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FLEXURAL PROPERTIES OF COMPRESSION MOULDED KENAF POLYETHYLENE COMPOSITE

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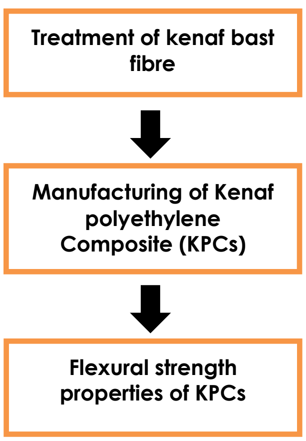
Graphical abstract



Abstract

The use of natural fibres at high percentages of loading in thermoplastic composites for the production of sustainable and green materials in consumer goods, furniture, automotive industry and construction industry is encourage. Several studies have been conducted by many researchers to improve the mechanical properties of the fibres and the fibre-matrix interface for better bonding and load transfer especially when high fibre loading is used. The natural fibre hydrophilic properties make the poor interface and poor resistance to moisture absorption when used to reinforce hydrophobic matrices. Therefore, this study investigates the effects of different surface treatment of kenaf bast fibre on the flexural strength of kenaf polyethylene composite (KPC). These composites, made using high-density polyethylene (HDPE) as the matrix polymer, kenaf core and kenaf bast fibre as the reinforcing filler at different percentages of filler and maleic anhydride grafted polyethylene (MAPE) as compatibilizing agents. Overall, KPCs with bast fibre treated with 0.06M $MgCl_2$ and 0.06M NaOH enhanced the flexural strength of the composites as compared to untreated bast fibre in the composite. Besides, the flexural properties of the KPCs significantly decreased with increasing kenaf bast fibre content, due to the reduction of interface bond between the fibre and matrix.

Keywords: Kenaf Core, Kenaf Bast Fiber, Flexural Strength Properties

1.0 INTRODUCTION

During the past decade, increasing environmental awareness, new global agreements and international governmental policies and regulations have been the driving force behind the renewed interest in the natural fibres for producing composites. Natural fibre polymer composite (NFPC) are composite material that comprised of combination of polymer thermoplastic or thermosetting and being reinforced by natural fibre [1]. The objective of NFPC development is to produce a product with performance characteristics that combine the positive attributes of natural fibre and polymer [2]. Natural fibre reinforced polymer attracted attention because of their low cost, low density, low abrasion, biodegradable and good specific mechanical properties [3-5].

Natural fibre consists of wood and non-wood. One of the most common wood flour/fibre used in thermoplastic industry is wood waste, whereas produced commercially from post-industrial sources such as planer shaving and sawdust [6]. However, forests, the major sources of wood fibres, are declining at the alarming rate of 13.0 million hectares per year in developing countries. Due to the global demand for fibrous materials, worldwide shortage of trees in many areas, and environmental awareness, research on the development of composites prepared using various waste materials is being actively pursued [7, 8]. Therefore, non-wood fibre from fast grown plantation crop has good potential to replace the usage of wood fibre as fibre reinforcement in thermoplastic composite. Kenaf is one of the non-wood fibres that grow well in tropical and sub-tropical areas. Kenaf (Hibiscus cannabinus, L. family Malvacea) has been found to be an important source of fiber for composites, and other industrial applications [9]. Malaysian kenaf is composed of two distinct fibres, bast and core, with a makeup of about 35% and 65%, respectively. Kenaf bast fibre has superior flexural strength combined with its excellent tensile strength that makes it the material of choice for a wide range of extruded, moulded and non-woven products [10]. Meanwhile, application of kenaf core is not well established and often considered as waste due to its shorter fibre compared to kenaf bast and high absorbency characteristic [11].

A challenge for natural fibre reinforced thermoplastic composites is the limited compatibility between the hydrophilic for natural fibre and the hydrophobic thermoplastic matrix [12]. Several studies have been conducted by many researchers to improve the mechanical properties of the fibres and the fibre-matrix interface for better bonding [13-15] and load transfer especially when high filler loading is used. Nevertheless, the higher filler loading (50 wt.%) resulted in greater reduction of flexural strength due to week in bonding [16]. Researchers have noted that polypropylene (PP) thermoplastic composite with increment of higher filler content (10 to 50 wt.%) as filler significantly decrease the flexural strength [17]. This may be due to the poor interfacial adhesion between fibre and polymer and the low affinity between the polymer matrix and the wood fibre.

