

Flexural Properties of *Arenga pinnata* Fibre Reinforced Epoxy Composites

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Abstract: The aim of this study is to determine the flexural properties of *Arenga pinnata* fiber as a natural fiber and epoxy resin as a matrix. The *Arenga pinnata* fibers were mixed with epoxy resin at the various fiber weight percentages of 10, 15 and 20% *Arenga pinnata* fiber and with different fiber orientations such as long random, chopped random and woven roving. Hand lay up processes in this experiments were to produce specimen test with the curing time for the composite plates is in the room temperature (25-30°C). Results from the flexural tests of *Arenga pinnata* fiber reinforced epoxy composite are that the 10 wt.% woven roving *Arenga pinnata* fiber showed the highest value for maximum flexural properties. The flexural strength and flexural modulus values for 10 wt.% of woven roving *Arenga pinnata* fiber composite are 108.157 MPa and 4421.782 MPa respectively. The results above indicate that the woven roving *Arenga pinnata* fiber has a better bonding between its fiber and matrix compare to long random *Arenga pinnata* fiber and chopped random *Arenga pinnata* fiber.

Key words: Flexural properties, epoxy resin, matrix, *Arenga pinnata*, Natural fiber composites

INTRODUCTION

Since the 1990s, natural fiber composite are emerging as realistic alternatives to replacement the glass-reinforced composite in many applications. Natural fiber composites such as hemp fiber-epoxy, flax fiber-polypropylene (PP) and china reed fiber-PP are attractive material in automotive application particularly because of lower cost and lower density. Natural fiber composites are also claimed to offer environmental advantages such as reduced dependence on non-renewable energy/material sources, lower pollutant emissions, lower greenhouse gas emission, enhanced energy recovery and of life biodegradability of components^[1].

Natural fibers such as banana, cotton, coir, sisal and jute have attracted the attention of scientists and technologists for application in consumer goods, low-cost housing and other civil structures. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture. Natural fibers have many advantages compared to synthetic fibers, for example low weight, low density, low cost, acceptable specific properties and they are recyclable and biodegradable. They are also renewable and have relatively high strength and stiffness and cause no skin irritations. On the other hand, there are also some disadvantages, for example moisture uptake, quality variations and low thermal stability. Many investigations have been made on the potential of the natural fibers as reinforcements for composites and in several cases the result have shown that the natural

fiber composites own good stiffness but the composites do not reach the same level of strength as the glass fiber composite^[2].

In the past, various studies have been carried out on natural fiber composite. Hemp, sisal, cotton, flax, coir and jute are the most commonly fibers are used to reinforce polymers such as polyolefin, polystyrene, epoxy resins and unsaturated polyester, while the study of *Arenga pinnata* fiber is still scarce. And the fact that *Arenga pinnata* fiber is fiber that also obtained directly from natural resource and has cheap price make it even more attractive in terms of sustainability and environmental awareness. However, very limited studies have been reported available for information and data dealing with that mechanical properties polymer composite reinforce with *Arenga* fibers. In this study, *Arenga pinnata* fiber for reinforcement and epoxy resin as a matrix for composite fabrication were selected. The main idea is to try to explore the new natural resources, considering abundance available material in Malaysian local nature.

The study is significant because it explore the potential of the abundant resources from forest for used as fiber in reinforced composite. The use of *Arenga pinnata* fiber also has an economical advantage because glass or carbon fiber can be replacement fiber by *Arenga pinnata* fiber. Although the use of *Arenga pinnata* fiber based epoxy is not popular as a mineral or inorganic fiber, epoxy – derived *Arenga pinnata* fiber. The significance of this study is to generate the idea and to try to explore the new natural resources with low production cost considering on abundance readily

available in natural particularly, in Malaysian tropical forest.

The aim of this study is to investigate the technical viability of *Arenga pinnata* fiber as epoxy composite reinforcement. The objectives of different studies conducted are to determine flexural properties of *Arenga pinnata* fiber reinforced epoxy composite.

MATERIALS AND METHODS

The selected raw material of the fiber for this project was *Arenga pinnata* fiber and the matrix was selected from epoxy resin group.

