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Impact Strength of HDPE Composites Roofing Panel from Natural Fibre

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Abstract*: Residues from agricultural waste has increased in demands due to its useful products. This paper will focused on the density and type of fibres effects on roofing panel strength made from natural fibre reinforced HDPE. Natural fibre reinforced HDPE with three different types at different ratios for each composite were prepared in laboratory. Dynatup 9250HV was used to test impact strength of the composite. The impact strength of all composite boards was determined based on the Energy (J) value. Both the density and types of natural fibre have significantly affected the impact strength. Bamboo fibre gave the best impact properties compared to coconut coir and kenaf. There is only slightly difference between impact strength value for bamboo and kenaf which is in the range of 2.76MPa to 3.82MPa. Ratios at fourty (40) gave higher density value and results in better impact strength. In general, there is significantly difference between the ratios among the fibres.

***Keywords* : bamboo, coconut coir, HDPE, impact strength, impact behaviour, kenaf, reinforced composite.**

I. INTRODUCTION

Farming segment contributes plenteous buildups. These days, agribusiness products have the potential as supplementary crude materials due to deficiency of woodland assets. These materials can be completely used as new item through a combination of non-biodegradable materials. Composite materials based on polymer matrix have gain interest the industries and researcher in recent decades. Composites reinforced natural fillers from natural resources were demanding more attention among researcher [1]. It was due to tall cost of the petroleum items, the real risk, public concerns and awareness of global warming [2]. Natural fibres are generally lignocellulosic, consisting of cellulose with lignin and hemicellulose [3]. Cellulose is a polymer with more prominent quality and firmness. Lignin was the compound that gives strength to the fibre [4].

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The use of natural fibre reinforced composite materials was mainly affected by the moisture absorption and the effect on composite performance [5]. Application of composite materials for buildings made from natural fibre (coconut coir, kenaf and bamboo) is an interesting method in helping our environment and act as a valid replacement for current materials [6], [7].

II. MATERIALS AND METHOD

A. Materials and Specimen Preparation

Fibre reinforced high density polyethylene (HDPE) composite were used. The raw materials used in this study were kenaf fibre, coconut coir and *Gigantochloa scortechinii* (buluh semantan) as in Fig. 1. The percentage of filler loading was depending on the mass of the compound. The polymer composite was crushed using crusher machine to form pallet from three type polymer composites. Fig. 2 refers to pallet made from bamboo composite, kenaf composite and coconut coir composite. The pallet was molded using standard mold 150 × 150mm in length and width with 3mm thickness. Roofing Panel Bamboo Composite (RPBC), Roofing Panel Coconut Coir Composite (RPCC) and Roofing Panel Kenaf Composite (RPKC) were formed. Each board types were produced with two fibre ratios each at 40% and 30% as indicates in Table I. The ratios were derived based on previous research done by [8] and [9] which stated that the best ratio for fibre composites are not less than thirty percent and not more than fifty percent. The natural fibre reinforced HDPE composite was cut into specific sizes for the test samples. There were 10 specimens used for each test. The sizes of the physical properties were in accordance to ASTM standard.

Table I: The Natural Fibre Reinforced HDPE Composite Boards

Type	30:70	40:60
Coconut Coir	C30	C40
Bamboo	B30	B40
Kenaf	K30	K40

Note:
40:60- ratios of 40% fibre with 60% HDPE
30:70- ratios of 30% fibre with 70% HDPE

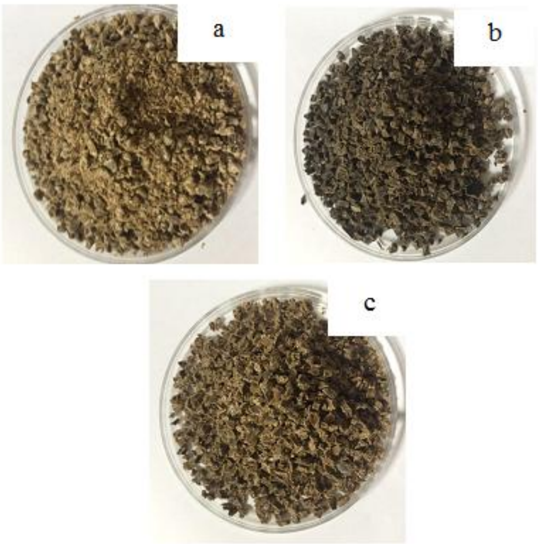

Fig. 1. Composite Pallet made from Bamboo (a), Coconut Coir (b) and Kenaf (c)

