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The Application of Biocomposite Material as Drain Cover

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ABSTRACT

This paper presents the study on the application of coconut coir fiber reinforced polypropylene composite as drain cover. The tensile and flexural test of the coconut coir fiber reinforced polypropylene composite was examined at three different ratios, 90PP:10CC, 80PP:20CC and 70PP:30CC of coconut coir particles according to ASTM D638 and ASTM D790-99 respectively. Water absorption test was also conducted to determine the water absorption and thickness swelling and were performed using ASTM D570-98. Experimental results showed that the tensile and flexural properties of the composite grew as the filler particle content increased. The results also revealed that as the elastic modulus of the composite intensified, the tensile and flexural strength of the composite weakened. The water absorption and thickness swelling also has a linear relation with the filler particle content as when the filler content increased, the water absorption and thickness swelling rose as well.

Keywords: *Biocomposite, coconut coir, polypropylene, drain cover*

Introduction

Biocomposite, also known as natural fiber composite produced from local and renewable resources provides exceptional sustainability where industrial ecology, green chemistry and eco-efficiency are leading the development of the next generation of materials, processes and products [1]. Many sectors have shown promising growth in the usage of biocomposite materials such as building materials, circuit boards and also in the aerospace and automotive sectors. For now, the implementation of biocomposite materials are still limited. However, with suitable and further enhancements of its properties, biocomposite materials can enter new markets and create a surge in demand. Further investigations and improvements on the biocomposite materials have its merits because natural fibers have great potential in replacing petroleum or non-renewable materials in various applications [2-3].

Natural fibers advantages include low cost, low density, renewable, sustainable and also possess low abrasive wear during production [4]. This makes it very suitable to be utilised in low cost and low strength applications. This research is focused on the application of biocomposite material as drain cover. Drain cover is a grating used to cover the water drain. It prevents larger objects from falling into the drain and clogging it. Most of the drain cover nowadays is made of metal. The most common type of metal used is mild steel. There are also concrete and polymer type drain covers. However, for the past decades, research has been shifting their interest from monolithic materials to fibre-reinforced polymeric materials [5]. Therefore, this study is made with the prospect of replacing the monolithic materials such as steel, polymer and concrete as the drain cover material.

Malaysia is very famous for its agriculture but it also produces large amounts of agricultural waste. According to the Malaysian Agricultural Research and Development Institute (MARDI), from June 2017 until December 2017, the total amount of yard waste generated was 16.75 tonnes on the dry weight basis [6]. Coconut coir is one of the wastes that can be reused as a composite material reinforcement. The coconut residue is usually burned in open air or disposed. Instead of discarding these fibres, it can be utilised as a biocomposite material. Studies have shown that the addition of coconut coir can improve the properties of thermoset and thermoplastic materials [1].

Currently, the type of polymer used to make the drain covers available in the market is sturdy polypropylene. Therefore, by adding coconut coir as the reinforcement in the polypropylene matrices, it can improve the properties of the polypropylene. Other than that, it can also reduce the production cost of the drain cover as compared to the current design made entirely of polypropylene material. In addition, this research is beneficial as the biocomposite can be a suitable alternative material for manufacturers due to its low cost, improved properties and is also eco-friendly and reduces agricultural waste.

Methodology

Material preparation

For this study, the reinforcement material is the coconut coir fibres. The fibres are extracted from used coconut fruits through conventional methods. The brown fibres of the coconut coir was chosen over the white fibres as it has better strength properties. Polypropylene will be the polymer matrices for this composite. The material was supplied by Polypropylene Malaysia Sdn. Bhd. The coconut coir (CC) particles will be used as the filler for polypropylene. First, the CC was extracted from the fruit conventionally which involves repeating retting and decortication actions. The CC is located between the outer skin and the shell. Normally, the CC is wet therefore all the CC extracted was dried in the oven for twenty four hours at 80 °C. This step is to prevents any moisture from existing in the fibres which can affect the properties of the composite. Next, the dried CC was sieved using a siever to produce particles of 500 µm. The CC particles are then mixed with the polypropylene (PP) pellets in the dispersion mixer. The composite was then processed and mixed in the mixer at a temperature of 180 °C and 6 rpm. The CC particles were weighed before mixing according to the ratio intended which are 90 PP:10 CC, 80 PP:20 CC, and 70 PP:30 CC. Then the mixed composites were taken to a crusher machine to change the shape of the mixed composites into pellet shape with uniform size.

