THE EFFECT OF DIFFERENT TYPES OF FILLER ON THE MECHANICAL AND PHYSICAL PROPERTIES OF WOOD PLASTIC COMPOSITE FROM *EUCALYPTUS* spp.

Noorshashillawati Azura Mohammad[1*], Siti Noorbaini Sarmin[1], Nurul Husna Mohd Hassan[1], Siti Zalifah Mahmud[1], Nurrohana Ahmad[1], Fatma Adhira Shafiqa Mohd Akil[1]

[1]*Department of Wood Industry, Faculty of Applied Science*
Universiti Teknologi Mara UiTM Pahang, 26400 Bandar Jengka

[*]*Corresponding author: noorshashillawati@uitm.edu.my*

Abstract

Nowadays with increasing environmental concerns, many researchers start using biocomposites such as wood fiber, bamboo, sisal, hemp and flax for composites manufacturing. Generally, wood plastic composites (WPCs) have gained interest in commercial markets for automobile (interior panels, trunk liners, spare tire covers, and package trays) and construction (deck boards, stairs, post sleeves, and hand rails) fields. WPC needs lower maintenance than the alternatives of solid wood treated with preservatives or solid wood of rot-resistant species and claimed as more environmentally friendly by manufacturers. Since it can performs like conventional wood, it does not require special fasteners and design changes in application. In this study, our attempt for development of WPCs is focused on using wood fibers (*Eucalyptus sp.)* with polypropylene. Polypropylene is used, as it has high melting point of 170 °C and its mechanical properties are constant at ambient temperature. It also has dimensional consistency, impact resistance and high strength-to-weight ratios. Two types of fillers (virgin and recycled polypropylene) and three types of filler loadings (10%, 30% and 50%) were used for compounding with wood fibers. In addition, recycled polypropylene is used instead of recycled ethylene because of the availability of virgin polypropylene supplies in study area. Recycled polypropylene can be easily obtained from broken plastic buckets, basins, bottles and others.

Keyword: filler loading, mechanical and physical properties, types of filler, wood plastic composites

Introduction

In Malaysia, population growth has also lead to an increase in generation of solid waste. An increasing volume of waste from private households is disposed of in open landfills every year. As reported, food waste is a major component of generated waste (45%) and more than 30% potentially recyclable materials such as paper, plastic, aluminium and glass are still directly disposed of in landfills (Keskisaari & Kärki, 2018). Plastic wastes also can be easily decompose in landfills and blown into waterways, they may leak pollutants (phthalates and bisphenol-A) into the soil and surrounding environment (Schwarzkopf and Burnard, 2016). Wood based industry also creates a ton of waste such as offcuts, sawdust, bark and unusable logs. Branches, stumps and saw dust mainly are disposed by burning which lead to pollution of nature. Practitioners are likely to burn since it is easy and low cost without thinking of environmental concern. The development of wood plastic composite has a significant effect on wood use, enabling to use available timber resources, smaller diameter and lower quality logs. (Viksne et al., 2010). Wood plastic composite (WPC) needs less maintenance than the alternatives of solid wood treated with preservatives or solid wood of rot-resistant species and was claimed as being more environmentally friendly by manufacturers. Since it can performs like conventional wood, it does not require special fasteners and design changes in application (Zhang et al., 2018).

Environmental factors that lead to discoloration, rot, termite attack and dimensional instability of wood may cause product degradation which is unfavorable to manufacturers and users. Wood plastic composite seems the best option to be alternative choice or to replace the conventional wood materials. Wood plastic composite has quite similar properties and characteristics compared to natural wood. After sanding and layering with emboss materials, the appearance of finish composite is nearly comparable to the solid wood. WPC can covers the disadvantages of solid wood, it is much better in term of bending strength (Keskisaari & Kärki, 2018).

