ISSN 2278-3091
Volume 9, No.1.1, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse7591.12020.pdf
https://doi.org/10.30534/ijatcse/2020/7591.12020

Utilization of PEFB Reinforced Box Waste Coated Super-hydrophobic Coating for Shoe Sole Applications

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ABSTRACT

This paper presents the utilization of palm empty fruit bunches (PEFB) reinforced with box waste for shoe sole applications. The main objective of this study is to determine the optimum composition of PEFB reinforced with box waste for shoe sole application. The use of PEFB and box waste for shoe sole as alternative to solve the environmental problem and change waste into zero waste which can support the green campaign and attain sustainable environment since both materials are low cost, daily waste materials and environmental friendly to reuse and modify into new products. The preparation of samples was involved grinding process of PEFB fiber and box waste, blending process of different percentage of PEFB in 20%, 40%, 60% and 80% with 50% of box waste, followed by mixing process with epoxy and hardener and finally coated with superhydrophobic coating based palm oil eco-resin by using spray gun techniques. The bonding between fiber-matrix of PEFB and box waste by ratio of 2:1 for epoxy resin and hardener as a binder. The physical test shows that the higher percentages of PEFB which is 80% was produced the lowest density of 1.06g/cm3 and highest porosity up to 0.44%. In term of water droplet test, all the percentages of PEFB produce the water contact angle up to 155.23° with coated superhydrophobic while 75.08° for uncoated surface. It is also conclude that 80% of PEFB reinforced with 50% box waste produced the most optimum composition for shoe sole application in term of physical properties.

Key words: Palm empty fruit bunches, Box waste, Shoe sole, Epoxy, Superhydrophobic coating

1. INTRODUCTION

The oil palm tree arises from tropical forests of West Africa which has now become a major rural crop and is cultivated commercially in Malaysia. Oil palm tree generally produced 10% palm oil and 90% biomass waste. By referring to Malaysian Palm Oil Council, 5.00 million hectares of land in Malaysia is under oil palm development nowadays which delivers 17.73 million tons of palm oil [1]. Based on Department of Environment (DOE), palm oil milling process

produced one tonne of fresh fruit bunches (FFB) which transformed into biomass waste in the form of palm empty fruit bunches (PEFB) around 0.234 tonne, then converted into PEFB fibre after being screw pressed [2]. Many million tons of PEFB had been produced annually throughout the world [3]. PEFB is an industrial biomass waste which is left unutilized after the removal of the oil seeds for oil extraction [4]. Previously, PEFB was always thrown and left to be rotten as no value-added product or burned into ash as fertilizer which led to global warming issue. Instead, it can be utilized as a very abundant, low cost, biodegradable, renewable resource for many applications [5]. Hence, in this study, the utilization of PEFB fibre as a reinforcement in shoe sole has economical as well as environmental benefits. Not only biomass waste, box waste also used in this study for reinforcement filler in shoe sole.

In this study, box waste that came from used corrugated paper box also utilized as the raw material for shoe sole application as shown in Figure 1. Accordance to Thanam Industry Sdn. Bhd. which is scrap and recycle specialists in Kuala Lumpur, Malaysia stated that every month, over 57,000 tonnes of paper product which can occupy 456,000 cubic metre of landfill area are thrown into landfills in the Malaysia, which equivalent of cutting down 680,000 trees of marketable size [6]. Therefore, reuse the box waste for shoe sole application can attain a better environment. This may help the industries to increase the level of economic opinion which turns waste into high added value product and promote ‘zero waste’ concept. The objectives of the study are to determine the optimum composition of PEFB reinforced with box waste for shoe sole application, and to evaluate the mechanical and physical tests based on different percentage of PEFB fiber reinforced with box waste. The physical tests such as density, porosity, water droplet test and SEM analysis of shoe sole samples was presented in this paper.

Figure 1: Shoe sole applications of EPFB mixed box waste

2. METHODOLOGY

2.1 Materials

In this study, PEFB fibers, box waste, epoxy resin and hardener were used as materials. PEFB fiber and box waste were used as raw materials to fabricate shoe sole. The PEFB fibers were purchased from T & H Coconut Fibre Sdn Bhd, Batu Pahat, Johor, Malaysia. The box wastes were freely provided from Wellward Shopping Centre, Parit Raja, Johor, Malaysia.

