Post Impact Tensile and Single Edge Notch Bending Test of Kenaf Hybrid Composite

S. Yunus, Z. Salleh, Y. M. Taib, N. R. N. M. Masdek, M. F. C. Hassan

***Abstract** The improvement of elite building items produced using regular assets is expanding around the world due to renewable and ecological issues. Among the wide range of characteristic assets, kenaf plants have been broadly abused in the course of recent years. The aim of this research is to develop long kenaf composites and long kenaf with woven glass reinforced polyester resin composites. Tensile test helps to determine how the material will react to forces being applied in tension. The test that was conducted included Post Impact Tensile test and Single Edge Notch Bend. Tensile test determines strain-stress while single edge notch bend determines the fracture of the specimen. The experiment was conducted using Universal Testing Machine (UTM) to find the mechanical properties. The experiment considered ASTM D3039 for tensile test and ASTM D5045 for single edge notch bending. From there, the damage area of the composites could be predicted. Meanwhile, it showed the best configuration for the newly developed material in impact test. So, these hybrid composites are viable to be extended into a newly developed material for further investigation.*

***Keywords** Kenaf, Natural fibre composites Post Impact tensile, Single edge notch bending.*

I. INTRODUCTION

Composite is a useful material for engineers all around the world, particularly for structural purposes. It is the combination of two or more materials to gain a rare and uncommon combination of properties. The material can be accepted as a composite if these three criteria are fulfilled. Firstly, both materials should be available in reasonable proportions which are probably around 5% and above. Next, it is only sufficient if both materials have different properties and the properties can be notifying. As an example, despite the fact that plastic contains small quantities of lubricants, ultras-violet absorbers and other components for commercial purpose such as economy and ease of processing, all of these criteria need to be satisfied in order to be classified as composites. Hybrid composites are those composites which have a combination of two or more reinforcement fibers [1].

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The most common hybrid composites are carbon-aramid reinforced epoxy (which combines strength and impact resistance) and glass-carbon reinforced epoxy (which gives a strong material at a reasonable price). Hybrid composites are usually used when a combination of properties of different types of fibers wants to be achieved, or when longitudinal as well as lateral mechanical performances are required. Kenaf is picked because of its low density, non-abrasiveness during handling, high specific mechanical properties, and biodegradability [2], [3]. Recently, kenaf has become an alternative as a raw material for mash and paper ventures instead of wood to prevent destruction of forests. Furthermore, kenaf has also been utilized as non-woven tangles in automotive industries, textiles, and fiber-board. Fibre-reinforced polymer (FRP), also Fibre-reinforced plastic, is a composite material made of polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, while phenol formaldehyde resins are still in use. FRPs are commonly used in aerospace, automotive, marine, and construction industries [4]. Glass reinforced polymer matrix composite material has just been developed to be a sort of essential building material because of its light-weight feature. Additionally, its great mechanical properties likewise prompt an extensive variety of utilization all around the world. There are many surface treating techniques to protect glass fiber from harm and enhance the attachment among fiber and matrix. Also known, silane coupling assumes an important job in the field of glass fiber's surface treatment, for example, enhancing the scraped area among fibers and upgrading interfacial grip by shaping a useful interlayer, which has been confirmed by a lot of past inquires [5]. Polyester resin is a thermosetting unsaturated polymer resin, which is formed from the reaction between organic acids and polyhydric alcohols. It is used for various domestic and industrial applications. There are several types of polyesters being used, and their properties depend upon the acids and alcohols used in their formation. Furthermore, the fiber orientation for hybrid composite will influence the mechanical properties of post impact tensile and single edge notch bending test.

II. MATERIALS AND METHOD

A. Materials

Table I shown the material selected to produce fiber reinforced polymer made up of kenaf fiber and fiberglass.

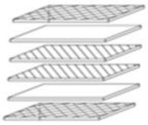
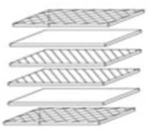
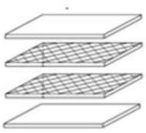
Table I: Material selection

Material selected	Description
Kenaf	Long kenaf fibre
Glass	Woven glass fibre
Polyester	Miracast
Hardener	Methyl ethyl ketone peroxide

B. Arrangement of FRP Composite

Table II shows the arrangement of FRP composite.