In addition, another factor lead to the production of WPC is the abundant thermoplastic waste generated and thermoplastic waste is listed as one of the huge global municipal solid waste (Najafi, 2013). High availability of the waste make it as a potential raw material for plastic composite. The advantage of plastic waste is; it can be reprocessed to produce new polymeric source. The process can be made at the end of its life cycle. From 1990 and onwards, WPC manufacturers had used recycled polymer as the ingredients. However, Adhikary et al. (2008) stated that there was very little studies on recycled polymer of WPC. This is most probably due to contaminations in the plastic that can give uncontrollable properties of WPC and the unpleasant scent from used material (Yeh et al., 2009). The non-controllable performance may also occur since the recycled polymer had been exposed to different storage conditons and process condition (Najafi, 2013).

Properties of used plastic usually can be differentiated from pure one but in some condition, the properties can be alike (Najafi, 2013) and (Jayaraman & Bhattacharya, 2004). Despite the arguments made by the authors, the environmental issue due to the high waste and lower investment on recycled materials should be prioritized by utilizing used materials instead of new materials (Haggar & Kamel, 2011).

Materials and Methods

Sawdust Preparation

Eucalyptus spp. was harvested from Forest Reserved, UiTM Jengka Campus, Pahang, Malaysia. Eucalyptus tree was selected and felled at 30cm above the ground level. The logs were then gathered and transported to Composite Manufacturing Workshop, UiTM Jengka Campus. The logs were then further cut into bolts and debarked. The debarked bolts were then chipped by using chipper. The chips were air dried for one week before they were further refined using a Knife Ring Flaker. The wood particle were then oven dried in an oven at 80°C for 24 hours. Screening process was done to separate particles according to their sizes; 2mm, 1mm, 0.5mm, 0.25mm and dustpan. The collected dustpan materials were further ground and screened using a small vibrator wire screen with diameter 200mm in accordance to BS 40-1. In this study, sieve of mesh size 250µm was used.

Preparation of Wood Plastic Composite

In this study, the thermoplastic used was polypropylene (PP), which can easily be commercially available at low price compared to other plastic. PP has a melt flow index of 8.0 g/10 minute and a density of 0.90 g/cm^3. Two different types of PP were used which comprised of virgin polypropylene and recycled polypropylene. The recycled PP obtained from used and crushed basins, where they were cut into smaller random sizes. The mixing of wood particles with PP was done using a dispersion mixer. Initially, the mixer was heated up to 180°C before PP was being added. The mixer was rotate at 950rpm. When the thermoplastic has melted, wood flour was added and the mixer left to run for 30m until the mixtures were well mixed. The mixtures then extracted and rolled to facilitate crushing process. The mixtures were then fed into a crusher to produce granules of wood plastic.

Boards of wood plastic composite were moulded by using plated mould of dimension 150 mm × 150 mm × 2 mm for tensile test and 150 mm × 25 mm × 6 mm for bending test. The thermoplastic pellets were pressed under heat and pressure in the hot press to produce board for testing. For tensile testing, the moulding process was at 180 °C under 2400 psi for 240 s. For bending testing, the temperature and pressure were similar with tensile testing board but the pressing time is 360 s. After being hot pressed, the moulds were cooled at 20°C and pressed in a cold press. Wood plastic boards were cut and conditioned at 27°C and relative humidity of 65% in accordance to the requirement to British Standard, BS 2872 for 24 hrs.

Wood Plastic Composite Board Evaluation

The WPC were tested for their mechanical and physical properties in accordance to British Standard. The mechanical properties carried out were flexural and tensile test by using an Instron Universal Testing machine. For physical properties, the test carried out was water absorption (WA).

Result and Discussion

Figure 1 shows flexural strengths of WPCs filled with two different types of fillers, virgin and recycled polypropylene and three different filler loadings (10%, 30% and 50%). The figure indicates that the higher filler loading leads to lower modulus of rupture (MOR) of composite. Wood plastic composite made up from virgin PP and 10% filler loading has the highest flexural MOR among the samples tested. At high filler loading, brittleness occurred and reduced the elongation at break. The stress concentration at the fibre ends and poor interface bonding between wood and matrix have been recognized as the leading causes for the embrittlement (Adhikary et al., 2008).

