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Kenaf/Glass Hybrid Composites

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Abstract*: *Natural fibres develop many options to substitute synthetic fibres in composite industry. However, due to the certain limitations of natural fibres such as moisture absorption, low density and strength, it has been reinforced along with synthetic fibres to transforms their limitations into advantages. Hybrid composites are reasonably high in strength, low in weight and environmental friendly. Moreover, kenaf/glass fibre/epoxy hybrid composites approached the quality perfor-mance and are hybrid composites approached the quality performance and are gaining huge attraction by many researchers. Present, article highlights the reported research focusing on kenaf fibre and glass fibre properties besides this also provide valuable insight on their epoxy-based hybrid composites as advanced materials for varied applications.

Index Terms*: *application of hybrid composites, epoxy polymer, glass fibre,hybrid composites, kenaf fibre

I. INTRODUCTION

The utilization of renewable sources to produce next generation materials have been considered as rapid growing area of research.

Natural fibres are extracted from the plant cell wall and hollow cavity lumen. Southeast Asian countries such as Malaysia, Indonesia and Thailand are among the main producers of natural fibres where it can easily be found due to high humidity [1][2][3]. Natural fibres offers low cost, biodegradability, material renewability, and ease of recycling [4][5][6][7]. Synthetic fibres are used to improve naturally existing animal and plant fibres. Its comes from organic

synthetic compound in high-molecular state and mixture of petroleum oil.

Previously, most studies performed on the woven form of textile composites were on synthetic fibre, rather than natural fibre [8][9] [10]. Synthetic fibres such as glass fibre, carbon, aramid and Kevlar have the characteristics of long fatigue life, ease of fabrication and improved specific properties such as high stiffness, high strength and low density. Synthetic fibres are high in costs and non-renewable resources even though they are extremely used in many industries.

Composites with higher fibre strength will increase the strength of the composite materials and hence its mechanical properties. Earlier, the composites were not preferred by many industries [11] [12] [13] [14]. However, in the next century, they choose to fully utilize composite materials. The composite materials usage nowadays in transportation sector tends to make a tremendous increase due to its insignificant cost reduction and improvement in material performance [15-20]. This is because of its less in weight, highly resistance to corrosion and fatigue behavior enabling it as key player for the industries to make a research contribution. Substantial demands for improving environmental friendly outcomes can be achieved by reducing its costs and modifying its materials, such as implementing a hybrid composite material [21] [22] [23] [24].

Most research nowadays focusing on the properties of the natural fibre composites [25-28]. The strength of natural fibres depends on its fibre length and diameter. The reinforcement by the natural fibre itself may possible to replace up to 50% weight percentage for better load capacity of the composite materials [29] [30] [31][32]. The aim on using natural fibre is to minimize the usage of synthetic fibre thus preserving the environment [33] [34] [35] [36]. The challenge faced by the scientists, engineers and re-searchers are to develop the technology needed by transforming renewable sources utilization revolution to reality Compared to carbon and Kevlar, glass was preferably being used due to its reasonable strength and more cost effective. Thus, the aim of this paper is to provide a short overview on kenaf/glass hybrid composites.

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A. Kenaf Fibre

Kenaf(Hibiscus cannabinus) fibre is natural fibres from Malvaceae family; extracted from kenaf plant (Fig. 1). This plant is an annual herbaceous plant having different flowering schedule originating from west Africa and well spread to Asia via Egypt in tropical and sub-tropical areas [37] [38] [39] [40]. The production of six to ten tons of dry fibre per acre per year with an average yield of 1700kg/ha makes kenaf lead the harvestable size of other trees including pine tree [41] [42] [43] [44].

Fig. 1: Kenaf trees [21].

Kenaf trees grow quickly up to 1.5 till 3.5m tall and not always branched with the diameter of it stems around 1 to 2 cm [45] [46] [47] [48]. Kenaf contains two fibre types, long and short. Common types of kenaf fibre are in state of unidirec-tional long fibres and randomly oriented short fibres [49] [50]. The plant's stalk (Fig. 2) consists of core in the inner fibre approximately 60% and bast at the outer fibre made up the rest of 40% that later been extracted and dried to remove the absorbed moisture [51] [52] [53] [54]. The fibre cell alone having up to 6 mm in length and 6.3 µm in thickness [55] [56] [57] [58]. The dried bast is the raw product of kenaf fibre (Fig. 3). Kenaf trees are renewable sources.

Currently kenaf fibre is one of the natural fibres that have fascinated researchers to discover their potential as a rein-forcement element where the physical properties of natural fibres having significance effect on the composite product's properties [59]. Kenaf fibre has lower strength however it is still at par with any other synthetic fibre [60].

