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Cold-pressed Kenaf and Fibreglass Hybrid Composites Laminates: Effect of Fibre Types

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***Abstract*—**Natural fibres have emerged as the potential reinforcement material for composites and thus gain attraction by many researchers. This is mainly due to their applicable benefits as they offer low density, low cost, renewable, biodegradability and environmentally harmless and also comparable mechanical properties with synthetic fibre composites. The properties of hybrid composites highly depends on several factors, including the interaction of fillers with the polymeric matrix, shape and size (aspect ratio), and orientation of fillers [1]. In this study, natural fibre kenaf composites and kenaf/fibreglass hybrid composites were fabricated by a combination of hand lay-up method and cold-press method. The effect of different fibre types (powder, short and long) on the tensile properties of composites is investigated. The kenaf composites with and without the addition of fibreglass were then characterized by tensile testing and scanning electron microscopy. A significant improvement in tensile strength and modulus were indicated by the introduction of long kenaf/woven fibreglass hybrid composite. However, the opposite trends are observed in kenaf powder composite. Fractographic observation shows that fibre/matrix debonding causes the fibres pull out. This phenomenon results in the fibre and matrix fracture.

***Keywords*—**Kenaf, Fibreglass, Hybrid Composite, Tensile Strength, Tensile Modulus.

I. Introduction

NATURAL fibres as an alternative reinforcement in polymer composites have attracted the attention of many researchers and scientists due to their advantages over conventional glass and carbon fibres [2]. These natural fibres include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others [3]. The various advantages of natural fibres over manmade glass and carbon fibres are low cost, low density, comparable specific tensile properties, non-abrasive to equipment, a non-irritant to the skin, reduced energy consumption, less health risk, renewable resource, recyclability and bio-degradability [4]. Most composite materials are developed to improve mechanical properties such as strength, stiffness and toughness. However, the strength of the composite is much more relied on the geometry of the reinforcement. The reinforcement acts as the major contributor to the strengthening mechanism of composites.
Hence, the effect of different types and shapes of fibres becomes a major concern in this study.

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Hybrid composite is well known because it uses more than one kind of reinforcement in the same matrix. The idea of this study is to get the synergistic effect on the properties of reinforcement on the overall properties of hybrid composites. It is believed that hybrid composites can achieve a more favourable balance between the advantages and disadvantages inherent in any composite material. Hybrid composites offer three main advantages over conventional composites. First, they provide designers with a new freedom of tailoring composites to achieve required properties. Second, a more cost effective utilization of expensive fibres such as carbon and boron can be obtained by replacing them partially with less expensive fibres such as glass and aramid. Third, they provide the potential of achieving a balanced pursuit of strength, stiffness and ductility [5] [6].

Usually, the mechanical properties of natural fibre composites are improved by hybridizing them with another synthetic or natural fibre of superior mechanical properties. The synthetic fibre mostly used for this purpose is glass fibre. Although the biodegradability of the composite is reduced, this can offset the advantages gained by the increase in mechanical properties.

Kenaf (Hibiscus Cannabinus L.) is a fibre plant native to east-central Africa where it has been grown for several thousands of years for food and fibre. It is a common wild plant of the tropics and subtropical regions of Africa and Asia. It has been a source of textile fibre for such products as rope, twine, bagging and rugs. With this fast growing plant, rising to a height of 4-5m within 4-5 months would give an opportunity to produce products with similar qualities to that of wood. Due to these reasons, kenaf has been selected as the reinforcing material in this study.

This study aims to report on the influence of fibreglass has in kenaf composites, surface morphology and strength properties of natural fibre/fibreglass hybrid composites.