Moreover, at higher filler loading, agglomeration occurred. A large agglomeration formed when high wood ratio adhere to each other which mean with higher wood ratio, the composition of composite not well blended. According to Ashori and Nourbakhsh (2009), various factors affecting the mechanical properties of wood composite including the filler loading, fibre-matrix adhesion, stress transfer at the interface and blending temperature.

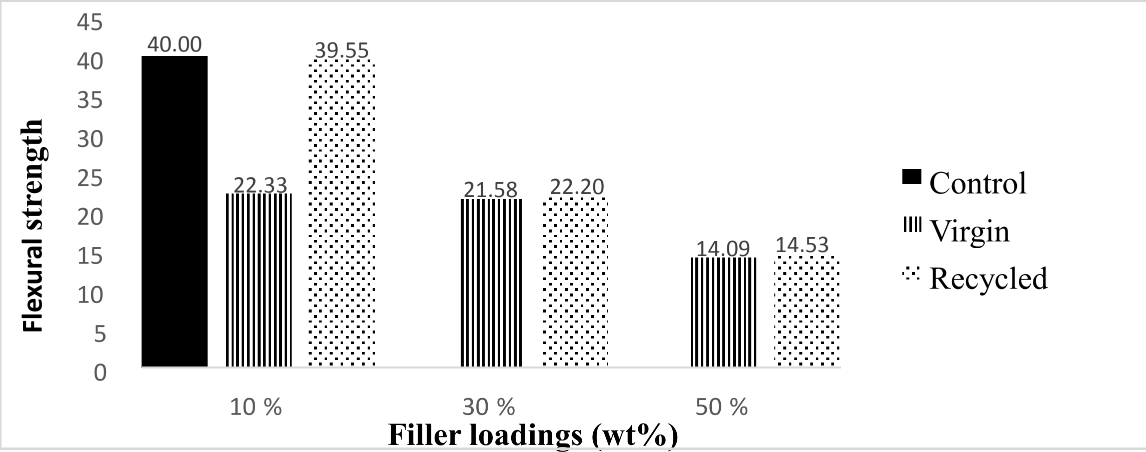

Figure 1 Flexural strength of WPCs filled with different types of fillers and filler loadings

Figure 2 shows the influence of WPC made up from different filler loadings and types of filler on flexural modulus. The figure trend is inclining from 10% filler loading to 50% filler loading. This shows a sign that higher filler loading is able to create higher flexural modulus boards. The addition of filler to polymer matrix increase the flexural modulus due to rigidity properties of filler particles. When WPC is harder or more rigid, it is caused by lesser free mobility in the composite which avoid deformation. Therefore, the higher filler loading the higher flexural modulus.

As stated, the overall data shows that samples from recycled PP have higher flexural modulus than that of virgin samples. Similar findings found by Najafi et al. (2006), stated that the composite containing recycled PE and recycled PP blend exhibited statistically higher flexural modulus compared to those made of mixed virgin plastics (virgin PE/PP). Besides, similar result was also reported for mixed recycled PP and PE by Turku et al. (2018). La Mantia and Gardette (2002) said in their study that this is probably because of reduction of molecular weight during recycling process which lead to increasing in crystallinity.

