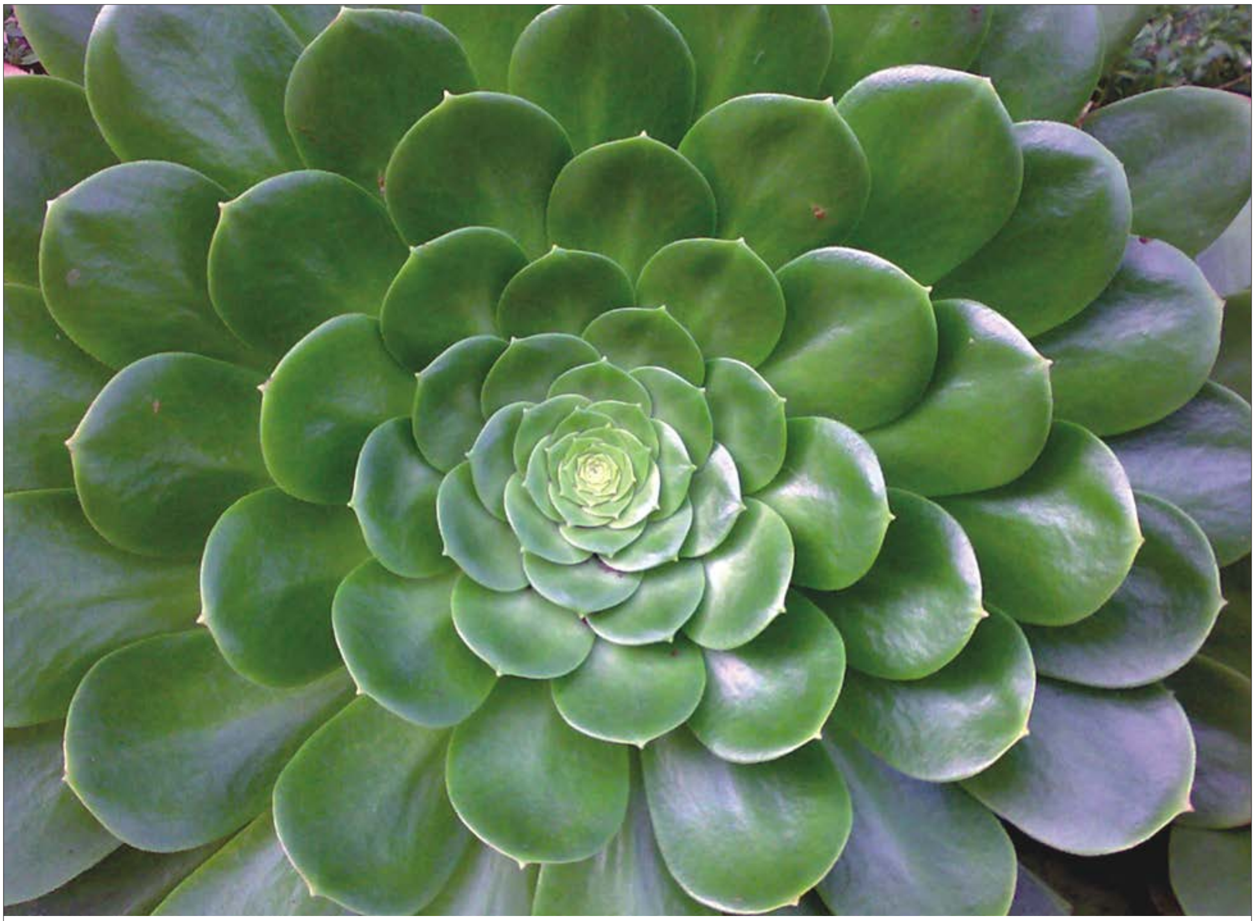

Journal of

Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Plant Sciences

ISSN 1816-4951
DOI: 10.3923/jps.2016.22.30

Research Article
Physical, Mechanical and Morphological Studies on Bio-composite Mixture of Oil Palm Frond and Kenaf Bast Fibers

[1]Razak Wahab, [2]Hashim W. Samsi, [2]Mohd Tamizi Mustafa, [1]Mazlan Mohamed, [1]Mohd Sukhairi Mat Rasat and [1]Madihan Yusof

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
[2]Forest Research Institute Malaysia, 52109 Kepong, Selangor, Malaysia