Therefore, this study looked into improving bondability of fiber to resin by pre-treatment the kenaf bast fiber and by addition of compatibilizer and their effect on the flexural strength properties.

2.0 EXPERIMENTAL

2.1 Material

Kenaf bast fibres were supplied by MARDI (Malaysian Agricultural Research and Development Institute). Meanwhile, the kenaf core with 80-100 mesh sizes (0.180mm- 0.15mm) were processed at Everise Crimson Sdn Bhd at Bachok, Kelantan.

The polymer used was a High Density Polyethylene (HDPE) was supplied by Polyethylene Malaysia Snd. Bhd (ELINAS brand polyethylene) with a melt flow index of 7 g/10min as measured by ASTM D-1238 and the density of HDPE is 0.961g/cm^3. This specification data was provided by Polyethylene Malaysia Snd. Bhd.

In addition, Maleic anhydride grafted polyethylene (MAPE) was used as the coupling agent. MAPE (OVERAC 18302) with a density of 0.912 kg/m^3, supplied by Polyethylene Malaysia Snd. Bhd

The chemicals used to treat kenaf bast fibre were sodium hydroxide (NaOH) and magnesium chloride ($MgCl_2$). Both chemical were supplied as general laboratory agent.

2.2 Fibre Treatment

Kenaf bast fibre were treated either with sodium hydroxide (NaOH) or magnesium chlorite ($MgCl_2$) separately. The fibres were soaked in distilled water for approximately 3 hours to clean and remove impurities on their surfaces and later placed between tissue paper overnight to remove excess moisture followed by further drying in an air-circulating oven overnight at 80°C. The fibres were immersed in a 0.06M NaOH, and 0.06M $MgCl_2$ solution separately for 24 hours and later cleaned with distilled water. Excess NaOH were neutralized by soaking in dilute acetic acid (0.01M) for 5 minutes followed by rinsing with distilled water three times. Litmus paper was used to verify that all the acid had been washed out. The fibres were placed in an oven at 80°C overnight. The 0.06M NaOH was chosen base on the study done by other researcher which reported that improvement in mechanical properties of cellulose fibres when alkalized at different NaOH concentrations and found that 0.06M was the optimum concentration in terms of cleaning the fibre bundle surfaces and retaining a high index of crystallinity [18-20].

2.3 Sample Preparation

The preparation of kenaf polyethylene composite (KPCs) fabrication is based on mix formulation as shown in Table 1.

Table 1 Mixture formulation of KPCs and kenaf as fibre reinforcement

Total Filler (%)	Kenaf core waste to Bast	Kenaf Formulation (%)	
		Core waste	Bast
70	70/0	70	0
	60/10	60	10
	50/20	50	20
	40/30	40	30

The kenaf core and kenaf bast prepared in section 2.2 was further dried at temperature 120°C to moisture content below 1% using drying machine. Kenaf core with 80-100mesh sizes, kenaf bast fibre with 40 mesh size and high density polyethylene (HDPE) were mixed together with 3% compatibilizer (MAPE) by using high speed mixture machine. After that, the mixture was compounded into KPC pallet during extrusion process at temperature of 190°C to prevent degradation of the kenaf using counter-rotating twin-screw extruder. About 4kg of blended material (kenaf, HDPE and MAPE) were prepared for each of experiments. The total residence times of the blending operation were dependent on proportions of kenaf and HDPE present. The extruded composite material were palletised and dried at 80°C for 24 hours. The pallet materials of KPC were loaded into mould and pressed at temperature of 158°C for 10minutes. Cooling down was carried out for another 10 minutes under a constant pressure. The compression-moulding machine pressed at 10MPa to form the KPCs boards with dimension of 153mm x 153 mm x 3 mm. The KPC boards were placed in conditioning room at 25°C with relative humidity of 65±5%. These manufacturing processes conducted at Kenaf Factory, Malaysian Agricultural Research and Development Institute (MARDI).

