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The Investigation of Mechanical Properties on Natural Fiber Composites for Recurve Bow Material Selection

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ABSTRACT

Substitution of synthetic fiber composites with natural fiber in the applications such as automotive and construction are increasing. However, the usage of natural fibers in sports applications are still in its infancy stage. In this paper, the investigation of mechanical properties of the untreated and treated short kenaf fiber, pineapple leaf fiber (PALF) and mengkuang fiber reinforced epoxy composites were presented. These fibers were treated using sodium hydroxide (NaOH). The NaOH concentration were varied from 1%, 3% and 5%. The mixture of natural fibers reinforced composites were poured into the glass mould and left to dry in a room temperature for 24 hours. The fibers were soaked in 1%, 3% and 5% NaOH concentration and was dried in aging oven. Results showed that tensile strength and flexural strength increase with increasing NaOH concentration. It was concluded that kenaf fiber, PALF and mengkuang fiber have different optimum NaOH concentration

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INTRODUCTION

The substitution of synthetic fiber with various natural fibers have increased the interest of many researchers after the attempts on substituting automotive parts were greatly success. In addition, the added-value of this fiber such as biodegradable, renewable, low cost and lightweight make it more noticeable [1, 2]. Kenaf fibers (*Hibiscus cannabinus, L. family Malvaceae*), pineapple leaf fiber (*Ananascomosus*) and mengkuang fiber (*PandanusAtrocarpus*) are some of the natural fibers that have high commercial potential and are widely cultivated in Malaysia. Despite of the hydrophilic nature of the natural fibers, their mechanical properties may be enhanced through interfacial treatment. Nonetheless, the usage of natural fibers in various applications such as sports, automotive and constructions are restricted because only fibers with strength properties were selected. Wood, flax, bagasse, hemp, kenaf and abacca are the examples of fiber that have an opportunity to be applied on various applications [3]. However, further study need to be conducted on these types of natural fibers. More types of natural fibers must be tested, so that the number of natural fibers used in various applications can be increased. Furthermore, the reinforcement of natural fiber with thermosetting polymer such as the reinforcement of unidirectional kenaf fiber/epoxy, Palmyra palm leaf stalk fiber/jute fiber/ polyester, woven coir fiber/polyester, bamboo/polyester [4-7].

Many researchers presented their works related to properties of the natural fiber composites. Yan *et al.* [8] studied the effect of alkali treatment of flax, linen and bamboo single-strand yarns on their mechanical properties. Mylsamy and Rajendran[9] studied the effect of alkali treatment and fiber length on short Agave fiber/epoxy hand lay-up and compression mould technique. The study shows that alkalization process using 5% NaOH concentration increase the mechanical behavior of the fiber. Kenaf/glass fiber produce a similar flexural strength, flexural modulus, Young's modulus and tensile strength with glass mat thermoplastic (GMT), material used for car bumper manufacturing [10].

The objective of this paper is to investigate the effect of different NaOH concentration on mechanical propertiesof the kenaf fiber, pineapple fiber (PALF) and mengkuang fiber composites. The tensile properties and flexural properties of the untreated fiber, 1%, 3% and 5% NaOH concentration are discussed in this section

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as to establish its application in sports application. This paper presents the methodology and results of the mechanical properties on the kenaf fiber, PALF and mengkuang fiber. The last section then concluded this study.

Methodology:

Materials:

Short kenaf fibers, PALF and mengkuang fiber have the density of 1.2 g/cm^3 were used as the reinforcement. The resin used is Epoxy DER 331 and curing agent, Jointmine 905-3 was selected for this study. The mixing ratio of the hardener and resin was 2:1. The 10% of fiber content were used for the kenaf fiber, PALF and mengkuang fiber.

Chemical Treatment:

Kenaf fiber, PALF and mengkuang fiber were immerged in 1%, 3% and 5% concentration of aqueous solution sodium hydroxide (NaOH) for 1 hour at room temperature. It then washed by using tap water until odorless, expecting to remove any residual NaOH. The fibers then were left to dry in aging oven for 24 hours at 90°C.

