BEHAVIOUR OF OIL PALM BROOM FIBRE REINFORCED CONCRETE

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Abstract: Fiber reinforced concrete was developed by incorporating discrete fibers into the concrete mass to combat the brittle reaction of concrete. The durability of natural fibers such as oil palm broom was established through an experimental investigation in which the fiber was treated to an alkalization-related treatment procedure. The research is based on the investigation of the use of Oil Palm Broom Fibres (OPBF) in structural concrete to enhance the mechanical characteristics of concrete. The OPBF were subjected to an alkali treatment with the use of sodium hydroxide of 4 %, 6 %, 8 % and 10% with removal times of 1 hr, 2 hrs, 8 hrs and 24 hrs respectively. The flexural strength of OPBF concrete was determined after 28 days where the treated fibres were included in fresh concrete mix. The discrete OPBF of 75 mm length were washed and dried in open air and randomly included in the concrete at 0.3 % of the volume of the beam size 100 x 100 x 600 mm with mix ratio of 1:2:4 and water-cement ratio of 0.55 to assess the suitability and durability of the fibre in concrete. It was observed that the rate of water absorption of the treated fibres increase compared to untreated fibres and the treated OPBF with alkalization improves the flexural strength of concrete beam at a concentration of 6 % NaOH for a duration of 1hr and the SEM images of OPBF cross section shows dispersed cavities. The OPBF is appropriate for use in concrete as a brief discrete fibre reinforcement for low cost construction.

Keywords: alkalization, concrete, durability, flexural strength, oil palm broom fibre

1. INTRODUCTION

More concrete is used in construction than all other building materials combined, by a factor of two. Future construction projects will almost definitely still use concrete as a building material. However, with such widespread usage of the material, any flaw or issue with concrete or reinforced concrete buildings will be a source of substantial public concern - both in terms of safety and the accompanying costs of correction [1]. Its use in construction of buildings, highways, bridges, dams, retaining walls, stadiums, and airports, among other things, has led to an increase in both its daily demand and its price.

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Concrete is a brittle material, with a high compressive strength but a very low tensile strength. It is generally well known that when the compressive stress in the concrete reaches about one-tenth of its ultimate strength, a plain concrete part loaded to create tension would fail in tension.

In Ghana and many other developing countries, concrete slabs used in walkway or pedestrian pavement and road lay-by construction are generally unreinforced, and therefore constitute brittle elements. The use of such unreinforced concrete elements arises as a result of the high cost of steel reinforcements and the lack of awareness of the use of locally available natural materials as suitable fiber reinforcement in concrete to improve its flexural tensile strength, ductility and resistance to impact, fracture and abrasion. Recently, there has been a lot of interest about possible applications of natural fiber-reinforced concrete all around the world. Investigations have been carried out in many countries on various mechanical properties, physical performance and durability of concrete materials reinforced with fibers from sugarcane, palm stalk, sisal, coconut husk, sisal, and palm kernel [2]. Palm kernel fibers have been found to improve the tensile strength and crack development in concrete [3]. The formation and distribution of cracks in a reinforced concrete member are generally controlled by the characteristics of the reinforcement.

The term "Oil Palm Broom Fiber" (OPBF) refers to the broom fiber made from the oil palm leaflet ribs and used to make the traditional Nigerian broom used to sweep light household dirt in homes and residential areas. In Nigeria, OPBF is widely and abundantly available. It is light in weight, does not quickly absorb water, does not decay, and possesses a certain amount of rigidity and elasticity. While working as a group, OPBFs exhibit a noteworthy synergy of strength (trying to break a group of broomsticks as an example); the strength of the group has been larger than the sum of the individual strengths of the members even when completely dry. Although individual fibers may become brittle as their moisture content drops, the collective action actually increases as the fibers grow drier. Generally, oil palm fibers don’t disintegrate quickly and they are either dumped into the environment as waste or used as cooking fuel in developing countries [4, 5]. Variations in physical and mechanical qualities exist in natural lignocellulosic fibers, as they do in other natural lignocellulosic fibers, even amongst fibers obtained from same oil palm species [6]. Aside from fiber contaminants such as wax, fatty compounds, and globular protrusions (known as tyloses), hemicellulose, lignin, and pectin dissolve rapidly at the fiber-matrix contact and are responsible for poor matrix bonding [7, 8, 9]. Additionally, natural fibers are dimensionally unstable due to their hydrophilicity. In order to increase fiber strength, get rid of undesirable substances, cut down on water absorption, and improve bonding with matrix, natural fibers are treated.

