Mechanical Properties of Medium Density Fibreboard Composites Material Using Recycled Rubber and Coconut Coir

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Abstract

Natural fibre reinforced composite has emerged as highly potential replacement for synthetic fibres. Various natural waste fibres have been adopted for various engineering applications. This paper investigates the mechanical properties of medium density fibreboard composites material fabricated using recycled rubber and coconut coir. The suitability of using recycled rubber and coconut coir as a raw material and polyurethane as a resin in the manufacturer of medium density fibreboard was also studied. The medium density fibreboards were fabricated at prescribed percentages of filler. The performance of composite was evaluated by its mechanical and physical properties. Experimental investigation indicated that the mechanical strength of medium density fibreboards such as modulus of rupture and modulus of elasticity increased with increasing board hardness. Overall, the results showed that medium density fibreboard had been produced with acceptable properties, thus providing alternatives to manufacturing and agricultures economic planning.

Keywords: Coconut coir, Mechanical Properties, Medium Density Fibreboard, Recycled Rubber.

1. INTRODUCTION

The uses of natural fibres in various applications have received considerable attentions to many researchers. Normally, waste natural materials are burned or dumped, thus creating environmental problems. There have been efforts to utilise these waste materials for something beneficial to human. These include waste materials from tea –leaf fibre, coconut fibre and rice wood [1-3]. The research focuses on sound absorption panel that can be used in various applications. Another investigation focuses on producing the medium density fibreboard that can be applied for furniture, cupboards and flooring.

Medium density fibreboard (MDF) is made from lignocellulosic fibres combined with a synthetic resin or other suitable bonding system that are combined together under heat and pressure [4,5]. MDF is denser than plywood or particle boards hence widen its applications. Reinforcing a polymer matrix with lignocellulosic materials have been attributed to several advantages such as lower density, high stiffness, less abrasive to equipment, biodegradable and lower cost [6-7]. The However, the major concern in producing good lignocelluloses–thermoplastics composites, especially in term of mechanical and physical properties, the compatibility between the constituent materials should have been resolved.

In general MDF uses wood based fibres as the raw material and urea formaldehyde as the resin. However, the decreasing in wood supply and health hazard produced by urea formaldehyde are of concerned. Alternative material is needed for replacement to conventional material. One of the potential natural wastes is coconut coir fibres. The coconut coir fibre contains a high lignin ratio and thus low cellulose content, as a result of which it is resilient, strong and highly durable. That makes this fibres stiffer and tougher [8-9].

This paper investigates the viability of coconut coir fibre added with recycled rubber as the potential material for MDF. The effect of adding recycled rubber particles and the influence of polyurethane are investigated as the potential replacement of synthetic and mineral fibres.

2. MATERIALS AND METHODS

2.1 Materials

The study utilised coconut coir and recycled rubber as the fillers, whereas polyurethane was chosen as the resin. Polyurethane is selected due to its structural versatility, e.g. thermosetting, thermoplastic, rigid, elastomer, and flexible. They are also more compatible to fibre compared to other resins, due to possible reaction of hydroxyl groups of the fibres and the isocyanate groups of the polyurethane.

Initially, the coconut coir and recycled rubber need to undergo pre-processing stages before they can be used to form MDF composite. For instance, coconut coir need to be grinded to produce small grains, soaked in water, washed and dried. Similarly, recycled rubber needs to be cut into small particles. Here, a recycled tyre tube was used as the sample. These two materials are then equally mixed together with the polyurethane as the binder, at prescribed percentages, as shown in Table 1 and 2. Here, the percentage of polyurethane varies in order to investigate the influence of resin on the performance of coconut coir composites.

Table 1: Composition of coconut coir, recycled rubber with 25 percents of polyurethane

Sample	Coconut Coir (%)	Tube tyre (%)
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60

Table 2: Composition of coconut coir, recycled rubber with 35 percents of polyurethane

Sample	Coconut Coir (%)	Tube tyre (%)
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60

The mixture were then pressed for 15 minutes using the hot press machine at 90°C with 10 tonnes of pressure to produce composite board, as demonstrated in Figure 1.