Preparation of *Arenga pinnata* fiber: The *Arenga pinnata* fiber was collected from local resources (Banda Aceh, Indonesia), retting process was applied in order to separate the stalk from the core of the *Arenga pinnata* fiber. In this process, bundles of *Arenga* fiber were soaked into water tank until the dirt vanish from the core section and the stalk was separated from the core. The *Arenga pinnata* fiber stalks were occasionally stirred to facilitate the separation process. Water was changed several times in order to reduce the dirt resulted from the retting process. Before using the *Arenga pinnata* fiber, it was dried about two weeks under the room temperature like traditional system. The ratio between epoxy resin and hardener for this study was 4:1 by weight.

Molding design for specimen test: The dimension of the *Arenga pinnata* fiber composite boards were 200 mm (L) x 150 mm (W) and the boards had 3 mm thickness. The required equipments for the mould that was used to lay the material down into mats were including glass, transparency plastic for the bottom layer and spacer frame.

Fabrication of composite plate: The mould was made from the glass and transparency plastic and the process of making the mould used 3 layers of double-sided tape to form it into square shape. The long random fiber and woven roving fiber was cut based on the mould size. Then the fiber was placed over the transparency plastic in the bottom of the mould which has been prepared before.

Initially epoxy and hardener were mixed together based on the weight percentage to form a matrix, then the matrix was poured over the fiber and compressed and distribute evenly until it achieved thickness between 3.0 mm-3.2 mm. After that, the remaining mixture of epoxy resin and hardener was poured over the unfinished composite plate then pressed and pushed down with the finger to avoid and eliminate the bubbles. The best way to prepare the curing process to produce a standard quality specimen test was by mixing the epoxy and hardener for approximately 10 minutes.

The curing time was around 20–24 hours until the composite plate dried evenly if applied at the room temperature condition of 25-30 °C.

Specimen test preparation: Each composite board was cut into test sample (number of specimen for each type of fiber model are 5 samples). The cutting processes were using handsaw and other equipments. All specimens test were conditioned based on the standard procedures of ASTM D618-99 before mechanical tests were assessed. The test specimens were done in the room condition of 23 ± 2 °C in temperature and with relative humidity $50 \pm 5\%$ for not less than 40 hours prior to the property assessment test. All involved tests were conducted in the standard laboratory atmosphere at temperature 23 ± 2 °C and relative humidity $50 \pm 5\%$.

Data Analysis: All the mechanical properties assessment processes were carried out in Malaysian Institute Nuclear Technology (MINT) Selangor, Malaysia. The types of mechanical test that were measured in this research are flexural tests. Each mechanical test was carried out based on natural fiber composite. Five specimens were prepared for each mechanical test.

Flexural test: Flexural test were performed on the same machine using the 3-point bending method according to ASTM D790-99^[3]. The specimen dimensions were 127 mm (L) x 12.7 mm (W) and had 3.2 mm thickness. The specimens were tested at a crosshead speed of 1 mm/min.

RESULTS AND DISCUSSION

Long random *Arenga pinnata* fiber composite: The flexural strength of epoxy is about 78.4 MPa. With the increase of fiber loading percentages from 10% to 20 wt. % long random *Arenga pinnata* fiber, the flexural strength value enhance regularly from 77.466 MPa to 92.648 MPa respectively (Fig. 1 and 2). The condition above indicates that 10% and 15 wt. % long random *Arenga pinnata* fiber is stiffer and stronger than virgin epoxy. This reveals that 20 wt. % long random *Arenga pinnata* fibers is weaker than 10 wt. % and 15% wt. of long random *Arenga pinnata* fiber and weaker than virgin epoxy.

Chopped random *Arenga pinnata* fiber composite: The flexural properties of chopped random *Arenga pinnata* fiber reinforced composite indicates that 15 wt. % chopped random *Arenga pinnata* fiber reinforced epoxy composite has a maximum flexural strength and Young's modulus values of 83.308 MPa, 3631 MPa respectively. While 20 wt.% chopped random *Arenga pinnata* fiber has the lowest tensile strength and Young's modulus values (Fig. 3 and 4).

