Effect Of Bamboo Fibre Length On The Mechanical Properties Of Bamboo Fibre/Polypropylene Composite

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Abstract*-The natural fibre plays an important role in developing biodegradable FRP to resolve the current ecological and environmental problems. The utilization of bamboo fibres (BF) as reinforcement in FRP composite materials has increased tremendously and this has undergone a high-tech revolution in recent years as a response to the increasing demand for developing biodegradable, sustainable, and recyclable materials. Therefore, in this study, BF was used as a reinforcing material in a polymer matrix that is polypropylene (PP). This research studies the effects of BF length (4, 3 and 2 cm) and BF loading on the mechanical properties of BF/PP composite. Various ratios of BF/PP composite were analyzed and the ratios of composition in the BF/PP composite was fixed at 70:30, 60:40 and 50:50. An alkaline treatment was conducted to extract thin bamboo fibre bundles and enhance the BF properties before the formation process of BF/PP composite using hot press. The mechanical properties of BF/PP composite were determined using tensile test, flexure test, hardness test, density measurement and macrostructure analysis. The results show that the 2 cm fibre length showed the best mechanical properties because it gives the optimal results as compares to other FB length of 3 cm and 4 cm. Mechanical properties of samples decreases with increasing fibre length. Meanwhile, for BF loading of 50:50 in composition ratio (BF/PP), the best mechanical properties than 60:40 and 70:30 composition ratios.

Keywords— Bamboo Fibre; Polypropylene (PP); Fibre Reinforced Polymer (FRP); Flexural Strength and Tensile Strength component.

I. INTRODUCTION (*HEADING 1*)

A "composite" is define as two or more different materials are combined together to create a superior and unique material. Composite materials can be divided into two main groups, which are filler/reinforcement and matrix/binder/resin [1]. The history of composites dates back to ancient times for construction applications. Straw was mixed with mud to form a building material known as adobe. The straw provided the structure and strength, while the mud acted as a binder, holding the straw together in place [2]. Since the days of adobe, the use of composites has evolved to commonly incorporate a structural fibre and a plastic known as Fibre Reinforce Plastic (FRP). Like straw, the fibre provides the structure and strength to the composite, while a plastic or polymer holds the fibre together. Common types of fibres used in the production of FRP composites include aramid, carbon, boron, basalt, fibre glass and also natural fibre [1-2]. This type of composite is used extensively throughout our daily lives. Common everyday applications of FRP composites include aircraft, boats and marine, sporting equipment, automotives equipment, wind turbine blade, body armor, building materials, water pipes, bridges, tool handles and ladder rails. In comparison to common materials used today such as metal and wood, FRP composites can provide a distinct advantage. The primary driver and advantage in the adoption of FRP composites is the lightweight properties. In transportation, less weight equates to more fuel savings and improved acceleration. In sporting equipment, lightweight composites allow for longer drives in golf, faster swings in tennis, and straighter shots in archery. While in wind energy, the less a blade weighs the more power the turbine can produce. Besides weight savings, the most important benefits of composites include, non-corrosive, non-conductive, low maintenance, long life and also design flexibility [2].

Bamboo fibre is one of the most attractive candidates as a strengthening natural fibre. It has several advantages, such as the environmental load is small, because it is grows rapidly and takes only several month to grow up, thus it is easy to regenerate after cutting, and the bamboo fibre has relatively high strength compared with other natural fibres such as jute and cotton. Additionally, the bamboo is a typical bio-resource which has not been fully utilized. Other than that, it is also low cost, low density, ecologically friendly, sustainability and biodegradability [3-5]. Bamboo is an abundant natural resource in Asia and South America. It has been traditionally used to construct various living facilities and tools. The high strength with respect to its weight is derived from fibres longitudinally aligned in its body. Therefore, bamboo fibres are often called 'natural glass fibre' [6-8]. To practically apply the benefit of bamboo fibres, it is necessary to develop a process to fabricate bamboo composites as well as to extract qualitatively controlled fibres from bamboo tress. However, it is difficult to extract bamboo fibres since they have superior mechanical properties. The bamboo fibre is often brittle compared with other natural fibres, because the fibres are covered with lignin. Therefore, a new process should be adopted to extract the bamboo fibres for reinforcement of the composites materials [9-11]. There need to be a reduction in harmful destruction of ecosystem in order to produce low cost fibre reinforced polymer (FRP) composites. Thus, our country needs researchers to study the policies for the manufacturing of composites using natural fibres which are entirely biodegradable. These policies have generated safe strategies to protect our environment. Furthermore, this study aims to investigate effect of BF loading and BF length on the mechanical properties in BF/PP composite and to explore the potential of this BF/PP composite. The effect of different loading of BF and BF length on the mechanical properties such as Tensile Stress, Flexure Strength, Hardness, Bulk Density and Microstructure are observed.

