Investigation of Tensile Properties of the Eco-Board of Hybrid Composite that Consist Of Oil Palm Empty Fruit Bunch (OPEFB) Fiber Added with Rice Husk

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Abstract. This project focuses on the oil palm empty fruit bunch (OPEFB) fibre that be added with rice husk (RH) as an alternative raw material to replace wood in a several types of industries. ASTM D3039 standard for tensile test was used to design and compose a composite of EFB fiber reinforced rice husk. In this study, the specimen were be created by the compression method based on the numerous ratio that be chosen which is specimen A, pure EFB, specimen B (93.3g EFB: 6.7g RH), Specimen C (86.6g EFB: 13.4g RH) and specimen D (66.7g EFB: 33.3g RH). The objective of this research is to identify the tensile properties of the Eco-board of hybrid composite and to determine the best properties to be introduced to the industry. The failure pattern and fractography failure mode were investigated using Scanning Electron Microscope (SEM). The tensile test was performed to characterize the hybrid composite properties using a GOTECH/AI-7000M Electronic Mechanical Testing Machine. Result showed that the higher the rice husk added to the EFB fiber, the higher its tensile strength up to certain ratio. As the conclusion, the rice husk help the EFB fiber to increase strength however at the optimum value ratio where the best properties of hybrid composite is specimen C with 9.685 MPa and suitable for many application.

1. Introduction
At present, there are various new composite materials are investigated to make products that able to facilitate human daily activities. Generally, the composites are made of two main types of fiber that are synthetic and natural fiber. Synthetic fibers generally come from synthetic materials such as petrochemicals, glass and carbon fiber. Natural fibers include those produced by plants, animals, and from agricultural by product [1]. These agricultural resources can be dated back in the primitive age such as wood, is used to make shelter, cook food, construct tools and make weapons. Natural fibers have been considerable demand in recent years due to its eco-friendly and renewable nature [2]. In addition, the advantages of using such resources is that, they are widely distributed in all zones of the world, low cost, strong, aesthetic and biodegradability compared to synthetic fiber [3]. Agricultural by product such as palm oil trunk, bamboo fiber, coconut fiber, and pineapple leaf fiber, has been studied as reinforcement for composite.

As we approach the 21st century, there is a larger consciousness of the need for materials in getting higher world population and increasing affluence [2]. At the same period, we have an awareness that our landfills are satisfying. Our resources are being used up, our planet is existence polluted, and that non-renewable resources will not last forever. Wood will continue to be a major source that has higher density than annual plants so there will be more bulk when using agricultural crop fiber. However, in this country where there is little or no wood possessions left or where area are in place to limit the use...
of wood, alternate sources of fiber are needed if there is to be a natural fiber industry. Empty fruit bunch (EFB) is one of the natural fibers selected to make a board and to replace a wood. EFB is obtained after the elimination of oil seeds from the fruit bunch for oil extraction. When the palm oil seed are harvested, a large amount of EFB remains because each oil palm plant cannot be used for the next harvest [4], and expansion of exploration of oil palm plantations has resulted enormous amounts of vegetable waste, creating problems in replanting process and exceptional environmental concerns. It is reported that, during recent past years, Malaysia alone produced about 30 million tons annually of oil palm biomass, including trunks, fronds, and empty fruit bunches [5]. Hence, without any addition cost EFB fibers as a waste product can be used for industrial purposes and will benefit the environment significantly.

The rice husk (RH) is also the natural fibers that be added with oil palm empty fruit bunch (OPEFB) as an alternative raw materials to replace wood in a several types of industries. Rice husk is an economical by-product of rice processing and is separated from rice grain during the rice milling process. Rice husk incineration is discouraged due to producing hazes, ash and toxic gases, which lead to serious air pollution [6]. The land area of the paddy planting in Malaysia is approximately 680,000 ha and 840,000 tons rice husk were produced every year [7]. Annually about 3.66 million tons of rice husk waste is left in the field. This values is predicted to increase to 7 million tons per year towards year 2020 due to evolving technology development in agriculture industries [8]. As a way to reduce it, the by product can be widely used in composite manufacturing such as cardboard, roofing tiles and for making some compound like silica silicon compounds [9]. A different ratio between oil palm empty fruit bunch and rice husk were includes in this project to make an Eco-board as a specimen and a urea formaldehyde uses as a resin.