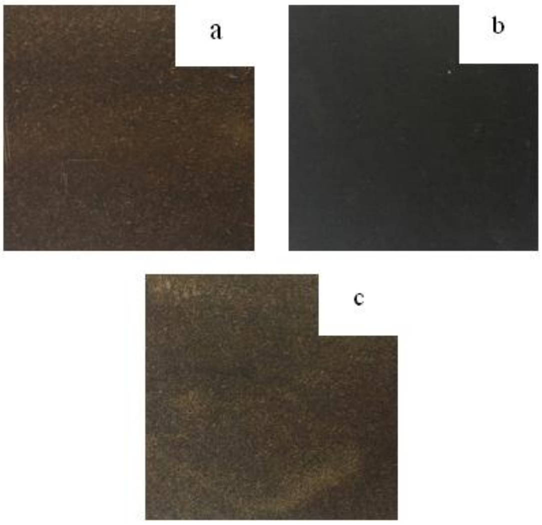

Fig. 2. Composite Board from Bamboo (a), Coconut Coir (b), and Kenaf (c)

B. Density

Density is the single indicator of the property of a material and is a major factor determining its strength. Density of each specimen was determined as the samples were oven dried for 24 hours at 103°C before being weighted. Density meter was used to obtain the density and was calculated using formula as in Equation 1.

$$\text{Density} = \frac{\text{Oven weight- dry weight}}{\text{Volume of sample}} \qquad (1)$$

C. Scanning Electron Microscopic Studies of HDPE Composite

The surfaces of specimen studied using Scanning Electron Microscopy (SEM). The adhesion among fibre and matrix were observed at 500X magnifications.

D. Impact

Fig. 3 shows impact testing machine used in this study. An impactor was placed with a stated dimension at the centre of specimen. The drop height and the test results were recorded. The natural fibre reinforced HDPE composite was cut into specific sizes for the test samples. After cutting, the samples were placed in humidity chamber or at least 40 hours according to the ASTM D 618-99 before testing at 23±2°C, 50±5%.This step was necessary to ensure that all specimens exposed to similar humidity, moisture content, temperature and other influences prior to testing.

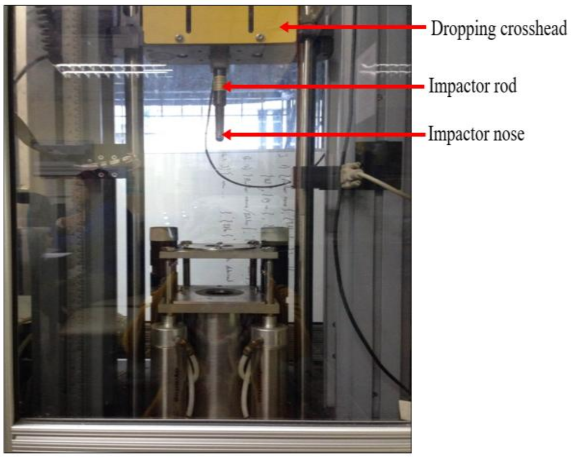

Fig. 3. Impact Testing Machine

III. RESULT AND DISCUSSION

A. Density

Density is an important factor because it influences the impact strength behavior of the composite. Table II presents the density and impact strength of the composites with different fibre ratios. From the results, it shows the density for all types of composite ranging from 1.73g/mm³ to 1.83g/mm³. By adding fibres to the HDPE it will slightly increase the density of composite due to the higher density of fibre compared to HDPE [10].

