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Mechanical Properties Study on Different Types of Kenaf PVC Wall Panel Product

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ABSTRACT

Kenaf fibre is one of the natural fibers that has received much attention of many researchers because of its good properties and flexible use. Kenaf fibre composites have been proposed as interior building materials. In this study, the recycling effect on the kenaf PVC wall panel is focused. The main objective of this study is to determine the mechanical properties of different types of kenaf PVC wall panels. The samples were formulated based on the first and third recycling process. The specimens were subjected to several types of tests, namely, tensile, izod impact, flexural and hardness based on ASTM D3039, ASTM D256, ASTM D7264 and ASTM D785, respectively. The results indicate that the mechanical properties of the third recycled kenaf PVC wall panel product is better than the virgin and first recycled specimen. This shows that the recycling process enhances the mechanical properties of the product. On the other hand, the hardness of the specimen decreases after first recycling due to the reheating effect.

Keywords: Kenaf fiber, kenaf PVC wall panel, mechanical properties, recycling

INTRODUCTION

The demand for using natural resources in engineering products in the building structure has increased in recent years due to global environmental issues. Natural resources such as natural fibre composites used in engineering application are hence, encouraged as these are environmental friendly and can provide good properties compared to synthetic fibres. The natural fibre composite offers tailorable durability, good fatigue performance and is of low cost (Humpreys, 2003). It also has

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high specific strength and specific stiffness but is much cheaper than glass fibre (Bledzki & Gassan, 1999; Salleh et al., 2014). Moreover, natural fibre has low density, availability and biodegradability which makes natural fibre favourable as reinforcing material for composite products (Nishino, Hirao, Kotera, Nakamae, & Inagi, 2003).

The potential of natural fibre such as kenaf has attracted many researchers. The exploitation of kenaf fibre for building material has been extremely widespread due to its ability to grow faster than any other natural fiber. The kenaf tree can grow in only three months (after sowing). It is also able to grow under a wide range of weather conditions, to a height of more than 3 m and a base diameter of 3 to 5 cm (Aziz, Ansell, Clarke, & Panteny, 2005). The growing speed of kenaf may reach up to 10 cm/day under optimum ambient conditions (Nishino, 2004). Thus, it can be harvested and be used regularly for many applications. The kenaf tree has three types of fibres showing its versatility in engineering application. The type of fibre strongly influences the tensile properties of a composite (Salleh et al., 2012). Kenaf is scientifically known as *Hibiscus cannabinus*, has 65.7% cellulose and 15.7% lignin. Fibre reinforced composite as a building material has been widely applied for a long time. The applications include compound curved roofs (Hollaway, 2002), pedestrian and vehicle bridges, bridge decks (Federal Hyway Administration, 2002), energy absorbing roadside guardrails (Bank & Gentry, 2000), modular rooftop cooling towers (Barbero & Ganga Rao, 1991), access platforms for industrial, chemical and offshore (Hale, 1997), electricity transmission towers, power poles and marine structures such as seawalls and fenders (Nishino et al., 2003).

One of the kenaf fibre composites in building material industry is the Kenaf Plastic Composite (KPC) product. KPC product such as wall panel, decking, fences and skirting are examples of popular building materials. KPC has good properties such as being lightweight, eco-friendly, and has high strength and rigidity. This unique characteristic has made KPC product to be one of the most highly potential building materials.

However, KPC product itself is still a new building material and not much study has been done especially on recycled products. The recyclability of the product itself, although has been considered as an advantage for reducing and wasting natural resources, is yet to be explored. Hence, the study is aimed to focus on the mechanical properties of virgin and recycled kenaf PVC panels.

MATERIALS AND METHODS

Specimen Preparation

The specimen used in this work is kenaf PVC wall panels. The panels can be used as wall panels or ceiling panels (interior design building materials). The panels were obtained directly from the manufacturer, Everise Crimson (M) Sdn. Bhd. which is located in Kelantan, Malaysia. There are three different types of samples used in this research, that is, virgin, first recycled and third recycled. Figure 1 shows the kenaf PVC wall panel specimens. The product was made from 40 mesh kenaf powders.