The tensile properties on Eco-board of hybrid composite will be observed using tensile tests equipment. The results of tensile tests are used in choosing materials for engineering applications [10]. Tensile properties commonly are included in material specifications to ensure quality. Tensile properties frequently are measured during development of new materials and processes, so that different materials and processes can be compared. In this study, the experimental of tensile test are be conducted with different ratio of EFB fiber and RH. Therefore, the best properties of tensile strength will be found to introduce to industry and the failure mode was investigated using scanning electron microscope (SEM).

2. Material and Methods

2.1. Materials
Oil palm empty fruit bunch and rice husk were supplied by Makmal Konkrit, Fakulti Kejuruteraan, Universiti Malaysia Sabah. The empty fruit bunches as solid waste have been discharged at palm oil after the elimination of oil seeds for oil extraction. The fibers are partially loose and partly paralleled lapping to each other in thickening formation through soft composition. It is not truly rounded. The EFB been cut to have requires 3 - 8 mm long fibers and then immediately treated with boiling water mixed with detergent powder to removes impurities and change the dull blunt brown colour to light-golden colour, which is similar to natural wood colour. However, the range of fiber length that be compressed is between 0.3 mm and 0.5 mm as shown in Figure 1. Rice husk is a rice processing obtained from the factory after it was separated from rice grain during the rice milling process. Figure 2 to shows the rice husk that have been dried before used as reinforcement material with EFB. The specimen of Eco-Board was formed by using cast iron mold with molding size is 150 mm x 150 mm x 150 mm as shown in Figure 3. Figure 4 was the oven that be used to heat the mold at temperature 120ºC - 200ºC.
Table 1 shows the physical and mechanical properties of oil palm fibre that get from the Bismarck et al., Plant fibers as reinforcement for green composites. Table 2 is the properties of urea formaldehyde that get from Sepanggar Chemicals Sdn. Bhd. Kota Kinabalu, Sabah.

**Table 1. Physical and mechanical properties of oil palm fibre**

| Properties               | OPEFB Fibre          |
|--------------------------|----------------------|
| Density (g/cm³)          | 0.7 - 1.55           |
| Tensile strength (MPa)   | 0.1 - 0.4            |
| Young’s Modulus (GPa)    | 1 – 9                |
| Elongation at break (%)  | 8 – 18               |
| Cellulose content (%)    | 49.6                 |
| Lignin content (%)       | 21.2                 |

Sources: Bismarck A. Mishra S, Lample T. Plant fibers as reinforcement for green composites.

**Table 2. Properties of Urea Formaldehyde**

| Properties              | Value          |
|-------------------------|----------------|
| Viscosity / 30°C        | 164 cps        |
| Specific Gravity / 30°C | 1.1935         |
| pH value                | 7.6            |
| Free Formaldehyde       | 1.20%          |
| Pot Life                | 75 Min         |
| Solid Content           | 51.4%          |

Sources: Sepanggar Chemicals Sdn. Bhd, Kota Kinabalu, Sabah, Malaysia.
2.2. Methodology

2.2.1. Specimen Preparation

The specimens of Eco-Board were manufactured in the Makmal Konkrit, Fakulti Kejuruteraan, Universiti Malaysia Sabah through compression mold. Matrix material which is urea formaldehyde (UF) reinforced with empty fruit bunches (EFB) and rice husk (RH). These materials are mixed well in ratio of EFB to RH 10:0, 93.3:6.7, 86.6:13.4, 66.7:33.3 then mixed with 50 g of UF. This ratio determine by different weight of EFB and RH as shown in Table 3.

| Specimen | Empty Fruit Bunches (EFB), g | Rice Husk (RH), g |
|----------|-----------------------------|------------------|
| A        | 100                         | 0                |
| B        | 93.3                        | 6.7              |
| C        | 86.6                        | 13.4             |
| D        | 66.7                        | 33.3             |

In the first process of manufacturing the Eco-board, EFB and RH were weight based on the ratio above and mixed well with the UF with manually hand to make sure it were in proper mixing. Then, the composite materials were put into a mould that has been heated in the oven before uniformly as shown in the Figure 5. After that, a steel plate is placed on the composite materials as a cover for a compression process to obtain flat surfaces. Compressive strength machine was used to compress the composite materials as a compression method for load around 300 kN. The mould was placed at the centre point position in the compressive strength machine and rod was put in the mold as a load to compress the composites as shown in Figure 6.