Hot pressing is the process to produce the three-dimensional samples of the material. The mould used is a hand layout mould with size 250 x 210 x 3 mm. Three steps were carried out when hot pressing the composites. First, the composite pellets were filled into the mould cavity according to the weight measured and were preheated for five minutes. The temperature for the preheating process was 200 °C. The mould was then pressed for five minutes at a pressure of 500 psi. Lastly, the composite was transferred from the hot press machine and was then cold pressed and let to cool at room temperature.

Mechanical Testing

Three-point flexural bending tests were performed abiding to ASTM D790-99 on an Instron universal testing machine at room temperature. The speed of the crosshead was 2 mm/s. The measurement of the specimen tested was 120 x 12.7 x 3 mm. The supported span for the specimen was 70 mm.

Tensile testing were done following ASTM D 638 which included tensile strength, tensile modulus and elongation. This test was made to measure the force needed to break a plastic specimen and their extension ability when the specimen was under tensile force. The machine used for this testing was an Instron universal testing machine. The measurement of the specimen was 150 x 20 x 3 mm. The test speed used was 2mm/min. the result of this experiment can be calculated from the stress-strain curve. The initial results of the test which is the relation of the stress and the strain was linear.

Water absorption and thickness swelling test were done following the ASTM D570-98 with modified specimen size of 10 x 10 x 3 mm. The purpose of this test was to measure the rate of water diffusion into the material and the dimensional stability of the material when submerged into water. First the specimen was conditioned at relative humidity of 60 ± 5 % and temperature of 23 ± 2 °C. Then, the weight of the specimen was measured to the nearest 0.001 g. All the specimens were then completely immersed into distilled water at room temperature for 24 hours. After 24 hours, the specimens were taken out from the distilled water, dried and wiped the surface using tissue paper and immediately weighed. The initial and final reading of the weight were recorded.

Results and Discussion

Bending strength

Figure 1 and 2 shows the value of Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) for 100 % PP, and mixture of PP and CC with different ratios. In this study, the bending strength of 100 percent PP will be compared to the biocomposites of PP and CC at ratios of 90 PP:10 CC, 80 PP:20 CC and 70 PP:30 CC. Based on the results obtained in Figure 1, 30 percent CC has the highest value of MOE which is 1018.96 MPa. This was followed by 20 percent CC, 10 percent CC and 100 percent PP. From these results obtained, the pattern shows that as the ratio of CC increases, the MOE of the composites also increases. MOE is a quantity that measures the object resistance from being deformed when stress is applied on it. Therefore, the higher the MOE values, the stiffer the object. Thus, 30 percent CC is the stiffest material when compared to the other three ratios. This occurs due to the extra support provided by the reinforcements which is the CC particles. CC particles itself have its own mechanical strength and modulus of elasticity. Hence, the addition of CC particles into PP will increase the mechanical properties. According to the study done by Sapuan et al. [7], it also shows a linear relation between the percentage of CC and the mechanical properties of the composites where they reported as the percentage of CC increases, the flexural properties of the composite also increases.