Abstract

The physical, mechanical and morphological properties of bio-composite from a mixture of Oil Palm Fronds (OPF) and Kenaf Bast Fibers (KBF) are investigated. Urea formaldehyde resin used in cementing the mixtures together. The OPF and KBF were mixed at five different ratios. Testing for the physical and mechanical properties made by the European EN standards. Testing on the physical properties includes the density, water absorption, thickness swelling and wettability. Mechanical testing includes static bending for modulus of elasticity and modulus of rupture, besides internal bonding of the boards, revealed the enhanced values after increasing the resin content. The morphological studies were conducted using micrograph's structures obtained by scanning electron microscope used in determining the distribution of the resin in the boards. The overall results showed that boards with 100% OPF and 50:50% (OPF:KBF) at 14% of resin content exhibited the highest properties compared to the other boards.

Key words: Bio-composite boards, urea formaldehyde, physical properties, mechanical properties, morphological properties

Received: January 28, 2016 Accepted: March 08, 2016 Published: April 15, 2016

Citation: Razak Wahab, Hashim W. Samsi, Mohd Tamizi Mustafa, Mazlan Mohamed, Mohd Sukhairi Mat Rasat and Madihan Yusof, 2016. Physical, mechanical and morphological studies on bio-composite mixture of oil palm frond and kenaf bast fibers. J. Plant Sci., 11: 22-30.

Corresponding Author: Razak Wahab, Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
Tel: +6019-8628787

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The wood-based industry will face problem in getting a consistent supply of raw materials in the near future . Supply of timber especially from the fast growing timber species are not reliable especially in the third world countries, where the timber plantation has not reached the matured stage just yet. As an alternative, an agriculture waste and non-timber resources such as oil palm fronds and kenaf bast in the form of the composite can play a significant role in structural and non-structural applications previously dominated by timber (Rasat *et al*., 2011). The utilization of the non-timber natural resources is an answer to overcome the environmental issues of using the native timbers from the forests. Study carried out on natural resources and agricultural residue fibers have leads to new polymer science and engineering study for sustainable technology. Natural resources fibers with excellent properties can be used to produce bio-composite materials. These materials are renewable raw material and have the capacity to be recyclable (Akil *et al*., 2011).

Kenaf (*Hibiscus cannabinus* L.) is a warm-season annual fiber crop has been used as a cordage crop to produce twine, rope and sackcloth. Kenaf natural fibers has been successfully incorporate in a variety of application. Various new applications for kenaf including paper products, building materials and absorbents animals feed. Kenaf bast fibers found in the stems of the plant providing strength for them. The fibers run across the entire length from the stem and are very long. While, the oil palm fronds fibers are found in abundant all the year round in the palm oil plantations in Malaysia. The oil palm fronds considered as agricultural residues are not fully utilized and are left to rot in the fields.

Bio-composite from the lignocelluloses resources has a high potential to be used as an alternative to the wood. The composite made from the agriculture residues are eco-friendly and can utilize for non-structural and light structural purposes. Kenaf bast and oil palm fronds fibers are renewable resources and abundantly available. The combination of these materials as composite boards has high potential to replace wood due to the inadequacy in obtaining them by the timber industry. Kenaf bast fiber have superior mechanical properties compared to the other parts of the plant (Aji *et al*., 2009).

The present study explored the potential of turning a mixture of kenaf bast fiber with oil palm fronds as a bio-composite boards at a particular ratio. The aims of this studies were to evaluate the physical and mechanical properties of oil palm fronds and kenaf bast fiber composite and to correlate these propertie's composite at different resin content and mixture and to study the morphological structure of the composite by using Scanning Electron Microscope (SEM).

MATERIALS AND METHODS

The oil palm fronds collected from an oil palm plantation in Tanah Merah, Kelantan, Malaysia. The fronds collected from oil palm trees aged between 8-10 years. While, the five-month-old kenaf stalks collected from a Malaysia Agriculture Research Development Institute (MARDI) station in Pasir Puteh, Kelantan.

The OPF put into drum chipper and then further cut using knife ring flakes to get particles of acceptable length. The particles of oil palm fronds were screened to get 0.8 mm size fibers dried in an oven at 60°C to reduce the moisture content up to 5% before composite fabrication.

Kenaf bast fiber separated from the core using kenaf decorticating machine. The separated kenaf bast fiber was then refined using fiber cutter. The kenaf bast fibers of 1 mm length were dried similarly as OPF before composite preparation and the size of kenaf bast fibers screened by shaker machine.