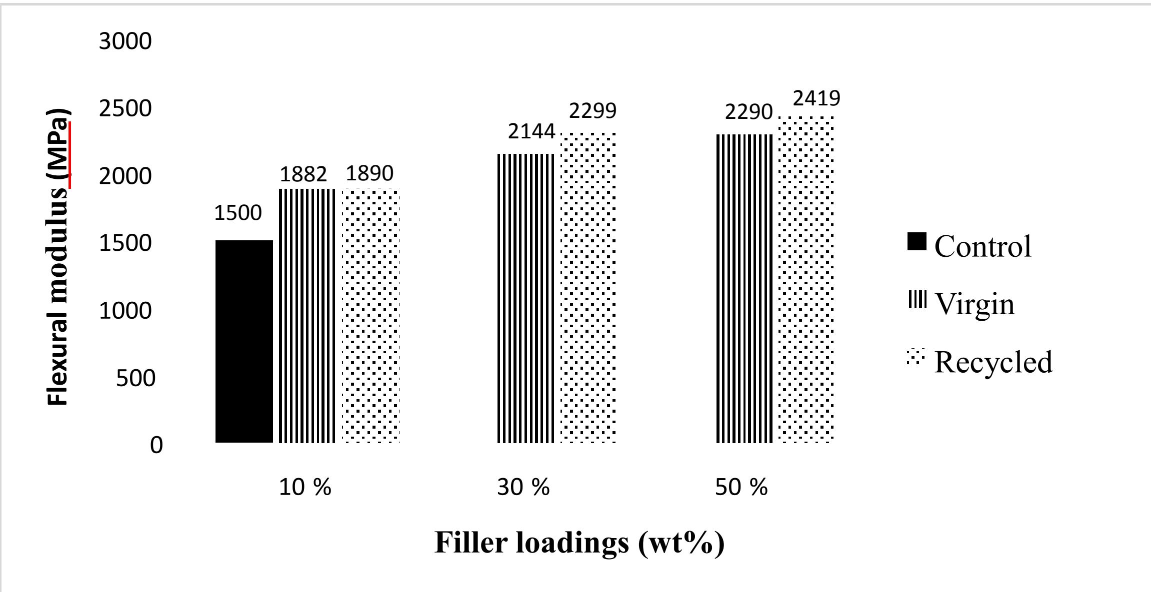

Figure 2 Flexural modulus of WPCs filled with different types of fillers and filler loadings

Figure 3 demonstrates the effect of wood ratio and type of filler on the WPC. As stated, the filler loading clearly made an impact to the tensile behavior of the composite. The figure is in a declining pattern, from 10% of wood ratio to 50% of wood ratio. This means that higher filler loading produce lower tensile strength. Virgin polypropylene shows a constant data differences between the filler loading percentages as compared to recycled polypropylene. Lower tensile strength occurred because of insufficient dispersion as filler loading increase and leads to poor matrix filler bonding. Moczo & Pukánszky, 2008 reported that aggregation arise from poor dispersion of the mineral fillers in the matrix. The aggregation as well as the incompatibility of raw materials reduces the properties of composites seriously.

