Effect of Fibre Length and Sea Water Treatment on Mechanical Properties of Sugar Palm Fibre Reinforced Unsaturated Polyester Composites

A.M.N. Maisara, R.A. Ilyas, S.M. Sapuan, M.R.M. Huzaifah, N. Mohd Nurazzi, S.O.A SaifulAzry

Abstract*: *This study presented the effect of different fibre length and seawater treatment on mechanical properties of the fabricated composites. The composite was reinforced with fixed 30wt.% of fibre loading. Sugar palm was treated using sea water for 30 days and have been cut into three different lengths by 5cm, 10cm and 15cm. The mechanical properties of the untreated and treated fibre with different fibre length composites were characterised includes tensile test and flexural test. Treated sugar palm fibre composites with 15cm fibre length exhibited higher tensile strength at 18.33 MPa. However, it shows the lowest value for the tensile modulus at 4251.96MPa. The flexural strength shows an increasing trend as the fibre length increased up to 15cm and the maximum flexural strength was exhibited by treated sugar palm fibre with 5 cm at 80.80MPa.

Index Terms*: *Sugar palm fibre, Seawater treatment, Unsaturated polyester, Mechanical properties.

I. INTRODUCTION

In these recent years, utilizations of natural fibre as main component in composites materials are well known and turned into a pattern. Indeed, even these days in industry, for example, automotive industry, they additionally utilized natural fibre composites to enhance mechanical properties of automotive parts [1]–[5]. Besides, natural fibre offers extraordinary mechanical properties when reinforcing with polymer materials. Malaysia has a lot of natural fibre sources accessible such as sugar palm, sisal, pineapples, rice husk, and jute fibre [6]–[9]. These fibres have a huge potential to be used as filler for polymer composites. The reinforcement of natural fibre gives new properties to the polymer composites. In biocomposite, as well as in any other natural fibre composite materials, the reinforcement of fibres within polymer have to show a high stiffness and tensile strength, whereas the embedding polymer matrix provides the shape of the composite structure, in which transmits the shear forces between the fibres, and hence protects them against aggressive media and radiation [8], [10]–[12].

The selection of suitable natural fibres can be determined by the required values of the tensile strength and stiffness of a composite. However, additional benchmarks for the choice of suitable reinforcing natural fibres must be considered such as processing costs, price of the natural fibre, thermal stability, dynamic and long term behaviour, elongation at failure and adhesion of fibres and polymer matrix. The mechanical properties of natural fibre and synthetic fibres are display in Table 1. Based on Table 1, it can be observed that tensile strength of natural fibre are 3 times lowered compared to synthetic fibre of E-glass and S-glass. However, in term of tensile modulus to weight ratio; flax, hemp and pineapple fibres and sugar itself are comparable to the properties of synthetic fibres [13].

Since there is a limitation of the interface issue between natural fibres (hydrophilic) and the polymer matric (hydrophobic), the interfacial bonding and interaction between the reinforcing fibres and the resin have become an important element to consider in the manufacturing of composite [14]–[16]. As an alternative, the surface modification of the fibres by chemical treatment has become one of the main interests of researchers nowadays. Comparing the chemical treatments listed [17], alkali treatment is the most common chemical treatment used which low cost and very effective surface modification and improve mechanical natural fibre properties [18].

A study on tensile properties of single sugar palm (*Arenga pinnata)* fibre was conducted by Bachtiar et al., [19]. Sugar palm fibres are cellulose-based fibres extracted from the sugar palm tree (*Arenga pinnata*) plant [20]–[25]. In this study, the fibres were undergoing retting process before were soaked in water tank. Based on the experiment result, the average tensile properties were obtained. The tensile modulus is 3.69GPa and tensile strength is 190.29MPa and lastly strain at failure is 19.6%. There are also other studies related to the sugar palm which is to determine effects of alkaline treatment

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and compatibilising agent on tensile properties of sugar palm fibre reinforced high impact polystyrene composited [26]. In this study, two different concentrations of alkali solution and two different percentages of compatibilising agent were used. About 40wt.% of sugar palm fibre was used. The findings from this study found all of the treated fibres composites shows enhancement in tensile strength compared to the untreated fibres composites. However, for the tensile modulus, there were no improvement observed.