The oil palm fronds and kenaf bast fibers mixed at ratio of 100:0 (OPF:KBF), 70:30 (OPF:KBF), 50:50 (OPF:KBF), 30:70 (OPF:KBF) and 0:100 (OPF:KBF), respectively. The mixed fibers added with urea formaldehyde using a blender machine with a loading percentage of 10, 12 and 14%. The fibers and the resin were mixed in the blender for about 5 min to ensure they are evenly mixed.

The OPF and KBF were removed from the mixer and scattered in a square-shaped former with the dimension of 340×340 mm, which first placed on a cauls plate covered with a teflon fiber sheet. The furnish of mixed oil palm fronds and kenaf bast fiber with resin was pre-pressed at the pressure of 35 kg cm^{-2} and subsequently pressed in the hot press machine to 12 mm thickness at a temperature 165°C for 6 min. The fibers were then left to cool down for the curing of the resin. Boards with density 700 kg m^{-1} produced. Three replicates prepared for each ratio of mixed OPF and KBF at respective resin contents.

Physical properties

Density: The test carried out according to EN 323:1993. Board test specimens were cut into (5×5×0.48 cm). The test piece was square in shape and conditioned to a constant mass in an atmosphere of a relative humidity of 65% and a temperature of 20°C. The samples were placed in an oven at temperature

105°C±2 for 24 h or until the weight become constant. After 24 h, the samples were placed in a desiccator for 15 min and weighed. These steps repeated until the constant weight obtained.

Water absorption: This test was conducted to study the dimensional stability of the boards. Tests were carried out according to BS EN 317:1993. The samples (W_1) immersed in the water and weighed after 24 h (W_2).

Thickness swelling: This test was carried out also according to BS EN 317:1993. The depth at the center of a test measured to the nearest 0.48 mm with the digital micrometer. It was immersed in water of 20°C±1 horizontally about 3 cm below the water surface for 24 h then reweight. The dimensional stability of the board determined with water absorption and thickness swelling tests. The water absorption and thickness swelling ability calculated after immersing the samples in the water at 20°C for 24 h (Anonymous, 1993).

Wettability: This test was used to study the wetting characteristics of solid materials (Walinder and Strom, 2001). The contact angle analysis was used to determine the wettability of board surface in this study. Wettability test was carried out using water. The method of contact angle determination was done based on the previous study by Sulaiman *et al*. (2008). A video camera used to record the image of the droplets. Ten microliters of the water was dropped manually using micropipette onto the surface of the board. The pictures of the droplet were recorded using a video camera for 60 sec. Five replicate used in the determination of contact angle for each liquid.

Mechanical properties

Static bending: Static bending was carried out according to BS EN 310:1993. Static bending conducted with a load of 10 mm min^{-1}. The specimen size used for bending test has a dimension of 50×290×150 mm.

Internal bonding: Internal bonding was also carried out according to BS EN 319:1993. A sample test adhered to the internal bonding blocks and then placed in the machine. Tension load applied vertically to the board face, with the tension loading speed at 2 mm min^{-1}. The maximum load (P) measured at the time of failing force (breaking a load of perpendicular tensile strength to the board).

Testing procedures: All samples placed in a conditioning room and set at temperature 20±2°C and 65±5% RH for 3 days before testing. The mechanical tests carried out on the samples were static bending for MOE and MOR (Anonymous, 1993) and internal bonding (Anonymous, 1993). The tests conducted using an Instron Universal Testing Machine Model 4204.

Microscopic study: Microscopic study conducted using Scanning Electron Microscope (SEM) at the Forest Research Institute Malaysia testing laboratory, Kepong, Selangor. The samples were viewed in a cross-cut direction to see the adhesive line, which is the interaction between adhesive and substrate and penetration through the board. Clean cut sample with dimensions of 1 cm lengthx1 cm width used. Initially, the samples were dried in the oven at 105°C and were cleaned from any contaminants. The samples were then coated using sputter coating POLARON 515 with gold approximately 20 nm thick. The SEM equipment connected to a computer for image storage and processing. The picture of the sample viewed according to the desired angle for the clearer picture using a computer and images were selected based on preference for evaluation. The procedure used by Wahab *et al*. (2005, 2002) adopted in the microscopy study here.

RESULTS AND DISSCUSION

Physical properties: The results of the physical properties studies, which include the density, water absorption, thickness swelling and wettability shown in Table 1.