![Figure 5. EFB fiber for specimen A that put into a mould](image1)

![Figure 6. Mould placed on the compressive Strength machine](image2)

The composites was taken out from the mould and left at room temperature for a while. Then, the 4 board of dimensions of 150 mm X 150 mm X 5 mm with different ratios were manufactured as in Figure 7.
2.2.2. Specimen Testing

The Figure 8 shows the Universal Cutting machine that been used to get the reshaped specimen with 150 mm X 25 mm X 5 mm dimension with 50 mm gauge length for tensile testing in accordance with ASTM requirements [11]. All the specimens are tested using GOTECH/AI-7000M Electronic Mechanical Testing machine with speed rate 1 mm/min. Specimens are placed in the grips of the machine at specified grip separation and pulled until failure. The machines will automatically produces a stress versus strain diagram, thus the mechanical behaviour of the composites can be interpreted from the diagram. The specimen will elongate as the tensile test starts. The load value (F) is recorded up to the point the specimen breaks. The instrument software which provided with the machine equipment will calculate the tensile properties such as the tensile, yield strength and elongation.

2.2.3. Scanning Electron Microscope (SEM)

Scanning electron microscope as shown in Figure 9 was be used in this project to study the surface of the four different composites samples after the tensile testing. SEM is a type of electron microscope that images of the sample surface is scanned with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample’s surface topography, composition and other properties such as electrical conductivity.
3. Result & Analysis

3.1. Tensile Properties

The maximum load, tensile strength and elongation of specimen as shown in Table 4 was interpreted from the stress versus strain diagram of automatically machine after the tensile test be done.

Table 4. Results of the Tensile Test

| No | Specimen          | Max Load (N) | Tensile Strength (N/mm²) | Elongation (mm) |
|----|-------------------|--------------|--------------------------|-----------------|
| 1  | Specimen A        | 581.79       | 4.65                     | 2.94            |
|    | (100g OPEFB: 0g ARTO) |             |                          |                 |
| 2  | Specimen B        | 686.74       | 5.49                     | 2.41            |
|    | (93.3g OPEFB: 6.7g ARTO) |         |                          |                 |
| 3  | Specimen C        | 1210.62      | 9.68                     | 1.86            |
|    | (86.6g OPEFB: 13.7g ARTO) |         |                          |                 |
| 4  | Specimen D        | 713.14       | 5.71                     | 1.45            |
|    | (66.7g OPEFB: 33.3g ARTO) |         |                          |                 |

Figure 10 represents the line graph load that applied to the specimen with different ratio of the empty fruit bunch (EFB) fiber and rice husk (RH) against the displacement. Based on the graph, it shows the load and displacement slightly increase and the testing machine performed under control of loading rate until it reach the maximum load level, a sudden failure of the specimens occurs. The machines gives small increments of load to the specimen and resultant deformation is measures, as result, when the incremental load goes over the maximum level, the specimen fracture suddenly. From the gathered data, it shows that the highest maximum load applied is at specimen C (86.6% EFB: 13.4% RH) which is 1210.62 N where the specimen can support and followed by specimen D (66.7% EFB: 33.3% RH) 713.14 N, specimen B (93.3% EFB: 6.7% RH) 686.74 N and the lowest is specimen A with pure EFB which is 481.79 N. It can be said that the addition of rice husk into the specimen will increase the inter-bonding relation within the materials as the maximum load applied keep on increasing. This can be supported by Irina M.M.W et al. [12] stated that hybrid composites has the ability to increase stiffness, reduced weight an also balancing up modulus properties and thus explaining the increasing of applied forces needed to break the composites specimen.
Figure 10. Graph Load (N) against Displacement (mm) of the Specimen.

Figure 11 shows the graph of tensile strength against type of specimen. The tensile strength of the specimen get from the calculation of maximum load from Figure 10 over the area, where an area of the each specimen is 125 mm². A specimen gives the lowest maximum load so that it have the lowest tensile strength which is 4.65 MPa. As the specimen load move up from the yield strength, the stress on the specimen increases until it reach a maximum applied stress, where it can support the specimen. Then, the tensile strength follows by the specimen B (93.3% EFB: 6.7% RH) which is 5.49 MPa, specimen D, 5.71 MPa (66.7% EFB: 33.3% RH) and the highest maximum tensile strength is specimen C with 86.6% of EFB fiber added with 13.4% RH equal to 9.68 MPa.