Table II: Arrangement of FRP composite

COMPOSITE MATERIALS CONFIGURATION	DESCRIPTION
1.Kenaf with inner woven fiberglass (6 layer)  [0/90/±90 $_{FG}$/90/0]	Layer of composite are as follow : 1) Horizontal (0^0) kenaf fiber 2) Vertical (90^0) kenaf fiber 3) Single layer of woven fiberglass 4) Single layer of woven fiberglass 5) Horizontal (0^0) kenaf fiber 6) Vertical (90^0) kenaf fiber
2. Kenaf with outer woven fiberglass (6 layer)  [±90$_{FG}$/0/90/90/0/±90$_{FG}$]	Layer of composite are as follow : 1) Single layer of woven fiberglass 2) Horizontal (0^0) kenaf fiber 3) Vertical (90^0) kenaf fiber 4) Vertical (90^0) kenaf fiber 5) Horizontal (0^0) kenaf fiber 6) Single layer of woven fiberglass
3. Kenaf without woven fiberglass (4 layer)  [0/90/90/0]	Layer of composite are as follow : 1) Horizontal (0^0) kenaf fiber 2) Vertical (90^0) kenaf fiber 3) Vertical (90^0) kenaf fiber 4) Horizontal (0^0) kenaf fiber

The aluminium flat bars were glued to make the frame for the mold. 400x300 mm of the steel plate was also fabricated. Long kenafs were rolling strings to the aluminium frame (350x260mm). After that, polyester and hardener were mixed and stirred together with a ratio of 100:1.5. The mixture was then poured into the mould. The A3 laminates plastic with wax spray covered the mould. 10 kN cold press machine was used to compress the mould for 1 hour to ensure no bubble was formed and homogeneity of the final product. Then the samples were left for 24 hours. The same steps were repeated for kenaf with inner fiberglass and kenaf with outer fiberglass. Finally, when the specimen was totally cured, it was cut out following the size of ASTM D3039 (250x25x3mm) for the tensile test and ASTM D5045 (44x10x3mm) for the single edge notch bending.

C. Post Impact Tensile Test

The specimen was prepared according to ASTM D3039. Post impact test was carried out by using hemispherical nose of diameter 12.7mm impactor as its drop weight. Post impact was applied to the specimen with the impact of 2J, 4J, 6J, 8J, 10J, 12J, 14J and 16J. The specimen was cut with specific dimension according to standard for tensile test as shown in Figure 3.12. Then, the specimen went through the tensile test. The stress strain curve was plotted during the test for the determination of ultimate tensile strength and elastic modulus.

D. Single Edge Notch Bend

The specimen was prepared according to ASTM D5045. A depth with 4mm notch was made using milling machine. After that, a pre-crack was made after the v notch with 0.5mm, 1.0mm, 1.5mm and 2.0mm using a blade. To make sure the pre-crack follows the length needed, an optical microscope was used to measure the length. A three-point load method was applied to SENB test specimens using an Instron 3382 mechanical testing machine with a crosshead speed of 10 mm/min. The fracture toughness was calculated.

E. Scanning Electron Microscope (SEM)

The scanning electron microscope was used to analyse the surface fracture of the specimen. To create a mixture of signs at the surface, the focused beam of high-energy electron was used on the solid surface [6]. To observe the surface fracture, it is important to zoom in at the right area where the fracture is shown. Another way to improve the image is by adjusting the brightness and contrast of the image.

III. RESULT AND DISCUSSION

A. Post Impact Tensile Test

Fig. 1 shows graph stress against strain of the fiberglass inner. From the curve, the points of fractured and ultimate tensile strength of the specimens were determined. Fiber is considered to be behaving elastic until failure [7]. The data and graph can be observed such that when the impact increases, the maximum stress decreases. The graph in Fig. 2 was plotted of str ess against strain based on fiberglass outer data. The data shows a trend in which increasing the impact on the specimen caused the maximum stress to decrease. Based on the graph, the composite did not experience plastic deformation. It had no or very minimum plastic region. Instead, it stretched uniformly in elastic region up until it reached its ultimate tensile strength and then fractured right away. This shows that the composite possesses brittle characteristic.