2.2 Preparation Samples of Shoe Soles

Four samples of shoe sole were prepared with different composition percentages of PEFB fibers reinforced box wastes as referred to Table 1. Firstly, PEFB fibers and box wastes were cleaned from any contaminants, such as sand and glue. Then, PEFB fibers and box wastes were chopped by using grinding machine. Next, the chopped PEFB fibers and box wastes were ground using grinder machine DF-15 Jooshun Model into nearly powder form approximately 20µm with speed of 3450 rpm. The ground PEFB fibers and ground box wastes were blended together using dry mill based on the different composition percentages. Then, the mixture of ground materials were stacked and mixed together with epoxy resin and hardener. When the blended form of PEFB fibers and box wastes were completely wet by resin, the final mixture was poured into closed aluminum mold size of 302 x 302 x 3 mm. Before using mold, the aluminum mold was first polished and a layer of silicone spray lubricant was sprayed on surface to act as mold-releasing agent. The mold with a fixed thickness of 3 mm is then pressed and sandwiched between other two aluminum molds, followed by locking into eight directions using screws and cured at room temperature for 24 hours. After one day, the shoe sole samples was taken out using scraper and hammer. Figure 2 showed the sample of shoe sole prepared.

2.3 Preparation Samples of Shoe Soles

The solution of superhydrophobic coating is required for formulate. Superhydrophobicity of the coating provide a self-cleaning or water-repellent characteristic that prevents peeling, thereby extend the life expectancy of the coating [7]. The components are the important parts for superhydrophobic coating solution. The solvent and hardener were used for mixture of superhydrophobic coating solution. The ratio for solvent to hardener in this study is 3:1. The magnetic stirrer is used to mix solvent, hardener and addictive in a beaker for well mixed solutions. The mixed solution is loaded into the spray gun, and uniformly sprayed on to the surface of the sample by maintaining the spraying pressure at 0.2 - 0.3 MPa, the distance between the nozzle and sample is at 25 cm, and the spray angle is at 45º. The transparent coatings are deposited onto sample and water droplet is being transferred from dispenser syringe onto sample surfaces as referred in Figure 3.

Table 1: The composition percentage of raw materials in fabricating shoe sole

Samples	PEFB fibers percentage	Box wastes percentage	Ratio of epoxy resin and hardener
A	20%	50%	3:1
B	40%	50%	3:1
C	60%	50%	3:1
D	80%	50%	3:1

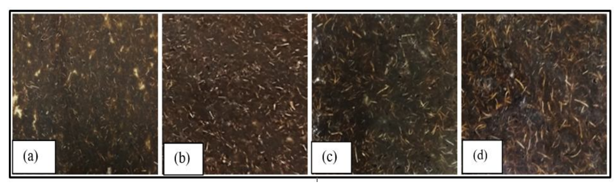


Figure 2: Shoe sole samples with different percentages of PEFB (a) 20%, (b) 40%, (c) 60% (d) 80% reinforced with 50% box waste

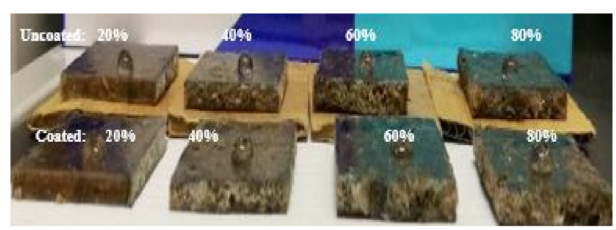


Figure 3: The sample of shoe sole uncoated and coated of superhydrophobic coating with different percentages of PEFB

3. RESULTS AND DISCUSSION

3.1 Density and Porosity Test

Density and porosity test (ASTM C20-00) had been carried out to measure the bulk density of sample by measuring its mass and volume, and void fraction (known as apparent porosity) of the sample as a fraction of volume of voids over total volume in between 0 - 100 %. The determination of density and porosity are performed by means of Archimedes principle (buoyancy method), which stated that a body immersed in a fluid apparently loses its weight by an amount equal to the weight to the fluid it displaces.

Figure 4 showed the density result of all samples which indicated in descending trend as the percentage of PEFB increased. The lower percentage of 20% PEFB obtained the higher density of 1.084g/cm^3, subsequently 40% of PEFB with 1.078g/cm^3, followed by 60% of PEFB with 1.074g/cm^3, lastly the higher percentage of 80% PEFB obtained the lower density of 1.057g/cm^3. This is due to the composition of higher percentage of PEFB in sample had the lesser amount of matrix which predominantly had a higher of 1.1g/cm3 density than reinforcement of PEFB and box waste itself. It is observed that the presence of fibers as fillers in epoxy matrix reduces the density of sample and hence makes it lightweight. This may be due to presence of the high air content inside sample [8].

