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A Review On Mechanical Properties Of Bamboo Fiber Reinforced Polymer Composite

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Abstract: Characteristically, polymers consist of the long chain molecules constructed of atoms (such as carbon and hydrogen) in the various arrangements with the different elements in the forming of basic building block of a polymer chain. Besides its primacy to the safety and environmental issues, polymer is becoming more widely used in today's industrial products due to its inherent advantages, such as inexpensive, durable, and flexible. Based on this reason, this study review the mixing of polymer with natural fibers (Bamboo) as an alternative of natural materials based on the potential properties as the reinforcing materials in polymer composite. This paper reviews the topic of bamboo mechanical properties in polymer composite. It highlights previous work done in bamboo fiber in terms of the reinforcement composite material. This literature study will be a good source for those who are interested in doing research for this topic.

Key words: Bamboo, Polymer Composite.

INTRODUCTION

Towards consumer product, plastics play the most important role in our daily used product. (Athijayamani *et al*., 2010; Dweib *et al*., 2004 and Burguenoa *et al*., 2005). In fact, most of them are parts made from petroleum-based and having environmental harmful potential. Therefore, the alternatives materials are needed and required to answer that situation. First, not only by replacing them, but also by creating and providing the materials which having the appropriate characteristics of mechanical, physical, and thermal performance while preferably also reducing the cost for the final product. For that reason, natural fiber plastic composites as an alternative are becoming widely accepted as a segment of the commodity plastics market (Athijayamani *et al*., 2010; Dweib *et al*., 2004; Burguenoa *et al*., 2005 and Rowell *et al*., 1997). This is due to the polymer composites reinforced with natural fibers offer a viable alternative of interest in which they can contribute to the viability of various products. This is as previously discussed by van Rijswijk *et al*., (2001) that composites are now as a part of everyday life and have entered nearly all major industrial sectors, including aerospace, ground transport, packaging, sports industry and civil engineering.

Second, by using the composite materials that are rapidly increased both in terms of the research and applications, the advantage over other conventional materials related to specific properties investigated such as on tensile, impact and flexural strengths, stiffness and fatigue characteristics, which enable structural design to be more versatile. Here, their features are also distinguished from synthetic fibers in relation to the low cost of acquisition, the light weight, low abrasiveness, and the great strength-to-weight ratio and increased the rate of biodegradability of the material viewing on the lucrative prospect of composite.

Third, although the composites of polymer and bamboo fiber are, in facts, having the differences and incompatible each others in terms of their polarity structures, the using fiber treatment or compatibilizing agents (such as Sodium Hydroxide - NaOH or polypropylene with maleic anhydride –PPMA) will help to reduce interfacial tensions and improve the adhesion between the matrix and fiber. By using fiber treatment or compatibilizer are expected will cause the material having an appropriate behaviour of the many applications based on mechanical forces required for different application related in which the mechanical behaviour of samples need to be known through the tensile tests, bending, impact and fatigue.

Fourth, bamboo composites can supplement and will, eventually, replace petroleum based composite materials in several applications, and thus offering new agricultural, environmental, manufacturing, and consumer benefits (Krishnaprasad *et. al.,* 2009; Han *et. al.,* 2008 and Chung *et. al*., 2002). Overall, the potential for bamboo composites to have a positive impact on materials for the mechanical properties is great. On that reason, composite materials based on renewable resources can lead to viable low-cost components and viable alternatives to polymer materials for product applications. The availability of low-cost composite components based on renewable resources will also be simpler in life cycle time. Besides, engineering applications for bamboo are prospective areas for development, and the utility of the bamboo makes it a viable option for

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employment generation and rural development (Lie *et. al*., 2010 and Ismail *et. al*., 2002). Further systematic and persistent research on bamboo composite technologies will lead to greater scope in the use of this plant resource.

This paper reviews the topic of bamboo mechanical properties in polymer composite. The review about bamboo, treatment and their mechanical properties will be discussed in sub-topic part. For a better understanding on how the natural fiber can contributes to various form of products will made, this study use the bamboo mixed with polymer in which to improve the bonding between fiber and matrix. Specifically, the reason of the study to use bamboo fiber is due to they have low density and high mechanical strength as well as raw material cost makes it economically viable. While, the using of polymer is due to they can be processed at temperatures below of the degradation temperature.

Bamboo:

Bamboo plants are giant, fast-growing grasses that have woody stems. The characteristics of each vary in size, growth habit, sun tolerance, soil moisture needs and heat/ cold temperature tolerance. Several investigators have examined bamboo as a source of bast fiber and as a source of cellulose from pulping the bamboo [Ahmad *et. al*., 2005; Rajulu *et. al*., 1998 and Chen *et. al*., 1998). One of benefits using bamboo fibers is that the bamboo is an abundant natural resource in Asia and Middle & South America. Bamboo fibers are often known as natural glass fiber due to its high strength with respect to its weight derives from fibers longitudinally aligned in its body (Okubo *et. al*., 2004). The tensile strength of bamboo is relatively high and can reach 370 MPa (Thwe *et.al*., 2003). This makes bamboo an attractive alternative to steel in tensile loading application.

