Microstructure and Sorption Properties of Alkaline Surface Modified Coir Bio Fibre

Kure, M.A[1a], Olawuyi B.J[1b], Ogunbode E.B[1c], Apeh J. A[1d]

[1] Department of Building, Federal University of Technology, P.M.B 65 Minna
aliyukure7707@gmail.com; babatunde@futminna.edu.ng; ezekiel@futminna.edu.ng; apehjoe@futminna.edu.ng

Abstract

Natural fibres have attracted the attention of researchers and scholars due to its advantage over conventional fibres. Coir fibre is a natural bio fibre extracted from coconut plant with the advantage of low cost, low density, specific tensile properties, renew-ability, recyclability; bio-degradability and is non-abrasive to the equipment. It contains lignin, hemicellulose, wax and cellulose. The hydrophilic nature of bio fibres poses a challenge in utilisation as reinforcement for structural applications in concrete, mortar and polymer. It has however been found in recent times to be an effective reinforcement material in cement and phenolic matrices when subjected to better surface that modifies its hydrophilic nature. This paper presents an investigation into the alkali surface treatment of coir fibre and its effect on the cleanliness of the surface from dirt and fibre sorption characteristics. The natural fibre was treated by immersion in varied NaOH concentration (0 to 20% at 2.5% step increment) of sodium hydroxide solution (NaOH) for varied period of 6 hrs. interval up to 108 hrs. The specimens were also examined for morphology and microstructure properties using the scanning electron microscopy (SEM). The SEM micrograph revealed the specimen treated in 10% NaOH concentration at 24 hours of immersion period as having the smoothest surface and most cleaned. The examined sorption characteristics of the treated fibres further affirm that the water absorption became relatively stable for all specimen after 24 hrs and optimum within the 24 to 48 hrs treatment, while lowest absorption for the fibre treated in 10% NaOH being a value 383% at both 54 hrs and 72 hrs.

Keywords: *Bio fibres, Coir fibre, surface treatment, fibre sorption, composite construction*

Introduction

Shelter or housing is one of the three main needs of Man while a healthy and comfortable living environment has been adjudged as a means of mitigating spread of diseases and avoiding pandemic. Concrete though being a major material in construction and is noted to be subject to a variety of environmental conditions throughout its service life. The durability of a concrete structure is therefore defined by its ability to withstand these exposed conditions without major rehabilitation. It is believed that concrete is an inherently durable material, which can last many decades or even centuries with little maintenance. However, the relatively low tensile strength and brittle behaviour in tension necessitates the use of reinforcement (steel bars or fibres) in most structures. While steel bars are still predominantly applied and the use of fibres is also developed in the past decades.

Generally, normal concrete is known with very low tensile strength, little ductility, low resistance to cracking and limited energy absorption. It is an acceptably brittle material when exposed to impact load and normal stress, where its tensile strength is roughly one tenth of compressive strength, reinforcement with steel bars is required to withstand tensile stresses and recompense for the deficiency of ductility and strength. Improving the toughness of the concrete and decreasing the size and possibly the weaknesses would lead to better concrete performance. However, fibres incorporation in concrete is becoming necessary due to its ability to enhance concrete performance at its peak. The inclusion of fibres into concrete mixture could be of solution towards enhancing its tensile strength, flexural strength and ductility, which are improved sort of reinforcement that could enhance concrete ingredients in the bonding with cement composite (Ogunbode et al., 2015.

The main barrier against the selection of fibrous materials in construction work is its moisture sorption ability at all levels. The moisture absorption by natural fibres leads to swelling of the material, dimensional change, reduction in rigidity of cell wall, poor strength and stiffness. In moisture sorption process; hemicellulose, non-crystalline cellulose, lignin, and surface morphology of fibre plays an important role. Hence, to make good choice of lignocellulosic materials, it is highly required to understand, estimate, and overcome the water intake behaviour of the natural fibres. However, for proper analysis and comparison of the water absorption of untreated and alkali treated fibres, it is imperative to prepare fibre bundles in the same pattern (Mwaikambo *et al.*, 2006).