II. Methodology

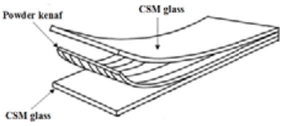
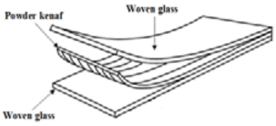
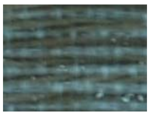
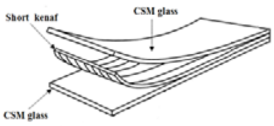
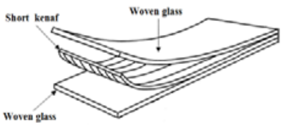
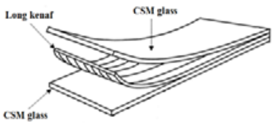
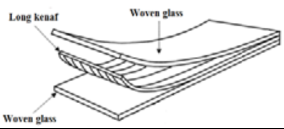
A. Material

Short kenaf and long kenaf were supplied by Innovative Pultration Sdn. Bhd. Powder kenaf was supplied by Symphony Advanced (M) Sdn. Bhd. All kenaf were used without any surface treatment. A standard unsaturated polyester resin was supplied by Mostrong Industries Sdn. Bhd. and chopped strand mat (CSM) and woven fibreglass were provided by a local company.

B. Manufacturing Composite

The lower pressure hand lay-up technique was used in the fabrication of kenaf composites and kenaf/ fibreglass hybrid laminates. To fabricate a laminate, the matrix material was prepared from a general purpose polyester resin and catalyst in a weight ratio of 100:2. A steel frame mould of size 300 mm x 210 mm was used in making the laminates. The mould was covered by plastic film for easy removal and to create a smooth surface finish of the laminate. A cold press of approximately 10kN of load was applied for 20 minutes at room temperature to ensure the homogeneity of the end product and no bubble formation. In the end, the specimen would be ready and taken out from the mould and cured for 24 hours at room temperature. Samples were made from the laminates with parallel edges of dimensions 125 mm x 20 mm, following the BS EN ISO 527:1997 as shown in Fig. 1.

TABLE I
ILLUSTRATION OF KENAF COMPOSITES AND KENAF/ FIBREGLASS HYBRID COMPOSITES

Type of composite	Illustration of hybrid composite	Hybrid composite
Kenaf powder composite	kenaf powder and polyester	
Kenaf powder/CSM glass hybrid composite		
Kenaf powder/woven glass hybrid composite		
Short kenaf composite	short kenaf and polyester	
Short kenaf/CSM glass hybrid composite		
Short kenaf/woven glass hybrid composite		
Long kenaf composite	long kenaf and polyester	
Long kenaf /CSM glass hybrid composite		
Long kenaf/woven glass hybrid composite		

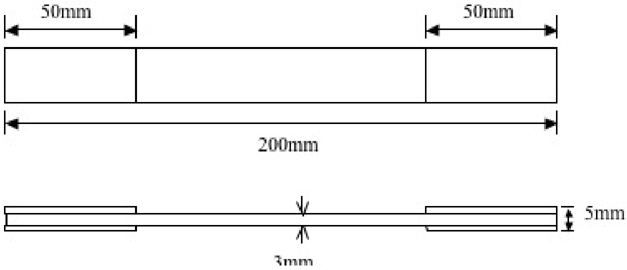


Fig. 1 Dimensions of sample according to BS EN ISO 527 (1997)

Two layers of fibreglass were formed with dimensions of 295 mm x 205 mm size. The average weight of the fibreglass used in kenaf/fibreglass hybrid composite laminates is 38 gram. 20% wt. of kenaf fibre was mixed in all composites. TABLE I illustrates the lamination of kenaf composites and kenaf fibreglass hybrid composites.

C. Mechanical Testing

Mechanical properties of the specimens were determined using a mechanical testing machine (INSTRON 3382) operating at a crosshead speed of 1 mm/min and a 25 mm extensometer attached to the specimen. The modulus of the material is determined from the secant slope of the stress–strain curve in the strain range 0.05–0.25%. The testing is according to standard ISO 527.

D. Fracture Surface Examination

The surface morphology of kenaf composite and kenaf fibreglass hybrid composite was observed by a SUPRA 40 VP (Carl Zeiss) of Field Emission Scanning Electron Microscope (FESEM) coated with thin conductive coating sputtered gold. The damaged interface between the fibre and matrix was examined after undergoing the mechanical testing.