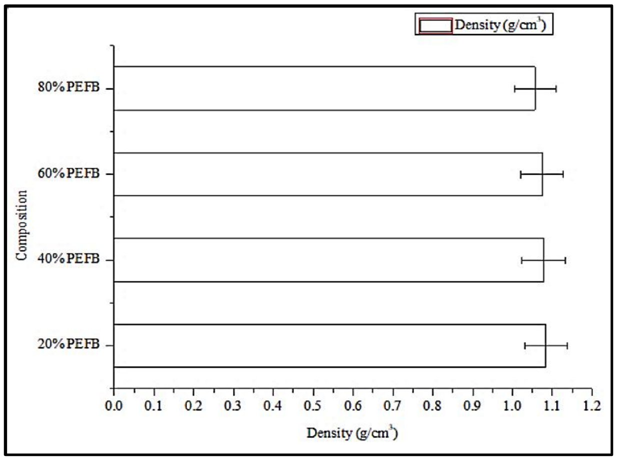


Figure 4: Density results at different percentage of PEFB

Figure 5 showed the apparent porosity of all samples which indicated in ascending trend as the percentage of PEFB increases. 80% of PEFB obtained the higher apparent porosity of 0.44%, subsequently 60% PEFB with value of 0.34%, followed 40% PEFB with apparent porosity of 0.31%, lastly was 20% PEFB with apparent porosity of 0.19%. The apparent porosity increases proportionally with increasing PEFB fiber loading. This significant increase in apparent porosity is due to the presence of fiber reinforced which caused creation of fiber–matrix interfacial areas and thus the concomitant formation of voids in the sample [9]. The increase in porosity with rising fiber content tended to make fibers clumping together during mixing, which resulted in entrapped of water-filled spaces that subsequently turned into voids [10].

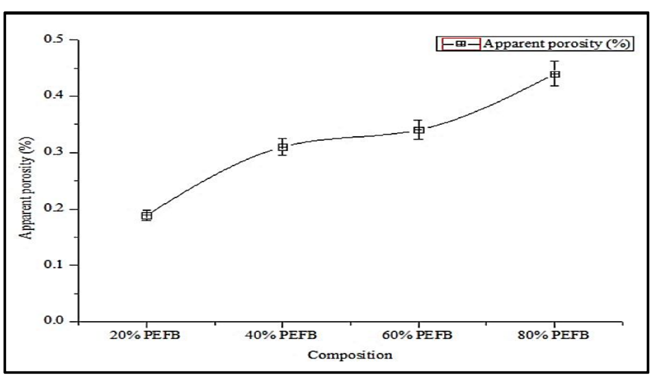


Figure 5: Apparent porosity results at different percentage of PEFB

3.2 Water Droplet Test

Water droplet test (ASTM D7334-08) was carried out to measure water contact angle of water repellency by direct measurement of angle from the drop profile. Water droplets were placed onto the sample with certain technique. The surface contact angle of the water droplet was taken photo using camera and measured using protractor. The angle below 90° is hydrophilic surface while the angle above 90° is considered as hydrophobic surface. For more than 150° is called superhydrophobic surface [11].

Table 2 showed the result of the actual angle of contact for uncoated sample is between the range of 63° to 77°, whereas for coated sample, the water contact angle is between the range of 91° to 100°. It can be concluded uncoated samples have a hydrophilic surface that tend to absorb water while coated samples have a hydrophobic surface that tend to repel water. The hydrophobic properties can be observed and evaluated based on the appearance and shape of water droplet. The water droplet shown on uncoated sample have a hemisphere oval-shape while the coated sample have hemisphere circle-shape. The water droplet is more spherical in shape for sample that have hydrophobic properties due to coating than the sample did not have hydrophobic properties [12]. As referred to Figure 6, the water contact angle of sample with hydrophobic coating is gradually decreased as composition of PEFB fiber increased. This might due to the hydrophilic nature of fiber that made the super hydrophobic coating had a lower function of making water repellent on sample surface. This super hydrophobic formulation has been observed would not stable in its structure due to higher amount of PEFB fiber and box waste in sample that generate hydrophilic residues on the coating. The result portrayed that the coated 20% of PEFB produced excellent hydrophobic characteristic at 155.23°.

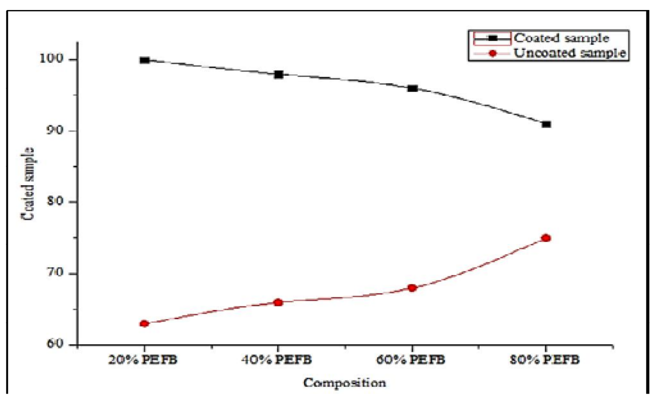


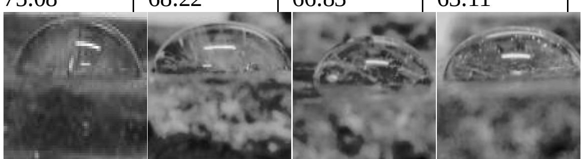
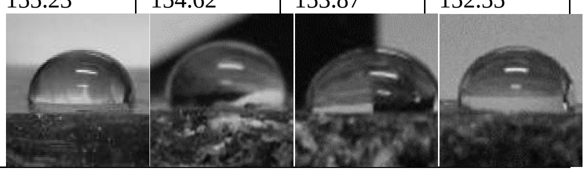
Figure 6: The water contact angle for uncoated sample and coated sample of different percentage of PEFB