Natural fibre (coir) has become of great interest to researchers because of its superior properties to other fibres. Natural fibres are prone to water absorption due to their chemical composition and the richness in cellulose and hydrophilic in nature. Water absorption of natural fibre is more likely to increase with the increase in cellulose content of the fibre due to the increase in the number of free hydroxyl groups existing in the fibre. Also, moisture absorption capacity increase with an increase in fibre content and due to moisture absorption, microcracks get initiated in the composite (Ogunbode et al., 2016).

Moisture absorption capacity increase with time and get saturated after reaching the saturation point after which it becomes constant. Considering the advancement in technology, chemical treatment can be used to reduce the water absorption capacity. In this paper, Coir fibre as one of the best natural fibres was studied. It is noted to be of advantages over others such as being; cheap, renewable, of low-density, non-abrasive. The hydrophilic nature of coir fibre makes the composites to absorb water which in turn reduces the interfacial bonding between fibres and resin. In order to reduce the amount of water absorption, fibres are pre-treated (Hosne et al.,2021).

Alkali treatment of coir fibres could improve the interfacial bonding properties and the wettability of the fibres by leading to the enhancement in mechanical properties of concrete. Natural fibres are known with different behaviour after absorption of moisture. Previous studies have shown that under wet conditions bio composites achieve better wear performance as compared to dry conditions. Damping capacity of material shows its amount of elasticity. Moisture affects the fibre structure differently as it has both positive and negative impacts on the fibre performance. These effects constitute the following: crack propagation, sliding surface reaction and body layer of accumulated wear debris (Awasthi et al., 2021).

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Materials and Methods

Portland cement type II (PC CEM II 42.5) in compliance with the standard of ASTM C 150-07 was used and the coir fibre used was collected from local sources in Minna and it environ. The fibre was treated with varied percentages of sodium hydroxide concentration and washed thoroughly in clean distilled water to remove all remnant of alkali on the fibre surface. The fibres were prepared for water absorption test by the alkali (NaOH) treatment process, which included scouring of the fibres, rinsing, neutralization and finally exposed to air for drying (Fig.1) before the sorption test was carried out.

Figure 1: Coir fibre (a) un-treated, (b) treated

The treated fibres were then uncurled by hand and combed with a steel comb before putting it in required arrangement. The average diameter of the coir fibre used in this experiment is 0.25mm. The fibre was treated by soaking it in various concentrations (0 to 20 at 2.5% incremental steps) of NaOH solutions. They were then drained and weighed to determine the sorption property. The percentage sorption (S %) was then calculated using the formula below.

$$S = \frac{w-wo}{wo}\, x\, 100 \tag{1}$$

where: S= Absorption; w = weight after immersion; w_o = weight before immersion (initial weight).

The fibres (treated and untreated) were then air-dried and sent to Rolab Research and Diagnostic Laboratory in Ibadan, Oyo State, Nigeria for scanning electron microscopy -SEM (Fig. 2) to study the morphology and microstructure as effected by the treatment using the SEM machine (JOEL-JSM 7600F) as shown in Fig. 2.

Figure 2: SEM Machine (JOEL-JSM 7600F)

Results and Analysis

Table 1 presents the results of sorption of the Coir fibre subjected to varied concentration of NaOH (0 to 20% at 2.5% steps interval) at different immersion periods (0 to 108 hrs at 6 hrs step intervals).

Table 1: Sorption Properties of Coir Fibres Treated in NaOH Solution (in %)