The use of Oil Palm Broom fiber subjected to alkalization treatment for reinforcement in concrete constructions is examined in this research, along with its physical, mechanical property to boost fibre strength, remove undesirable chemicals and limit water absorption. The process of treating plant fibers with alkalis in order to improve their shape and physico-mechanical characteristics is known as alkalization. Alkali treatment also leaches hemicellulose, lignin, pectin, and waxy compounds, leaving behind cellulose-the main structural component [10]. As a result of the development of micropores, the fibers' surface roughness rises [11]. Tensile strength improvements during alkalization are also attributable to an alkali-induced increase in the crystallinity of the fiber cellulose [12]. Since it can completely change the cellulose structure into a lattice, unlike other alkalis, sodium hydroxide is commonly used to treat vegetable fibers [13]. The paper hopes to establish the durability of using oil palm broom fibre as reinforcement in reinforced concrete production for lightweight structures.

2. METHODOLOGY

2.1. Concrete Materials

The raw material used in this research work are namely Portland cement, Oil Palm Broom Fibre, sodium hydroxide (NaOH), fine aggregate, coarse aggregate and water:

a) Cement: Portland cement, Dangote brand was obtained from Nigeria and it conforms to [14];
b) Fine aggregate: The fine aggregate used was obtained from a local natural river sand, without any organic contaminants. This fine aggregate had a specific gravity of 2.44;
c) Coarse aggregate: The coarse aggregate used was 12 inches in size and the specific gravity for the coarse aggregate was 2.86.

2.2. Method

Oil Palm Broom Fibre (OPBF) was obtained from Lagos, Nigeria in the form of leaflets. The Oil palm leaflets were shredded with the aid of a knife and scissors. The specific gravity for the OPBF obtained was 1.97. Each

OPBF, with lengths of 75 mm from the fibre head were cut in four categories. The OPBF were subjected to alkali treatment with the use of Sodium Hydroxide (NaOH). The alkali, sodium hydroxide used were obtained from Chemical market in Nigeria. After treatment, the fibres were included randomly in the concrete at 0.3 % of the volume of beam size (100x100x600 mm). Using a mix ratio of 1:2:4 and a target water-cement ratio of 0.55 for the concrete. Some set of fibres were prepared for water absorption test and SEM. The fibers were submerged in sodium hydroxide solutions of 4, 6, %, and 10. For each alkali solution, the removal times were 1 hr, 2 hrs, 8 hrs, and 24 hrs. The fibers were washed using water from the tap and dried in open air. Each concrete mix was carried out for 3 beam samples for each alkalization treatment with various durations in which the average of each sample was determined.

3. RESULTS AND DISCUSSION

Design Grade 15 concrete was employed for determination. Water-cement ratio was kept constant at 0.55. The length of OPBF used was 75 mm and percentage inclusion was 0.3 % (Table 1). The mixing method is critical to the properties of Oil Palm Broom Reinforced Concrete (OPBRC). The addition of fiber has to be uniformly dispersed in the concrete in order to obtain homogenous concrete mixture.

Table 1. Mix Proportion of OPBF concrete.

S/N	COMPONENT	WEIGHT(Kg)
1.	Cement	5.7
2.	Fine Aggregate	12.66
3.	Coarse Aggregate	28.8
4.	W/C ratio (0.55)	3.14
5	Fibre (0.3%)	0.1415

3.1. Water Absorption of OPBF

From Figure 1, it was observed that the rate of water absorption of the treated fibres increased compared to untreated fibres as a result of the alkalization treatment. The increase in surface roughness of the fibres occur due to the presence of micropores and allows for higher water absorption rate characteristic of the fibre. Alkali concentrations over a specific threshold concentration for a given vegetable fiber result in a reaction that embrittles the cellulose structure [15]. Yet in the proper concentration, alkali treatment lowers surface tension, boosts aspect ratio, and improves bonding with matrices via interdiffusion, electrostatic adhesion, chemical reaction, mechanical interlock, or a combination of these mechanisms [16].