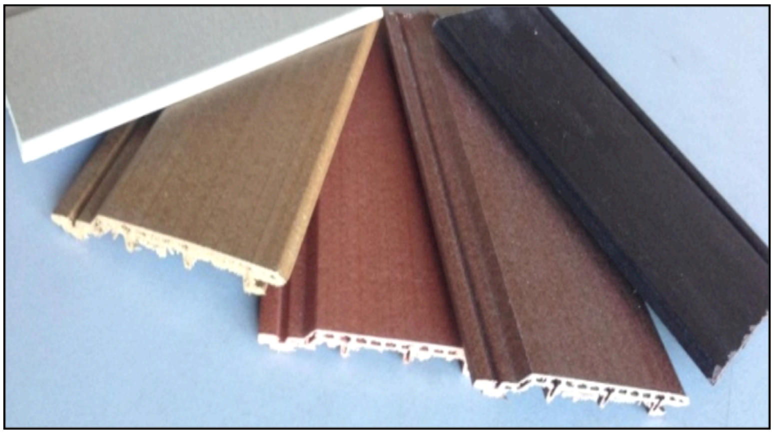

Figure 1. Kenaf PVC wall panel products

The fabrication process of the three different types of samples is as follows:

i. Virgin - The original product was produced from extrusion molding process.

ii. 1st Recycled - The specimen was made from the excess or unused virgin product. The virgin product was crushed into powders form and was named as the 1st recycled material.

iii. 3rd Recycled - The specimen was made from the 2nd recycling. The 2nd recycled specimen was crushed into powders form and was termed as the 3rd recycled material.

In every recycling process, chemicals designated as LX 551, Chlorinated Polyethylene (CPE), PE Wax and Calcium Zinc were added into the crushed materials.The purpose of adding the chemicals is to maintain the original properties of the product during the extrusion molding process.

Mechanical Testing

The tensile properties of the specimen were tested according to ASTM D3039, using the model 3382 of Uniaxial INSTRON Tensile Machine. The recommended dimension of the specimen according to the ASTM D3039 was 250 mm × 25 mm × 5.5 mm. The specimen was pulled at the speed of 2 mm per minute.

The flexural test was conducted based on three points bending configuration where the specimen was supported on both ends while the force was applied at the center of the specimen. The test was conducted according to the ASTM D7264. The dimension of the specimen was 88 mm × 13 mm × 5.5 mm. The speed used in the test was 2 mm per minute and the support span size was 48 mm. The testing equipment was the model 3382 of Uniaxial INSTRON Tensile Machine.

Izod impact test was conducted on the sample using India model International Equipment (IE) computerised Izod impact tester, according to the ASTM D256. The recommended dimension according to the standard was 60 mm × 10 mm × 5.5 mm. The notch used for this type of specimen was V-notch. The hardness of the specimen was conducted according to ASTM

D785 using the Rockwell Hardness Test Machine. The hardness of the test was determined by the indention depth of the specimen.

The surface fracture of the specimen after the mechanical properties testing was observed under Hitachi model TM3030Plus SEM machine.

RESULTS AND DISCUSSION

Tensile Properties

Five samples for each type of wall panel products was subjected to tensile test. The data obtained was analysed and the mean value was calculated. The best set of data was selected according to the mean values. The data is summarised in Table 1.

Table 1
The modulus, tensile stress and tensile strain of kenaf PVC panel products

Types of product	Tensile modulus (MPa)	Ultimate tensile strength (MPa)	Ultimate tensile strain (mm/mm)
Virgin	495.08	7.4587	0.0149
1st Recycled	598.75	8.9601	0.0134
3rd Recycled	683.93	10.5973	0.0124

Indeed, the results shown in Table 1 indicate that the recycling process strongly affects the tensile properties of the samples. Tensile modulus lies between 495.08 MPa to 683.93 MPa, which is considered low to be applied in many engineering applications. Hence, the product is currently recommended for interior use only. The modulus of the virgin sample is 495.08 MPa. The modulus increased after 1st recycled product, that is, about 21% compared to the virgin product. The modulus of the 3rd recycled product was recorded as the highest, which is 683.93 MPa, a noticeable increase of about 38% compared to the virgin sample.