Density: The highest and lowest value of density 715.32 and 681.19 kg m^{-3} was found in samples (OPF:KBF/70:30) and (OPF:KBF/0:100), respectively with 14% resin loading (Table 1). The mean values of the density for samples given in Table 1. Density is expressions of how much substance is present in given volume, while the density of the board is a ratio of dry weight of board to its volume (Erwinsyah, 2008). Haslet (1990) reported that decreasing the density of oil palm fronds because of its population of the vascular bundle, where the oil palm frond has a more vascular bundle with fiber cell and fewer parenchymatous tissues. Most mechanical properties of boards closely correlated to density. It reported that these properties commonly found in all types of materials (Haygreen and Bowyer, 1996). Desch and Dinwoodie (1981) stated that the strength properties of wood have a close relationship with its density. The increment of density value increases most of the mechanical properties of wood, including bending strength.

Table 1: Density, water absorption, thickness swelling and wettability of Oil Palm Fronds (OPF) and Kenaf Bast Fibers (KBF) composite boards

		Ratios of OPF-KBF				
Physical properties	Resin content (%)	100:0	70:30	50:50	30:70	0:100
Density (kg m^{-3})	10	684.72	706.28	688.83	715.18	678.96
	12	687.34	687.43	700.83	674.49	677.35
	14	685.01	715.32	704.74	704.99	681.19
Water absorption (%)	10	93.66	124.60	105.60	119.30	128.94
	12	80.27	95.61	99.82	112.86	123.11
	14	72.03	86.91	82.25	92.28	103.18
Thickness swelling (%)	10	33.55	41.40	39.38	45.35	41.73
	12	28.95	35.55	37.86	41.13	37.05
	14	22.44	34.52	25.35	30.55	30.97
Wettability (degree)	10	55.08	65.83	47.23	56.31	63.43
	12	57.99	68.75	64.88	57.65	64.32
	14	72.82	73.91	68.75	65.77	66.80

Water absorption: The water absorption results revealed that the water absorption decreased with the increased resin content. The results of the water absorption test summarized in Table 1. The obtained results are corroborated by the fact that chemical components in the resin are capable of cross-link with the hydroxyl group of oil palm fronds and kenaf bast fibers, hence, reducing the hygroscopic expansion. The other factors that contribute to such effects are the type of resin such as the monomer, the polymerization rates, the cross-linking and pore sizes of the fibers and bond strength.

Water absorption of the composite is a serious concern, especially for their potential indoor and outdoor applications. For a given composite from the different ratios of oil palm frond and kenaf bast fibers, the water absorption characteristic depends upon the content below the fiber, fiber orientation, temperature, area of the exposed surface, the permeability of fibers, void content and the hydrophilic of the individual components.

From the result of the mean value of water absorption of oil palm fronds and kenaf bast fibers composite showed that the highest water absorption was 128.94% at ratio 0:100 (OPF:KBF) at 10% of resin content. While, the lowest was at ratio 100:0 (OPF:KBF) at 14% of resin content 72.03%. This shows that 100% of kenaf bast fibers composite absorb more water in the short run than 100% of oil palm fronds composite. The increasing of water absorption in the 100% of kenaf bast fiber's board showed the rapid moisture penetration into the composite materials. The pattern can be attributed to the penetrability of water and capillary action, which becomes active as water penetrates into the interface via void-induced by swelling of kenaf bast fibers (Mazuki *et al*., 2011).

Water absorption is a condition when the fiber expands due to the absorption of moisture and water. Water absorption experiments were conducted because the absorption of water can cause changes in shape, debonding or loss of strength in products regularly exposed to moisture (Tserki *et al*., 2006). For a given particleboard, the water absorption characteristic depends upon the content below the fiber, fiber orientation, temperature, the area of the exposed surface and permeability of fibers, void content and the hydrophilicity of the individual components (Dhakal *et al*., 2007).

Paridah and Anis (2008) and Wahab *et al*. (2008) reported that parenchyma behaves like a sponge and can quickly absorb moisture. While, Tajvidi *et al*. (2006) state that the larger the particles or fibers size, the higher the water absorption, thus, the effect of fiber length on water uptake is dependent on fiber content. This can be explained in two ways, which are larger fibers lead to a greater hydrophilic exposed surface and poor adhesion between wood particles and the matrix generates void spaces among the wood particles. An increasing in moisture makes the ability fiber to absorb or desorb moisture should consider when evaluating the suitability of fiber for various applications (Mohanty *et al*., 2000). In this study, the test showed that composite from kenaf bast fibers absorbs more water in the short run as expected kenaf as natural fibers. Kenaf bast fiber composites absorb water in the fibers and matrix plus water also existed in the voids of the composite.