Preparation of Composite Material:

Specimen fabrication of natural fiber composites were prepared by using hand lay-up technique. A glass mould with dimensions of 200 mm x 200 mm x 3 mm was used (see Figure 1). To avoid any trapped air bubbles, the mixture of the kenaf fiber and epoxy resin were poured gently in the glass mould. A semi-solid kenaf fiber reinforced epoxy was covered by a plastic in order to reduce the presence of the air bubbles on the surface. The composites were left in the room temperature for 24 hours to let it harden before it were cut by following ASTM D790. Preparation for PALF and menkuang fiber the same procedure, replacing the kenaf fiber. Besides that, the preparation for treated fibers and untreated fibers follow same procedures.

Fig. 1: Natural fiber reinforced epoxy in a glass mould.

Mechanical Testing:

Tensile test was executed by following ASTM D3039 using INSTRON 3369 universal tensile machine. The crosshead speed for the test was set to 1 mm/min at room temperature. Seven specimens for each condition were tested for this testing. The average result of tensile strength and tensile modulus were calculated.

Flexural test was conducted by using universal INSTRON machine model 3369. The rate of loading was set to 1mm/min while span-to-depth ratio is 16:1. Seven specimens with dimension 125 x 12.5 x 3 mm for each condition were carried out at room temperature in this test. The average of flexural strength and flexural modulus of the composites were calculated. The INSTRON 3369 machine used for both tensile and flexural test was shown in Figure 2.

RESULTS AND DISCUSSION

The effect of NaOH concentration on the flexural properties of kenaf fiber, PALF and mengkuang fiber will be addressed in the next sub-sections. Their flexural strength and flexural modulus are discussed in the current studies.

Tensile Properties:

Figure 3 and Figure 4 respectively show tensile strength and tensile modulus of kenaf fiber, PALF and mengkuang fiber. Figure 3 shows tensile strength of kenaf fiber increases as NaOH concentration increased. On the other hand, on PALF and mengkuang fiber, 1% and 3% NaOH concentration exhibit the highest tensile strength by comparing to UT fiber. However, Figure 4 shows tensile modulus of kenaf fiber, PALF and mengkuang fiber were fluctuated. One possible explanation is that strong adhesion between the fiber and the matrix was increased as the NaOH concentration increased. This was supported by Gu[11] that suggest the surface roughness of a fiber increase with the fiber treatment. As the fiber roughness increase, the interfacial bonding between matrix and fiber could be strengthened. Mulinari *et al*. [12] verified through scanning electron microscope (SEM) image that the removal of pectin, cellulose and lignin increased the surface roughness of coir fiber.

Fig. 2: Universal INSTRON model 3369 machine.

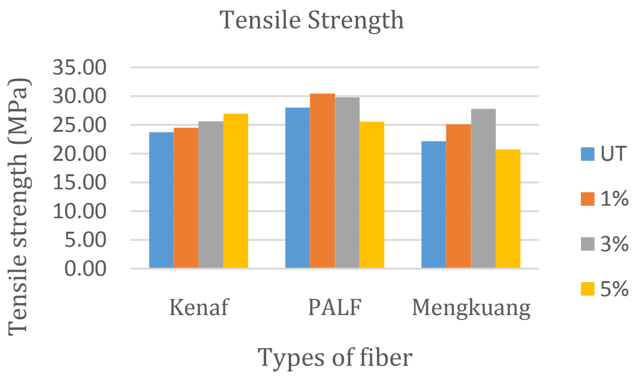

Fig. 3: Tensile strength of untreated and treated kenaf fiber, PALF and mengkuang fiber.

Flexural Properties:

The flexural strength and flexural modulus of the untreated kenaf fiber, PALF and mengkuang fiber are shown in Figure 5 and Figure 6, respectively. From Figure 5, 5%, NaOH concentration on mengkuang fiber exhibit lower flexural strength compared to UT. On top of that, 1%, 3% and 5% NaOH concentration on kenaf fibers and PALF show higher flexural strength as compared to UT fiber. One possible explanation is that the alkalization process on the natural fiber reduced the hydrophilic nature of the fiber. This was supported by Yousif *et al*. [13] that have conducted a study on long kenaf fiber reinforced epoxy. The results have proven through SEM image that alkali treatment roughen the surface of the fiber, which can increase the adhesion between fiber and matrix. On the other hand, the presence of Na^+ and OH^- reduce the amount of fiber constituents such as pectin, lignin and cellulose which resulted to a rough fiber surface [11]. The results also show that on PALF and mengkuang fiber, the trend was decreased after 3% NaOH concentration due to the damage on the fiber inter-laminar bonding [14].