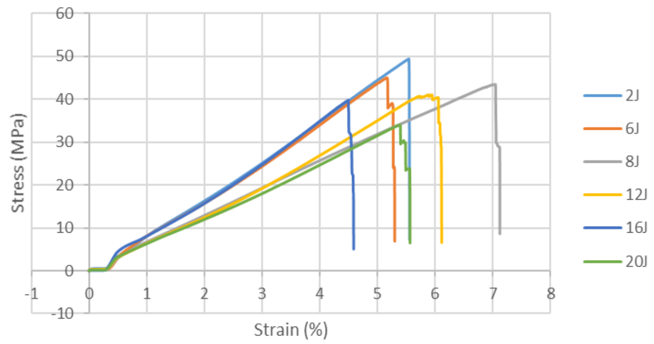


Fig. 1. Graph stress vs. strain fiberglass inner

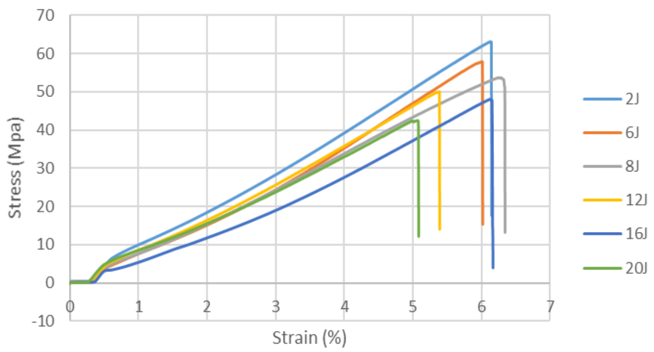


Fig. 2. Graph stress vs. strain fiberglass outer

From the image in Fig. 3, the fracture that occurred in the effect area was expected because the damage part lost the bulk of its strength from the impact. This fracture is mainly due to separation of matrix and fibers due to effects. The shear breaks occurred at the tip of the high stress cracking of the fiber matrix interface in the impact area. After that the cracks spread across the fibers without breaking the fibers. Then the fibers will eventually break as a result of crack opening which drives high tensile pressure [8].

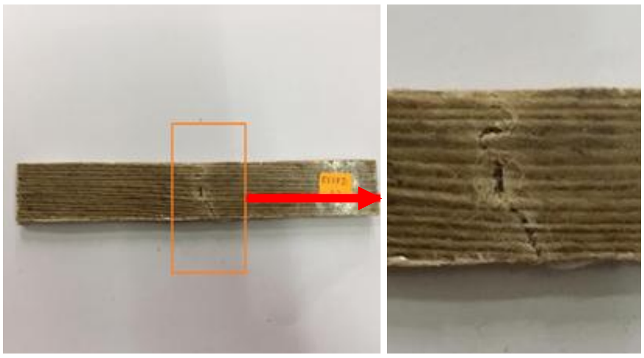


Fig. 3. Specimen after post impact tensile test

According to the data in Fig. 4, a comparison graph between stress and impact of fiberglass inner and fiberglass outer was plotted. The data showed a consistency between fiberglass inner and fiberglass outer. By referring to the graph above, the result of fiberglass inner was lower compared to the result of fiberglass outer. It shows that the fiberglass outer had more strength compared to fiberglass inner. This is due to the fiberglass inner that has low fiberglass composition. The graph shows the stress value for 2J impact at fiberglass outer was 63.117 MPa while the fiberglass inner was 49.385 MPa. Moreover, at the highest impact of 20J, it also showed that fiberglass outer had a higher value than fiberglass inner with 42.448 MPa and 33.979 MPa respectively. The failure strength follows from the increased strength of the glass fiber [9]. The cracks extend across the fibers. Then the fiber without bending the fiber will eventually fracture as a result of the opening of the crack that drives high tension stress [8]. For hybrid composites, the sandwich configuration with the skin made of fiberglass and the core made of kenaf fibers is suitable for high impact on resistance [10].