Thickness swelling: Results of thickness swelling given in Table 1. The thickness swelling measured by calculating the difference between the thicknesses of the sample before and after soaked in water for 24 h. It found that the result of thickness swelling decreased with increasing the resin contents. The highest thickness swelling is 45.35% at ratio 30:70 (OPF:KBF) at 10% resin content, followed by 0:100 (OPF:KBF) also at 10% of resin content 41.73%. While the lowest thickness swelling was at ratio 100:0 (OPF:KBF) at 14% of resin content 22.44%.

Table 2: Modulus Of Elasticity (MOE), Modulus Of Rupture (MOR) and internal bonding of oil palm fronds and kenaf bast fibers composite boards

		Ratios of OPF-KBF				
Mechanical properties	Resin content (%)	100:0	70:30	50:50	30:70	0:100
MOE (MPa)	10	2279.25	1927.97	1754.45	1198.88	1452.32
	12	2567.11	2176.43	2215.23	2449.45	1547.46
	14	2809.74	3029.13	2803.32	2663.27	1896.58
MOR (MPa)	10	14.38	9.75	13.79	4.06	8.46
	12	20.82	13.30	18.47	15.97	9.78
	14	21.38	17.33	19.95	18.93	11.39
IB (MPa)	10	0.73	0.19	0.36	0.30	0.34
	12	0.78	0.41	0.43	0.41	0.34
	14	0.83	0.54	0.61	0.60	0.40

MOE: Modulus of elasticity, MOR: Modulus of rupture and IB: Internal bonding

Thickness swelling of the composite board is proportional to water absorption. When the water absorption is high, the thickness swelling will also be great. This attributed to swelling of the fiber inside the fabricated composite board. Thickness swelling generally will occur due to the swelling of the fibers itself when soaked in the water for 24 h.

The highly porous structure of the oil palm fronds and the kenaf bast fibers composite board allows water to uptake resulting in high-water absorption that at the same time, causes the board to swell and subsequently causes a rise of thickness swelling.

Wettability: The measured contact angles shown in Table 1. A significant different was found between the contact angles of every ratio of oil palm fronds and kenaf bast fibers composite boards with the different ratios. The highest contact angle was at ratio 70:30 (OPF:KBF) at 14% of resin content was 73.91° compared with 50:50 (OPF:KBF) at 10% resin content that gives the lowest value of contact angle 47.23°. If the contact angle is less than 90° the liquid is said to be non-wetting. It is clear from the results that ratio of 70:30 (OPF:KBF) at 14% resin content increased wettability than the other's ratios.

Wettability defined as a condition on a surface that determines how fast a liquid will wet and spread over the surface or whether it will repel and not spread over the surface (USDA., 1999). Wettability is an essential property of wood adhesion (Gray, 1962). The phenomenon of wetting or non-wetting of a solid by a liquid is a better understanding of studying known as the contact angle (Zisman, 1976).

Wetting on surface occurs when the contact angle approaches zero (Vick, 1999). The liquid spreads spontaneously or entirely on the surface of the solids (Baier, 1970). Therefore, the liquid wetting processes include information about the contact angle formation, spreading and penetration (Shi and Gardner, 2001). By referring to the contact angle in the wetting process, it could be defined as the angle between the edges of drop water and the surface of the composite board.

Previous work has shown that after the modification of fibers, its contact angles decreased (Wu and Dzenis, 2006). The above results can be related to the theory of contact angle measurements, which predicts that if the values of contact angles are low, the liquid will spread or wet well while, high values indicate poor wetting. This mean that ratio at 70:30 (OPF:KBF) have a poorer wettability than the other's ratios.

The higher contact angle is important to reduce the ability of particle surface to absorb water during used and reduced the probability of composite board to damage because of water absorption such as swelling. In tropical wood glued with urea formaldehyde resin shows a linear relationship between surface wettability and glue bond strength (Chen, 1970). The lower the contact angle, the better wettability will improve the gluing properties.