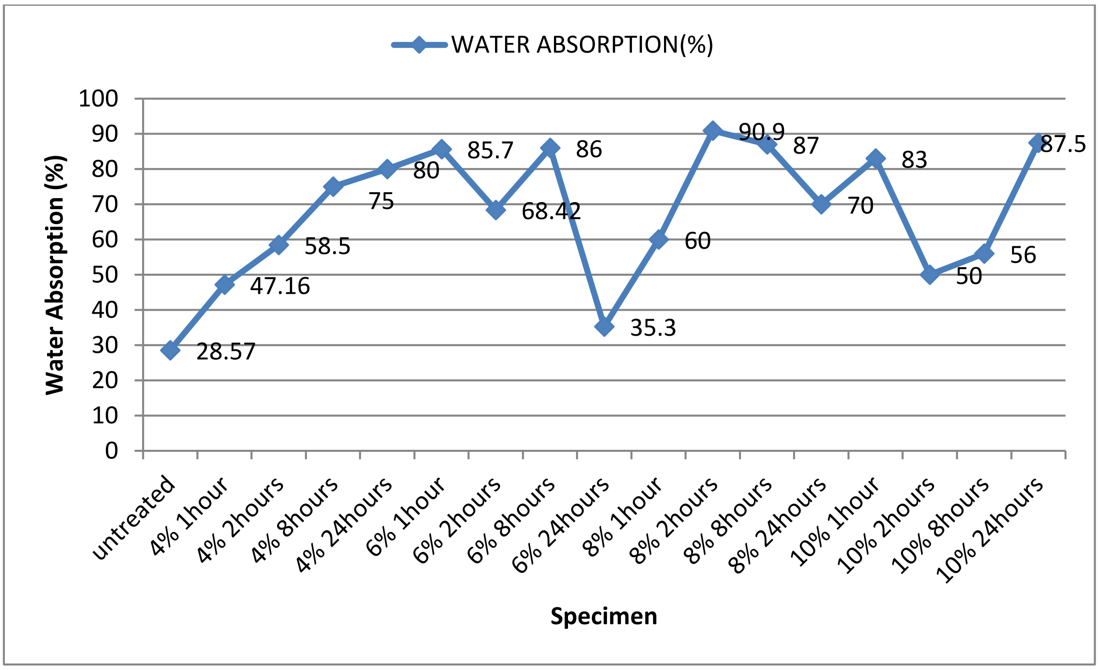


Fig. 1. Water absorption of Oil Palm Broom Fibre.

3.2. Water Absorption Behaviour of OPBF

This was carried out on a set of treated fibres and untreated fibres (dried) immersed for 24 hours at normal temperature. This was done to determine the effect of alkalization on the OPBF. Water absorption was calculated using the expression given in equation (1) below:

$$W_A\,(\%) = \frac{W_{wet} - W_{dry}}{W_{dry}} \text{ x } 10 \quad (1)$$

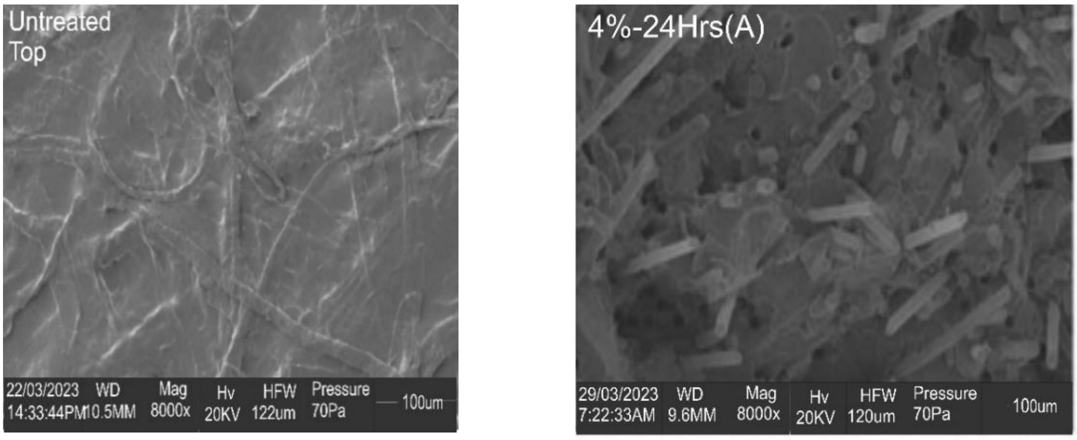
3.3. Flexural Strength of OPBF

The modulus of rupture of the beam sample was assessed during this test. A total of 54-(100x100x600) mm beam samples were prepared and left to cure for 28 days. Flexural strength was calculated using equation (2) below:

$$\boldsymbol{f} = \frac{\boldsymbol{Pl}}{\boldsymbol{bd}^2} \quad (2)$$

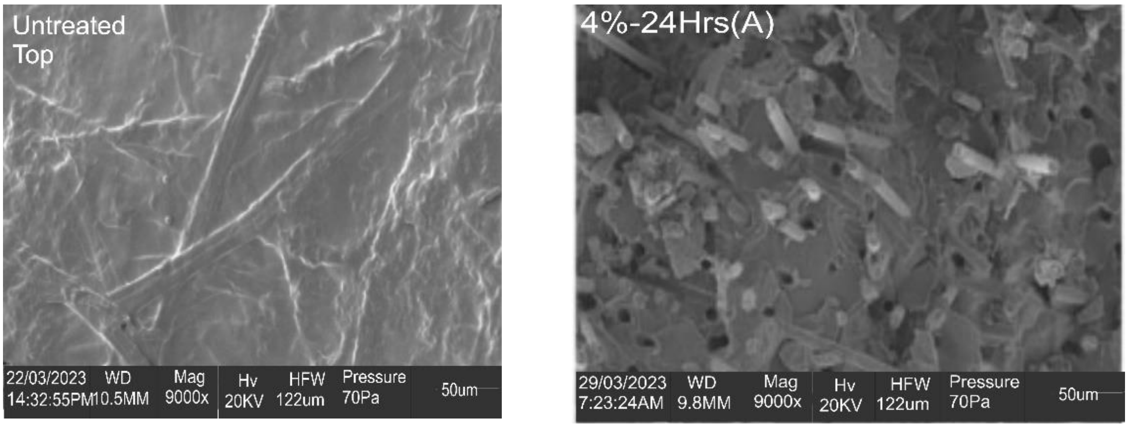
3.4. Surface Topography

The influence of alkali on OPBF shape can be seen in the SEM images shown in Figures 2(a) and (b) and Figures 3(a) and (b). Figure 2(b) indicates clearly a cleaner but rougher surface topography across the length of the fibre after treatment in 4% NaOH solution after 24 hours compared to Figure 2(a) which was untreated. Figures 4(a) and 4(b) show the cross section of the OPBF and 4(a) indicates a close structure and undegraded cellulose structure while 4(b) indicates the presence of micropores on the alkali treated OPBF which was also confirmed in other studies [8, 17, 18, 19].



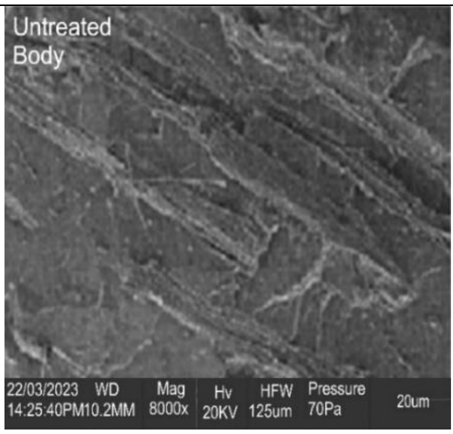
a) b)

Fig. 2. SEM Images of OPBF surfaces (a) Untreated OPBF 8000x (b) Alkali treated OPBF- 4% 24 hours 8000x.

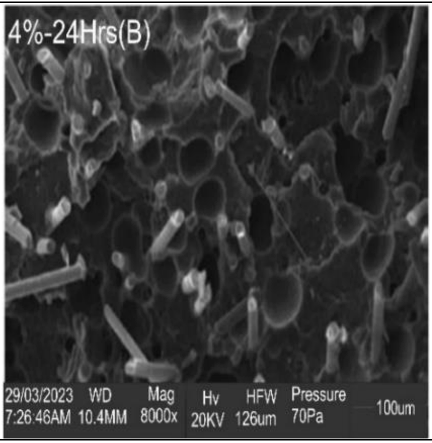


a) b)

Fig. 3. SEM Images of OPBF surfaces (a) Untreated OPBF 9000x (b) Alkali treated OPBF- 4% 24 hours 9000x.



a)



b)

Fig. 4. SEM Images of OPBF cross sections (a) Untreated OPBF 8000x (b) Alkali treated OPBF- 4% 24 8000x.

3.5. Flexural test

Figure 5 provides result of how alkalization affects OPBF placed in concrete. The effect of alkalization on the flexural strength of concrete beams was noticed at 6 % NaOH 1hr. Concrete Beam with untreated fibre recorded an improvement in flexural strength of about 46 % compared with pure concrete beam without fibre (control). Highest improvement in flexural strength (81 %) was recorded at 6 % NaOH at 1hr. Another satisfactory flexural strength was noticed at 6 % NaOH concentration at a duration of 2 hr recording an improvement of 57 % in flexural strength.