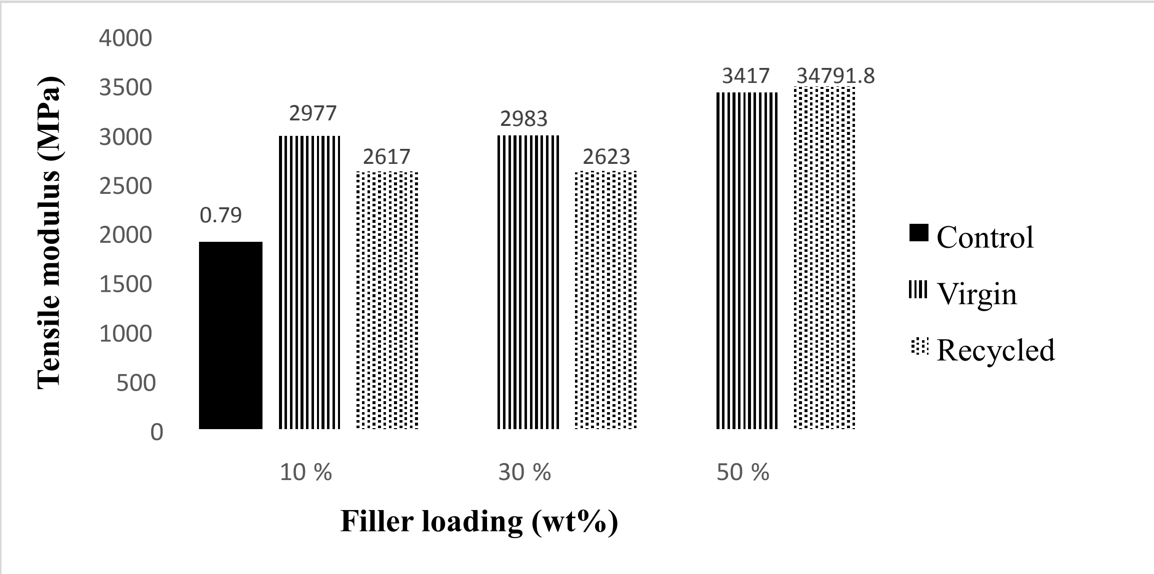

Figure 3 Tensile strength of WPCs filled with different types of fillers and filler loadings

Figure 4 shows the result of tensile modulus for WPC made up from different filler loadings and types of filler. The figure shows an increasing trend going from lower filler loading (10%) to higher filler loading (50%). Higher filler loading produces greater tensile MOE value. The lowest MOE value is recycled specimen of 10% filler loading which mean it is the most ductile and flexible whereas the highest MOE value is virgin specimen of 50% filler loading which indicates it is the most brittle among all tested specimens.

The higher filler loading also facilitate in interfacial adhesion between matrix and fibre. Therefore, more uniform distribution of applied stress occurred. The firm structure needs more energy to break apart or debond (Ashori & Nourbakhsh, 2008).

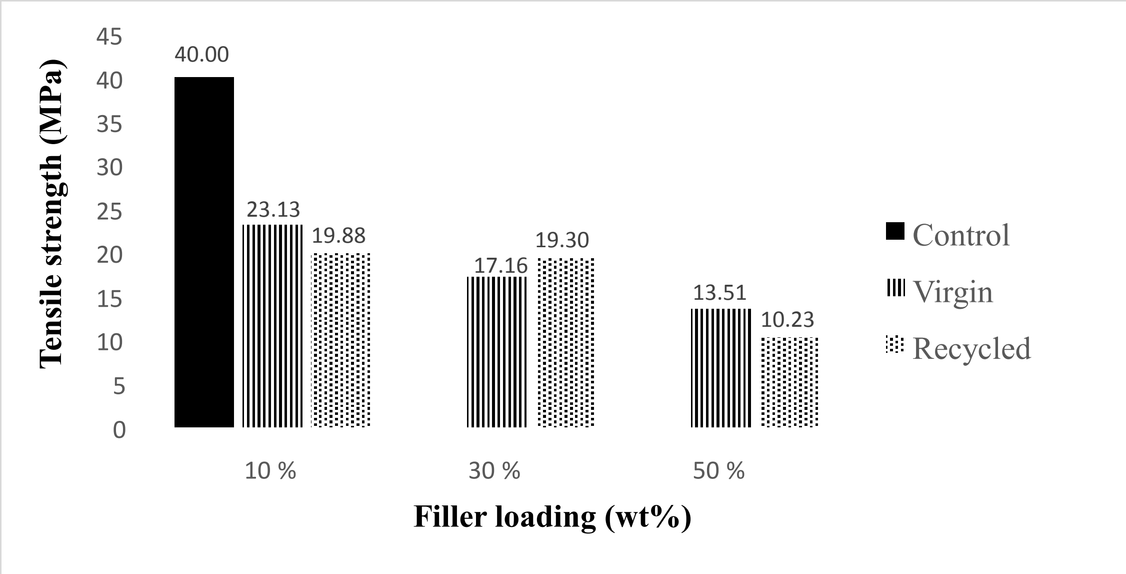

Figure 4 Tensile modulus of WPCs filled with different types of fillers and filler loadings