Mechanical properties: The results on the mechanical properties of the bio-composite boards of OPF and KBF summarized in Table 2. These include the Modulus Of Elasticity (MOE), Modulus Of Rupture (MOR) of the static bending and internal bonding.

Static bending

Modulus Of Elasticity (MOE): The MOE is the quantified a material's elastic that is recoverable resistance to deformation under load. The MOE is solely a material property and stiffness depends both on the material and the size of the beam. Large and small beams of similar material would have similar MOEs but different stiffness. The MOE calculated from the stress-strain curve as the change in stress causing a corresponding change in strain.

Based on results showed in Table 2, the MOE results of the composites from oil palm fronds and kenaf bast fibers were gradually increasing from 10-14% of resin content. The highest

Table 3: Relationship coefficient between physical and mechanical properties of oil palm fronds and kenaf bast fibers composite boards

	RT	RC	D	WA	TS	WT	MOE	MOR	IB
RT	1.000	0.000[ns]	0.271**	0.148**	0.319**	0.208**	0.066[ns]	-0.087**	-0.497**
RC		1.000	0.039[ns]	-0.634**	-0.708**	0.692**	0.635**	0.594**	0.441**
D			1.000	0.018[ns]	0.116**	0.126**	0.103**	0.064[ns]	-0.076[ns]
WA				1.000	0.815**	-0.437**	-0.593**	-0.681**	-0.704**
TS					1.000	-0.306**	-0.730**	-0.772**	-0.798**
WT						1.000	0.417**	0.278**	0.154**
MOE							1.000	0.807**	0.602**
MOR								1.000	0.670**
IB									1.000

Total number of samples for each testing = 90, **: Significant at $p \leq 0.01$, ns: Not significant, RT: Ratio, RC: Resin content, MC: Moisture content, D: Density, WA: Water absorption, TS: Thickness swelling, WT: Wettability, MOE: Modulus of elasticity, MOR: Modulus of rupture and IB: Internal bonding

average value of MOE is 3029.13 MPa for ratio 70:30 (OPF:KBF) at 14% of resin content. The mean value of MOE for 10% resin content of ratio (OPF:KBF) 100:0, 70:30 and 50:50 are 2279.25, 1927.97 and 1754.45 MPa, respectively. This indicates that the addition of resin into the board has increased MOE or makes the board stiffer. The results are tallied with the previous studies (Rasat *et al*., 2011; Muehl *et al*., 1999).

Static bending

Modulus Of Rupture (MOR): It is clearly observed the value of MOR increased through increasing the resin content. The results revealed that bio-composites with 14% of resin material have the MOR as compared with the other composites with different resin content. Also, the ratio 100% of oil palm fronds possessed the highest value to each resin content value. According to the obtained results for static bending, summarized in Table 2 for MOR, the average values of the 10% resin content for ratios (OPF:KBF) (100:0), 70:30 and 50:50 are 14.38, 9.75 and 13.79 MPa, respectively. Also, the average value MOR for 14% of resin content are 21.38, 17.33 and 19.95 MPa for ratios (OPF:KBF) (100:0), 70:30 and 50:50 ratio group, respectively. The mean MOR value for the resin content 12% of urea formaldehyde at ratio 50:50 (OPF:KBF) surpassed the minimum value of the EN 310:1996 standard.

Since the MOR indicates the ability of a specimen to withstand a transverse (bending) force perpendicular to its longitudinal axis, MOR results from the composite at higher resin contents can withstand such force. The amount of resin plays a significant role in improving the MOR value across the composite's board. Adhesive can efficiently transfer and distribute stresses, thereby increasing the strength and stiffness of the composite. By the fact that urea formaldehyde has higher solids content, thus, Abdullah (2010) found that the penetration of high viscosity urea formaldehyde resin probably would break the cell walls of the oil palm fronds and kenaf bast fibers composite boards. This action would make it impossible for the fiber and matrix to withstand greater loads. From the previous study by Paridah and Anis (2008) reported that parenchyma behaves like a sponge and can quickly absorb moisture. Therefore, the composite from oil palm fronds and kenaf bast fibers board can quickly absorb urea formaldehyde resin. It can assumed that the urea-formaldehyde resin enhanced the strength of MOR of the resulted composites.