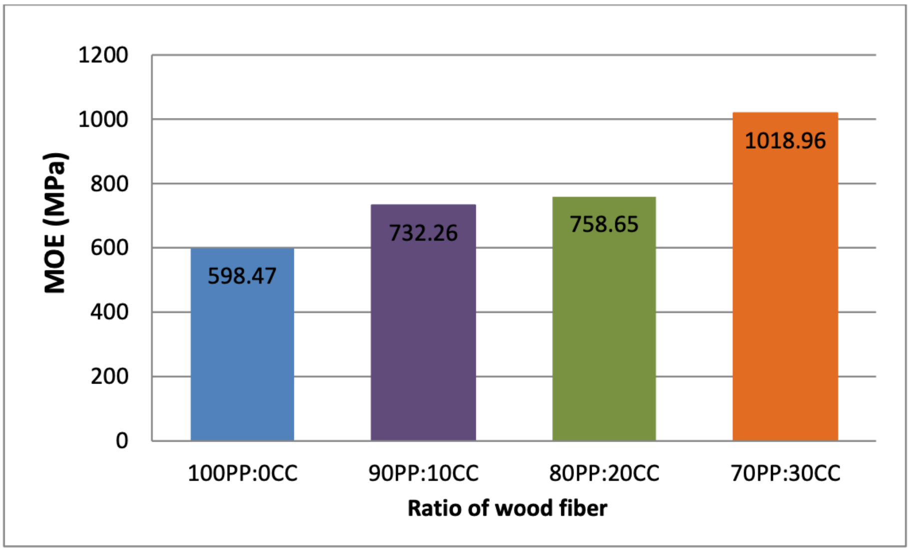

Figure 1: Modulus of Elasticity (MOE) for different ratios of PP and CC.

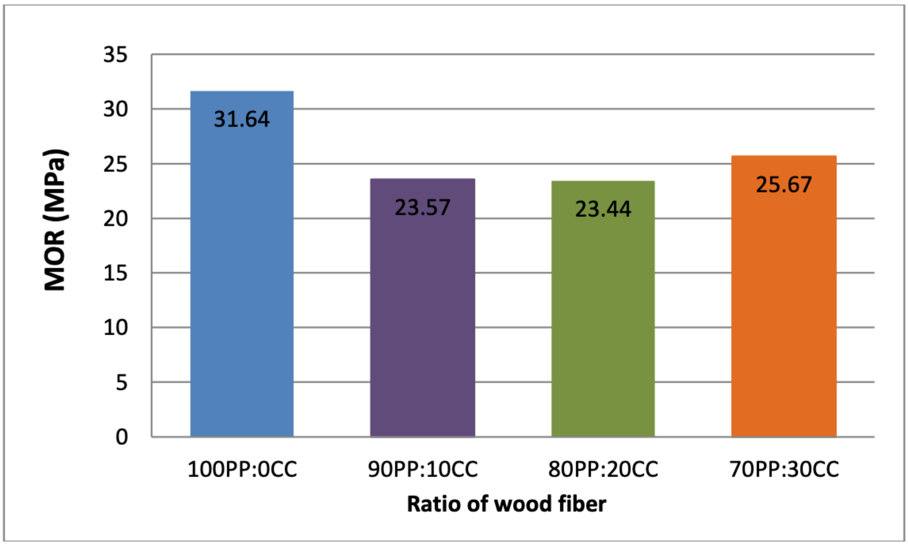

Figure 2: Modulus of Rupture (MOR) for different ratios of PP and CC.

Meanwhile, it can be seen from Figure 2 that 100 percent PP has the highest value of MOR with value of 31.64 MPa. It is then followed by 30 percent CC, 10 percent CC and 20 percent CC. MOR or also known as flexural strength is the value of stress before the material yields. The pattern of MOR from the results is irregular. However, the pattern should be linear but the opposite with MOE where the higher value of MOE leads to lower value of MOR. This irregularity may happen due to bubbles that occur in some of the five specimens. The MOR of 10 percent CC should be higher than 20 percent CC MOR and 20 percent CC MOR should be higher than 30 percent CC MOR but due to bubbles present in the samples, it affects the strength of the material. Thus, specimens with bubbles result in lower value of MOR than it should be. This leads to irregular pattern of overall MOR results. According to study by Lai et al. [8], the results show that as the weight percentage of reinforcement increases, the flexural strength decreases and the flexural modulus increases. This supports the results of this test where the MOE increases with the increases of ratio of PP while MOR decreases with increases of ratio of PP.