Table II: The Mean Value, Standard Deviation and Statistical Analysis of Three Types HDPE Composite on Density and Impact Strength

	Coconut Coir		Bamboo		Kenaf	
	C30	**C40**	**B30**	**B40**	**K30**	**K40**
Density (g/mm³)	1.73^{b} (0.12)	1.79^{a} (0.06)	1.79^{b} (0.12)	1.82^{a} (0.05)	1.80^{b} (0.07)	1.83^{a} (0.11)
Impact Strength (MPa)	1.80^{b} (0.40)	1.86^{a} (0.49)	3.09^{b} (0.65)	3.82^{a} (1.26)	2.76^{b} (0.19)	3.53^{a} (0.64)

Means with the same letter within the same material are not significantly different at the 5% level of probability.
Numbers in parentheses are standard deviations from the sample mean.
Note:
30 and 40- density
C- coconut coir
B- bamboo
K- kenaf

B. Scanning Electron Microscopic Studies of HDPE Composite

The SEM micrographs represent the coconut, bamboo and kenaf composites respectively. Fig. 2a, 3a, 4a show the SEM micrograph of HDPE composite at thirty percent (30:70) ratios of fibre at 500X magnifications while fourty percent fibre (40:60) ratio of the HDPE composite are illustrate in Fig. 1b, 2b and 3b. As the ratios of fibre decreased, the amount of HDPE increased, mixture of the composite became rough as in Fig. 2b, Fig.3b and Fig. 4b.

a) Coconut Coir

Fig. 4a show the mixtures of composites well mixed compared to Fig. 4b. The uncompounded blend was observed when the compound is insufficient It is shows that fibre blends is low.

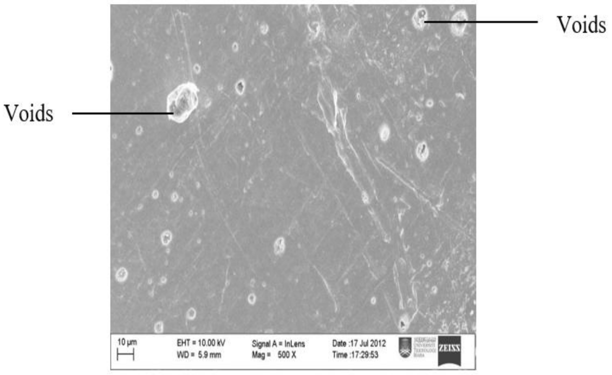

Fig. 4a. The Morphology of Coconut Coir HDPE Composite at Ratio 30:70

The voids observed might be the result in the mixing procedure that have created spaces between the fibres [11]. When stress was applied, the fibres were easily torn from the matrix and hence, the stress will not be effectively transferred. These shows similarity as loses strength values reported in the mechanical performance of coconut coir HDPE composite.

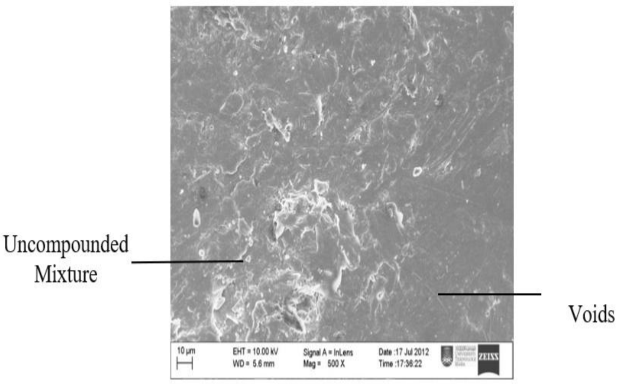

Fig. 4b. The Morphology of Coconut Coir HDPE Composite at Ratio 40:60

b) Bamboo

For the Fig. 5a and 5b, both show a very similar overview of the bamboo composite mixture. The compounds were well mixed but are not uniformly distributed. Since, the percentage of the HDPE used is sixty percent with forty percent of fibres, the fibre-matrix compound seen to have uncompounded mixture even both fibre and HDPE are well mixed in the dispersion mixer machine during production of the composite. This was due to fibre clot during drying process and lead to uncompounded mixture. [1] found there was less void produced even the surface is irregular in composite.