Fig. 1 Sample of coconut coir – recycled rubber composite fibre board

2.2 Physical properties

The physical properties measured for MDF composites consist of four tests, e.g. porosity, density, water absorption and microstructure tests. Porosity is a measure of the void spaces in a material, normally calculated as the fraction of the voids volume over the total volume. The porosity value is denoted in range, between 0–1, or as a percentage between 0–100 percents; of which zero value indicates no pores is existed, whereas value 1 or 100% indicates total pores is existed.

Density is a physical property of matter, as each element and compound has a unique density associated with it. Density is defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. Density plays an important indicator of a composite's performance, where it virtually affects all properties of the material. Moisture content was examined using the ASTM D 1037-99 (American Society for Testing and Materials, 1999) method.

The water absorption was determined by weighting the samples at regular intervals. A Mettler balance type AJ150 was used with a precision 0f ± 1 mg. The percentage of water absorption, M_t was calculated by where W_d and W_N are original dry weight and weight after exposure, respectively. Equation (1) shows the relationship of water absorption for MDF composite.

$$W_t = \frac{W_N - W_c}{W_d} \times 100\% \tag{1}$$

Finally, in order to ascertain the property of MDF composite, the microstructure of the sample is observed. Here, characteristics of fillers (coir and rubber) and the resin is determined using scanning electron microscopy (SEM), where the information about porosity, void spaces between fillers and resin and the surface textures of the MDF composite can be identified.

2.3 Mechanical properties

The MDF composite was also tested for its mechanical properties, e.g. hardness and bending tests. The Shore Hardness (Durometer Hardness) is measured by determining the depth of penetration of the indenter in the material being tested. This measurement is then transmitted to a linear scale in increments of 0 to 100, which one increment equals to one hardness point. The hardness tests were performed according to standard of D 2240. Bending strength from three points was done according to ISO 178:93 by a SHIMADZU Universal Testing Machine (Model AG-1). These tests were carried out to determine the modulus of rupture (MOR), and the modulus of elasticity (MOE). Charpy impact test with 4 J loads was performed on the MDF composite board to measure its impact strength. The composite samples were cut into 8cm length, 2cm width and 1cm thick. The impact strength was calculated by dividing the impact energy with the cross-sectional area of the specimen.

3. RESULTS AND DISCUSSION

3.1 Physical properties

Figure 2 demonstrates the experimental result obtained for porosity test. It shows that porosity value is increased when the percentage of coconut coir is increased. It is also demonstrates that sample 5 with 40 percents of coconut coir and 60 percents of recycle rubber have the highest porosity value.

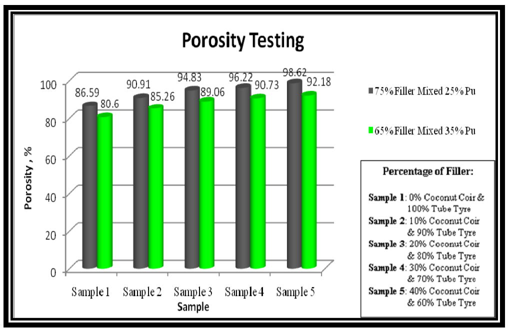

Fig. 2 Values of porosity for various percentages of coconut coir and recycled rubber

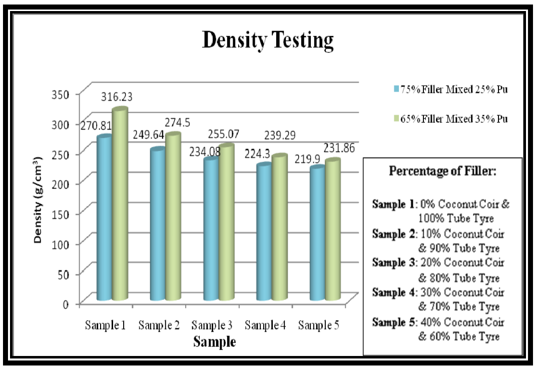

Fig. 3 Values of density for various percentages of coconut coir and recycled rubber