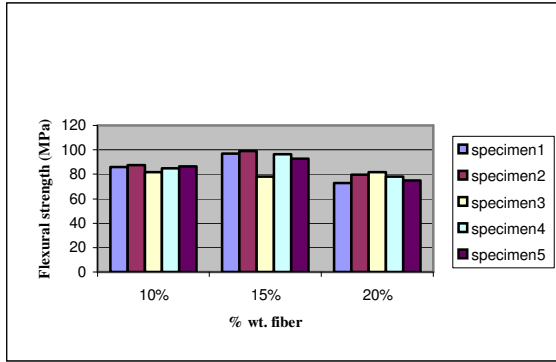


Fig. 1: Flexural strength versus % wt. of long random fiber

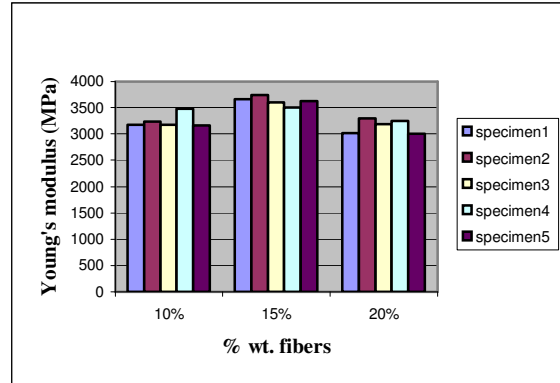


Fig. 4: Flexural modulus versus wt. % of chopped random fiber

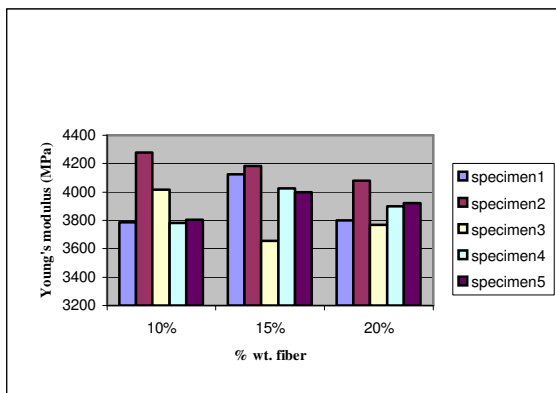


Fig. 2: Flexural modulus versus % wt. of long random fiber

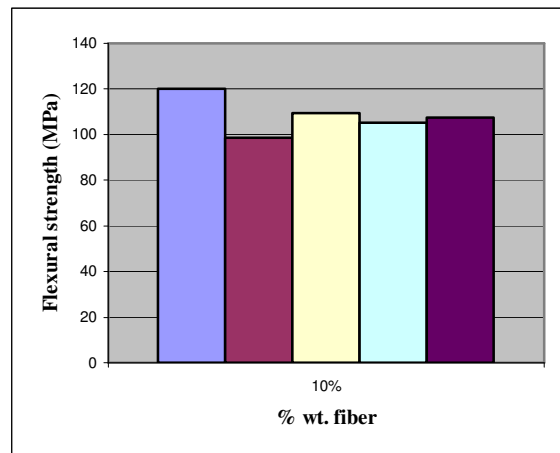


Fig. 5: Flexural strength versus % wt. of woven roving fiber

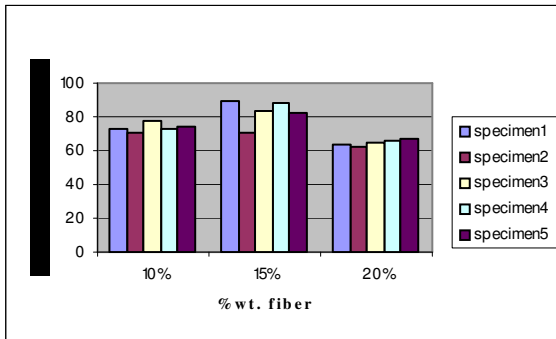


Fig. 3: Flexural strength versus % wt. of chopped random fiber

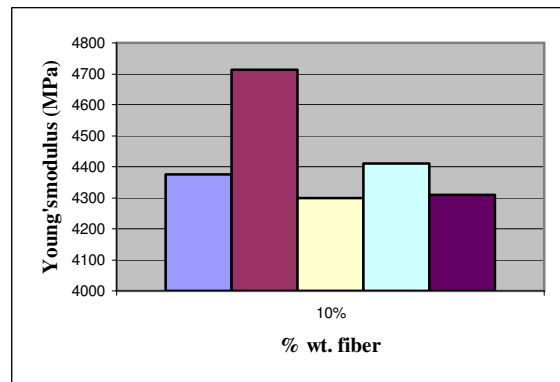


Fig. 6: Flexural modulus versus % wt. of woven roving fiber

Woven roving *Arenga pinnata* fiber composite: Woven roving *Arenga pinnata* fiber reinforced epoxy composite has the highest tensile strength and tensile modulus values has been explained before. Figures 5 and 6 show the results of flexural test properties of woven roving *Arenga pinnata* fiber and it will compared to the result of long random *Arenga pinnata* fiber and chopped random *Arenga pinnata* fiber reinforced epoxy composite.

Figure 7 and 8 show the flexural strength and Young's modulus charts respectively of long random

Arenga pinnata fiber composite, chopped random *Arenga pinnata* fiber composite and woven roving *Arenga pinnata* fiber composite.

Figure 7 shows the flexural strength of *Arenga pinnata* fiber-epoxy composite. The trend is observed here whereby the woven roving *Arenga pinnata* fiber composite and long random *Arenga pinnata* fiber composite has a superior flexural strength result

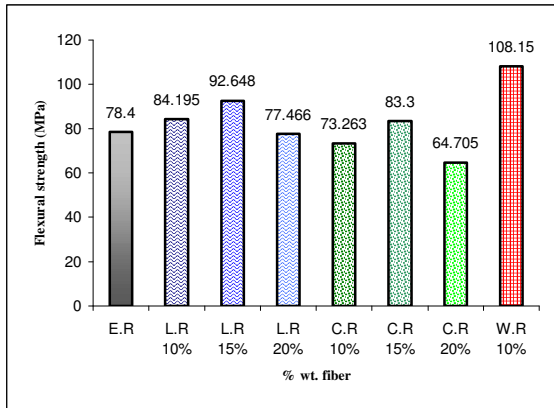


Fig. 7: Flexural strength versus fiber percentages and orientations

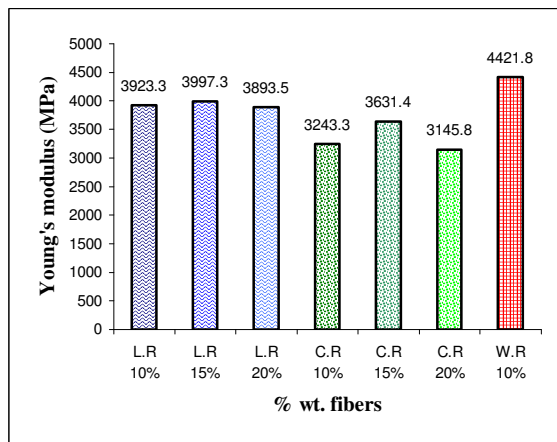


Fig. 8: Young's modulus versus fiber percentages and orientations