	NaOH concentration (%)								
hrs	0	2.5	5	7.5	10	12.5	15	17.5	20
6	36 (600)*	24 (400)	21 (350)	22 (367)	22 (367)	24 (400)	26 (433)	22 (367)	25 (417)
12	36 (600)	26 (433)	21 (350)	24 (400)	27 (450)	26 (433)	24 (400)	22 (367)	22 (367)
18	38 (633)	24 (400)	19 (317)	24 (400)	25 (417)	25 (417)	22 (367)	26 (433)	22 (367)
24	32 (533)	25 (417)	24 (400)	23 (383)	28 (467)	27 (450)	27 (450)	26 (433)	24 (400)
30	32 (533)	26 (433)	24 (400)	24 (400)	29 (483)	25 (417)	24 (400)	25 (417)	24 (400)
36	33 (550)	27 (450)	24 (400)	26 (433)	29 (483)	26 (433)	26 (433)	26 (433)	23 (383)
42	36 (600)	28 (467)	23 (383)	24 (400)	29 (483)	23 (383)	25 (417)	26 (433)	23 (383)
48	38 (633)	28 (467)	24 (400)	25 (417)	29 (483)	24 (400)	25 (417)	26 (433)	22 (367)
54	41 (683)	29 (483)	25 (417)	28 (467)	23 (383)	24 (400)	26 (433)	27 (450)	23 (383)
60	44 (733)	28 (467)	21 (350)	24 (400)	28 (467)	23 (383)	22 (367)	24 (400)	23 (383)
66	44 (733)	28 (467)	22 (367)	24 (400)	28 (467)	23 (383)	24 (400)	25 (417)	22 (367)
72	46 (767)	28 (467)	24 (400)	28 (467)	23 (383)	22 (367)	24 (400)	25 (417)	22 (367)
78	46 (767)	28 (467)	21 (350)	23 (383)	28 (467)	23 (383)	22 (367)	24 (400)	22 (367)
84	49 (817)	28 (467)	21 (350)	22 (367)	28 (467)	21 (350)	23 (383)	24 (400)	22 (367)
90	49 (817)	28 (467)	24 (400)	28 (467)	22 (367)	22 (367)	24 (400)	24 (400)	22 (367)
96	52 (867)	27 (450)	20 (333)	23 (383)	27 (450)	23 (383)	21 (350)	24 (400)	22 (367)
102	52 (867)	28 (467)	21 (350)	22 (367)	28 467)	21 350)	21 (350)	23 (383)	21 (350)
108	52 (867)	28 (467)	24 (400)	26 (433)	22 (367)	21 (350)	24 (400)	24 (400)	22 (367)

*Values in parenthesis () represents the percentage absorption relative to the initial fibre weight.

The Table reveals that the NaOH treatment greatly reduced the sorption tendencies of the fibres. While the untreated fibre has absorption value was as high as 600% of the fibre weight, the absorption of the treated fibres generally increased (350 to 400%) as the NaOH solution concentration increased up to 10% except for the 2.5% NaOH solution which seems higher. The sorption value however showed a decline in sorption value thereafter. Similarly, the sorption of the treated fibres for all concentration of NaOH solution generally increased with increase in period of immersion up to 24 hrs, beyond which the absorption value became relatively constant up to the 48 hrs immersion period (Table 1 and Fig.3). It can thereby be inferred that the 10% NaOH solution treatment of the fibres for 24 hrs period can be accepted as the possible optimum treatment required for effectiveness of the fibre. A look at Fig. 3 (yellow values) revealed the steady/stable sorption values observed within the 24 to 48 hrs immersion period for the 10% NaOH solution treatment of the Coir fibre.