From the gathered data, the pure empty fruit bunch (specimen A) gives the lowest tensile strength because it only have one mechanical properties of fiber acts on tensile testing. Different with the other specimen which the hybrid composite have the increasing stiffness, and balancing up the modulus properties of the specimen. Thus, the tensile strength is increase when it was hybrid with other composite rather it stand in pure EFB. This is supported by H Ku et al. [13] that said addition of fibre to composites matrices will improve the tensile strength due to the stiffness value and higher the strength of the fibres. In addition, with the addition rice husk into empty fruit bunch fibre improve inter locking bonding between materials thus improve its tensile strength. Khoathane et al. [14] found that the tensile strength and Young’s modulus of composites reinforced with bleached hemp fibers increased in credibly with increasing fiber loading.
Figure 12 represents the chart of elongation of the Eco-Board until it breaks versus the type of specimen ratio. This data interpreted from the Figure 10, graph load versus the displacement of the specimen. The ductile specimen experiences significant deformation before it eventually breaks. The brittle specimen typically have higher yield strengths than ductile materials. Based on the chart, it shows that a specimen A with 100% pure EFB gives the longest elongation which is 2.96 mm before the specimen start to break. Then, it followed by specimen B (93.3% EFB: 6.7% RH) with 2.41 mm, specimen C (86.6% EFB: 13.4% RH) 1.86 mm and the lowest elongation until it breaks is specimen D (66.7g EFB: 33.3g RH) with 1.45 mm. Based on the data obtained, it is clearly shows that the increasing of rice husk to the empty fruit bunch board will decrease the ductility of the Eco-Board on the same time increase the brittleness of the specimen. G. Jordi et al. [15] found that the addition of any filler to composites will lead to decrease of elongation at yield and break. Therefore, a specimen D is a most brittle and the specimen A has most ductility material.
3.2. **Scanning Electron Microscope (SEM)**

The crack propagation and the morphology of surface structure of oil palm empty fruit bunches with rice husk in four different ratios (100:0, 93.3:6.7, 86.6:13.4, and 66.7:33.3) were investigated by SEM. Figure 13 shows the micrograph of surface failure under tensile test for specimen A (100g EFB: 0g RH). The Figure 13 (a) is under 80X in magnification and the other figures are under 25X in magnification. Based on these figure, the small crack growth appeared on the surface. For this pure 100% EFB shows that there are much void that occurred on the surface structure. Without any combination of RH, the void for specimen is much easy to be occurred. From this figure, the 100% pure EFB explained that the matrix and the fibre are more likely to having gap/void between them even the fibre tries to hold up the uniform matrix by carrying loads. Hence, this figure also shows that the fibre is not good in orientation. The stresses transfer from matrix to fibre in a composite that take place by shear at the fibre-matrix interface. Thus, strong interfaces will give high strength and stiffness but low in fracture toughness composites [16].

It is difficult to assess the fibre breakage and roughness of the surface with macroscopy to confirm the identification of the fracture failure. Therefore, microscopic is necessary to continue the analysis. At crack origin, a set of fibre bundles was found to be broken, shows on Figure 13(c). This acted as a stress concentrator for initiation and propagation of crack under tensile test. On Figure 13(d), shows that the fibre pulled out or no matrix between the fibre. The failure occurred along the fibre-matrix interface leads the fibre to pull out on further straining [17]. It show that, the strong the interfacial bond strength causing strong stress concentration and a tendency for crack to pass through large bundles of fibre without much deviation [18]. By analyzing figure above, it was observed that the random discontinuous of fibres can decrease the interfacial bond strength between fibres and matrix [19]. Hence, it is seen that the composite were not bonded strongly with each other and has high possibility to separate as shown in figure above.