Tensile strength

Figure 3 and 4 shows the value of Young's Modulus (YM) and Ultimate Tensile Strength (UTS) for 100 percent PP, and mixture of PP and CC with different ratios. In this study, the tensile strength of 100 percent PP will be compared to the biocomposites of PP and CC at ratios of 90 PP:10 CC, 80 PP:20 CC and 70 PP:30 CC. Based on Figure 3, 30 percent CC has the highest Young's Modulus (YM) with values of 816.65 MPa followed by 20 percent CC, 100 percent PP and

10 percent CC. There is slightly a non-linear pattern in the values of YM where YM of 10 percent CC is lower than YM of 100 percent PP. The relationship should be linear that is when the CC percentage increases, the YM also increases. This non-linearity might occur due to bubbles that have been found in the specimens of 10 percent CC for the tensile test. The voids caused by bubbles affect the tensile modulus of the composites. Hence, it makes the YM values for 10 percent CC to be lower than the actual value. However, the linear pattern can be seen through 100 percent PP, 20 percent CC and 30 percent CC where the ratio of CC increases, the YM value increases. Results shown by Sapuan et al. [7] also indicates that as the weight percentage of the filler increases, the Young's Modulus also increases.

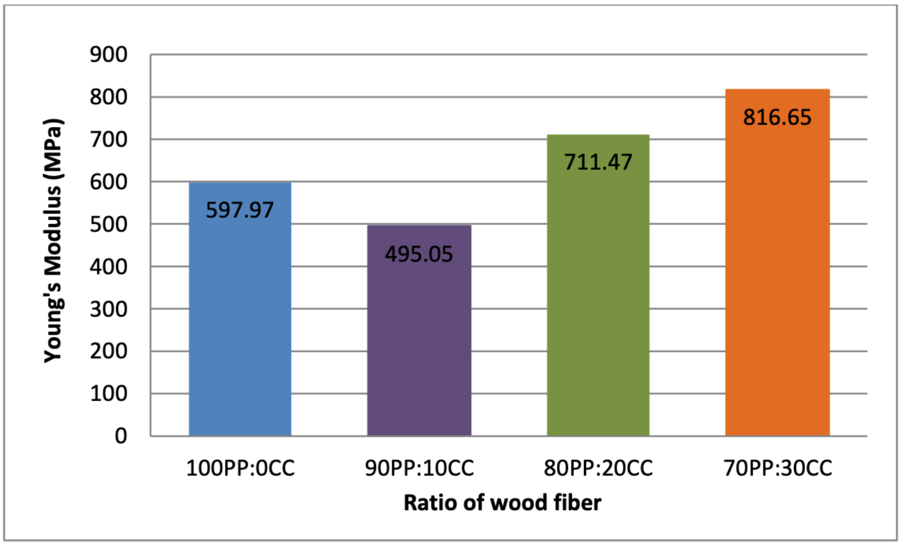

Figure 3: Young's Modulus (YM) for different ratios of PP and CC.

Based on Figure 4, 100 percent PP has the highest value of Ultimate Tensile Strength (UTS) with value of 26.27 MPa. Which is then followed by 20 percent CC, 30 percent CC and 10 percent CC. It also has slightly non-linear pattern where the value of UTS for 10 percent CC is lower than 20 percent CC and 30 percent CC. The UTS of 10 percent CC should be higher than both of 20 percent CC and 30 percent CC. This is also due to the bubbles that appear in the specimens of 10 percent CC. However, the decreasing pattern can be seen through the decreasing of UTS from 100 percent PP to 20 percent CC and 30 percent CC. Similar findings were also reported where the tensile strength decreases as the weight percentage of the filler increases [7]. It also reported that, as the value of Young's Modulus increases, the value for tensile strength will decreases.