Besides that, there was other study on alkaline treated sugar palm fibre using different matrix. The study was conducted to determine the effect of alkali treatment on flexural properties of sugar palm fibre reinforced epoxy composites [27]. The composites were reinforced with 10% of weight fraction of fibre. They used two different concentration of sodium hydroxide (NaOH) with different three soaking time which are 1hour, 4hour and 8hours. Moreover, other study that was conducted by Bachtiar et al. [28] showed that the flexural, and thermal properties of untreated short sugar palm fibre reinforced high impact polystyrene (HIP) composites increased after the addition of natural fibre. In their experiment, five different weights of fibre loading (10 to 50%) were used. By increasing the weight loading of short sugar palm fibre within HIP was able to improve flexural moduli of the composites. Another study done by Norizan et al. [29] is to determine the effect of sugar palm yarn fibre loading on physical, mechanical and thermal properties. The composites used in this study had different weight fraction (10, 20, 30, 40 and 50wt.%) of sugar palm yarn fibre that were prepared using hand lay-up method. The mechanical properties of the composite show the optimum loading achieved at 30wt.% of fibre loading.

Therefore, the aim of this study is to determine the effect of fiber length on mechanical properties of treated and untreated randomly distributed sugar palm fiber reinforced unsaturated polyester composites. In this study, two types of specimen were fabricated. The first type using untreated SPFs while the second type using treated SPFs. The second types of specimens are treated using seawater. There are two parts involve in this study. First part is preparation of natural fiber composite samples and second part is experiment process. For the first part, 3 groups of different length of sugar palm are weighted. All of these 3 groups will have 70wt.% of unsaturated polyester and 30wt.% of sugar palm fiber. Next, for the second part, experiment is conducted to determine the mechanical properties for the specimen prepared in first part. Two mechanical testing will be conduct; there are tensile test and flexural test. Eventually, these will define the mechanical properties of the composites.

II. MATERIALS AND METHODS

A. Materials

The sugar palm fibres were obtained from the villagers in Kg. Kuala Jempol, Negeri Sembilan, Malaysia. The unsaturated polyester used as polymer matrix was supplied by Sue Evergreen Sdn. Bhd, Semenyih in Selangor, Malaysia. The seawater for fibres treatment gain from Port Klang West Port, Malaysia.

B. Preparation of Sugar Palm Fibres

For the fibre treatment, fibres were soaked in the seawater for 30 days. After 30 days, the fibres were dried using laboratory oven with temperature 60°C for 24 hours. Then, the untreated and treated fibre was cut into three different lengths which are 5cm, 10cm and 15cm. Sugar palm fibres loading used for the manufacturing of composites was fixed at 30wt.% and unsaturated polyester is 70wt.%. Fig. 1 shows the treated fibres that had been prepared for fabrication process.

Fig. 1. Treated sugar palm fibre with different fibre length

C. Fabrication of Composites

Firstly, mould was sprayed with wax release agent to avoid sticking and easy to peel when the composites sample is cured. A hand lay-up technique is used in fabricating process. Sugar palm fibre was randomly distributed in closed steel mould with dimensions 150mm × 150mm × 3mm. Then, the mixed resin was poured over the fibre. After pouring, the mould was closed and the sample was left for 24 hours under the room temperature.

D. Fabrication of Composites

The tensile test was performed using an Instron 3365 test machine according to ASTM D3039. The dimensions of the samples were 150mm x 15mm x 3mm with a crosshead speed of 5mm/min applied for the test. For each length, 5 specimens are test to failure and used in calculating average tensile value. A flexural test was performed using the three-point bending method using an Instron 3365 test machine according to ASTM D790. The dimensions of the samples were 127mm x 13mm x 3mm. The crosshead speed was set at 5 mm/min and a support span-to-depth ratio is 16:1. For each length, 5 specimens are test for evaluating flexural properties of reinforced plastics.