In the case of ratios at seventy percent as in Fig.3b, the surface is differing. The fibre mixtures of bamboo composite also cleaner as contrast to other composites. Indeed, voids cannot be seen clearly. This case indicates that improvement in the fibre to matrix bonding. There is greater number of HDPE attached between the fibre. A large amount of matrix on the fibre clearly shows better interfacial adhesion between compounds. It can be also said that the compound appears to be uniform.

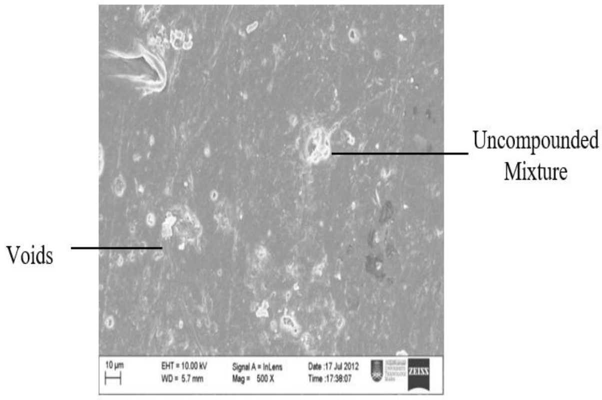

Fig. 5a. The Morphology of Bamboo HDPE Composite at Ratio 30:70

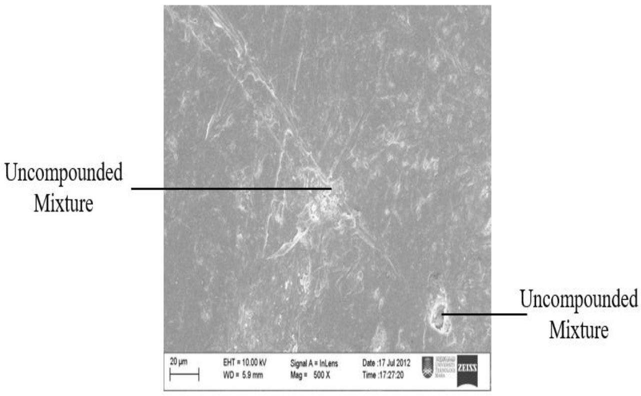

Fig. 5b. The Morphology of Bamboo HDPE Composite at Ratio 40:60

c) Kenaf

From Fig. 6a and Fig. 6b, it is apparent that the kenaf composite has a lot of uncompounded mixture and also some voids. The bond between fibre and matrix is low for kenaf composite. The fibre tear appeared in relatively less in comparison to coconut composite. Besides, the plastic adhered to the fibre surfaces are more visible. This supports better cohesion between kenaf fibre and matrix as compared to coconut rather than bamboo composite.