II. EXPERIMENTAL

A. *Materials*

The materials used in the fabrication the FRP composites are BF and PP. Figure 1 (a) and (b) show the image of BF and PP. Meanwhile, composition of this composite is listed in Table 1.

(a) (b)

Fig. 1, (a) and (b) Photograph image of BF and PP

Before the BF can be used as filler, an alkaline treatment was done. Tthe raw bamboo was first longitudinally cleaved into small slabs by the rolling mill machine. These small slabs were then immersed in NaOH solution at 70^{0}C for 10 hours. The concentration of the NaOH was 1%. Advantages of alkaline treatment include the removal of moisture content from the fibers thereby increasing its strength. Also, chemical treatment enhances the flexural rigidity of the fibers. Last, this treatment clears all the impurities that are adjoining the fiber material and also stabilizes the molecular orientation [12, 13].

TABLE 1, Samples of BF/PP composite

Ratio of PP/BF	Fibre length		
50/50	2cm	3cm	4cm
60/40			
70/30			

B. *Preparation of composites*

The samples of BF/PP composite were prepared using manual mixing technique, where they were mixed in a beaker. The composition of BF and PP composite has been fixed as shown in Table 1. After the mixing process, the compound between BF and PP was placed in the mold and then the mold was compressed at an elevated temperature. Following this, some mechanical testings were conducted that include tensile test (ASTM D 3039/D 3039M-00), flexure test (ASTM D 790-03), density test, shore hardness test and macrostructure analysis.

III. RESULTS AND DISCUSSION

A. *Effect of Fibre Length on Tensile Stress of BF/PP compositeand*

Figure 2 shows the bar chart of tensile stress (MPa) versus contents of 50%BF, 60%BF and 70%BF for various fibre lengths of 2, 3 and 4 cm, respectively. The graph shows that the tensile stress increases with the increase in fibre contents for 50%BF and 60%BF, while for the 70%BF content, it shows an inconsistent trend.

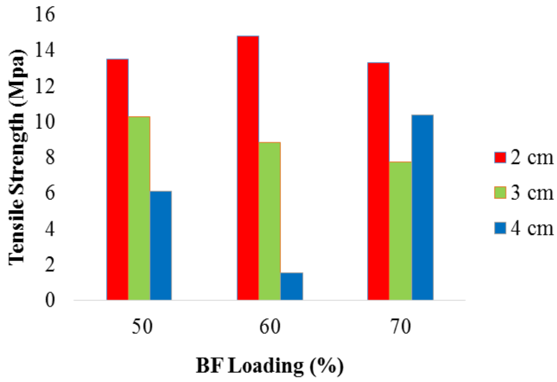


Fig. 2 Tensile stress of various BF loading wt% with various BF lengths

Based on the result of tensile strength (σ) and Young's Modulus (E) of the composite , the BF length of 2 cm shows the highest strength as compare to others BF lengths (3 and 4 cm). The values of E and σ, and BF lengths were monitored with different BF loadings. For BF lengths 3 and 4 cm, the value of E and σ are not too close for different BF loadings. Thus it shows that the increment of BF lengths affected the tensile strength (σ) and the Young's Modulus (E) of the composite.

B. *Effect of Fibre Length on Flexure Strength of BF/PP composite*

Figure 3 shows the bar chart of flexure strength (MPa) versus composition of 50%BF, 60%BF and70%BF for various fibre lengths of 2, 3 and 4 cm respectively. It shows that the flexure strength increases with the increase in fibre contents for fibre lengths of 3 and 4 cm. While for fibre length 2 cm, it shows a decrease in value of flexure strength as the BF content has increased. The values of flexure strength for fibre length 2 cm are higher as compare to other fibre lengths of 3 cm and 4 cm accepted for 70% BF contents.

It shows the effect of BF loading for various BF lengths of 2, 3 and 4 cm on flexure strength. According to the BF lengths for BF loading 50 and 60 wt%, the flexure strength has decreased with the increment of BF lengths. The value of flexure strength for each BF length also shows big gap among the values. However, for BF loading 70 wt%, the value of flexure strength did not exhibit much difference even though the value of flexure strength is not so high. Meanwhile, the BF length of 2 cm shows the highest value compare to other BF lengths for all BF loadings and the highest value is 82 MPa at the BF loading of 50 wt%. It shows that the increment of BF loading and BF fiber lengths have decreased the flexure strength [4] as illustrated in Table 3 about Microstructures of BF/PP Composites.