2.4 Preparing of Samples and Test Method

A series of specimens were prepared for flexural test. Samples were cut into 122mm x 50mm x 3mm in size as shown in Figure 1. The test is conducted at a crosshead speed of 3mm/min on an Instron Machine at Strength of Materials Laboratory (see Figure 2). Flexural strength test were determined in accordance with ASTM D 7264-07: Flexural Properties of Polymer Matrix Composite Materials. Five replicate were prepared for test as shown in Table 2.

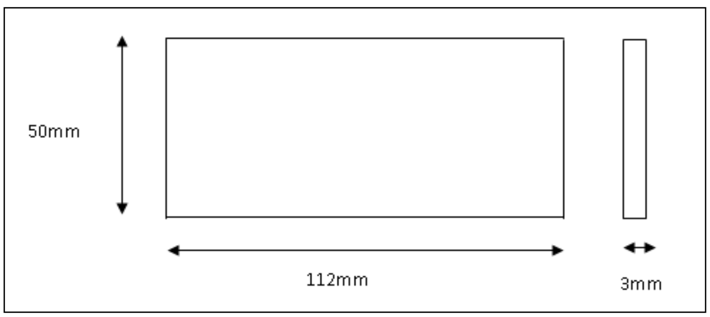


Figure 1 Dimensions of flexural test specimen

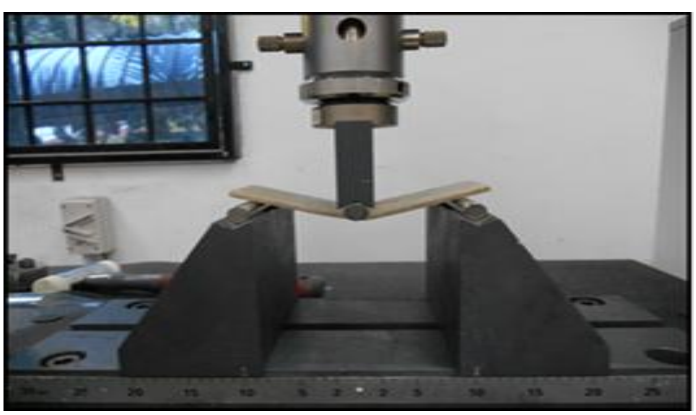


Figure 2 The specimen after bending test

Table 2 Number specimens for the testing

KENAF Core Fibre 80-100 mesh sizes (%)	Bast Fibre 40mesh sizes: Treatment	Bast Fibre 40mesh sizes: (%)	Total specimen for the testing: Flexural test
70	Control	0	5
60	Untreated	10	5
50		20	5
40		30	5
60	6% NaOH	10	5
50		20	5
40		30	5
60	6% $MgCl_2$	10	5
50		20	5
10		30	5

3.0 RESULTS AND DISCUSSION

3.1 Flexural Properties of KPCs

Table 3 shows the results for flexural strength and modulus of elasticity (MOE) for all types of samples.

Table 3 Summary statistic for flexural strength and MOE for flexural tests

Kenaf filler: Waste Core 80-100 mesh sizes (%)	Bast Fibre 40mesh sizes: Treatment	Bast Fibre 40mesh sizes: (%)	Flexural Properties: Mean Flexural strength (MPa)	Flexural Properties: Mean MOE (MPa)
70	Control	0	15.4 (0.15)	2755.4 (19.48)
60	Untreated	10	19.0 (0.14)	2944.1 (44.89)
50		20	17.5 (0.55)	2840.8 (20.09)
40		30	16.2 (0.28)	2774.2 (35.92)
60	0.06M NaOH	10	21.2 (0.36)	3284.5 (42.53)
50		20	19.8 (0.35)	3195.2 (28.76)
40		30	18.2 (0.14)	2977.9 (21.06)
60	0.06M MgCl2	10	24.8 (0.09)	3378.5 (15.04)
50		20	22.12 (0.23)	3210.6 (36.37)
10		30	20.13 (0.13)	3171.3 (41.07)

Note: ( ) Standard Derivation

For better understanding on the effect of bast fibre treatment on the flexural properties of the KPCs, Figure 3 and 4 were plotted.