compare to the chopped random *Arenga pinnata* fiber composite. It resembles the result of Azis and Ansell^[4] that reported the long fibers of hemp and kenaf fibers, which has superior flexural strength values compared to the short random of hemp and short random of kenaf fiber composite. The flexural strength values are dependent very much on the fiber orientation and the location of resin-rich areas. Therefore, long fibers tend to give better strength due to their good fiber orientation. The specimen test of chopped random *Arenga pinnata* fiber composite is broken easily and could not resist bending. It is possibly because the chopped random *Arenga pinnata* fiber orientation has caused many voids forms in the specimen curing process of composite materials.

Compared to the long random *Arenga pinnata* fiber composite, the Young's modulus of the chopped random *Arenga pinnata* fiber composite was much lower. This is due to the random orientation of the fibers, which makes their mechanical properties inferior, compared to the long random unidirectional orientation.

CONCLUSION

In this study, mechanical properties particularly for flexural properties of *Arenga pinnata* fiber reinforced epoxy composites are described. On the basis of the experimental evidence, the conclusions are as follows:

The results of flexural strength test of *Arenga pinnata* fiber reinforced epoxy composites showed that the 10 wt. % woven roving fiber has the highest value compared to other fiber content.

The results of present study have showed that using *Arenga pinnata* fibers as a reinforcement agent for the epoxy matrix could successfully develop a beneficial composite particularly in term of strong and rigidity.

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