Internal bonding: Internal bonding test conducted to determine the interfacial bonding strength between fibers in the boards. The results (Table 2) shows that the resin's content has significantly affected the mean internal bonding values of the boards. The internal bonding values increased with the increasing resin content from 10-14%. The values were better when loading of the resin content increased. In general, mean internal bonding values for ratios (OPF:KBF) 100:0, 70:30 and 50:50 at 10% resin content were 0.73, 0.19 and 0.36, respectively. While, at 14% resin content of internal bonding at ratios (OPF:KBF) 100:0, 70:30 and 50:50 were 0.83, 0.54 and 0.61, respectively.

The result indicated that higher amount of resin encourages stronger interfacial bonding between fibers in the boards, thus, prolong the ability for the boards to with stand the pulling force created by the test. By comparing the ratios, it was seen that board manufactured at 100% of OPF was superior in internal bonding, exceeding that 30:70 and 50:50. The lower mean internal bonding value found at 100% KBF expected due to the surface chemical properties of fibrillar fines-rich in extractives and lignin that influenced the absorption, adhesion and strength properties and finally interrupted the bonding properties of the sample as stated by Kangas and Kleen (2004).

Hammett *et al*. (2001) reported that weak bonding between particles and very little internal bonding strength within particle board arises when fibers are cut into small particles, some of the particles cannot be split and they

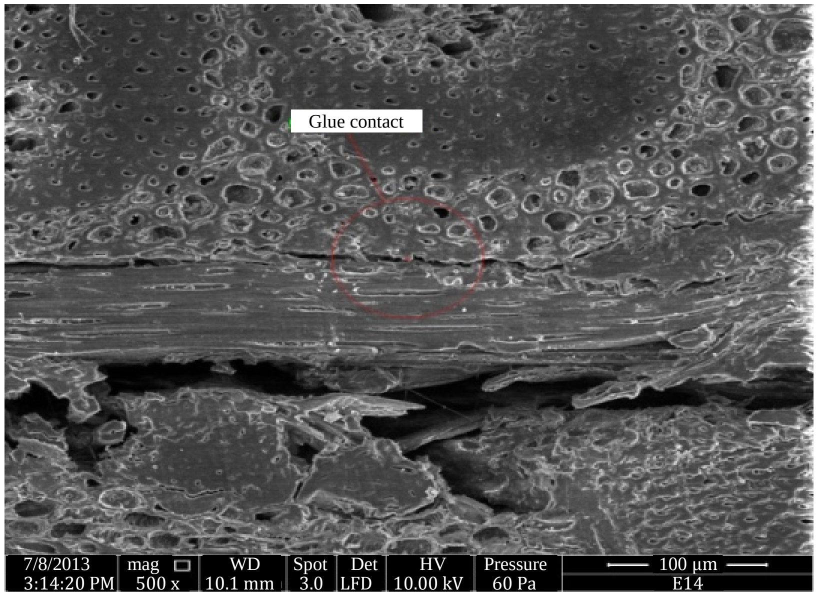

Fig. 1: Structure of oil palm fronds and kenaf bast fibers composite at 500x magnification

maintain a tubular shape, which prevents resin from reaching internal surfaces of the fibers. Almost all the failures observed internal bonding specimens originated from the board that has kenaf bast fibers located. Some of the cure resins were seen retained on the fiber surfaces, indicating insufficient penetration of the resin. The lack of inter-fiber bonding was responsible for the low internal bonding in all boards comprising kenaf bast fibers.

Relationship between physical and mechanical properties: The relationship between the physical and mechanical properties of the oil palm fronds and kenaf bast fibers composite presented in Table 3. There is a correlation between physical properties, density, water absorption, thickness swelling and the wettability of oil palm fronds and kenaf bast fibers with different ratios and resin content.

The results revealed that there was a significant correlation between mostly physical and mechanical properties with the ratios of varying oil palm fronds and kenaf bast fibers and resin content factors at 99% level of significant. Based on this study, all of the physical properties showed significant correlation with ratios between oil palm fronds and kenaf bast fibers and resin content except between density and resin content, thus, there was no encouragement of varying ratios to the density. Although, there were differences in value as the testing result for each part, which were the testing result from the ratios of oil palm fronds and kenaf bast fibers.

The result shows that the mechanical properties were a significant correlation with the difference of ratios and resin content except between MOE and ratios. There was a negative correlation between ratios with MOR and internal bonding. The negative correlations obtained between ratio and MOR of bending strength and internal bonding strength. The negative correlations between the ratios of oil palm fronds and kenaf bast fibers with mechanical properties MOR and internal bonding indicate that the strength of composite decreased from ratios (OPF:KBF) from 100:0-0:100. The mixing of the ratios between oil palm fronds and kenaf bast fibers influenced the mechanical properties of the composite.