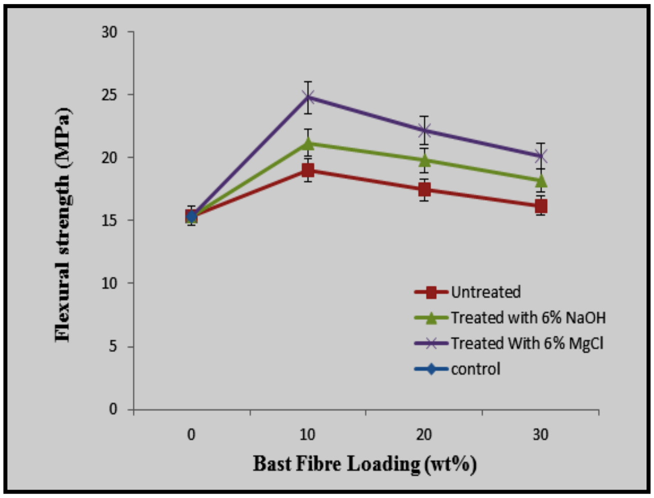


Figure 3 Average flexural strength result for untreated and treated kenaf polyethylene composite

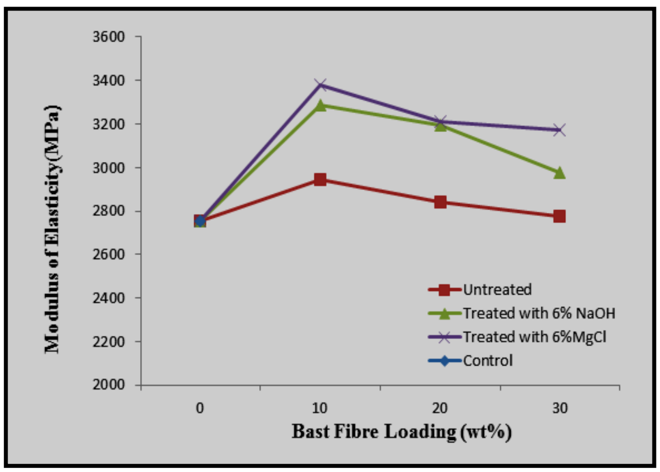


Figure 4 Average MOE result for untreated and treated kenaf polyethylene composite

Figures 3 and 4 show that KPCs containing 10 wt.% of kenaf bast fibre treated with 0.06M $MgCl_2$ gave the highest value of MOR and MOE with 24.78MPa and 3284.50MPa respectively. Besides, the KPCs made with 10 wt.% kenaf bast fibre either treated or untreated gave the highest result compared to other kenaf bast fibre loading.

In general, KPCs with bast fibre treated with 0.06M $MgCl_2$ and 0.06M NaOH enhanced the flexural strength of the composites as compared to untreated bast fibre in the composite, which is consistent with other studies [21, 22]. Aziz and Ansell [23] also discovered that the treated fibres gave superior flexural strength and MOE values for all the composite types compared to the untreated fibre composites. They stated that the treatment of fibres by alkalisation (NaOH) has helped in improving the mechanical interlocking and chemical bonding between the resin and fibre resulting in superior mechanical properties. Besides that, fibre treatment resulted in adequate levels of fibre separation and subsequently increased in fibre surface area [15], and this has contributed to the higher flexural strength of the 0.06M $MgCl_2$ treated fibres.

From both Figures 3 and 4, it is observed that the inclusion of kenaf bast fibres with the reduced amount of waste kenaf core in KPC boards increased the flexural strength and the MOE of the composites. It is apparent that the addition of 10% of the kenaf bast fibre in KPC significantly increased the flexural strength and MOE value of KPC as compared to 0% of kenaf bast fibre in KPC. The KPC boards with 0% of bast fibre content gave the lowest value of flexural strength and MOE with 15.38MPa and 27755.40MPa respectively. The addition of 10% kenaf fibre for untreated and treated fibre composites containing 0.06M NaOH and 0.06M $MgCl_2$ separately in KPC resulted in an increase of 23.5%, 37.7% and 60% respectively for flexural strength compared to control KPC. Similarly, the results of MOE, the addition of 10% kenaf fibre of untreated and treated fibre composites comprising 0.06M NaOH and 0.06M MgCl separately in KPC resulted in an increase of 6.8%, 19.2% and 22.6% respectively

However, the flexural strength and MOE of KPCs decreased proportionally to the increased in percentages of bast fibre filler loading at different bast fibre treatments.