Table 1 shows the comparison of natural fibers content and their mechanical and physical properties.

Table1: Composition of few natural fibers

Natural Fiber	Cellulose (%)	Lignin (%)	Pentosans (%)	Ash (%)	Tensile Strength (Mpa)	Density (g/cm^3)
Kenaf	44-57	15-19	22-23	2-5	930	1.45
Banana	65	5	-	-	500	1.35
Palm Oil	65	19	-	-	200-250	1.45
Rice husk	35	20	-	17	?	?
Sugarcane	55	15	25	-	290	1.25
Bamboo	26-43	21-31	15-26	1.7-5	140-230	0.6-1.1

Sources: Mathew *et.al*., 2006; John and Anandjiwala , 2008 and Premalal *et. al*., 2002)

Figure 1 and 2 show the bamboo tree and variation of bamboo fibers dimension during fabrication process of composites (Figure 1 & 2)

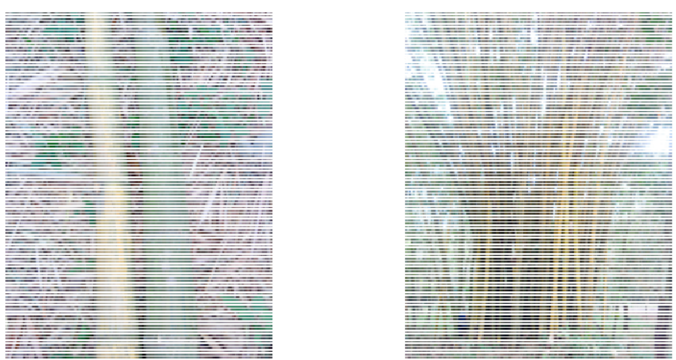

Fig. 1: Bamboo

Fig. 2: Bamboo fibers

Treatment:

Natural fibers are complex in structure and generally lignocellulosic consisting of helically wound cellulose micro fibrils in an amorphous matrix of lignin and hemicelluloses (Kelly, 1989). There are a few chemical methods available which can improve the interfacial adhesion between the fibers and the matrix. The chemical and physical surface modification studies on a variety of natural fibers have been devoted to understanding and enhancing the interfacial strength between the natural fibers and the polymer matrix, such as:

- coir fiber with alkali treatment (mercerization) and bleaching (Rosa *et. al*., 2009),
- coupling agent γ-aminopropyltrimethoxysilane (γ-APS) (Zainal *et. al*., 2010),

3-lycidoxypropyltrimethoxy silane (GPS), 3-aminopropyltriethoxy silane (APS), and 3-methacryloxypropyltrimethoxy silane (MPS) (Cho *et.al*., 2009),

- Polyethylene glycol (PEG) (Behjat *et.al*., 2009),
- Sodium Laulryl Sulfate (Thiruchitrambalam *et.al*., 2009),
- alkali treatment (Han *et. al*., 2007 and Lopez *et. al*., 2000),
- benzoic acid and sodium hydroxide (Wirawan *et.al*., 2010),
- sea water treatment (Ishak *et.al*., 2009),
- oil treatment (Manalo *et.al*., 2009).

Mechanical Properties of bamboo fiber:

The mechanical analysis is the study of a material's behavior when subjected to loads. The mechanical properties mainly provided by the cellulose content, which is influenced by many factors such as fibers volume fraction, fiber length, fiber aspect ratio, fiber-matrix adhesion or fiber orientation. Several papers have been published on the study of bamboo fiber reinforced composites reported that mechanical properties of bamboo vary because of the different testing methods used and the samples tested (Vasoya *et.al*., 2007; Suharty *et. al*., 2008; Kittinaovarat and Suthamnoi, 2009; Mohamad and Appanah, 1999; Lakkad and Patel, 1981; Latif *et. al*., 1993; Amada *et. al*., 1997; Kumar and Rakesh, 2012; Sun *et. al*., 2008; Bahari *et. al*., 2007; Obataya *et. al*., 2007; Van *et. al*., 2006; Ghavami *et.al*., 2003; Girisha *et.al*., 2012; Amada and Untao, 2001; Nugroho and Ando, 2000; Biswas and Xess, 2012; Biswas and Satapathy, 2010; Tokora *et. al*., 2008; Nugroho and Ando, 2001; Thwe and Liao, 2003; Thwe and Liao, 2000; Verma and Chariar, 2012; Porras and Maranon, 2012; Yeh and Lin, 2012; Yao and Li, 2003; Mahdavi *et.al*., 2012; Li *et. al*., 2002; Nogato and Takahashi, 1995; and samal *et al.,*. 2009).

Tokoro *et al*., (2008) reported that when three different types of bamboo (BF) were designated as short fiber bundle, alkali treated filament, and steam exploded filament mixed with polylactic acid (PLA) show the different values for highest bending strength and impact strength. The table 2 shows that PLA was not greatly improved by putting short fiber bundle but instead when steam exploded filaments were used as reinforcement.