3.3 Scanning Electron Microscopy (SEM)

Scanning electron microscope analysis (ASTM E766-14e1) was conducted using analytical Scanning Electron Microscope (SEM), model no: JEOL JSM-6380LA MP-19500014. The morphology of fiber-matrix bonding can be observed through this test. The magnification level is fixed at 50x for comparing the structure of each sample after destructive test.

Based on SEM analysis, it shown the 50x image magnification of matrix-reinforcement bonding for each shoe sole samples after conducting tensile strength. The best result obtained in 40% PEFB that shown a good matrix-reinforcement bonding as shown in Figure 7 (b). 20% PEFB as shown in Figure 7 (a) revealed the fiber being pulled out from sample and left a deep hole, indicated the poor adhesion between reinforcement and the matrix. For Figure 7 (c), 60% PEFB shown the matrix debris formed around with the fiber breakage and fiber splitting instead of being pulled out from matrix. The worst result for SEM analysis is 80% PEFB fiber as shown in Figure 7 (d) which had more fiber pull out from the matrix and left a wide deep hole, it might due to poor adhesion for matrix-reinforcement bonding due to lesser amount epoxy to form bonding with more PEFB fibers.

Table 2: Water droplet test of shoe sole samples for without superhydrophobic coating and with superhydrophobic coating

Composition / Type	Water contact angle			
	20% PEFB	40% PEFB	60% PEFB	80% PEFB
Without superhydrophobic coating	75.08	68.22	66.83	63.11
				
With superhydrophobic coating	155.23	154.62	153.87	152.55
				

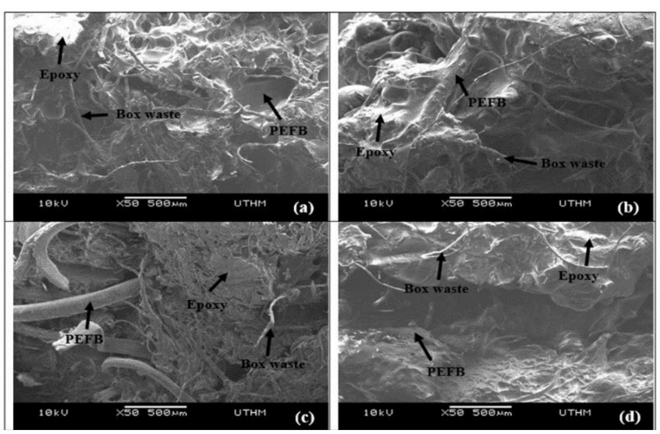


Figure 7: SEM analysis of matrix-reinforcement bonding in 50x image magnification by different percentage of PEFB (a) 20%, (b) 40%, (c) 60%, (d) 80%

4. CONCLUSION

In conclusion, the optimum composition percentage of PEFB fibers in 60% reinforced with 50% box waste is possible to be applied for shoe sole application. The physical tests were based on different percentage of PEFB reinforced with box waste for shoe sole application had been evaluated. Density of shoe sole samples was decreased as the PEFB fiber loading increased up to 80%. Porosity had shown the linear increasing when PEFB fiber loading increased up to 80%. This indicated the increasing fiber loading might formed water-filled spaces that turn into void formation and effect the tensile strength. For water droplet test, the contact angle shown the increasing trend of increasing of PEFB fiber loading for uncoated surface. However, there was different for the case of coated surface which shown the decreasing trend as fiber loading increases. This might due to the irresistible of hydrophilic nature of fiber that absorb water within pores despite it was coated with superhydrophobic coating. Scanning electron micrographs of tensile fracture surfaces were taken to study the morphology and failure mechanism of PEFB reinforced with box waste for shoe sole application and the best result is at 40% PEFB. Thus, PEFB reinforced with box waste is applicable for shoe sole application. The utilization of PEFB fiber and box waste for shoe sole application will eliminate the environmental problem of waste disposal and will lead to a new added-value product.

ACKNOWLEDGEMENT

The authos would like to thank the Universiti Tun Hussein Onn Malaysia for supporting this project under Contract Grant by UTHM Scheme under Vot U666

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