III. RESULT AND DISCUSSION

The tensile strength of the kenaf fibreglass hybrid composite is shown in Fig. 2. The tensile strength of all composites considered in the present study is increased with the influence of CSM and woven fibreglass respectively. It can also be observed that the tensile strength of the long kenaf/woven glass hybrid composite is the highest. Whilst the kenaf powder composite has the lowest tensile strength. The tensile strength of the kenaf composite has been improved by the addition of fibreglass. This is due to the orientation of continuous long kenaf fibres in the matrix composite. The alignment of long kenaf fibres provide resistance that transfer tensile strength force as compared to other fibre orientation (kenaf powder and short kenaf).

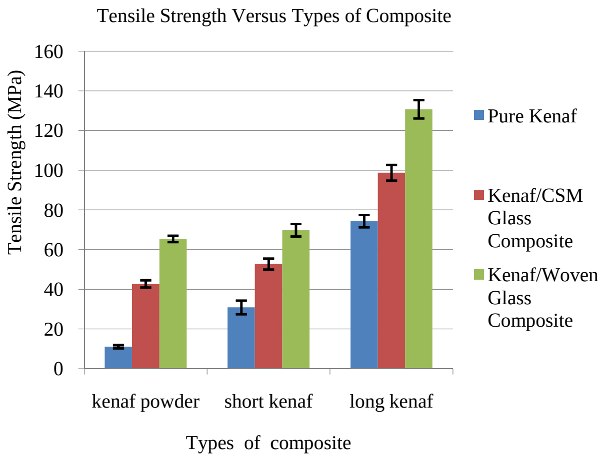


Fig. 2 Effect of different types of fibre on the the tensile strength of kenaf composite and hybrid composite

The tensile modulus of the different types of kenaf fibreglass hybrid composite is revealed in Fig. 3. The tensile modulus achieves the highest value of 8.36 GPa for long kenaf/woven hybrid composite. The same trend has been observed on previous work done on hemp/glass [7][8], oil palm/glass [9][10], sisal/glass [11] and OPFB/glass [9] composites. The hybrid composite has improved the effectiveness of interfaces in dissipating tensile damage. The tensile strength and tensile modulus of the composites are enhanced by the modification on the configuration of hybrid composites.

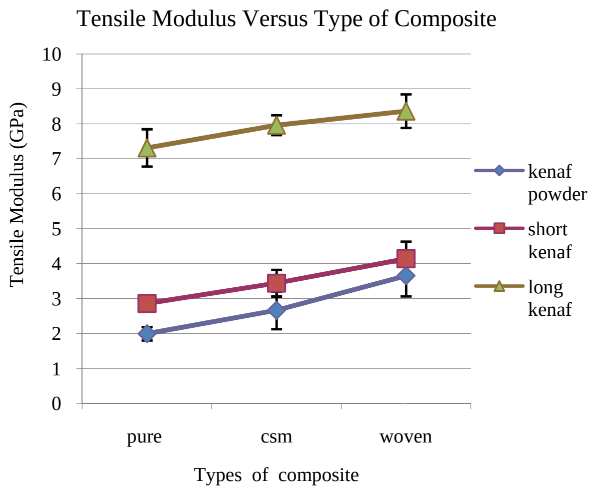


Fig. 3 Effect of different types of fibreglass on the tensile modulus of kenaf fibreglass hybrid composite

A significant and important concern for the kenaf composite and kenaf hybrid composite are the strain to failure values. From Table II, it can be seen that that the long kenaf/woven glass hybrid composite is substantially more ductile than the others.

