Effect of Strand Number on Tensile Strength of Oil Palm Empty Fruit Bunch Fibers

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Abstract. Extensive research has been conducted on the tensile strength of oil palm empty fruit bunch fibers. The main objective of this study was to measure the tensile strength of the multiple strands of the fibers. The fiber was obtained from a palm oil factory located in the Angsana District of Tanah Bumbu. After separating the fibers from the bundles and air-drying them, they were submerged for 90 minutes in a 1 N NaOH solution. Two fiber conditions were examined: untreated fiber and fiber treated with an alkaline solution. The fibers were examined using specialized apparatus once they had dried. Tensile strength was measured on multiple strands of fiber, ranging from one to four. The findings indicate that the average tensile strength of untreated and treated fibers is 104 MPa and 288 MPa, respectively, at strains of 9.34% and 12.06%. The tensile strength of multiple fiber strands is less than the sum of the tensile strengths of a single fiber. Treatment increases the tensile strength and durability of fibers compared to untreated fibers.

Keywords: fiber, palm oil, soil stabilization, alkali treatment.

1 Introduction

Numerous efforts have been undertaken to utilize natural fibers as construction materials. The addition of these natural fibers to composite materials, such as concrete, is expected to enhance their overall strength [1,2]. A fiber that is currently being investigated is the palm oil empty fruit bunch fiber (OPEFB). This fiber is classified as a natural fiber derived from the fruit of plants. Utilizing OPEFB fiber in concrete poses issues due to its high water absorption and hydrophilic nature [1,2]. However, when applied for soil stabilization, these two characteristics are advantageous since the absorption of water reduces the soil's water content, making it easier to compact [3,4].

The tensile strength of natural fibers is an important factor in their potential for use as construction materials. The OPEFB fiber exhibits remarkable tensile strength. The tensile strength of the fiber varies greatly among different trees, ranging from 21 to 260 MPa [5].

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Therefore, it is important to know the tensile strength of OPEFB fiber at a location where it will be used before use [6].

In composites, these fibers do not work as single fibers but together with other fibers. The conditions depend on the application. When fiber is used to stabilize slopes, a thin layer of soil with added fiber can be applied [7]. However, for soil stabilization, a possible use is for the fiber to be processed into geotextiles. Until now, the fibers used as natural geotextiles were jute and coir fibers [8]. Therefore, understanding the tensile strength of OPEFB fiber is fundamental in considering its suitability as a geotextile material.

Apart from tensile strength, an important component regarding the use of natural fibers as construction materials is their durability [6]. One of the most frequently used and easy methods is soaking it in NaOH solution [9]. Upon immersion in this solution, the fibers exhibit increased tensile strength compared to untreated fibers [5,10,11]. This study examines the effects of the quantity of treated fibers on the tensile strength of OPEFB fibers that are embedded in the soil over an extended period.

2 Material and method

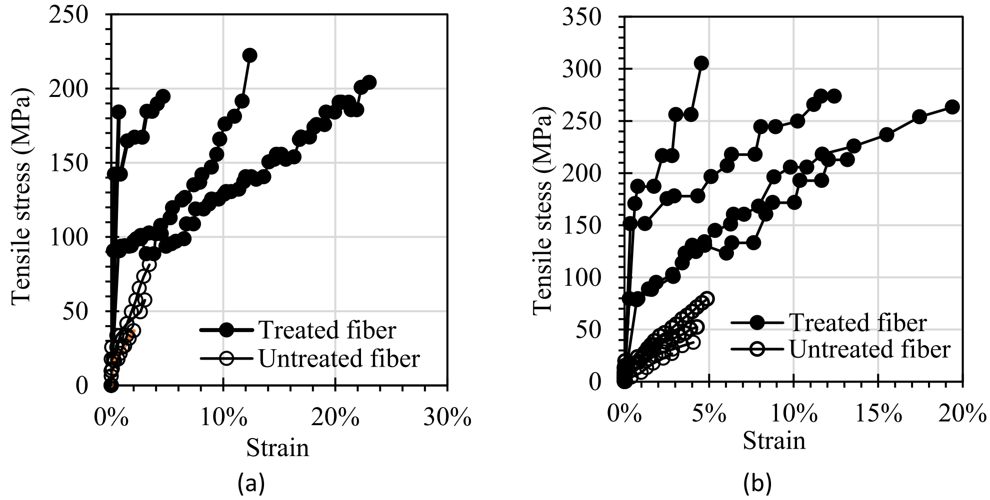
The OPEFB fiber used in this study was acquired from empty bunches, which are waste materials generated in the manufacture of palm oil at a factory located in Angsana District, Tanah Bumbu Regency. The utilized empty bunches remain fresh and have not exceeded one day since their production. The fibers are isolated and desiccated to prevent fungus growth. To enhance its performance, the fiber was immersed in a solution of 1N NaOH for a duration of 90 minutes [9]. Subsequently, the fibers undergo a washing process using water and are subsequently air-dried. The fiber was put into the soil layer, compressed, and allowed to remain for a specific duration. The fibers were extracted at intervals of 1, 7, 14, and 28 days and subjected to tensile strength testing.

