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Research paper

Mechanical Properties of Wood Polymer Composites (WPCs) After Prolonged Ultra-Violet (UV) Irradiation Exposure

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Abstract

This research aims to compare the mechanical properties of WPC made from 30 % of rice husk as fibre and 70 % of polypropylene as polymer with and without prolonged UV irradiation exposure. WPC samples are tested with UV irradiation at 5000, 10000, 15000 and 20000 hours with temperature 50 °C and tested with compression test (ASTM D695-15) and tensile test (ASTM D638-02), while physical properties characterization was done by density test (ASTM D792-13) and OM test. The compression and tensile result shows decrease value of mechanical properties due to the presence of chain breaking activity contributed from the process of photo oxidation throughout the UV exposure. The effect of UV exposure also resulted in decrease of WPC samples density value as the longer the exposure, the lower the samples density due to the losses of volatile particle. In conclusion, the weather ability of WPC was observed by prolonged exposure to UV radiation thus highlights the influence of parameters involved in the degradation rate of WPC as to contribute a good guidelines and resolution for the future growth of polymer composite structure.

Keywords: *Wood-polymer composites; rice husk, polypropylene; Ultra-violet; mechanical properties.*

1. Introduction

Polymer are type of natural or synthetic material made up of macromolecules, a composition of large molecules the macromolecules are formed after numerous unit of monomers, a simpler chemical unit is composed together. There are three types of polymers, which is thermoplastics, thermosetting plastics and elastomers. Thermoplastics polymers will reform when melted and hardened when cooled back [1].

Thermoplastic are material are built of polymers connected by intermolecular associations or Van der Waals forces, framing straight or extended structures. The greater the degree of combination of polymers, the higher the forces need to unattach the polymers from each other. Semi-crystalline thermoplastic resins consist of oriented macromolecules placed next to each other, pulled by auxiliary linkage forces. Typical semi-crystalline thermoplastic resins are like polyamide and polypropylene (PP). The degree of crystallization was based on the chain structure, versatility of chain molecule and weight of molecule [2]. Due to limited thermal stability of wood, types of thermoplastics that can be used for making WPC is the one that can be treated at temperature below 400°F (204.44°C) [3].

Polypropylene (PP) are the organic compound structured by linkage of larger quantity of many small unit known as monomers (propylene), where the process of compounding was called polymerization. Fiber is either a natural or synthetic material which its structure is hair-like threads, used in the production of other material. Natural fibers are a material produced mostly by vegetables fibers, animal fibers and minerals fibers [4-6]. Rice Husk (RH) are the tough cover that protects the grains of rice during their growth and need to be removed before the rice can be eat. RH are among one of the type of natural fibers from agricultural wastes and thus acts as reinforcing fiber in composites compositions. Use of rice husk in compositions of composite will increase the tensile strength and modulus of polypropylene and silica owing to the reinforcement effect of the particles [7].

There are few studies conducted to investigate the effect of UV exposure on mechanical properties and appearances of WPC. Composites based on PP decolorize faster than composites based on HDPE, both with wood content increment [8, 9]. Increase of wood fibers content also could decrease the elongation and impact properties of composites, but the tensile strength was gradually increased [10]. Value of stress and strain for samples also decreasing with the increment of hours of UV irradiation exposure due to the photo oxidation effect towards the composite, besides virgin composite sample shows higher compression strength and strain compared to the waste composites [11].

This research was conducted to study the effect of UV irradiation exposure to WPC samples and their mechanical properties with and without UV exposure are analyzed and observed in order to highlights the influence of parameters involved in the degradation rate of WPC as to contribute a good guidelines and resolution for the future growth of polymer composite structure.

2. Methodology

2.1. Sample Preparation

The overall dimensions of the WPCs decking 1225 ± 4 mm, 25.9 ± 4 mm and 147 ± 4 mm. The decking was then cut into respective dimension for compression test, tensile test and density test. All sample were cut using Vertical Bandsaw T-Jaw Model 360D that were available at the Lathe Machining Laboratory, UTHM.

2.2. Ultra Violet (UV) Weatherometer

The UV Weatherometer is an accelerated weathering test that exposed the samples to the alternating cycles of actual sunlight at predetermined and elevated temperatures and periods. Samples were exposed at 5000 hours, 10000 hours, 15000 hours and 20000 hours with temperature of 50°C. Machine used are UV Accelerated Weathering Tester (Haida International Equipment Co.).