III. RESULT AND DISCUSSION

A. Tensile Properties

The maximum load, tensile strength and tensile modulus were investigated, and the results are presented in Fig. 2-4. From the results, treated fibre composite shows the highest maximum load compare to untreated fibre composite. For treated fibre, composite with 15cm fibre length exhibited the highest average maximum load at 824.74N, followed by the 10cm (713.72N) and 5cm (675.69N) of fibre length composites. Result shows an increasing load trend when different fibre length were used for the composites. This might be due to the effects of stress transfer from matrix to sugar palm fibres, in which the longer the fibres the more efficient the stress transferred.

According to Atiqah et al., [30], this stress transfer plays an important role in determining the mechanical properties if the composite. Treated fibre composite can withstand high load when increase the length of the fibres. This specimen can be considered as rigid since it can withstand load higher then bending it. There is no clear difference in load value for untreated specimen for all fibre length but for treated specimen, load value increased when the fibre length is increased up to 15cm.

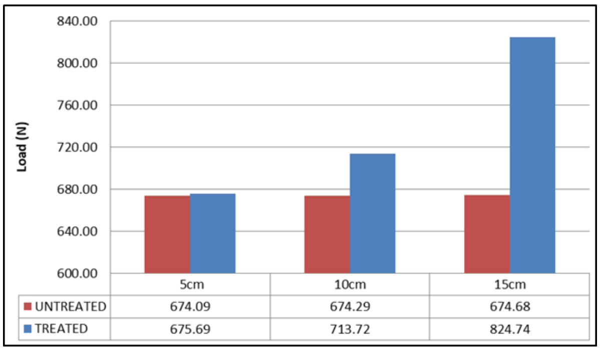

Fig. 2. Maximum Load

Fig. 3 demonstrates the tensile stress of the treated and untreated fibre composites. Based on Fig. 3, the difference in value are small where treated sugar palm fibre composite shows the highest tensile stress compare to untreated sugar palm fibre composite. For untreated sugar palm fibre composite with 15cm of fibre length shows the highest average tensile stress which is 18.33MPa, followed by the 10cm and 5cm fibre length, 15.86MPa and 15.02MPa, respectively. The results of treated fibre composite showed the ability to withstand more stress than the untreated sample.

Better tensile stress properties were observed at treated fibre composite as the fibre length increased. The enhancement in tensile stress of treated fibre composite is attributed to the improved wetting of treated fibre with the matrix. Indeed, by removing the impurities and waxy substance from the fibre surface and the creation of a rougher surface after the treatment, the mechanical interlocking and thus the interface quality will have promoted. Hence leads to higher strength of the composites structure [31]-[32].

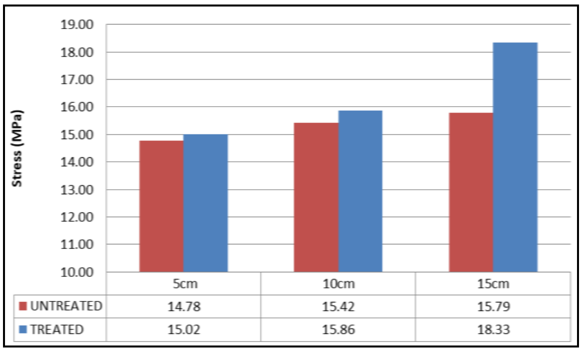

Fig. 3. Tensile strength

Fig. 4 shows the results of tensile modulus for treated and untreated specimen with different fibre length. The decreasing trend was observed for both untreated and treated fibre composite as fibre length increased. The highest tensile modulus for untreated fibre composite was achieved at 6812.19MPa while for treated fibre composite was achieved at 4776.44MPa, which mean 30% lower than the untreated fibre composite.