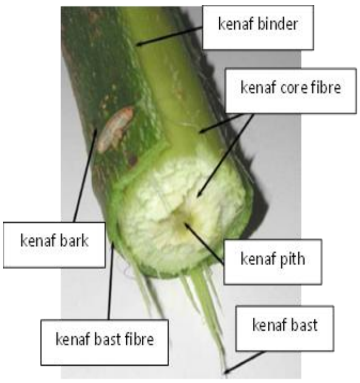

Fig. 2: Structure of kenaf stem [28].

Fig. 3: Kenaf fibre being extracted [21].

Kenaf composites has been studied extensively by other researcher, focusing on the hybridization effects [61]. The density of raw kenaf is 1.12 g/cm³ [62]. Most of kenaf fibre in woven types having the density of ±1.2 g/cm³, thickness of 2 ± 0.2 mm and average breaking strength of 100 Mpa [34]. Woven states offer better stability and high density with a simple process of manufacturing [63].

The compositions of natural fibres are different from one plant fibres to another mostly on the percentage of cellulose and lignin (Table 1) that play their roles as the main elements of natural fibres [64]. Celluloses will degrade faster, compared to lignin, which allow them to vanish easily from the main stem. This will then contribute to high absorption of moisture due to the nature mechanism of plant based fibres compared to the synthetic fibres.

Kenaf has high lignin content results high strength. However, excess in lignin after fibres extraction process will contribute to brittle fibre even though the texture is stronger [65] [66] [67]. Structural strength of the fibre can be increase by applying weaving technique [68]. This technique will make the material stronger, easy to form, and increase the energy absorption. Kenaf fibre have similar anisotropic mechanical properties to composites.

Table. 1: Composition of natural fibres.

Types	Cellulose (%)	Lignin (%)	References
Kenaf	31-39	15-19	[37-39]
Jute	61-72	12-13	[3,38,39]
Banana	63-68	5	[36,39]
Sisal	67-78	8-11	[3,37,39]
Hemp	70-74	4-6	[37,38]

B. Glass fibre

Plastic matrix that had been processed into a fibre reinforced polymer, when being reinforced by a fine glass fibre will produce a synthetic fibre namely glass fibre. Glass fibre (Fig. 4) is classified among the most compliance materials in industry for a wide range of application. Glass fibre has its own unique element provided during the manufacturing process [69].

Fig. 4: Rolls of glass fibre.

Glass fibre is consider to be the most versatile materials for industry nowadays that been used in wide range of applica-tions. Glass fibre alone having both stiffness and strong due to tension, but vice versa in compression due to buckling of long and narrow typical fibre [41]. Table 2 show the comparison between natural fibre and glass fibre on its mechanical properties.

In comparison with natural fibres, synthetic fibres are much more durable, stronger, easier to maintain, and washable. The less moisture absorption of synthetic fibres to natural fibres is significantly comparable. However, the application of syn-thetics fibre such as glass fibre, carbon fibre and Kevlar required high cost and not economical friendly. Synthetics fibre is not a biodegradable material. Furthermore, these materials may cause environmental hazards and negative effects on the environment [70]. Besides, the burning of synthetic fibres may emit poisonous gas that will pollute the air and surrounding.

C. Hybrid Composites

The technology of fibre reinforced or hybrid composites is continuing to evolve. Generally, these combinations consist of mixing an organic and inorganic compound. This combination is also depending on the specific purposes usage in variations of field where it serves including science and engineering. Hybrid composite of natural fibre and synthetic fibre can be manufactured by using hand lay-up method (Fig. 5) that later being cold press under room tem-perature [4,46]. Other manufacturing techniques are vacuum infusion technique (Fig. 6) or bagging method [25,30,35], and hot hydraulic press technique (Fig. 7) [34].

Fig. 5: Hand lay-up method [34].

Table. 2: Comparison betweenglass fibre and natural fibre.