Figure 5 shows the effect of different filler loadings of WPC when immersed in water for 24 hours. The composites made up from virgin and recycled polypropylene. The value is increasing gradually as the wood ratio increase. The 50% wood ratio composite has the highest water absorption percentage for both virgin and recycled polypropylene. This indicates that higher filler loading may cause the board to absorb more water and moisture because of the hydrophilic properties of filler. At higher filler loading (50%), more hydrogen bonding of water molecules to the hydroxyl groups on the cell walls of the wood as compared to lower filler loading. Hydroxyl group induces the filler surface of the composite make it easy to interact to one another, forming both inter and intra molecular hydrogen bonds, thus increase the water absorption (Gwon et al, 2010). The authors also mentioned that cellulose and hemicellulose both have many hydroxyl groups that give hydrophilic properties for the filler. In addition, they stated that hemicellulose has amorphous structure which allows it to absorb water.

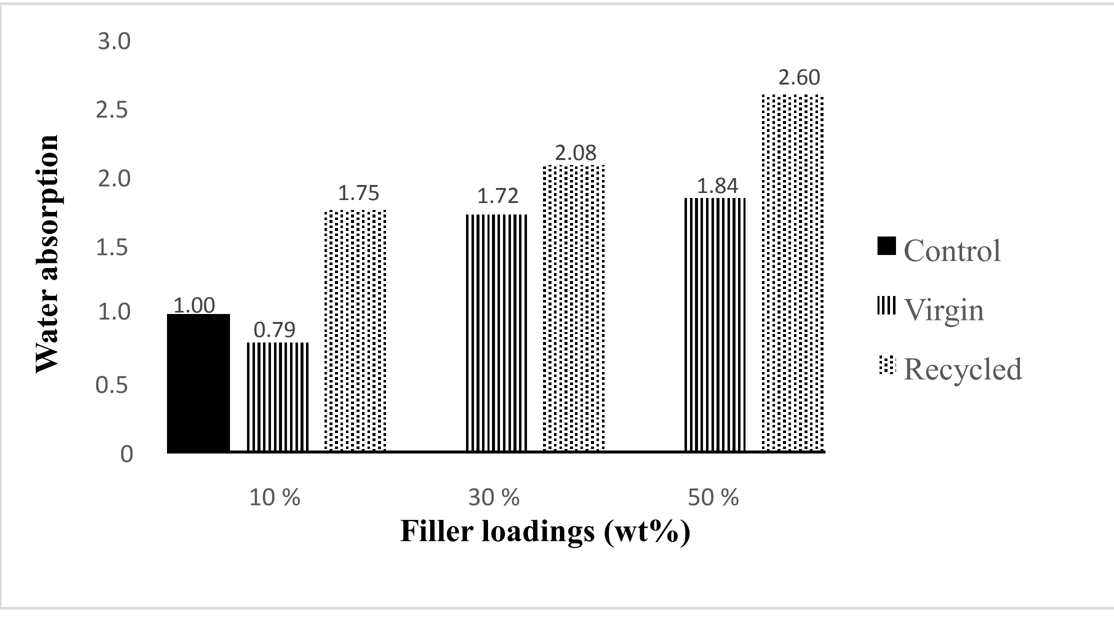

Figure 5 Water absorption of WPCs filled with different types of fillers and filler loadings

Conclusion

From the study shows that 10% of filler loading have the highest mechanical and best physical properties compared to 30% and 50%. It was due to the sufficient and uniform dispersion of polymer matrix which boost the interfacial adhesion between matrix and fibre. As for types of filler, virgin plastic showed that it is capable of enhancing both mechanical and physical properties of wood plastic composite. However, recycled PP shows an improvement for flexural modulus compared to virgin PP. Nevertheless, the gap difference between virgin PP and recycled PP was not too huge. So, recycled plastic can be considered as raw materials for WPC which provide a solution for plastic waste handling procedure.

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Conflict of interests

Author hereby declares that there is no conflict of interests with any organization or financial body for supporting this research.

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