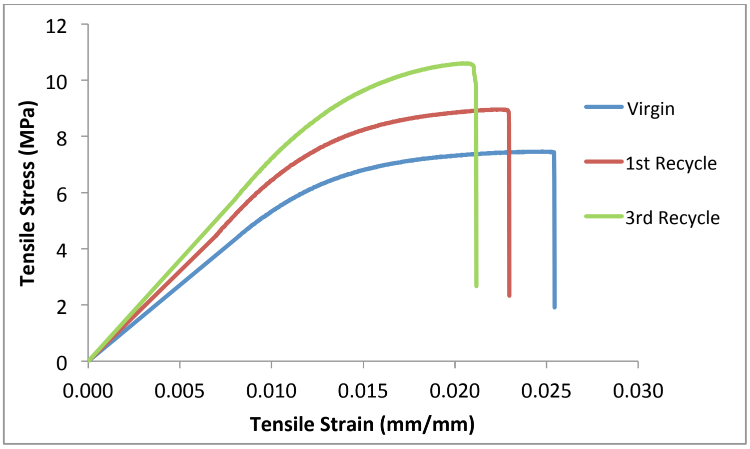

Figure 2. Typical stress-strain curve of kenaf PVC panel products

According to the stress-strain curve as shown in Figure 2, it is clearly seen that the 3rd recycled wall panel yielded a higher tensile strength and modulus but lower ductility as compared to the other samples. However, the ultimate tensile strain of the virgin sample is the highest, which is 0.0149 before failure, indicating better ductility than others. Although the tensile and modulus of the products were improved by the recycling process, the loss of ductility limited the product from its ability to deform further under the load.

Flexural Properties

In the flexural test, five specimens from each type of samples were prepared and tested. The best set of data was chosen from the five samples according to the mean values as tabulated in Table 2.

Table 2
The modulus, flexure stress and flexure strain of kenaf PVC panel products

Types of product	Modulus (MPa)	At maximum loading	
		Flexure stress (MPa)	Flexure strain (mm/mm)
Virgin	587.28	16.821	0.041
1st Recycled	665.87	21.137	0.044
3rd Recycled	753.00	23.438	0.049

From the data obtained, it is evident that the recycling process changed the flexure properties of the material. At 1st recycling, the modulus obtained shows an increase of about 13.38%, compared to the virgin sample. The modulus increased to 753 MPa for the 3rd recycled specimen, which is 28.22% higher than the virgin sample.

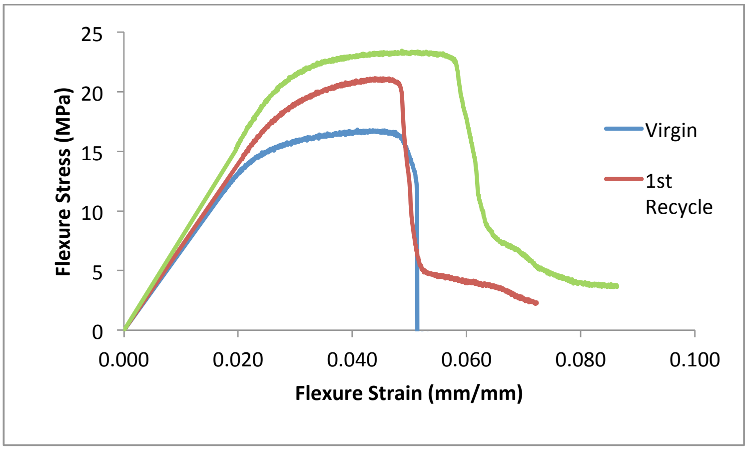

Figure 3. Typical flexure stress-strain curve of kenaf PVC products

In Figure 3, it is clearly revealed that the 3rd recycled specimen exhibited better flexure performance compared to other specimens. It shows that the virgin sample has the lowest yielding. The low flexure strain of the virgin sample indicates the brittle failure phenomenon.

The cellulose content of the kenaf fibre is believed to decrease after each recycling process, thus, it improves the flexure strain of the sample. The diminishing of cellulose in the fibre enhances the flexibility of the kenaf fibre because of plasticization effect (Ghani et al., 2012). The increase in modulus also indicates that the stiffness and rigidity of the product increase was proportionate to the recycling process.

Izod Impact Properties

Izod impact test was conducted at room temperature to obtain the comparative impact energy and impact strength of the kenaf PVC panel products. Five specimens of each type of sample were prepared according to ASTM D256. The weight of the hammer used was 0.452 kg, which produced a maximum impact energy of 0.271 joules. The impact energy absorbed by the material was recorded via the machine data logger. The average impact strength was calculated based on the impact energy per net cross-sectional area of the specimen as summarised in Table 3.

