IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Low density composite board from sugarcane residue and polymer of high density polyethylene

To cite this article: Sofyana *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **523** 012031

Low density composite board from sugarcane residue and polymer of high density polyethylene

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Abstract. Bagasse is one of biomass wastes often found in the sugar industry. In large quantities, such wastes are a problem for environmental sustainability because it is not handled properly. Likewise, plastic wastes are an environmental problem with difficulty coping. Both of these wastes can be integrated into a product with economic value by processing it into a composite board. The research aims to produce low-density composite boards and to study the process variables that influence its manufacturing process, namely the compressing temperature and Maleic Anhydride (MAH) as a coupling agent. HDPE plastic waste will be tested as an adhesive for the manufacture of composite boards. The composite board is made by preparing the raw material with the drying of the sugarcane residue and the dissolving of the plastic waste using xylene solvent. Furthermore, the mixing process is carried out with various coupling agents by 2, 4, 6, 8, and 10%, as well as the hot press temperatures by 160, 180, and 200°C. The results showed that the optimum value of the hot press temperature of the composite board was 160°C with 10% coupling agent concentration. The value of the thickness expansion was in the range of 0.0021–0.0153%, the water absorption was 0.067–0.640%, and the average density was 449.80 kg/m^3. Its MOE was 92.188–459.901 Mpa, the MOR was in the range of 1.92–3.07 Mpa, and the DSC analyses were 5.3 and 23.52 KJ/g at 2% and 10% MAH concentrations, respectively. The physical and mechanical tests of the composite board obtained have fulfilled the standard of SNI 03-2105-1996 with the exception for MOR.

1. Introduction

Sugarcane residue or bagasse is one of biomass waste produced from sugar industry. Its production ranges from 35 to 40% of sugarcane processed. In developing countries, it is commonly used as fuel in sugar industries. Bagasse contains 43.8% cellulose, 28.6% hemicelluloses, 23.5% lignine, 1.3% dust, and 2.8% other components. It can be utilized as raw material in production of plastic, paper, xylitol, furfural, animal feed, biogas, ethanol, glucose, and composite board [1-3].

Composite board is board made from lignocelluloses material combined with synthetic plastic adhesive. The commonly used lignocellulose is sawdust while adhesive utilized is urea formaldehyde. As its abundant availability in line with the mushrooming in street sugarcane drink, thorough research on the use of bagasse as a potential raw material for composite board is worthwhile.

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The previous research show on binderless insulation board shows that the use of bagasse can enhance the quality of the product as compared with the board based on coconut fibre. Bagasse based insulation board at density of 350 kg/m^3 performs satisfactorily for construction material as thermal insulation. Due to its environment-friendly process as no chemical adhesive is used, this product may compete its conventional counterpart where urea formaldehyde adhesive, which is dangerous for health and environment, is a common practice [1].

The main factors affecting characteristics and quality of composite board are density, form and humidity of particle, the pressing cycle, hot press duration and temperature, and quality and type of adhesive and many studies have been conducted to study the types of resins and boards. Plastic waste can be used as potential adhesive instead of urea formaldehyde. [4-9]. The utilization of recycle plastic of thermoplastic type for composite board production, such as polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), and high density polyethylene (HDPE) can at some degree solve environmental problem. The use of recycle plastic can decrease the board production cost [1], [10], [11].

2. Materials and Methods

2.1 Materials.

Materials used in this study were bagasse as a *filler*, white plastic bottle waste of HDPE type as matrix, and *maleic anhidrate* (MAH) as *coupling agent*.

2.2 Methods

Bagasse is prepared to have particle size of 120 – 150 mesh and density of 250 – 450 kg/m^3.The amount of coupling agent applied is , 4, 6, 8 dan 10 %w/w). Hot press temperature is varied at 160, 180 and 200 ^oC. Pressing time is 30 minutes. The ratio of filler to matrix is 50:50 %w.

2.2.1 Preparation of bagasse as raw material. Bagasse is sun-dried to have 10% water content. It is then dried using oven at temperature of 80 ^oC to obtain the water content of 6-7% [4]. After that, it is sieved to suit the relevant particle size.

2.2.2 *Preparation Board.* The size-reduced HDPE of 50 g is put in a three-neck flask and 20% xylene of 20 ml is added. The materials are then heated at temperature of 100-200 ^oC. After the HDPE is completely melted, the prepared bagasse is added and stirred for ±15 minute up to homogeny. The mixture is then unloaded into a container and the solvent is let to vaporize for 24 hours. After that, 30 minutes of hot pressing is implemented. After the temperature gets stable, the composite is ready to be formed as specimen suitable for testing.

2.2.3 *Board Testing.* The ASTM D-638, is used as standard for tensile test. Tensile Strength ASTM D-638, Strength ASTM D-790, and DSC (*Diffrential Scanning Calorymetri*) are used for tensile, break modulus, and thermal tests, respectively.

3. Result and Discussion

3.1. Board appearance

The physical characteristics of composites such as colour, surface condition, compactness and fragility can be implied by visual appearance. The difference appearance between the composites with pressing temperature 160 ^0C and 200 ^0C caused by the fact that the filler experiences overheated such that it turns deep brown at 200 ^0C. Beside that, type of filler used will also affect the visual appearance, physical and mechanical characteristics. Since bagasse contains much cellulose, its colour turns deeper as temperature increases during the pressing process. Also, distinct smell results during the process [1].

3.2Physical Properties

Thickness expansion, water absorbing capacity, and density are three physical properties adopted in this work. Thickness expansion indicates the dimension stability, while the water absorbing capacity indicates the capacity in absorbing water during soaking process. The concentration of coupling agent and hot press temperature provide real impact to the three properties, as shown in Figures 3 and 4.