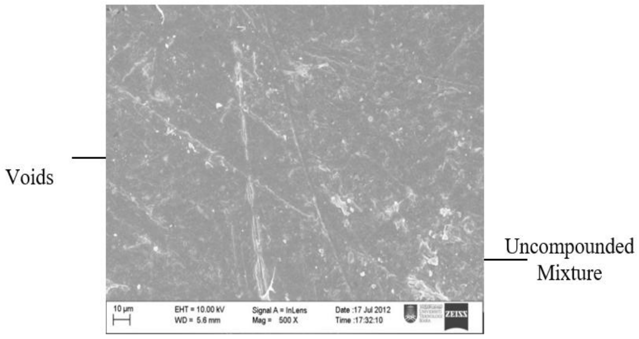

Fig. 6a. The Morphology of Kenaf HDPE Composite at Ratio 30:70

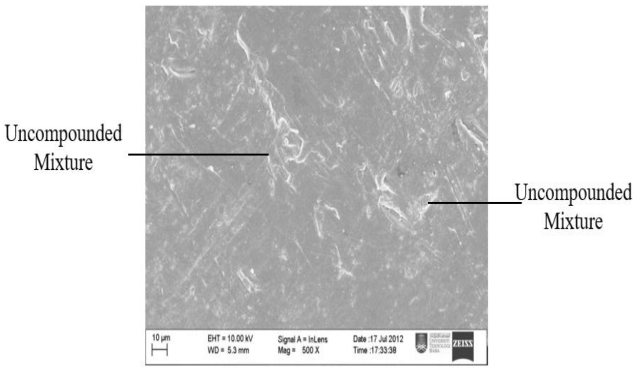

Fig. 6b. The Morphology of Kenaf HDPE Composite at Ratio 40:60

A great impregnating and wetting of the fibre is imperative to ensure that the mechanical and the physical bonds are solid and able to carry stack between the composite [1] However, this study visually indicated that that the fibres are separated from HDPE due to low interfacial bonding. The mixture is rough and uneven, suggesting that the compatibility between fibres and the matrixes is inadequate. Among these composites, bamboo composite shows better bonding between fibre and matrix. From SEM images, type of fibre affects the bonding between fibre and matrix. Plus, the ratios of matrix used also plays roles in developing better attachment between the fibre and matrix [12].

C. Impact Strength

The affect quality of composite is depending on the capability of fibre to assimiliate vitality that can halt break proliferation and poor interfacial holding that coming about in effortlessly break split [13]. Another reason of affect disappoiment of a composite was due to fibre drag out from the composite [14]. Even the density show slightly differs in values, but the crack behaviour on the impact energy show striking contrast.

Fig. 7,8 and 9 illustrate the fracture behavior of composite made form kenaf, bamboo and coconut coir fibre at the middle of each specimen. The fracture of all composites occurred at the point of impact and at the middle of the specimen once undergo drop impact test. The coconut coir HDPE composite show larger fracturing area compared to kenaf composite and bamboo composite. Generally, fibres enhance the impact strength of the thermoplastic. This is due to impact strength is a part of the fibre quantity and modulus. The higher the molecular weight, the longer the polymer chains. This in turn increases the energy absorption capacity of the composite [15]. Hoque et al., (2014) states the raise of bamboo contents into polymer composite influenced the quality of composite since the movement of polymer chains and diminished the ductility of composite.

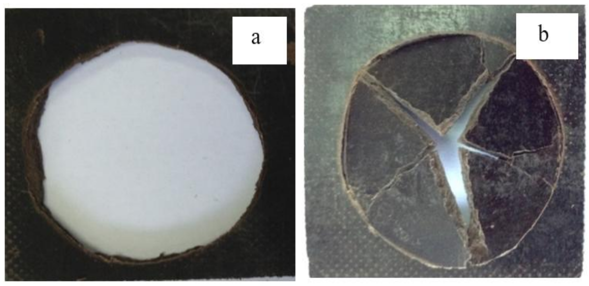

Fig. 7. Fracture Behavior of C30 (a) and C40 (b)

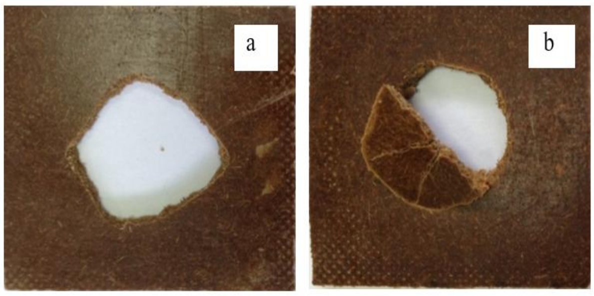

Fig. 8: Fracture Behavior of B30 (a), B40 (b)

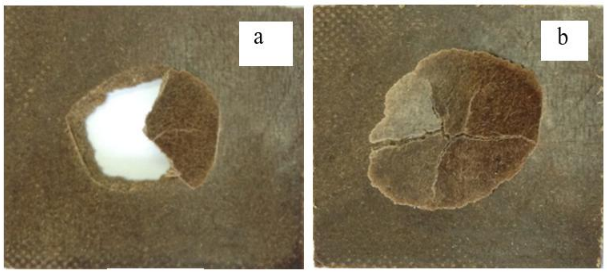

Fig. 9. Fracture Behavior of K30 (a), and K40 (b)

The affect quality on fibre fortified polymeric composite depends on several factors. Our study indicated that the impact strength of all HDPE composite increased with fibre loading, this recommend that the fibre able to retain its vitality since the solid interfacial bonding holding between composite. The impact failure due to fibre breaks from the composite [14]. It is well known that the affect reaction of fibre composites was exceedingly affected by the bond quality among composite [4].