TABLE II
STRAIN TO FAILURE (%) OF KENAF COMPOSITES AND KENAF FIBREGLASS HYBRID COMPOSITES

Type of composite	Strain to failure (%)
Kenaf powder composite	0.91 (0.002)
Kenaf powder/CSM glass hybrid composite	2.13 (0.005)
Kenaf powder/woven glass hybrid composite	2.94 (0.011)
Short kenaf composite	0.99 (0.010)
Short kenaf/CSM glass hybrid composite	2.24 (0.004)
Short kenaf/woven glass hybrid composite	3.59 (0.001)
Long kenaf composite	1.06 (0.003)
Long kenaf/CSM glass hybrid composite	3.12 (0.006)
Long kenaf/woven glass hybrid composite	4.09 (0.011)

Fig. 4 to Fig. 6 represents the SEM micrographs of different types of kenaf. In Fig. 4, it can be seen that the kenaf powders have various sizes and shapes randomly dispersed within the matrix. Short kenaf fibres in Fig. 5 contain short fibres or whiskers acting as reinforcement which is randomly oriented. As for long kenaf fibre in Fig. 6, the long and continuous fibres are unidirectional.

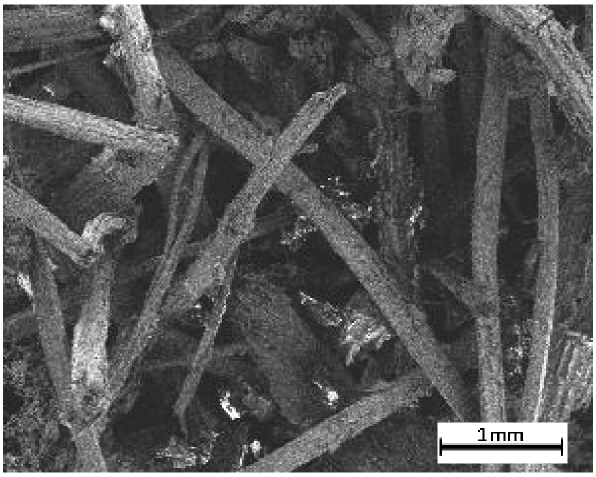


Fig. 4 SEM micrograph on kenaf powder

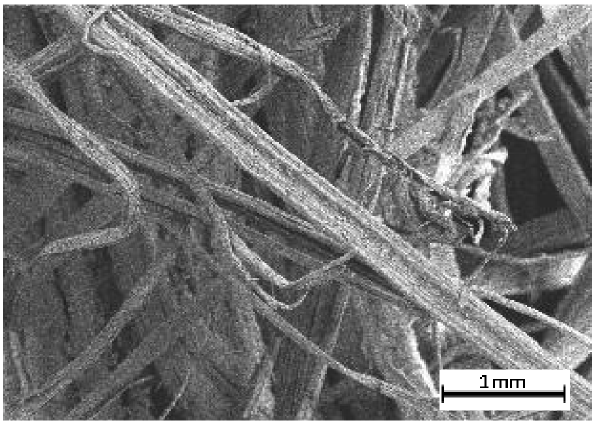


Fig. 5 SEM micrograph on short kenaf fibre

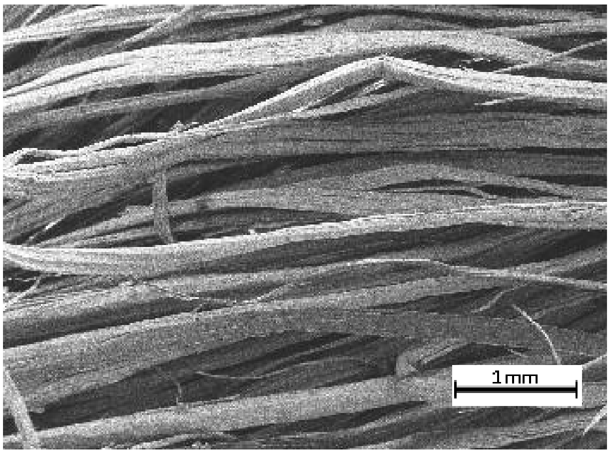


Fig. 6 SEM micrograph on long kenaf fibre

The scanning electron micrographs of long kenaf/woven glass hybrid composite and long kenaf/CSM glass hybrid composite is illustrated in Fig. 7 and Fig. 8 respectively. From both figures, the surface failure is contributed by matrix fracture, fibre-matrix debonding, fibre pull-out and fibre fracture. These phenomena of fracture normally happen for short fibre, however the same fracture behaviour is also evident for long kenaf.