2.3. Compression Test

Compression test of unirradiated and irradiated sample were conducted using the Universal Testing Machine (UTM) Testometric M500-100 kN, based on the ASTM D695-15 (Standard Test Method for Compressive Properties of Rigid Plastics). Total of 10 samples of 140 mm length, 25 mm width and 140mm height were used. The test parameters that were used in this test are standard speed of testing 1.3 ± 0.3 mm/min and also crosshead speed of 1 mm/min.

2.4. Tensile Test

Tensile test of unirradiated and irradiated sample will be conducted by using the ASTM D638-02a (Standard Test Method for Tensile Properties of Plastics) using the GoTech Tensile Tester Machine. Total of 25 samples of 28 mm length, 3.2 mm width and 140 mm height will be used. The test parameters used in this test were 100 cm initial distance between grips and crosshead speed of 5 mm/min.

2.5. Density Test

Density tests for the samples were carried out according to ASTM D3763 using density test instrument. Density tests was carried out on the samples after UV irradiation at prolonged hours.

2.6. Optical Micrograph (OM) Analysis

OM instrument was used to characterize structures of WPC by targeting at the surface defects after sample going through the compression and tensile test, in order to make simple failure analysis of components and contaminations of WPC samples.

3. Results and Discussion

3.1. Compression Test Result

Graph in Figure 1 shows the lowest maximum force obtained at 20000 hours with 46960 N and the highest compressive force was recorded at 5000 hours exposure with 58388 N. The maintained decreased value of maximum force was due to the losses of volatile particle when the samples is exposed to extended UV irradiation causing sample degradation and lower service life of WPC samples. [12]. Overall, the higher the UV irradiation exposure, the lower the maximum compressive force exerted by WPC samples before failure.

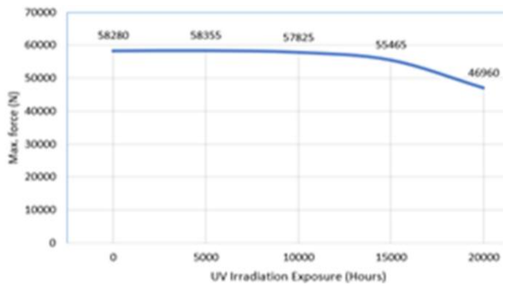

Fig. 1: Maximum force (N) vs UV exposure (hours)

Figure 2 shows that the lowest Young's modulus was obtained at 20000 hours with 78.086 MPa and the highest compressive force was recorded at 5000 hours with 129.96 MPa. This significant increment at 5000 hours may due to the stronger interfacial adhesion between PP matrix and rice husk fiber, contributed from the existence of coupling agent in WPC compositions [13]. Overall, as the UV irradiation exposure increased, the Young's modulus by WPC samples will decreased.

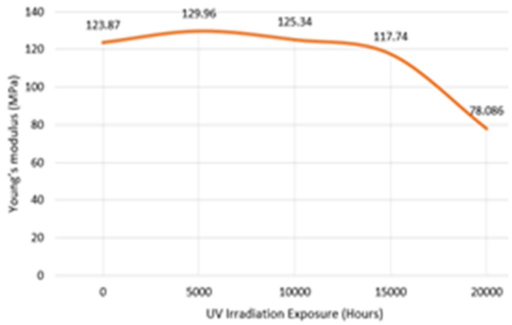

Fig. 2: Young's modulus (MPa) versus UV (hours)

3.2. Tensile Test

Graph in Figure 3 shows the maximum yield strength peaked at 0 hour with 22.122 MPa, while the minimum is recorded at 20000 hours with only 18.965 MPa. An addition of fibers to WPC compositions can significantly improve the tensile strength and modulus of PP composites as compared a WPC with lesser fiber percentage [14, 15]. The enhancement of tensile strength and modulus of composites was contributed by the addition of fiber adhesion together with the matrix. This improvement will then make the distribution of exerted stress will be more uniform besides need extra energy to de-bond fiber.