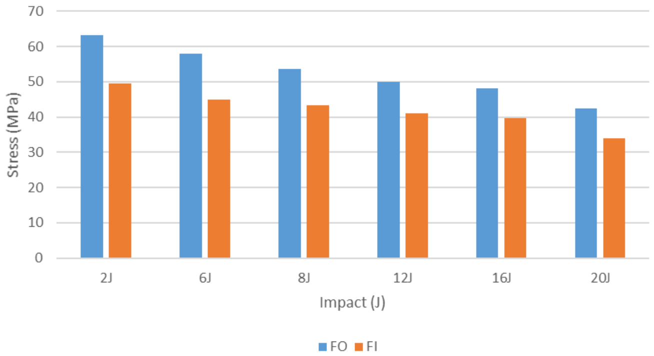


Fig. 4. Comparison graph stress vs. impact

Fig. 5 shows the maximum modulus elasticity against impact of post impact tensile specimen. From the graph, it can be seen that the value of fiberglass outer consistency was higher than the value of fiberglass inner. The modulus elasticity decreased as the impact increased. This is expected because the impact will reduce the area to distribute force. That in turn will reduce the maximum force that the specimen can resist before fracture. As a result, tensile strength will also decrease. When the strength reduces, the elastic modulus also reduces because they are directly proportional to each other. This was indicated by the value of 2J impact fiberglass outer which was 1.152 GPa and greater than 2J impact fiberglass inner which was 0.981 GPa. A similar pattern was shown by the 20J impact as the value of fiberglass outer (0.937 GPa) was higher than the fiberglass inner (0.684 GPa). However, the 16J impact cannot be proven because of the slight difference between fiberglass outer and fiberglass inner value which was higher than fiberglass outer. The varying result is different because of the inconsistency in thickness for each specimen due to manual hand lay-up process [11]. The graph pattern showed the higher value of fiberglass outer than that of fiberglass inner manifests greater strength of fiberglass outer than fiberglass inner which contains relatively low fiberglass composition.

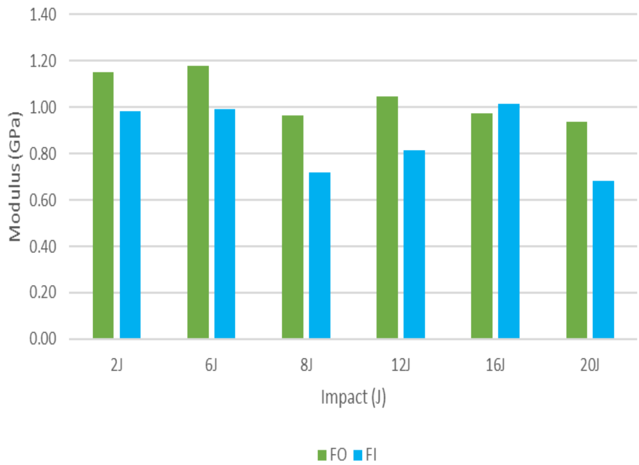


Fig. 5. Comparison graph modulus vs. impact

B. Single Edge Notch Bending Analysis

The single edge notch bending test was conducted based on three point bending configuration where the specimen was supported on both ends while the force was applied at the center of the specimen. Four samples with different configurations were prepared and tested using Universal Instron 3382 Machine. The specimens were initially made with pre-crack using sharp razor blade.

The flexural data properties presented in Table III were obtained after completing the single edge notch bending testing. Fig. 6 shows the graph of stress-strain curve for the 4 samples of fiberglass outer. Based on the data, it observed the trend of the graph in which when the pre-crack increased, the maximum flexural decreased. The result showed that maximum flexural stress increased from 0.5mm pre-crack to 1.0mm pre-crack but decreased as the pre-crack increased from 1.5mm to 2.0mm. The graph showed that 1.0mm pre-crack sample had the highest maximum flexural stress which was 46.499 MPa followed by sample pre-crack 0.5mm and 1.5 mm pre-crack which had the value of 42.802 MPa and 28.190 MPa respectively. Sample with pre-crack of 2.0mm had the lowest maximum flexural stress value which was 12.522 MPa. Furthermore, the result of maximum flexural modulus showed that it decreased as the pre-crack increased. Apart from that, sample with pre-crack of 0.5mm had the highest maximum flexural modulus (1.683 GPa) followed by 1.0mm with 1.290 GPa. The 2.0mm pre-crack had the lowest maximum flexural modulus where the value was 0.533 GPa while 1.5mm had the second lowest maximum flexural modulus which was 1.290 GPa. The highest flexural modulus indicates the highest stiffness of the specimen [12].