The tensile strength test was carried out using a tool specifically designed for this application [12]. Before testing, the fiber diameter was measured with a micrometer to obtain a relatively uniform fiber size and determine the cross-sectional area of the fiber, which is used in calculating the tensile stress of the fiber. During the testing process, the recorded tensile strength refers to either the fiber that was added and fractured in the center or the part of the fiber that was not pinched. This is conducted to prevent the measurement of the tensile strength of distorted fibers in the pressed part of the tensile device.

3 Results and discussions

Figure 1 shows the relationship between tensile stress and the strain of fibers tested in this study. Data with solid-fill bullets is data for NaOH-treated fibers, and empty bullets are data for untreated fibers. The difference between the three figures (i.e., Figures 1(a)–1(c)) is the number of fibers of 1, 2, and 4 strands, respectively, at different curing times, namely 1, 7, 14, and 28 days. According to Figure 1, the tensile stress rises as the strain increases. The fiber tensile test reveals three distinct regions: the elastic zone, plastic zone, and rupture zone (Y. F. Arifin et al., 2022). The maximum tensile stress achieved before rupture is the tensile strength of the fibers.

As all the figures show, the tensile strength of treated fibers is higher than that of untreated fiber for a single fiber (Figure 1(a)) and a group of fibers (Figures 1(b) and 1(c)).



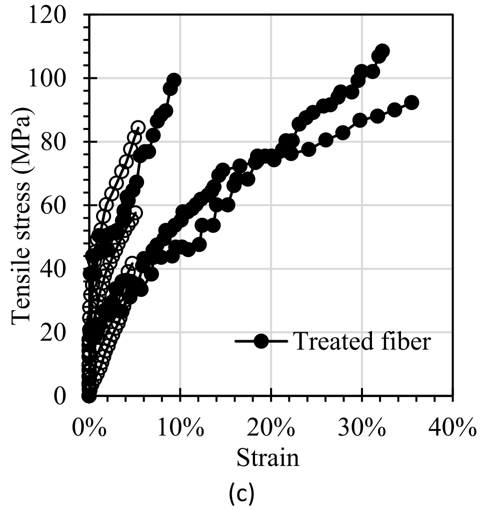


Fig. 1. Average tensile stress and strain relationship of OPEFB fiber for (a) 1 strand of fiber, (b) 2 strands of fiber, and (c) 4 strands of fiber

Meanwhile, the strain reached by the fiber at rupture is the maximum strain. A summary of the tensile strength test results can be seen in Table 1. As seen in Table 1, the tensile strength of fibers treated with NaOH for singles and groups is higher than that of untreated fibers. The average tensile strength of the fiber is the maximum tensile strength divided by the number of fibers, which is then plotted in graphical form as shown in Figure 2. It can be seen from Figure 2 that the average tensile strength of the treated fibers is in the range of 62.61–222.2 MPa. In contrast to untreated fibers, the average tensile strength tends to decrease with increasing time. Figure 2 also shows that the tensile strength of the fiber group is not the sum of the tensile strengths of the single fibers for the two fiber types. This is very likely to happen when these fibers are applied and woven to become geotextiles where the single fibers do not work together, so the calculation of the tensile strength of the geotextile must be tested before use.