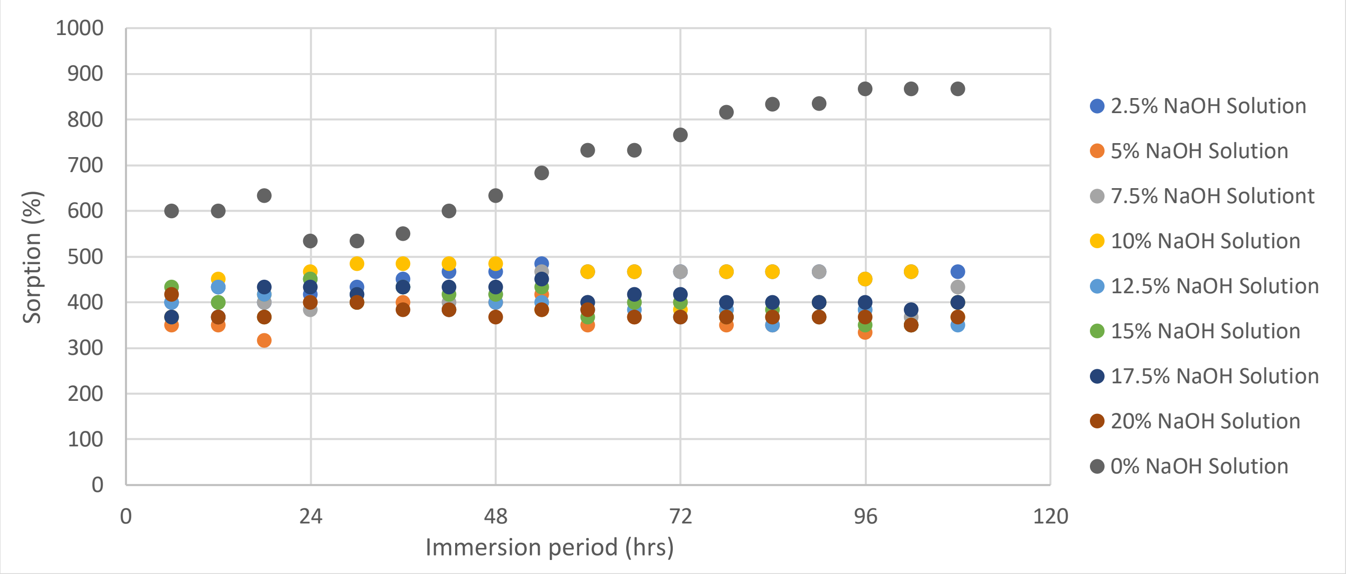

Figure 3: Sorption Properties of Coir Fibre Treated in NaOH Solution

Figures 4 and 5(a – h) shows the SEM micrographs of the Coir fibres subjected to varied NaOH solution treatment for 24 hrs immersion period. The natural coir fibres as seen in Figures 1a and 4 are clustered together (i.e., individual strings of the fibre could not be separated) while the treated fibres in Figure 1b had the individual strings clearly seen and identified.

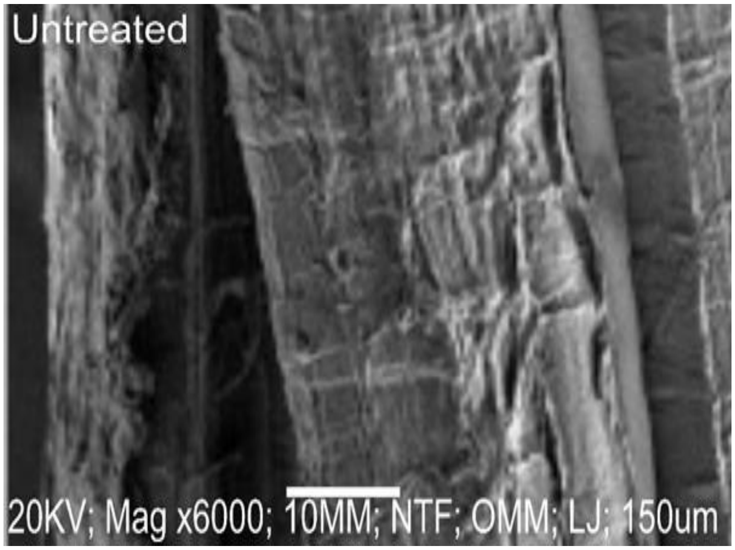

Figure 4: SEM Micrograph of Untreated Coir Fibre (i.e., in 0% NaOH)

The SEM micrograph of the treated fibres are presented in Figure 5 (a - h).