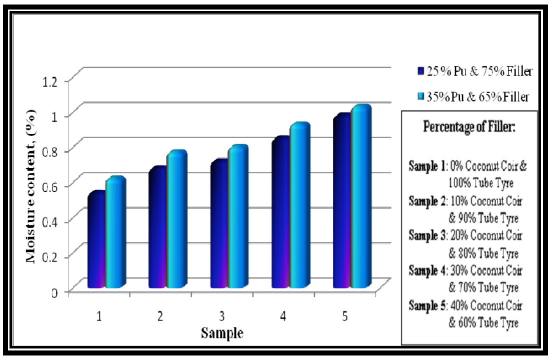

Fig. 4 Values of moisture contents for various percentages of coconut coir and recycled rubber

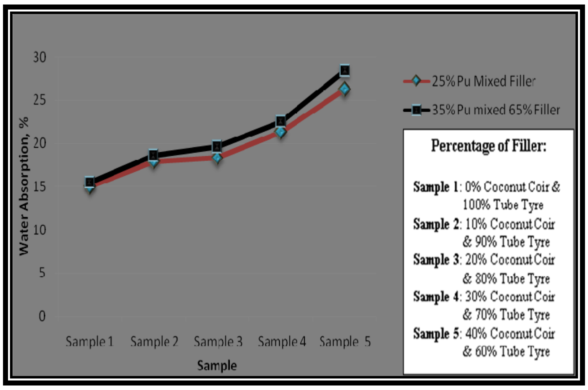

Fig. 5 Values of water immersion for various percentages of coconut coir and recycled rubber

Variations of densities, e.g. 25 and 35 percents of polyurethane were recorded for five different samples as demonstrated in Figure 3. The trend shows the decreasing pattern, with 25 percents yielded lower values for all samples compared to 35 percents of polyurethane. The results also indicated that density values of fibreboard are related to the percentage content of fillers. The density values are gradually decreased as the percentage of recycled rubber is decreased or percentage of coconut coir is increased. It was anticipated that the increased in recycled rubber percentages is reducing the pores in the samples. Again, sample 5 demonstrated the lowest density with 219.9 g/cm^3.

Figure 4 showed the comparison of moisture content between different percentage of filler and resin. The moisture contents of the composite boards ranged from 0.54 to 0.99 % wt. %. It is observed that sample 5 produced the highest moisture contents at about 0.99 percents. The increasing trend was observed that the coconut coir content linearly increased with the increase of moisture content. It is due to coconut coir has a good characteristic in water absorption. On contrast, tyre tube is not performing well in water absorption. In overall, MDF composite is suitable to be applied in industry since the moisture content recorded was below 3 percents.

Water immersion test of the composites reveals the behaviour of the composites, with respect to percentage of water absorbed. The result shows in Figure 5 indicated that the water absorption decreased when the recycled rubber is decreased or the coconut coir is increased. This is expected because the characteristic of coconut coir being a lignocelluloses material readily absorbs water into its cell wall through the formation of hydrogen bonding between its OH groups and the H from water. However, there is no significant difference in water absorption among the composites with various percentages of filler.

3.2 Mechanical properties

Figure 6 and 7 show the hardness values obtained for 25 and 35 percents of polyurethane, respectively. Both graphs demonstrate a linearly upward trend, with the hardness increased when the percentage of coconut coir is increased or recycled rubber is decreased. Sample 5 that contains 40 percents of coconut coir and 40 percents of recycled rubber demonstrated the highest values.