The reduction in this property might be attributed to the geometry of the kenaf bast filler. According to Ismail, *et al*. [24], the flexural strength of the composites decreases because of the inability of the fillers to support stress transferred from the polymer matrix due to irregular-shaped fillers. Moreover, the interfacial interaction in wood fibre-polymer matrix is believed to be stronger for smaller fibre lengths than for longer ones. It is because a more homogeneous dispersion of finer wood fibre in the matrix is provided [25].

Overall, the untreated and treated kenaf bast fibre at different content core to bast fibre display higher flexural strength and MOE value compared to 0 wt.% bast fibre content in KPC boards.

3.2 Mode of Failure of KPCs

All the specimens have similar failure modes. Figure 5 shows a typical failed surface under bending. The fracture surface failure was observed at cracks openned in an outward direction parallel to the tensioning direction.

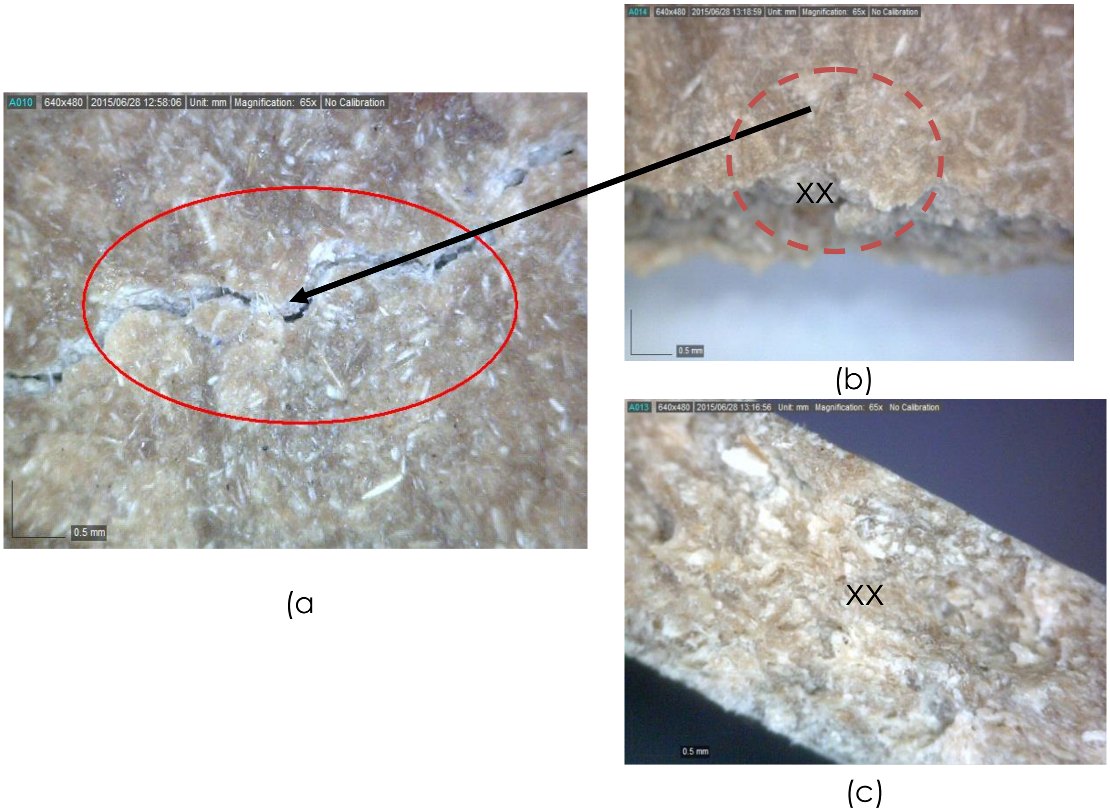


Figure 5 (a) crack opened (b) location of observation (c) fracture surface failure

4.0 CONCLUSION

Overall, in can be summarized that KPC with 10wt% of bast fibre treated with 0.06M $MgCl_2$ gave highest results in flexural properties as compare KPCs with 20% and 30% of untreated and treated bast fibre. Furthermore, the KPCs with bast fibre treated either with 0.06M $MgCl_2$ or 0.06M NaOH enhanced the flexural properties. It shows that, the treatment on bast fibres helps in improving the mechanical interlocking and chemical bonding between the resin and fibre resulting in superior mechanical properties.

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