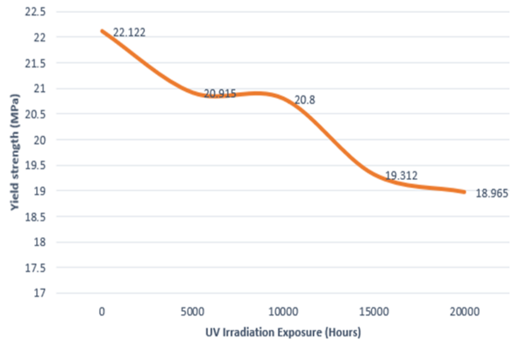

Fig. 3: Yield strength (MPa) versus UV (hours)

Figure 4 shows the tensile modulus of WPC at different UV irradiation exposure hour. Maximum tensile modulus shown at unirradiated hour with value 2396.73 MPa and the lowest is 1647.63 MPa at 20000 hours of irradiation. The slight increment at 15000 hours may due to the greater interfacial adhesion between PP matrix and rice husk fiber contributed from the existence of coupling agent [15]. Overall, as the UV exposure increased, the tensile modulus of WPC will decrease as an effect of photo degradation during the UV irradiation exposure.

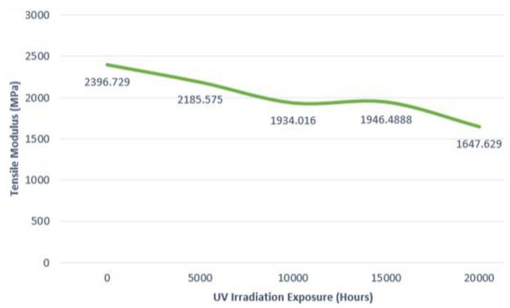

Fig. 4: Tensile modulus (MPa) versus UV (hours)

3.3. Density Test Result

Table 1: Density data of WPC

UV Irradiation Exposure (Hour)	Density (g/cm³)
0	1.4577
5000	1.4095
10000	1.3744
15000	1.3248
20000	1.2902

Table 1 shows the average result obtained from density test of WPC sample. Maximum value of density was recorded at 0 irradiation hour with 1.4577 g/cm³ and minimum value of density at 20000 irradiation hours with 1.2902 g/cm³. Figure 4 shows that UV irradiation does affect the density of sample as when the UV irradiation exposure is increased, the density of sample will decrease accordingly.

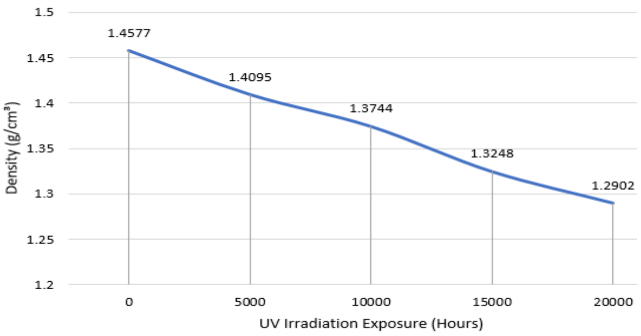

Fig. 4: Density (g/cm³) versus UV exposure (hours)

3.4. Optical Microscopy Analysis

It is clearly shown that at the fracture structure of WPC samples, rice husk fiber can be seen exist in WPC composition and voids are everywhere at WPC surfaces due to the fibre pull out. It is also observed that the main structure mechanism was fiber pull out and matrix cracks, specifically in tensile test while the main fracture mechanism in compression test was fiber breakage [12, 15-17]. Fiber pull out are due to the stress dispersion through the rice husk fiber and polypropylene matrix of tensile samples. The interface of the sample experienced a brittle fracture, which is a failure of a material that breaks into noticeable parts where deformation cannot be discovered.

4. Conclusion

Throughout this research, the objectives of this research have been successfully achieved which is the mechanical test of WPCs after extended UV irradiation exposure have been carried out. From the concluded results obtained from this research, it indicates that mechanical properties of WPCs with and without prolonged UV irradiation exposure has been compared from the mechanical and morphological tests conducted.

It can also be concluded that UV played a remarkable role in degradation of composite material strength and other mechanical properties as when the UV irradiation exposure increased, the mechanical properties of WPC will decrease too as an effect of photo degradation. Fiber tensile strength was found to decrease too with the increasing duration of UV hour.

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