	Glass fibre	Natural fibres	References
Density	Twice that of natural fibres	Low	[42]
Disposal	Not biodegradable	Biodegradable	[2,34,39]
Cost	Low, but higher than natural fibres	Low	[34,39,43]
Health risk when inhaled	Yes	No	[39,40,44]
Recyclability	No	Yes	[41,42]
Renewability	No	Yes	[2,41,42]
Distribution	Wide	Wide	[42]
Abrasion to machines	Yes	No	[41,43]
CO_2 neutral	No	Yes	[40]
Moisture absorption	No	Yes	[4,30]
Energy consumption	High	Low	[40,41]

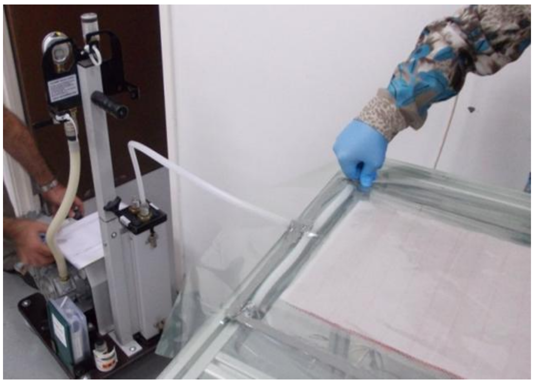

Fig. 6: Vacuum infusion [71]

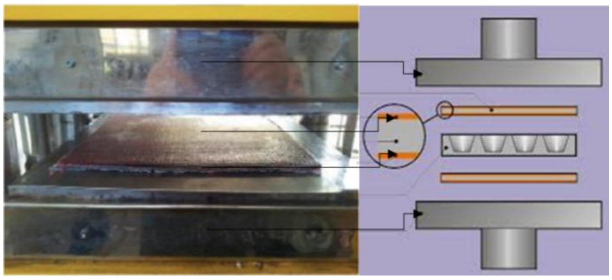

Fig. 7: Hot hydraulic press [72].

Several testings can be made

after fabrications for its structural strength such as tensile test (Fig. 8) according to the standards of ASTM D3039/ D3039M-17 (2017) [73] and flexural test (Fig. 9) standards of ASTM D790-10 (2010) [73]. While the impact strength of the hybrid composites can be measured by using either Charpy impact test (Fig. 10) [49,50] or drop test (Fig. 11) [73]. Damage from impact test can be detected using several methods, as example, dye penetrant, C-scan, radiography, optical microscopy [74].

Fig. 8: Tensile test [74].

Fig. 9: Flexural test [74].

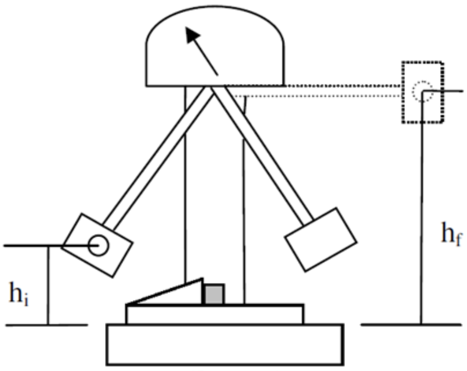

Fig. 10: Principle of charpy impact test (pendulum test) [74].

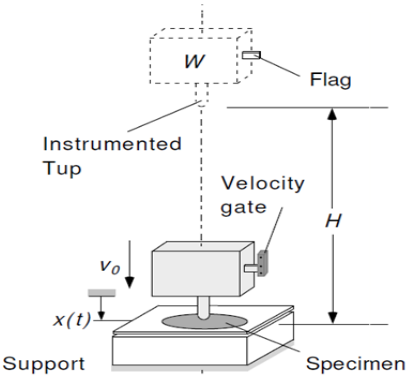

Fig. 11: Principle of drop test [74].

II. MECHANICAL PROPERTIES OF HYBRID COMPOSITES

The mechanical performance of the hybrid composites is influenced by the fibre orientations of the fibres where it can be analysed by using scanning electron micsroscopy (SEM) images. Different layering sequences may also affect the strength performance of the hybrid composite [75]. Normally, natural fibre hybridized with synthetic fibre has better performance in term of mechanical properties and moisture absorption [75].

III. APPLICATIONS OF HYBRID COMPOSITES

The application of fibre hybrid composite has been widely used in industry [75]. This helps to reduce the usage of steel and aluminum in the manufacturing process [76]. The replacement of synthetic fibres with hybrid composite fibres in Fibre-Reinforced Plastics (FRP) is become wide-spread [76]. Others unique properties of hybrid composites are low in cost, easy to fabricate and higher strength against impact resistance [76].

IV. CONCLUSION

Hybrid composite materials have an advantage in their lightweight and low-cost, which meet the requirement properties of the material. Different types of material combinations have different results in the low velocity impact test. Besides, even the same material combinations with different weight percentage will also results in different trends of impact. These results indicate the potential of glass fibre-kenaf fibre hybrid composites as an alternative to existing materials.Hybridization of kenaf fibre with glass fibre may enhance the physical and mechanical properties of composites and also decreased their absorption of water and moisture of individual elements specifically natural fibres.

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