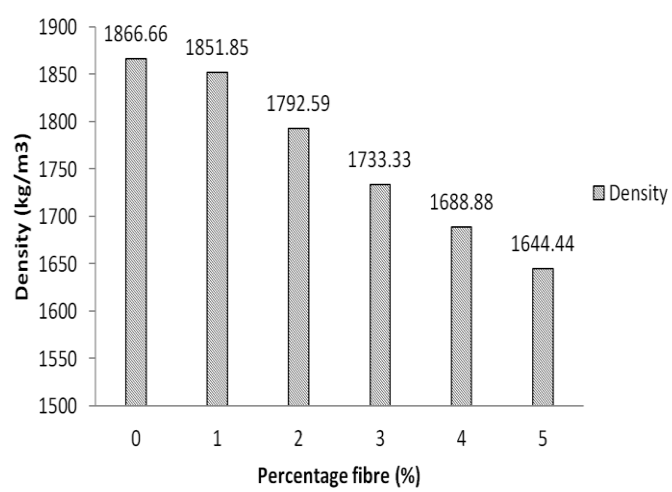

Figure 3: density of produced block samples

3.4 Water absorption

From Figure 4, it can be observed that increase in the fibre content of the block samples leads to an increase in the percentage of water absorption. The block sample

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containing 5% of palm nut fibre exhibited the highest water absorption percentage of 24.32%.

This could be as a result of hydrophilic nature of the fibres associated with its cellulose and lignin content [23] . According to [22], the presence of a hydroxyl group in cellulose and lignin leads to increased water absorption in palm flower and fruit fibres. However, when fibres are treated, their water absorption capacity is reduced leading to increase in strength [24].

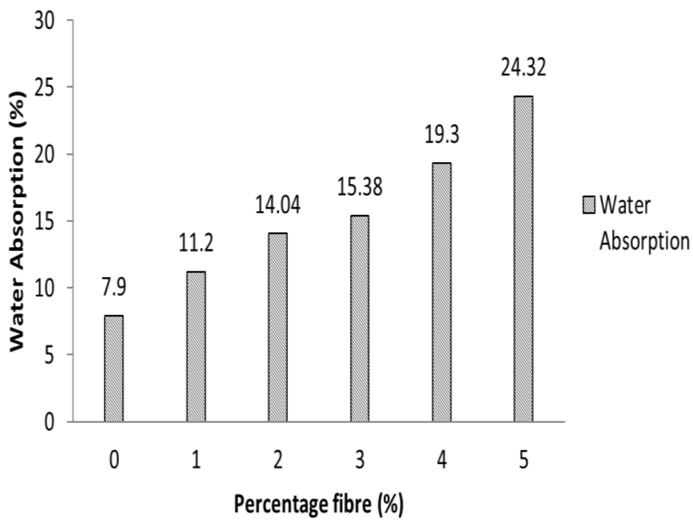

Figure 4: Water absorption of produced block samples

3.5 Compressive strength

The plot of results obtained from compressive tests of the produced block samples against fibre contents is shown in Figure 5. Compressive strength of the bricks were 1.74N/mm^2, 1.8N/mm^2, 1.91N/mm^2, 1.83N/mm^2, 1.45N/mm^2 and 1.35N/mm^2 for 0%, 1%, 2%, 3%, 4% and 5% respectively.

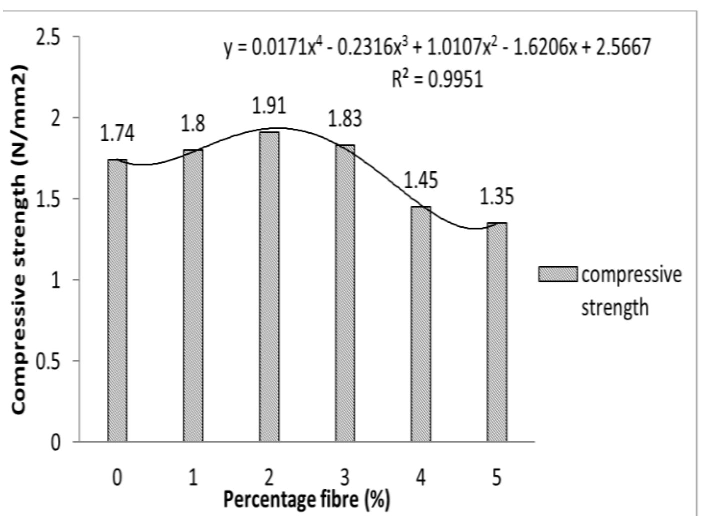

Figure 5: Compressive strength of produced block samples

It is observed that addition of the fibre increased the compressive strength of the blocks until 3% where the highest strength value was achieved. However, further addition of the fibre led to a decrease in the compressive strength. The increase in the compressive strength of the block can be attributed to the fact that the fibres present in the soil matrix can withstand stresses and tend to reinforce the soil. However, the strength decreases after 3% fibre addition. This resulted because increase in the fibre content above 3% makes them act like voids in the soil, this consequently reduces the strength.

4.0 CONCLUSIONS

The following are conclusions drawn from the findings of this research.

1. Untreated oil palm-nut fibre reinforced earth block is a sustainable building material
2. Untreated oil palm-nut fibre can be used as reinforcements to increase the compressive strength of pressed earth blocks.
3. Addition of Untreated oil palm-nut fibre to pressed earth blocks reduced the density of the blocks. This is headway towards lightweight construction.
4. Fibres increase the water absorption of earth blocks as it increases its permeability.
5. An optimum amount of untreated oil palm-nut fibre to obtain maximum strength is 3% fibre content by weight of the block.
6. The use of fibres to reinforce mud blocks yields adverse effects in terms of water absorption and hence is not recommended for use in blocks in high humidity environments.

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