Microscopy study: The structural and anatomical observation of oil palm fronds and kenaf bast fibers composite was carried out using Scanning Electron Microscope (SEM). The Scanning Electrons Microscope (SEM) of fibers contains in vascular bundles are displayed in Fig. 1 and 2. The observation showed the parenchyma cells of oil palm fronds that function as the ground tissues made up the bulk of oil palm fronds structures and used as storage for food. Parenchyma cells of oil palm fronds were mostly in the form of the spherical cell with the thin-walled and brick-like formation, but in the narrow space or area between vascular bundles.

Both figures showed the high porous morphology of the mixing oil palm fronds and kenaf bast fibers allowed the resin to be located and filled the void spaces between fibers in the composite. The strengths of oil palm fronds and kenaf bast

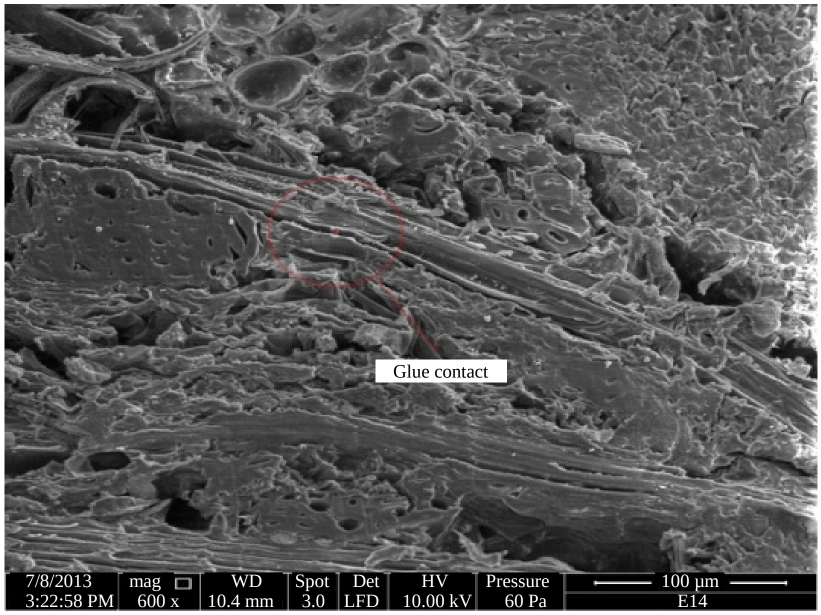

Fig. 2: Glue intact between oil palm fronds and kenaf bast fibers composite at 600x magnification

fibers composite board's increase with the increasing resin contents and it can observe that an increasing of resin retention resulted in increasing composite strength. This is because the resin reinforcement was applied to improve the wood features of and logically accepted despite the fact that the resin penetrated through the intercellular cavities of oil palm fronds and kenaf bast fibers composite.

The tested composite shows an increase in their mechanical properties, which includes the Modulus Of Elasticity (MOE) and Modulus Of Rupture (MOR) in static bending strength. This attributed to the resin applied to the composites resulting in the improved in the mechanical properties. Similar observations was made by Wahab *et al*. (2015) on their study on properties of empty fruit bunch oil palm (*Elaeis guineesis*) composite boards at different densities and resin contents.

CONCLUSION

The bio-composite boards at a ratio (OPF:KBF) of 100:0 and 50:50 at 14% resin exhibited superior physical and mechanical properties compared to the other boards. The boards at 100:0 (OPF:KBF) showed slightly better features to boards of 50:50 ratio.

The bio-composite boards produced from a mixture between OPF and KBF has the potential to be used as an alternative to future wood. It has properties that match some of the common tropical wood species that presently used in furniture or construction industry.

The improved properties attributed to the application of varying the content of resins and particlesize of fibers used as showed in the SEM studies. Thus, these hybrid composites of different fibers can be a good new candidate for high performance economic and environment-friendly bio-composite.

ACKNOWLEDGMENTS

Acknowledgment to Universiti Malaysia Kelantan (UMK) for the Research University Grant (R/SGJP/A03.00 /00485A/001/2011/000047). The financial assistance provided by UMK has enabled Siti Marlia Mat Dom, Madihan Yusuf and Amirah Fikri, to complete their post-graduate studies.

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