Figure 6 shows the variation of flexural modulus on kenaf fiber, PALF and mengkuang fiber. Similarly, results obtained by Meon *et al*. [14] showed an uncertain trend of treated short kenaf fiber. The cause of the data variation could be because variation of the sample thickness. This agreed by Arbelaiz *et al*. [15] that reported short fiber have an improper fiber arrangement. However, short natural fibers are receiving many attentions in manufacturing as it provides simple manufacturing process [16].

Conclusion:

A few of interesting conclusions were revealed on the present study. Firstly, natural fibers gaining its popularity due to its environmentally advantageous and availability. Short kenaf fiber, PALF and mengkuang fiber reinforced epoxy was fabricated by using hand lay-up technique and tested follow ASTM D3039 and ASTM D790 standards for tensile and flexural test respectively. Kenaf/epoxy composites may adapt a higher than 5% NaOH concentration as there is no deterioration of tensile and flexural strength on the data. Meanwhile, in flexural test, 3% of NaOH concentration yield the optimum NaOH concentration for PALF and mengkuang fiber. However, the NaOH concentration higher than optimum value could decrease the fiber strength. Further research on other properties such as physical and chemical properties need to be executed for the development of natural fiber composites. The effort to improve the performance of natural fiber composites for the usage of various applications i.erecurve bow is ongoing process.

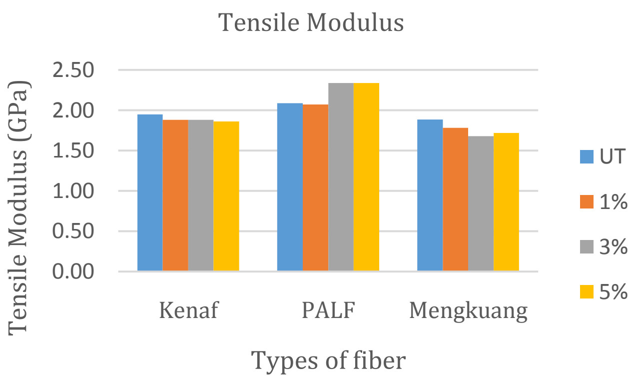

Fig. 4: Tensile modulus of untreated and treated kenaf fiber, PALF and mengkuang fiber.

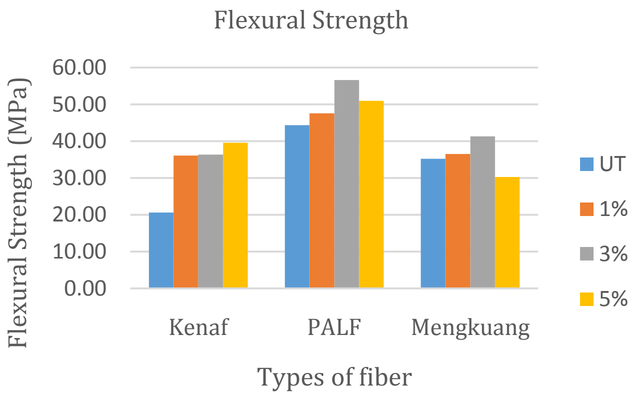

Fig. 5: Flexural strength of untreated and treated kenaf fiber, PALF and mengkuang fiber.

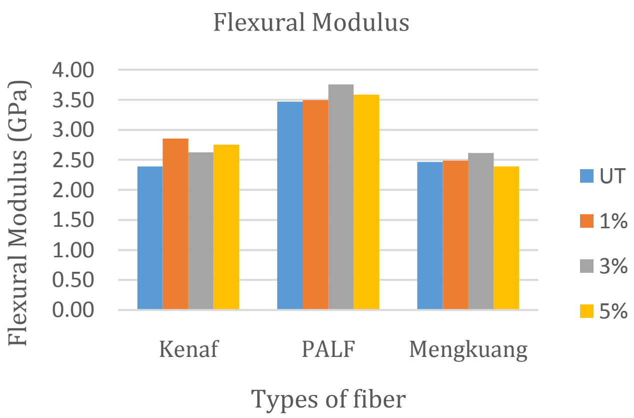

Fig. 6: Flexural modulus of untreated and treated kenaf fiber, PALF and mengkuang fiber.

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