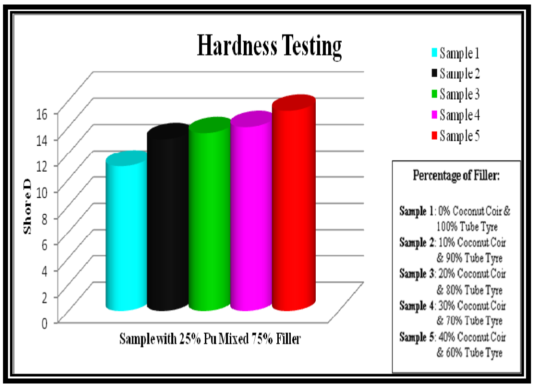

Fig. 6 Hardness value for PU 25% and Filler 75%

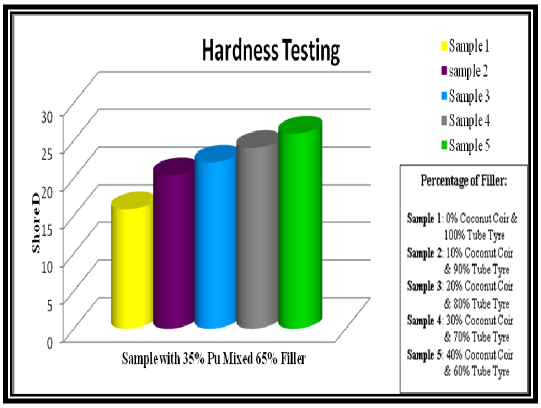

Fig. 7 Hardness value for PU 35% and Filler 65%

The bending modulus of rupture (MOR) of the MDF coconut coir and tube tyre is shown in Fig.8. Bending MOR increased slightly with the increased percentage of coconut coir or decreased in recycled rubber percentage. Increasing fibres in MDF content increases the flexural strength, as demonstrated by sample 5. The recorded flexural strength was 4.47 MPa for MDF with 25 percents of polyurethane.

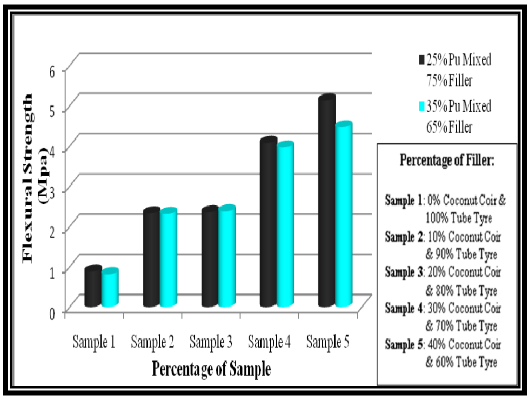

Fig. 8 Values of modulus rupture for various percentages of coconut coir and recycled rubber

The bending modulus of elasticity (MOE) is the slope of the tangent line at the stress point of proportional limit. Like MOR, the same trends also display by flexural modulus (MOE) results as shown Fig. 9. Generally it can be seen that irrespective percentage of the coconut coir increased and tube tyre decreased, the MOE of composites was increased. This indicates that the more addition of percentage fibre into the board was affected MOE results through the adhesive binding on the filler. The MOE value increases as the fibre increase, because the inherent stiffness of the fibre may positively contribute to the overall stiffness of the boards.

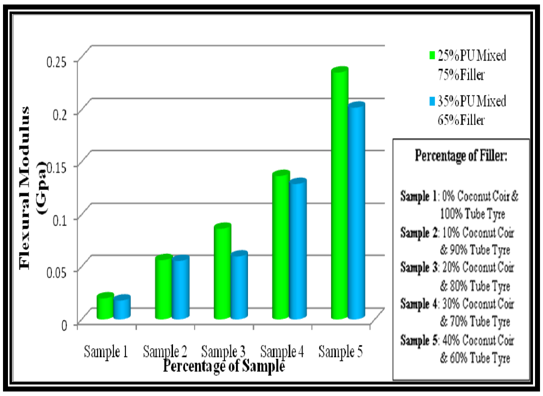

Fig. 9 Values of density for various percentages of coconut coir and recycled rubber

Referring to Figure 10, it can be seen that the Charpy impact strength of fibreboard goes up approximately from 4.13 to 4.95 kJ/m^2 as the coconut coir is increased from 0 to 40 percents. Impact behaviour is a measure of the energy required to cause damage and the progress failure within the composite. Any enhancement in toughness and stiffness due to the presence of natural fibres must rely upon the fibre matrix bond or the inherent toughness and stiffness of the fibres themselves. Moreover, the resin and fibre content might also influence the impact strength significantly. At higher resin and fibre content, it more covalent bonds and crosslink would from between fibre and resin. The former is common in composites with strong interfacial bond while the occurrence of the letter is a sign of a weak bond. With the chemical treatments has been reported to reduce the impact strength, so it can produce a good bond. This might resist the deformation of interface between resin and fibre, resulting in tougher fibreboard. Another reason must be the crosslink density of the MDF used. The low crosslink density MDF is far more readily toughened than the high crosslink density MDF.