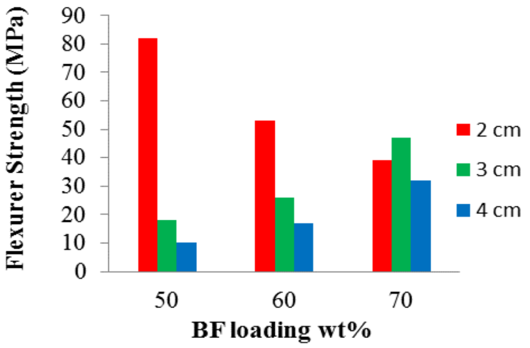


Fig. 3 Flexure strength of various BF loading wt% with various BF lengths

C. Effect of Fibre Length on Hardness of BF/PP composite

Figure 4 shows the graph of hardness (Shore D) versus composition of 50%BF, 60%BF and 70%BF for various fibre lengths of 2, 3 and 4 cm, respectively. The results show that all compositions have decreased the hardness value with the increased of BF contents. For the fibre length 2 cm has shown the highest value compared to 3 and 4 cm fibre lengths.

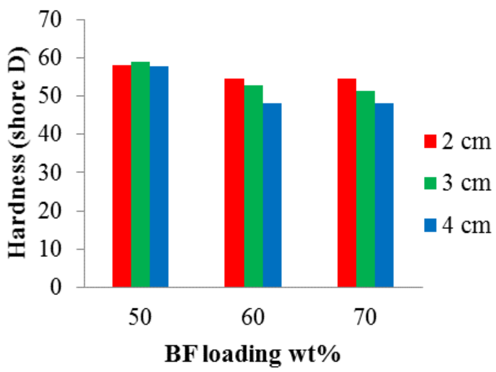


Fig. 4 Hardness vs various BF loading wt% with various BF lengths

The graph in Fig. 4 also shows the effect of BF loading for various BF lengths of 2, 3 and 4 cm on the hardness (shore D) properties of the composite. According to the BF lengths and BF loading, for a BF loading of 50 wt%, the hardness value is almost similar for all BF lengths. But for BF loading 60 and 70 wt%, the hardness decreased with the increment of BF lengths and the hardness values is slightly lower than that of the BF loading of 50wt%.

D. Effect of Fibre Length on Bulk density of BF/PP composite

Figure 5 shows the graph of density (g/cm³) versus composition of 50%BF, 60%BF and 70%BF for various fibre lengths of 2, 3 and 4 cm, respectively. The result shows that the density value increased with increased BF contents. While for 70%BF/30PP, it shows an inconsistent pattern, although the small difference is only 0.007g/cm³.

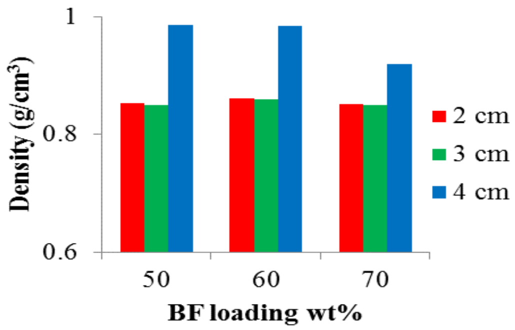


Fig. 5 Density vs various BF loading wt% with various BF lengths

Furthermore, the graph also shows the effect of BF loading for various BF lengths of 2, 3 and 4 cm on the density of the composite. According to the BF lengths and BF loading, for BF loading 50 wt%, the hardness value is almost similar for all BF lengths. Nevertheless, for BF loading 60 and 70 wt% the hardness decreased with the increment of BF lengths and the hardness values is slightly lower than of the BF loading of 50wt%.

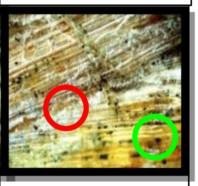
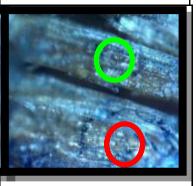
F. Microstructure of BF/PP composites

Table 3 shows the macrostructure of all composites BF/PP samples that were prepared. From the macrostructure analysis, the BF did not really have a good interfacial reaction with PP, as the PP content was reduced from 50% to 40% and 30%, respectively. Moreover, for the PP loading of 50% and 40% show a good adhesion between the BF and PP, especially for the short fiber (2 cm) compared to the long fibres. Other than that, it also shows some of the PP tends to congregate at certain spots especially for long fibre like 4 cm. Hence, it did not hold the fibre firmly and this effected their mechanical properties.

IV Conclusion

The effects of bamboo fibre length and bamboo loading on the mechanical properties of BF/PP composites have been studied and determined. Based on the results, it can be concluded that the tensile strength, flexure strength, hardness and density of the samples were decreased with increasing the fibre length. Secondly, the composition ratios of (BF/PP) for 50/50% and 60/40% is much better than that of the 30/70%. However, for a composition ratio of 70/30%, it is not suitable for composite materials because it shows inconsistent results. Furthermore, the 2 cm fibre is the best length because it gives the optimal results compared to those of the 3cm and 4cm fibre lengths.

Table 3 Microstructures of BF/PP Composites

Ratio (%)	**Fibre length (cm)**		
BF/PP	2cm	3cm	4cm
50/50			
60/40			
70/30			

PP BF

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