Table 2: Bending and Impact strength PLA and PLA/ Bamboo fiber composites

Testing	PLA	PLA/Short BF Bundle	PLA/ Alkali treated filament	PLA/ Steam exploded filament
Bending Strength [Mpa]	82	84	98	118
Izod Impact [KJ/m^2]	1.48	0.85	1.55	1.80

According to Thwe *et. al.,* (2003), although tensile strength of bamboo fiber reinforced polypropylene composite BFRP and bamboo- glass fiber reinforced polypropylene hybrid composite BGRP (with or without maleic anhydride polypropylene MAPP) systems could not reach that of neat polypropylene PP, the tensile and flexural strength and stiffness are actually enhanced by inclusion of a compatibilizer, MAPP, in matrix material as a result of improved interfacial bonding. It show that just compatibizer agent is not enough to utilized performance of mechanical properties of bamboo/ e-glass/ polypropylene hybrid composite although the improvement in the mechanical properties due to hybridization.

Okubo *et. al.,* (2004) using steam explosion technique to extract bamboo fibers and study a typical tensile stress –strain curve and the tensile strength distribution of improved bamboo fiber eco- composite BFEC and bamboo fiber cotton eco- composite BFcEC. The result show that the tensile strength and young modulus of the BFcEC increased from 15 to 390% respectively. It is also indicated that the elastic modulus of BFEC increased about 2.6 times higher that of neat MAPP/ PP (table 3).

Table 3: Mechanical Properties of BFcEC, BFEC and MAPP/PP

Types of	Tensile strength (Mpa)	Young modulus (MPa)	Failure strain (%)
BFCEC	35.1	4.69	1.18
BFEC	30.3	3.66	1.21
MAPP/PP	22.5	17.6	-

Thwe *et. al.,* (2003) compared the fatigue behavior under cyclic tensile load and the hygro thermal ageing of Bamboo fiber reinforced polypropylene (BFRP) and bamboo- Glass fiber reinforced polypropylene (BGRP). The results showed that although the tensile strength of BFRP is slightly lower than that of the PP samples, enhancement is found by inclusion of glass fiber with 3 % MAPP. It also showed that the BGRP has better fatigue resistance than the BFRP composites at all load levels. Thus, it shows the improvement in the mechanical properties due to hybridization.

Samal *et. al.,* (2009) studied the effect of addition of bamboo- glass fiber reinforcements to the polypropylene matrix (BGRP). Comparisons were made between the BGRP and the virgin polypropylene. Fiber loading was taken as a parameter. Results showed that the composites prepared at 30% fiber loading with 2% MAPP concentration showed optimum mechanical performance. As compared to the virgin polypropylene, at a glass fiber: bamboo concentration of 15:15, the tensile strength, flexural strength and the impact strength increased by around 69%, 86% and 83% respectively. Also, in the case of BGRP, less fiber pullout was noticed in case of hybrid composites.

Thwe *et. al.,* (2000) in study of characterization of bamboo-glass fiber reinforced polymer matrix hybrid composite found that the mechanical properties of the bamboo-glass fiber reinforced polypropylene hybrid systems depend on fiber weight ratios, fiber length, and adhesion characteristics between the fibers and the matrix. The result with different bamboo fibers 3 mm and 6 mm were obtained using mould press method and 10 % to 40 % bamboo fiber was loading with & without MAPP. It is seen that the average tensile strength only showed a slight improvement when bamboo fiber content was increased from 10 to 30%, and it was dropped by 16% at 40% (by weight) fiber content compared to the case of 10% (by weight) fiber content.

Similar results obtained by Krishnaprasad *et. al.,* (2009) in the investigation of microfibrils extracted from raw bamboo. Composites based on polyhydroxybutyrate (PHB) and bamboo microfibril were prepared with various microfibril loading. The results of tensile strength and impact strength of the composites were found to be increasing with increase in the loading of bamboo microfibrils, reached an optimum and thereafter decreased with further increase in microfibril loading.

Table 4: Mechanical properties of PHB and its composites with bamboo microfibrils

Sample	Tensile strength (Mpa)	Young modulus (MPa)	Elongation at break (%)	Impact strength (kg/ m^2)
PHB pure	10.99	1044	1.94	595
PHB 5	9.73	1256	2.28	953
PHB 10	11.05	1388	2.25	991
PHB 20	12.05	1824	1.70	748
PHB 30	11.17	2165	0.96	510

Conclusion:

In general, the modification of bamboo fiber will effectively removing the impurities and bond between fibers in which the various compositions classified in the different percentage will get the different results of testing. This is due to the hydrophilic nature of bamboo fiber, where the different methods required for improving interfacial surface adhesion. This means that by understanding the fiber structures and characteristics that influence to composite performance, it could lead to the development of additives, coating, binders, or sizing of the natural fiber and a variety of polymeric matrices.

1. Beside as an interesting alternative for reducing the inconveniences of polymer utilization, bamboo also give the advantages if we preserving and conserving its.
2. Previous mechanical testing results shows that bamboo fiber can be suggested for capability's mechanical product.
3. Fiber lengths, orientation, concentration, dispersion, aspect ratio, selection of matrix, and chemistry of the matrix need to be investigated thoroughly.

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