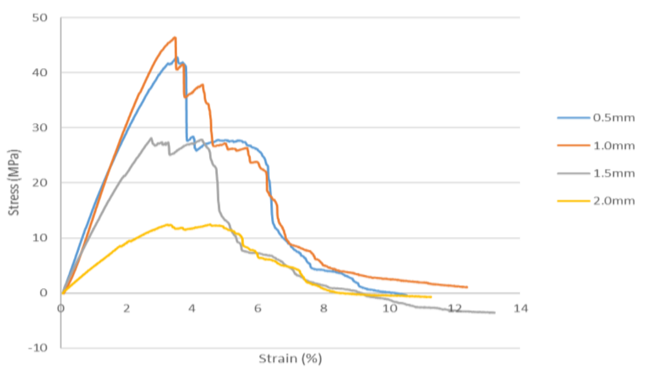


Fig. 6. Flexural stress vs. flexural strain fiberglass outer

Table III: Kenaf/woven fiberglass composite result (FO)

SAMPLE	FO		
	Maximum Flexure Stress,σ (MPa)	Maximum Flexure Strain, ε (%)	Maximum Flexure Modulus E, (GPa)
0.5mm	42.802±4.304	3.526±0.525	1.683±0.425
1.0mm	46.499±10.453	3.466±0.605	1.290±0.255
1.5mm	28.190±6.755	2.756±0.382	1.290±0.296
2.0mm	12.522±2.644	4.559±0.589	0.533±0.015

The graph in Fig. 7 was plotted as flexural stress against strain based on the data in Table IV. These results formed a pattern where the sample with larger pre-crack had lower maximum flexural stress [13]. This showed that the highest maximum flexural stress for fiberglass inner was 38.696 MPa which was on the sample 0.5mm pre-crack. It was then followed by pre-crack of 1.0mm, 1.5mm and 2.0mm which had the maximum flexural stress of 33.428 MPa, 30.286 MPa and 17.456 MPa respectively. Apart from that, the sample with pre-crack 2.0 mm showed significant drop of maximum flexural stress compared to other samples. Meanwhile, the highest maximum flexural modulus was 1.670 GPa on 1.0mm pre-crack. The graph showed that the maximum flexural modulus increased from pre-crack 0.5mm to 1.0mm but decreased when pre-crack increased from 1.5mm to 2.0mm. The values of maximum flexural modulus for 0.5mm, 1.5mm and 2.0mm pre-crack were 1.588 GPa, 0.852 GPa and 0.595 GPa respectively.

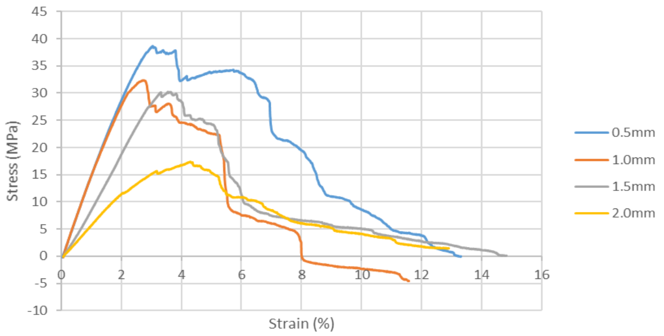


Fig. 7. Flexural stress vs. flexural strain fiberglass inner

Table IV: Kenaf/woven fiberglass composite result (FI)

SAMPLE	FI		
	Maximum Flexure Stress,σ (MPa)	Maximum Flexure Strain, ε (%)	Maximum Flexure Modulus E, (GPa)
0.5mm	38.696±2.777	3.051±0.286	1.588±0.279
1.0mm	32.428±2.392	2.729±0.431	1.670±0.139
1.5mm	30.286±3.191	3.621±0.459	0.852±0.082
2.0mm	17.455±1.066	4.303±0.070	0.595±0.074

The graph flexural stress against flexural strain in Fig. 8 was constructed based on the data collected. The data in Table V showed a trend that the maximum flexure stress decreased when pre-crack increased. The first sample (0.5mm pre-crack) showed the highest maximum flexural stress which was 28.190 MPa. Then the values of maximum flexural stress gradually decreased as the pre-crack increased which were 1.0mm, 1.5mm, and 2.0mm with the values of 13.050 MPa, 9.881 MPa, and 8.574 MPa. The difference between the highest and the lowest maximum flexural stress was about 69.6%. Furthermore, the maximum flexural modulus value also followed the same trend in which an increase in the pre-crack resulted in a decrease of maximum flexural modulus. This is shown by the highest maximum flexural modulus which was 1.290 GPa at 0.5mm and then decreased as the pre-crack increased for 1.0mm, 1.5mm and 2.0mm which were 0.515 GPa, 0.341 GPa and 0.337 GPa respectively.