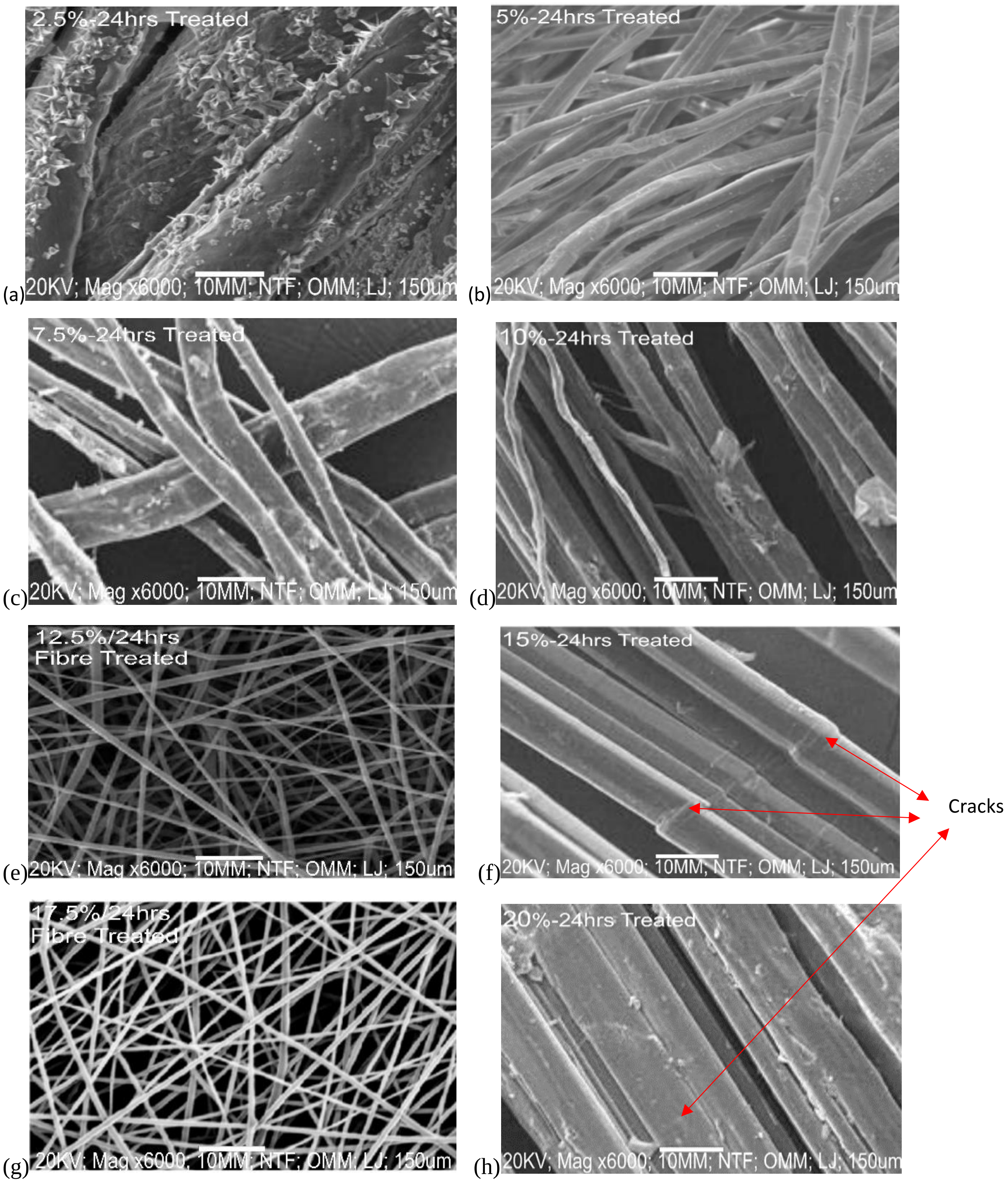

Figure 5: SEM Micrograph of Coir Fibres in (a) 2.5%; (b). 5%; (c). 7.5%; (d). 10%; (e).12.5%; (f). 15%; (g). 17.5% and (h). 20% NaOH Solutions

A keen view at the micrograph shows cracks in the fibres for treatments in concentrations of 12.5% NaOH and above, while treatments in concentrations between 0 and 7.5% shows some rough and unclear surfaces. The treatment in 10% NaOH solution was observed to be the clearest with no indication of cracks on the fibre. This is in agreement with the results gotten for the sorption properties of the fibre which indicated that treatment in 10% NaOH solution for 24 Hrs as the ultimate for the Coir fibre sample.

Conclusion

In this work, sorption and microstructure of Coir fibres subject to varied (0 to 20% at 2.5% steps) NaOH solution has been studied. The fibre immersed to 10% NaOH solution for 24 hrs was found to be the optimum treatment and observed to be of clear surface and not exhibiting cracks. It is thereby recommended for adoption as appropriate for treatment of Coir fibre for use in concrete or mortar works.

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