![Figure 13. Micrograph of surface failure under tensile test for specimen A](image-url)
Figure 14, shows the morphology structure on surface for specimen B (93.3g EFB: 6.7g RH) under 55X in magnification for Figure 14(a) and (b). While the Figure 14(c) and (d) under 75X and 40X in magnification respectively. Based on this figure, it shows that the void is less occurred on the surface structure for this ratio. This is because of the mixed with rice husk. The combination of oil palm empty fruit bunches with rice husk reduced the gap between the fibre and the matrix itself. Based on Figure 14(a), it shows that the matrix and the fibre are in good combination with no fibre pulled out or broke. However, the fine cleavage still occurred on the surface structure. Figure 14(c) the fibre cannot sustain the increased load, so the fibre will fail, leading to a single fracture surface. This figure is in unidirectional fibre-reinforced composite. As can be seen, the failure leads to fibre pulled out and thus further energy absorption [17]. Figure 14(d), represents that the fibre fails in fibre splitting. It is uncommon for fibre to develop kink band or splitting on the compression of side bent fibres. These cases, the energy absorbing mechanisms that contribute to the failure process are fibre pull out and fibre-matrix debonding [17].

![Image of Figure 14](image_url)

Figure 14. Micrograph of surface failure under tensile test for specimen B

Figure 15, above shows the morphology structure of the surface for specimen C (86.6g EFB: 13.4g RH). Figure 15(a) shows the SEM micrograph is under 47X in magnification, while Figure 15(b) under 65X, (c) under 30X and (d) is in under 32X in magnification. Based on this figure, it shows that there is no void occurred surface structure. However, it can be clearly see that fine dimples are occurred on the Figure 15(b). The region of initial crack growth was surrounded with fine dimples Figure 15(a). It shows that the small arrows indicate cracking on the surface. This combination ratio OPEFB with RH shows that, the RH reduced the gap between the fibre and the matrix. Chevron is usually formed from river line or also known as textured microflow. The riverline are found on this figure in the matrix adjacent to a fibre (in mode I fracture) interlaminar tensile fracture or in resin-rich regions [20].

Based on Figure 15(c), it shows that fracture occurs because of defect fibre pull out. It indicate that the random discontinuous improved the interfacial bond strength between fibre and matrix decreasing the value of the flexural strength of the composite. Some load transfer between fibres and matrix is
possible by interfacial forces due to matrix shrinkage into the fibres. After the fracture, the composite typically shows a matrix-crack plane. Analyzing Figure 15(c) it was observed the random discontinuous of the composite fibre, which can decrease of the interfacial bond strength between fibre and matrix [19]. Figure 15(d) shows, the fracture occurred because of the fibre bridging [20]. When the bundle of fibres is tied between two adjacent surfaces, it is a phenomenon of fibres bridging. It is prevalent in unidirectional ply surfaces and is one of the main features in mode I interlaminar tensile fracture. It is depends highly on the matrix and fibre interface quality and on the amount of resin in this region [20]. Matrix-wing phenomenon can also happen due to fibre debonding. Pieces of matrix adhere to the fibre after debonding.

Figure 15. Micrograph of surface failure under tensile test for specimen C

Figure 16(a), (b) was analyzed their fracture surface under SEM, with 85X in magnification while Figure 16(c) and (d) are under 40X and 27X in magnification respectively. As seen in figure (a), the fracture occurred because of the fine dimple. Appearance dimple on the surface structure will causing weak boundary. Figure 16(d) shows that it is well known that the fracture surface morphologies render the interfacial characteristic of the composites. Extensive fibres pull out usually indicate that a relatively weak fibre or matrix interfacial bonding, while little fibres pull out and short fibre pull out length illustrate a strong fibre or matrix interfacial bonding. Some load transfer between fibres and matrix is possible by interfacial forces due to matrix shrinkage into the fibre. The friction produces a non-uniform stress along the debonded fibres [19]. This will cause the fibre easily to break.
Figure 16. Micrograph of surface failure under tensile test for specimen D

4. Conclusion
It is determined that addition of the rice husk to Eco-Board increase the tensile properties of the board and at the same time decreasing the ductility of the specimen as an elongation of the Eco-Board keep on decreasing proportionate to the increasing the amount of rice husk added to the specimen. The ultimate forces also can be seen that increase on the hybridize specimen if compared to the pure specimen up until certain ratio where addition of more rice husk will decrease the ultimate forces. From the bonding and failure mode between fibre and matrix that studied through SEM, it can be conclude that the poor interfacial bonding will lead the fibre and matrices to break. Overall, the hybridization of Eco-Board with rice husk definitely increase some mechanical properties of material. So that it can be used to replace the usage of conventional woods in industry and the possible application that suitable for this composite material is fibre board, decoration and as furniture.

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