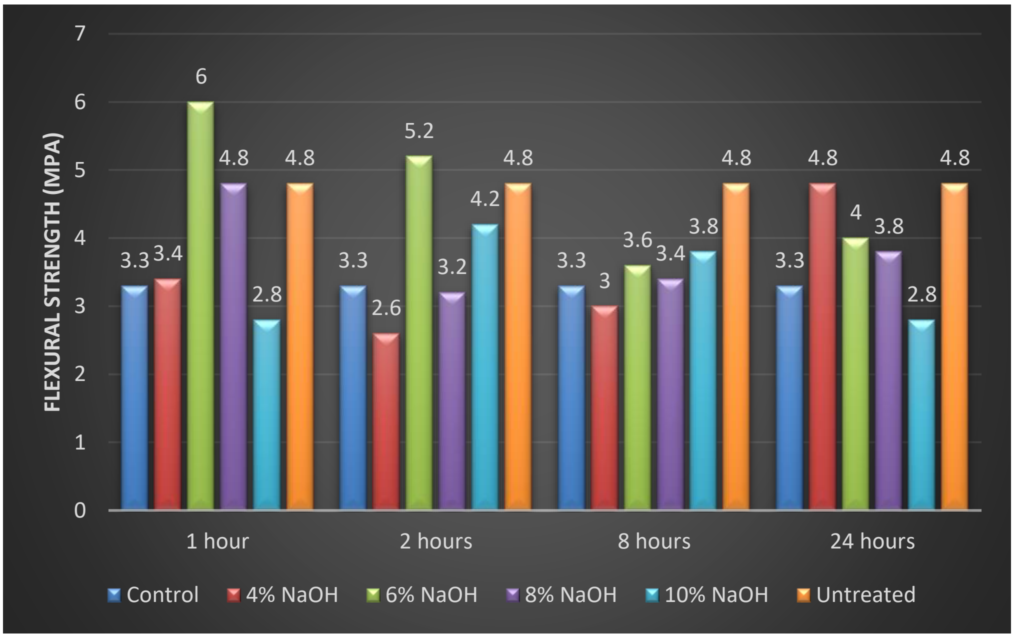


Fig. 5. Flexural strength of OPBF concrete after NaOH treatment at varied concentrations and time duration.

The flexural strength result indicates some values for concrete beams with treated fibres that are lower than that of untreated fibres. Variations in strength were a result of the fibers' innate variety. According to research, even in their untreated forms, fibres from the same plant species have a wide range of physical and mechanical qualities. The climatic conditions of the parent plant's cultivation zone are the factors responsible for these variances [20], the age of the parent plant, and the predominant cellulose type in the fibres [21]. Secondly, plants have cell-based mechano-sensors that convert external stimuli (such as wind) into biologically recognized signals, allowing them to govern the distribution of plant tissue in specific locations [22]. This occurrence suggests that plant fibers in various parts of the same plant might also exhibit variable stiffnesses and strengths. Also, because only healthy fibers were chosen, fibers with internal flaws might have gone unnoticed, which could account for some of the very low readings of OPBF concrete's flexural strength. Regardless, all OPBF concrete exhibits an increase in strength when compared to standard concrete beams (control).

4. CONCLUSIONS

Although there is little and recent research on OPBF, this study evaluated some of its physical and mechanical characteristics after being treated with NaOH (alkalization) and flexural strength. Discrete OPBF of 75 mm length was introduced at 0.3 % of the volume of the beam size in concrete to assess the suitability and durability of the fibre in concrete. Scanning electron microscopy (SEM) on treated and untreated fibers was also used to evaluate the impact of alkali treatment on OPBF.

Consequently the following conclusion can be drawn:

1. Alkalization effectively removes impurities from OPBF;
2. Treated OPBF with alkalization improves the flexural strength of concrete at a concentration of 6 % for a duration of 1 hour;
3. Excessive OPBF damage was observed when the alkali concentration exceeds 6 %;
4. Increase in the rate of water absorption of alkali treated OPBF;
5. OPBF is appropriate for use in concrete as a brief discrete fiber reinforcement in lintel beams, roofing tiles, and building bricks.

Recommendation. Following the integration of OPBF in concrete, further research into alkali treatment should be conducted in order to boost flexural strength. Other treatment known to serve as waterproof such as Silanization should be carried out to reduce rate of water absorption in OPBF.

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