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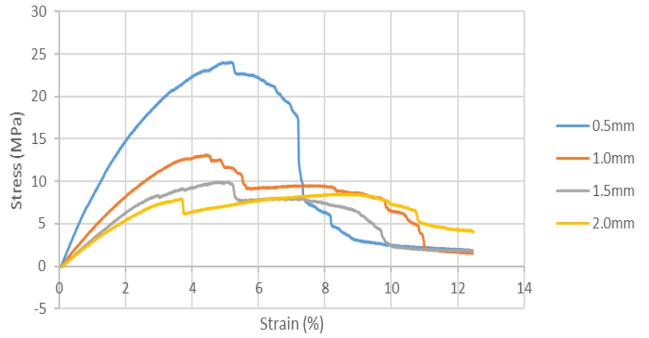

Fig. 8. Flexural stress vs. stain kenaf only

Table V: Kenaf composite result

SAMPLE	KO		
	Maximum Flexure Stress,σ (MPa)	Maximum Flexure Strain, ε (%)	Maximum Flexure Modulus E, (GPa)
0.5mm	28.190±6.755	2.756±0.382	1.290±0.296
1.0mm	13.050±2.382	4.432±3.310	0.515±0.089
1.5mm	9.881±0.3901	4.845±0.585	0.341±0.048
2.0mm	8.574±0.967	8.244±0.855	0.337±0.093

Based on the data, the graph in Fig. 9 was plotted between flexural stresses versus pre-crack. Firstly, it is noticeable that the pattern or trend for flexural stress decreased when the pre-crack increased. For the second observation, the value of maximum flexural stress of fiberglass outer was higher than fiberglass inner and kenaf only and the value for fiberglass inner was higher than kenaf fiber only. Furthermore, tensile stress for FO dropped about 70.7% from 0.5mm pre-crack to 2.0mm pre-crack. By reviewing Figure 4.9, the reason that KO of 0.5mm configuration was the lowest compared to FO 0.5mm configuration and FI 0.5mm configuration is because KO arrangement involved only kenaf fiber. Comparing KO to FI, FI had 27.2% more flexural stresses due to the FI configuration with the woven fiber glass which is placed in between kenaf fiber. For the highest flexural stresses value which was the FO, adding the woven fiberglass at the top and bottom kenaf fiber arrangement with sandwich configuration the FO gained 34.1% more flexural stresses than the KO arrangement with only kenaf. The study verified that different configuration with the same number of layers gave different mechanical properties [14]. Therefore, the configuration fiberglass outer was tougher compared to any configuration of the sample [15]. However, for the 2.0mm fiberglass inner pre-crack, the value for the maximum flexural stress was higher than fiberglass outer.

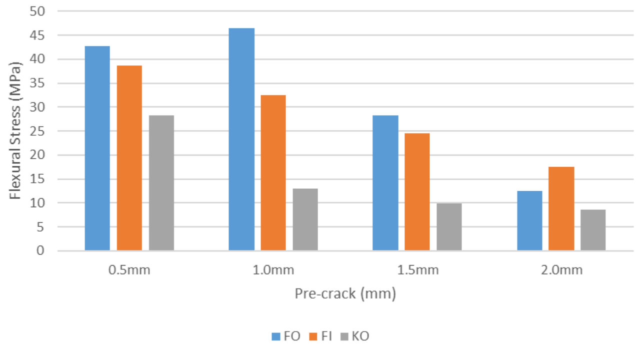

Fig. 9. Comparison graph stress vs strain

The chart in Fig. 10 shows the data of three specimen compositions to compare the composition strength of fiberglass outer, fiberglass inner and kenaf fiber. The pattern of the chart was observed in which fiberglass outer had a higher value compared to fiberglass inner and kenaf fiber only. For 0.5mm, FO showed that it dropped about 23.4% from the FO and 18.8% from the FI on the flexural modulus. The configuration of the fiberglass outer was stronger compared to the other configurations. However, samples with pre-crack of 1.0mm and 2.0mm fiberglass inner had a higher modulus. These variations in pattern are probably because of the hand process lay-up. Despite a slight increase in fiber composite thickness without sacrificing a lot of weight, it will affect the increase or decrease in bending and tensile properties [16].