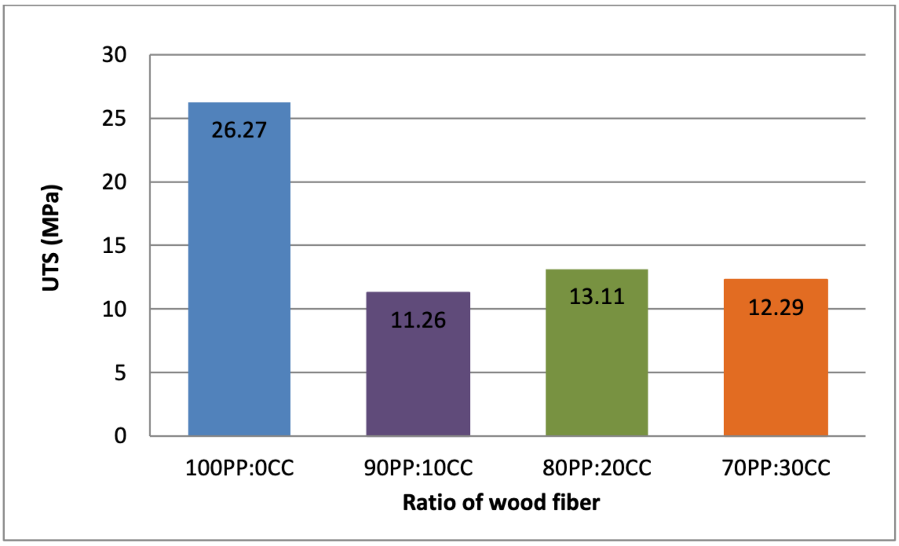

Figure 4: Ultimate Tensile Strength (UTS) for different ratios of PP and CC.

Water absorption and thickness swelling

Figure 5 and 6 shows the value of water absorption (WA) and thickness swelling (TS) for 100 percent PP, and mixture of PP and CC with different ratios. It can be seen that 100 percent PP does not have any WA or TS. From WA results in Figure 5 and 4, 30 percent CC has the most WA percentage which the value is 3 percent. Then it was followed by 20 percent CC and 10 percent CC. The values are 2.3 percent and 2.1 percent respectively. The pattern shows that as the CC percentage increases, the WA percentage will also increase. From Figure 6, it has been identified that 30 percent CC also the highest value of thickness swelling which is 3.9 percent. Then it was followed by 20 percent CC and 10 percent CC with values of 2.7 percent and 1.8 percent respectively. The pattern also shows that as the CC percentage increases, the TS percentage also will increase. Other than that, it also shows that as the WA percentage increases, the TS percentage will also increase. From the previous study by Lai et al. [8], it shows that as the Kenaf fiber loading increase, the water absorption percentage will also increase. One of the main factors of the water absorption is the percentage of wood fiber. According to a study done by Sommerhuber et al. [9] the existence of hydroscopic substances such as carbohydrates and lignin in a wood cell wall are the main cause of more water uptake. Therefore, as the filler percentage increase, it will increase the water absorption percentage. Other than that, it may also affected by internal air voids and porosity. According to Binhussain and El-Tonsy [10], moisture in the natural cellulose fibers produces steam and vapour during mixing of wood, high density polyethylene and maleic anhydride while at high melting temperatures, plastic decomposition creates a volatile organic compound which both of this leading to the development of porosity and internal air voids. This porosity and internal air voids would also affect the rate of water absorption.