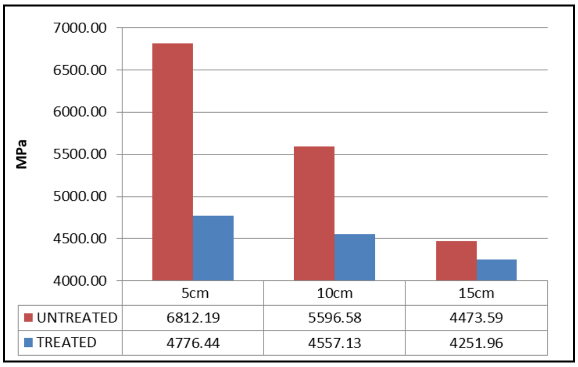

Fig. 4. Tensile modulus

B. Flexural Properties

Referring to Fig. 5 the load value for both untreated and treated composite increased as the fibre length increased. In flexural test, failures mainly occurred due to bending and shearing. The increased flexural strength of the composites with the increased of fibre length was mainly due to the increased resistance to shearing of the composites [33]. Comparing both, the higher load was achieved by treated fibre at 15cm fibre length (131.30N). Therefore, the significant result shows that the longer the length of fibre, the higher value of load the material can withstand until the failure occurred.

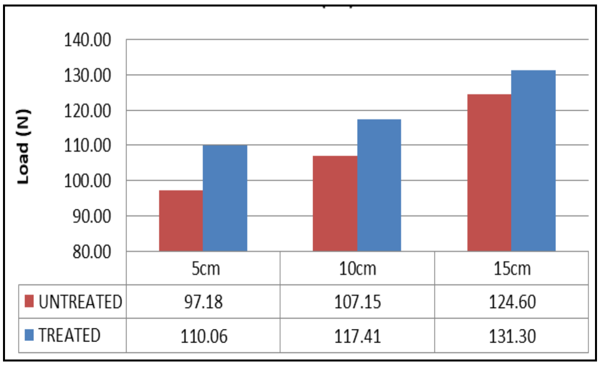

Fig. 5. Flexural load

Fig. 6 shows result of a maximum flexural strength . It is clear that treated fibre composite shows higher stress value than untreated fibre and the stress value increased as the fibre length increased. For the untreated fibre composite, the values showed increasing trend of strength for 59.80MPa at 5cm fibre length, 65.94MPa at 10cm fibre length and 76.68MPa at 15cm fibre length, showing an increasing interval around 10 MPa for each step size. While treated value show 67.73MPa higher than untreated at 5cm length, 72.25MPa at 10cm and 80.80MPa at 15cm of fibre length.

During flexural test, load was subjected at the middle of the composites until failure occurred, the incorporation of long and continuous fibres in the composites acted as carriers of the load and the stress was transferred from the matrix along the fibres. This led to an effective and uniform stress distribution. This happened at 15cm of fibre length reinforced composites. However, for the 10cm and 5cm of fibre length composites, the short and discontinuous (fibre end effects) fibres when the force was applied at the middle detracted from the effectiveness of the uniform stress distribution.

Besides that, the remarkable improvement value of flexural strength on the treated fibre composites from the untreated fibre composite was due to the better interfacial adhesion between the sugar palm fibre with unsaturated polyester resin [22]. The improvement of interfacial adhesion of the sugar palm fibre was due to removal of impurities and effect of fibrillation that caused unsaturated polyester resin easily to penetrate into the sugar palm structure and increased the surface contact area with the matrix. Hence, higher stress needed for the failure occur [23].

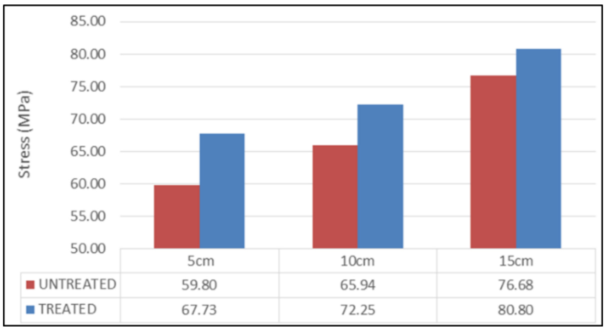

Fig. 6. Flexural load

IV. CONCLUSION

Overall, this study is conducted to identify the effects of fibre length on mechanical properties of treated and untreated on randomly distributed sugar palm fibre reinforced unsaturated polyester composites. Thirty samples of specimen have been tested. Based on testing results, the study found that treated fibres has better mechanical properties compared to untreated properties. Besides that, 15cm length of fibre has better performance compared to 5cm length and 10cm length. However, for tensile testing, the treated specimen is less elastics compared to untreated specimen. For the length different, the higher the length of the fibre, the less the value of the tensile modulus.

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