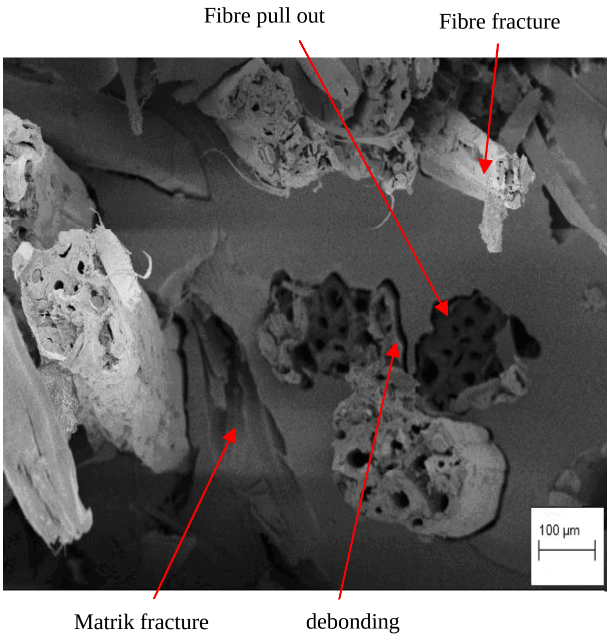


Fig. 7 SEM micrograph on surface fracture of long kenaf/woven glass hybrid composite

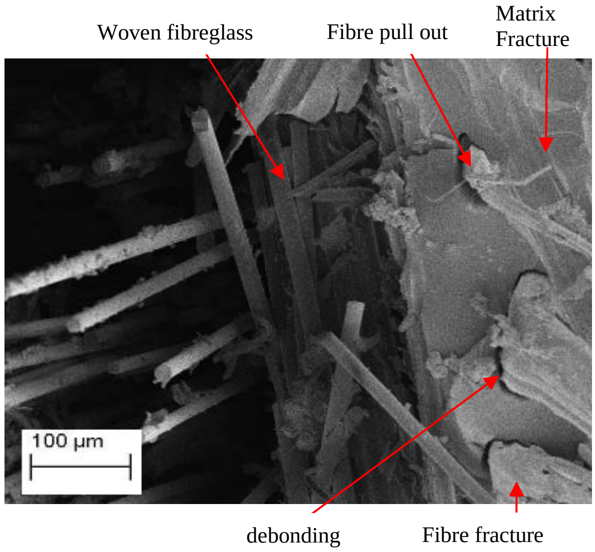


Fig. 8 SEM micrograph on surfacefracture of longkenaf/CSM glass hybrid composite

IV. Conclusion

Kenaf composite and kenaf/glass hybrid composites with different types of fibre are successfully fabricated using a combination of hand lay-up method and cold-press method. It is found that the types of fibre strongly influence the tensile properties of composites. Among all the composites, kenaf powder composite shows the lowest tensile strength and modulus. On the other hand, the combination of long kenaf woven fibreglass, in fabricating the hybrid composite, produces the maximum mechanical properties. The reason being is the association with the continuity of fibre length, bearing the applied load, and minimizing fibre-end defects. The tensile properties of the kenaf fibreglass hybrid composites are better than kenaf composite due to hybrid effects. This suggests that long kenaf/woven fibreglass hybrid composites have a potential to be used in many applications for non-critical stress bearing structures to replace the glass fibre composite. In the fracture surface, the similar fracture phenomenon occurs in the short kenaf and long kenaf/woven glass hybrid composites. The fibre/matrix debonding which causes the fibres to pull out finally contributes to composite failure.

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