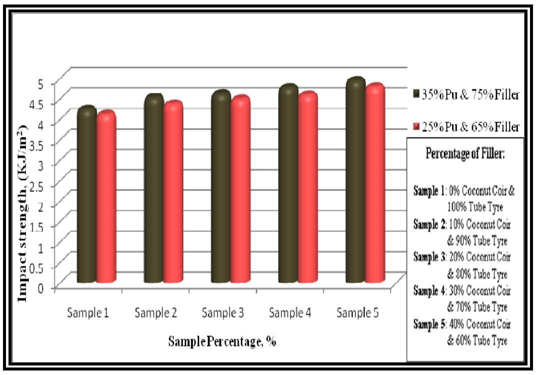

Fig. 10 Values of impact strength for various percentages of coconut coir and recycled rubber

3.7 Morphological

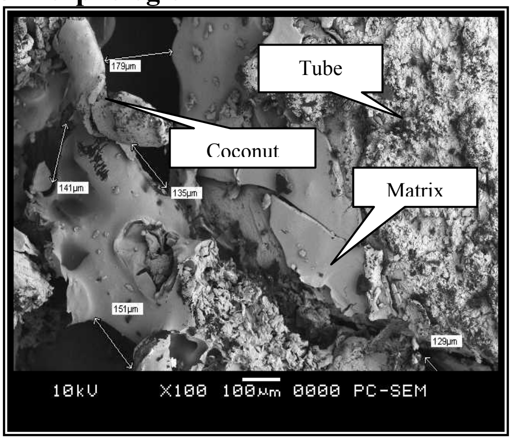

Fig. 11 Microscopic view for composite board with 25 percents of polyurethane

The density and porosity properties of the composite fibre boards were controlled by the gas quantity released during the isocyanate reaction. This affects the number of cells and their sizes. Figures 11 and 12 compare the surface structure between composites with 25 and 35 percents of PU content, respectively. It was observed that more pores have occurred in the sample with 25 percents PU with larger pore size. The recorded pore size obtained was between 129µm to 179µm. On contrary, composite boards with 35 percents PU and 65 percents fillers produced less pores and smaller pore sizes. The measured size recorded was in between 99µm to 110µm. The microstructure of composite fibre boards justifies the results obtained in density and porosity analysis, and reflecting into the acoustics properties of coconut coir composite boards.

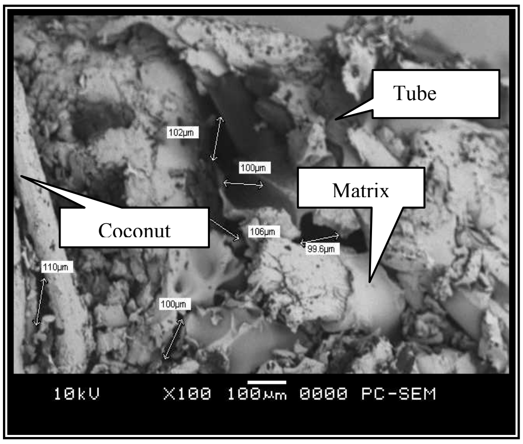

Fig. 12 Microscopic view for composite board with 35 percents of polyurethane

4. CONCLUSION

The mechanical and physical properties of medium density fibreboard (MDF) composites based on coconut coir and recycled rubber were successfully obtained. It was found that the content of fillers and resins play an important role in order to get good results. Here, the optimum composition was 40 percents of coconut coir added with 60 percents of recycled rubber. The new MDF composites combine cheap and highly available raw materials with have quite good in final properties is important to remark. The performance of such materials may be enhanced by improving the adhesion between both co-components. The lack of affinity between natural filler and recycled rubber may be improved by choosing an adequate compatible stabilizing agent. The usage of the MDF as filler also demonstrated a good result due to the MOE, MOR, impact strength, hardness, moisture content, porosity, and density properties of the fibreboard. Therefore this material make either alternative to reduce pollution rate and achieving mechanical and physical properties desired for many application such as interior lining for apartments, aircrafts, ducts, enclosures, sub flooring, interior surface for wall which can to reduce the reverberant.

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