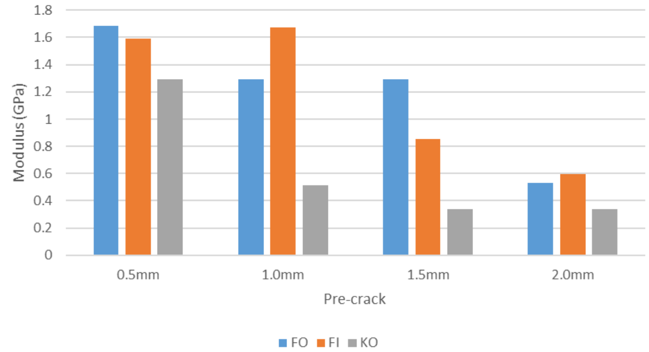

Fig. 10. Comparison graph modulus vs. pre-crack

Table VI presents the value of the critical stress intensity factor. For this research, the main study focused on the 0.5mm pre-crack. FO showed that it had the highest value of critical stress intensity, K_{IC} with 32.538 MPa√mm while the value of FI was 20.345 MPa√mm. The lowest value was for KO with 10.258 MPa√mm. Thus, by adding glass fiber into kenaf fiber had impressively improved the K_{IC} value than the specimen that was fabricated by using only kenaf fiber [17].

Table VI: Critical Stress Intensity Factor of long kenaf/woven

Sample	Critical Stress Intensity Factor, K_{IC} (MPa√mm)
Fiberglass Outer (FO)	32.538
Fiberglass Inner (FI)	20.345
Kenaf Only (KO)	10.258

C. Scanning Electron Microscope Analysis

Fig. 11 and Fig. 12 show fracture surface of post impact specimen and single edge notch bending test using scanning electron micrograph. The tensile surfaces of kenaf and fiberglass composite were analyzed. From the figure, the failure of the microstructure can be seen. The failure contributed into debonding, crack deflection, matrix cracking, fiber pull out and kenaf fiber fracture. Meanwhile, the fiber pull-out which showed interfacial bonding between fiber and matrix indicated a poor compatibility at the interface [18]. It is expected that a transverse crack has just been formed and that the debonding begins at the transversely crack matrix surfaces.

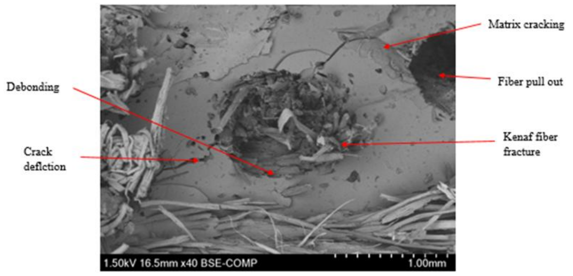

Fig. 11. Focused microstructure area of post impact tensile specimen

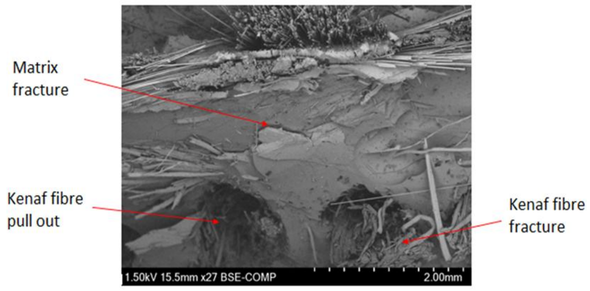

Fig. 12. Focused microstructure area of SENB specimen

IV. CONCLUSION

In conclusion, the objectives of the project were achieved. The hybrid composites were fabricated using long kenaf fibers, woven fiberglass, unsaturated polyester liquid and a sandwich configuration. The result and data obtained from both experiments clearly showed that fiberglass outer composites configuration gave more advantages than other configurations. The result of the configuration had better mechanical properties and young modulus compared to other arrangements. Meanwhile, the woven fiberglass had tougher and stronger properties compared to kenaf fibers.

Besides, the fiberglass is better to be used as the outer layer where the resultant mechanical properties are better. Fiberglass is able to strengthen the composites. This implies that the composite is best suit using a higher strength material as the skin on the composite arrangement.

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