Previous study by Clemons *et. al* [17], and Winandy *et. al* [18] stated there are a lot of advantages by using natural fibre as potential reinforcement in composite fabrication. Lee and Wang [19] mentioned that the coir fibres have higher lignin content (41–45%) and micro fibrillar angle (30–45%). Ou *et. al* [20] found that as the coir fibres content higher, the lignin content lower and hollow cellulose content decreased. This results in the weak stiffness and strength value of the coconut coir.

Bamboo fibre has better interface bonding strength between fibre and matrix and that significantly improved the adhesion that led to better interactions between the fibres to matrix interfaces. Better distribution of the bamboo fibre and bridging gaps between the fibre resulting better bonding were due to the improved fibre mixing [15]. The quality and the superior interfacial grip of the kenaf fibres was due to orientations of fibres and the adhesion between fibres and plastic [21]. Numerous potential applications using the kenaf fibre were explored due to its vast physical and mechanical properties [22].

D. Effect Density on Impact Strength of HDPE Composite

In accordance to the increase in density, the impact strength also increases linearly. The interfacial bond strength, the matrix and the fibre properties influenced the impact responses [4].

IV. CONCLUSION

In conclusion, it can be observed that as the fibre ratio increased, the impact strength of all HDPE composite increased. The densities of all the types were similar for each board produced. These reflected that the natural fibre HDPE was well distributed throughout the entire board. Thus, their affected on good results obtained for all tests performed and were also illustrated by the SEM result. It can be seen that the mixture with ratios of forty percent (40:60) of fibre seems to be relatively smooth compared to the thirty percent (30:70) fibre ratios since there is a few voids found in the mixture and the compound is homogenous. However, some voids were observed when the bonding between fibre and matrix was insufficient as the fibre ratios increased. Impact strength was higher in bamboo (B40) than kenaf and coconut coir HDPE composite. Higher amount of cellulose contents contribute to quality strength of the bamboo. Besides, the existence of long and parallel fibres embedded in a ligneous matrix significantly contributed to higher impact strength for bamboo itself.

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List of Publications

Water Resistance and Tensile Strength of High Density Polyethylene (HDPE) Composites. Advance Materials Research, Vol. 1134, pp. 34-38.
Accelerated Aging Cycle of Composite Reinforced High Density Polyethylene (HDPE) Roofing Panel. Applied Mechanics and Materials, Vols. 799-800: pp. 192-195.
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List of Publications

Syaiful Osman, Mansur Ahmad (2013). Flexural & Impact Properties of Bamboo Aluminum Sandwich Composites. Advanced Materials Research, Progress in Renewable and Sustainable Energy, Volume 608-609 pp 1728-1731

Syaiful Osman, Mansur Ahmad (2012), Reducing Env. Burden of Traditional Building Materials: study on Comp. Strength of Beting Bamboo Aluminum Sandwich Composites. International Symposium on Forest Environments and Low Carbon Growth, Kangwon National University. Pp 53-60

Syaiful Osman, Mansur Ahmad (2018). Chemical and thermal characterization of Malaysian bamboo lignin (Beting & Semantan) extracted via soda pulping method. AIP Conference Proceedings

Mansur Ahmad, Syaiful Osman, Zawawi Ibrahim. Utilizing Lignin from Malaysian Bamboo (Semantan) as Partial Replacement of Phenol in Phenol Formaldehyde (PF) Adhesives: Physico-Mechanical Characteristic of Sustainable and Environmental-Friendly Adhesives, January 2018, ASM Science Journal 11(2):263-271

Zawawi Ibrahim, Mansur Ahmad, Astimar Abd Aziz, Ridzuan Ramli, Kamarudin Hassan, Aisyah Humairah Alias (2019). Properties of Chemically Treated Oil Palm Empty Fruit Bunch (EFB) Fibres. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences Volume 57, Issue 1, pp 57-68

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