Table 1. Summary of the tensile strength test result

		Untreated fiber			Treated fiber		
Number of strands	Curing time (day)	Maximum tensile strength (MPa)	Average Tensile strength (MPa)	Strain maximum (%)	Maximum tensile strength (MPa)	Average Tensile strength (MPa)	Strain maximum (%)
1	1	81.32	81.32	3.40	194.54	194.539	4.64
1	7	57.43	57.43	3.00	222.20	222.202	12.37
1	14	36.76	36.76	2.00	204.02	204.019	23.03
1	28	33.55	33.55	1.40	184.11	184.11	0.68
2	1	112.54	56.27	4.90	273.58	136.79	12.41
2	7	76.37	38.18	4.30	263.2	131.60	19.39
2	14	55.40	27.70	3.70	212.72	106.36	13.18
2	28	45.95	22.97	2.80	305.26	152.63	4.56
4	1	142.45	35.61	5.40	397.04	99.26	9.35
4	7	96.22	24.06	5.10	369.04	92.26	35.50
4	14	71.57	17.89	4.30	434.00	108.50	32.27
4	28	58.00	14.50	4.00	250.44	62.61	4.18

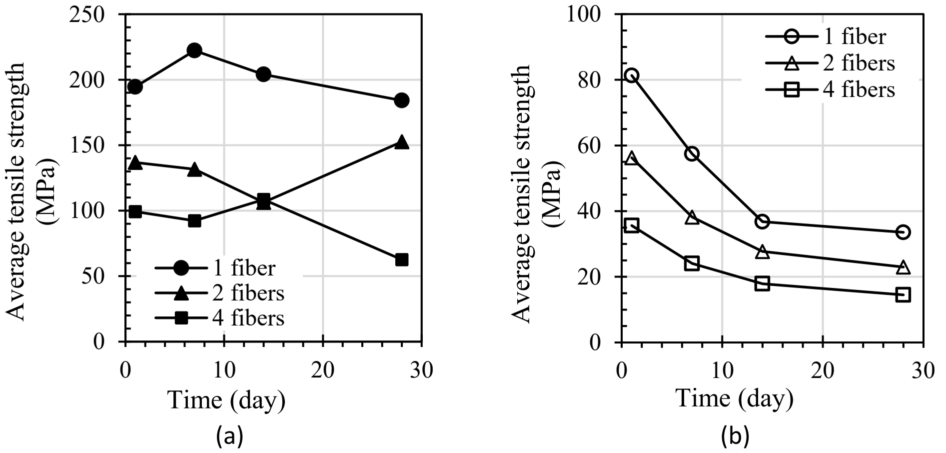
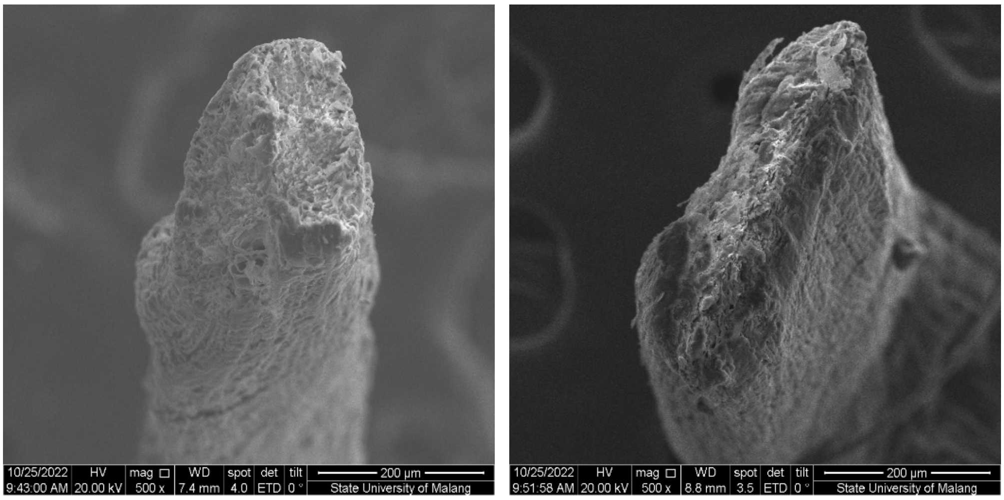


Fig. 2. Tensile strength of fibers and group fiber as a function of time for (a) treated fiber and (b) untreated fiber.