Table 3
Impact energy and the impact strength of kenaf PVC panel products

Type of product	Average Impact energy (J)	Percentage of impact absorbed from R1 hammer (%)	Average impact strength (kJ/m^2)	Changes in impact strength for each type of products compared to virgin (%)
Virgin	0.068	25.09	1.2364 (*SD=0.39)	-
1st Recycled	0.066	24.35	1.2000 (SD=0.10)	-2.94
3rd Recycled	0.106	39.11	1.9273 (SD=0.35)	55.87

*SD = Standard Deviation

According to the data in Table 3, the virgin and 1st recycled products absorbed 25.09% and 24.35% of the impact energy respectively from the hammer prior to fracture. However, the highest impact energy absorbed was obtained by the 3rd recycled product, which was 0.106J, and about 39.11% of energy impacted. This proves that the 3rd recycled sample has the highest impact toughness compared to other samples (Nielsen & Landel, 2003).

Similar results of the impact strength are presented in Table 3. The 3rd recycled sample recorded the highest average impact strength which is more than 55 % as compared to the virgin sample. As for the 1st recycled products, there was a slight drop of about 3 %, compared to the virgin sample.

Hardness

Hardness is defined as the ability of a material to resist scratching, abrasion or cutting (Bernard et al., 2011). From the result tabulated in Table 4, it is clearly seen that the hardness of the virgin sample is the lowest among all the specimens. The hardness of virgin sample is recorded as 21.28 RH. On the other hand, the hardest specimen is the 1st recycled product, which shows a reading of 48.80 RH.

Table 4
Hardness of kenaf PVC panel products

Type of product	Hardness value (Average)	Standard deviation
Virgin	21.28	5.185
1st Recycled	48.80	5.006
3rd Recycled	33.18	3.506

Microstructure of Fractured Surface

The SEM micrograph of the fracture surface is shown in Figure 4. A few fracture elements were identified in the SEM micrograph. The fracture elements are fibre matrix debonding, fibre fracture, fibre pull-out and the matrix fracture. The complex nature of the fracture mechanism in composite system is similar as reported in previous findings (Salleh et al., 2014).

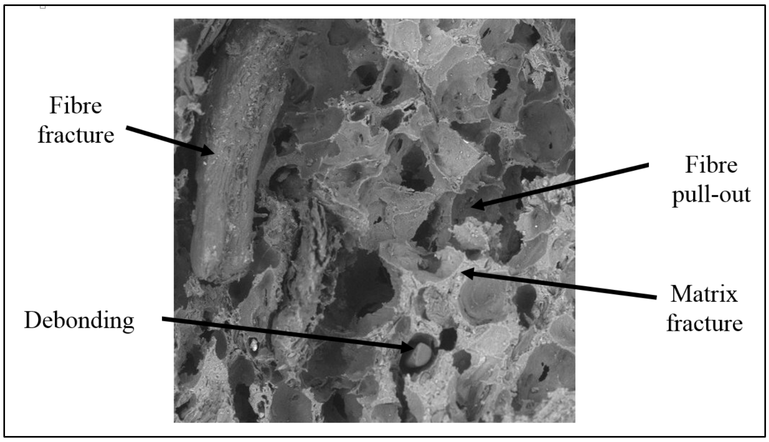

Figure 4. The microstructure of fracture surface of kenaf PVC wall panel product

In fact, the 3rd recycled product showed better properties than the virgin and the previous recycled specimen. This is because the tensile stress, flexure stress, modulus and the impact strength of the specimen was higher (Paul, Jan, & Ignaas, 2001).

CONCLUSION

Based on the results obtained, the recycling process of the kenaf PVC wall panel product modified the mechanical and physical properties of the composite. The tensile properties, impact strength and flexure properties of the samples increased due to the chemical addition during each recycling process. The 3rd recycled product performed better tensile, impact and flexure properties compared to the virgin and the previous recycled specimens. However, the specimen appeared to be brittle but with a slightly elastic behavior, causing the hardness of the 3rd recycled specimen to decrease. Anyway, the hardness of the 3rd recycled specimen performed better than the virgin product. Furthermore, like all other natural fibre products, the properties of kenaf fibre vary according to the conditions of growth and harvest. The degree of maturity at the time of harvest has a direct effect on the strength of the fibers obtained. It is recommended that the product be manufactured by using long kenaf fibre instead of kenaf powder. The addition of long kenaf fibre in kenaf PVC panel products in future studies will seek significant improvement in properties, particularly the impact strength, tensile strength and modulus.

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