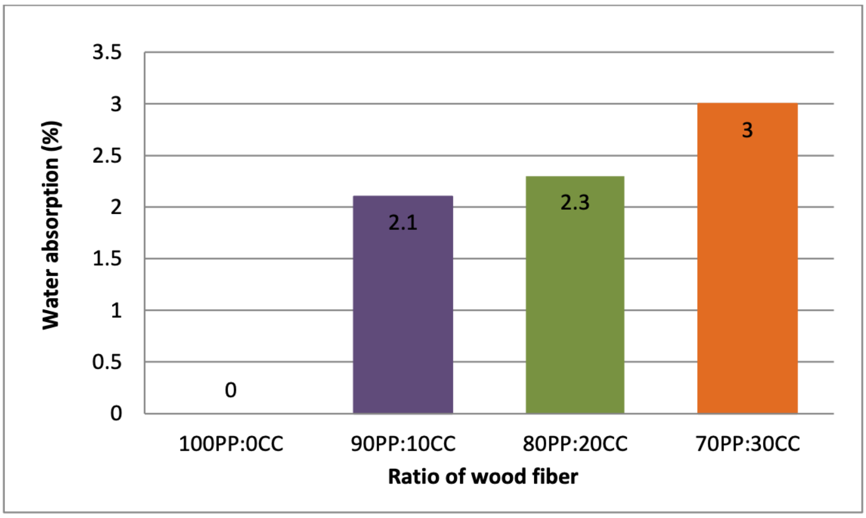

Figure 5: Water absorption (WA) for different ratios of PP and CC.

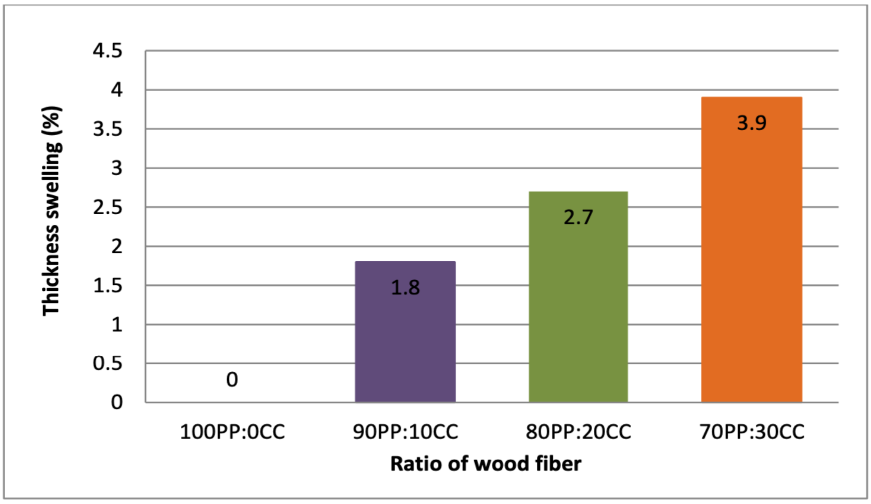

Figure 6: Thickness swelling (TS) for different ratios of PP and CC.

Conclusions

Based on the findings of this study, the addition of CC filler in PP provides better mechanical and physical properties when compared with 100 percent PP. Other than that, several conclusions can also be made from this study. First, the tensile and flexural strengths of coconut coir reinforced polypropylene composites were affected by the amount of filler in the composite. Next, it also shows that as the elastic modulus increase, the flexural and tensile strength will decrease. Furthermore it can also be concluded that addition of CC filler in the PP causes the composite to be stiffer which means, lesser strain allowed before the material ruptures. From the water absorption results, it was found that the more the filler percentage, the WA percentage and TS percentage will also be higher. Therefore, the biocomposite material is suitable to be used in the application of drain cover as it increases both the mechanical and physical properties of the material. Even though water absorption and thickness swelling might be in the way of the application, but the percentage of WA and TS when the material being submerge under water for 24 hours are small which are lower than 4 percent. Applications that relate to total submerge under water might have to be studied further, however for applications of drain cover it is applicable because drain cover does not submerge totally under water for a long time.

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