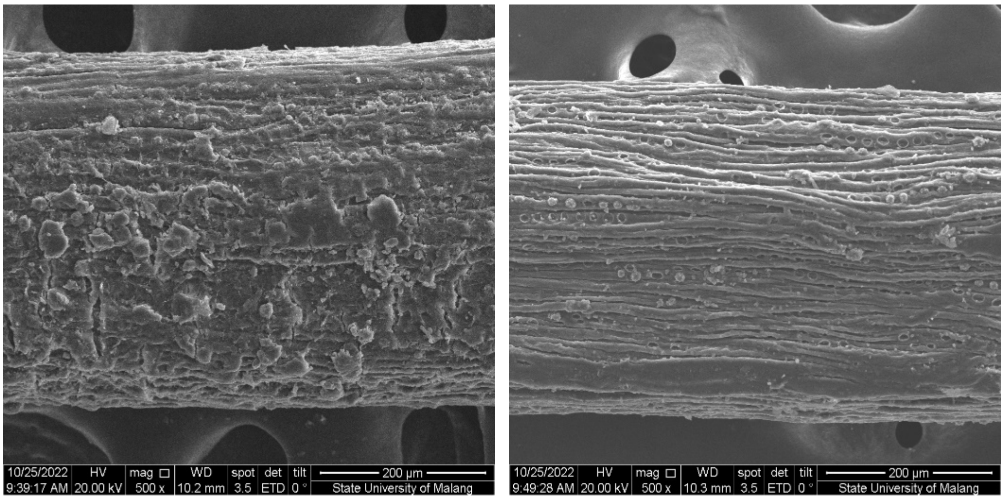
Figures 3(a) and 3(b) show the ends of the fibers that broke when tested for tensile strength for fibers that were not treated with NaOH and those that were treated, respectively. The fiber tip is enlarged up to 500×. It can be seen that the shape of the fiber ends is different, where untreated fibers tend to be rounder while treated fibers are flatter as a result of the addition of greater length (strain), as shown in Table 1. Soaking a portion of the OPEFB fiber in a NaOH solution causes it to become more solid as opposed to porous [9,13]. Thus, the tensile strength of the treated fibers becomes higher, and their durability in the soil becomes better.



(a) (b)

Fig. 3. Tip of OPEFB fibers (a) untreated fiber and (b) treated fiber

Figures 4(a) and 4(b) show the longitudinal surfaces of the fibers for fibers without NaOH treatment and those treated, respectively. It can be seen that without treatment, the surface of the fiber is not smooth, and there is still a lot of fat. This is from previous research where fibers without surface treatment still contain lubricate and are coarse, contaminant, and fatlike [11]. When OPEFB fibers that are not too long are connected to each other, a large amount of friction between the fibers is required for tensile strength. When the surface is not clean and contains a lot of fat, the friction between the fibers becomes small. The clean fiber shown in Figure 4(b) shows a better fiber surface.



(a) (b)

Fig. 4. Surface of OPEFB fibers (a) untreated fiber and (b) treated fiber

4 Conclusions

Tensile strength tests of treated fibers in groups have been carried out, described, and discussed. The tensile strength of group fibers treated with NaOH was higher than that of those not treated. The tensile strength of a group of fibers is not the sum of the tensile strengths of a single fiber; it will still be smaller. The absence of tensile strength change over time shows that treated fibers are more durable than untreated ones. Within the group, the maximum strain of treated fibers was higher than that of untreated fibers. The surface of the tip and the longitudinal surface of the treated fiber look dense and clean.

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