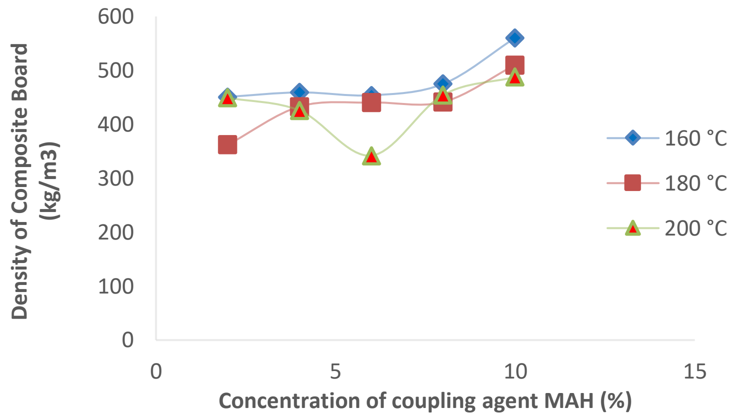

Figure 1. The effects of coupling agent concentration and temperature on the composite density.

Results shown in the figure suggest that the higher the temperature implemented the lower the density obtained. The degradation of composite board quality can occur during heating process. Excessive heating can cause filler and matrix to damage where voids are formed in the board and hence, the density decreases [12].

For the thickness expansion and water absorbing capacity, their low values are obtained at temperature 160 ^{0}C. At low pressing temperature, the composite is denser and of no void. Higher pressing temperature, e.g. 200 ^{0}C, can cause overheating on filler such that the adhesive cannot completely bind and hence, voids occur and water can easily penetrate into the board. The thickness expansion is related to the absorption of water by the composite. High water content can weaken inter-particle bonding and then the composite bulges. Hence, the dimension of the board changes [13].

The concentration of coupling agent affects the board capacity of water absorption in which the higher the concentration of coupling agent used the lower the capacity of water absorption. When more coupling agent, i.e. matrix, is used, voids between bagasse (filler) particles will be filled with it. Consequently, penetration of water can be hampered.

3.3Mechanical Properties

The mechanical properties adopted here in the modulus of elasticity (MOE) and modulus of rupture (MOR). Figure 5 shows the effects of temperature and concentration of coupling agent on MOE and MOR. The previous research suggests that the higher the temperature of pressing process and the longer the pressing time the higher the value of MOE [14]. In this work, as shown in the figure, however, this phenomenon does not appear. Over-curing and over-heating are suspected as the responsible factors. These factors make the filler degraded resulting in void formation, and hence, the decrease in MOE. Besides, the thickness of the composite also affects the level of MOE in relation to temperature [2].

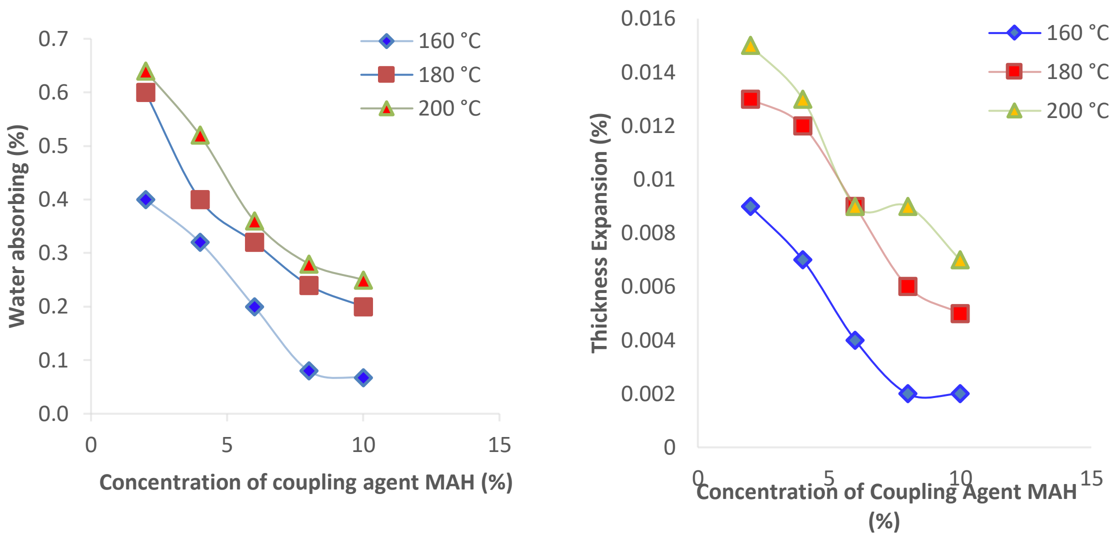

Figure 2. The effect of coupling agent (MAH) concentration on water absorbing capacity and thickness expansion.

The value of MOE, as shown in the figure, increases as the increase in the coupling agent concentration. The adhesive behavior between matrix and filler increases due to estherification processs between anhydride of maleic anhydride and hydroxyl that forms the filler. As a result, the bond between matrix and filler intensifies and hence, the elasticity of the composite increases. The higher the pressing temperature the higher the value of MOE. This phenomenon is also unseen in this work [5]. The same reason as mentioned above for the value of MOE is also applicable here. Temperature near 200 ^{0}C bagasse particles start to degrade leading to void formation [1]. In that condition, HDPE melts and the humidity of bagasse disappears leading to burning of hemicelluloses and cellulose and lignin degradation. The value of MOR obtained in this work ranges between 1,927 – 3,073 MPa, while the minimum allowable value for MOR as per SNI 03-2105-1996 standard is 9,881 Mpa. In this respect, therefore, all of the composite board produced in this work does not fulfill the standard.

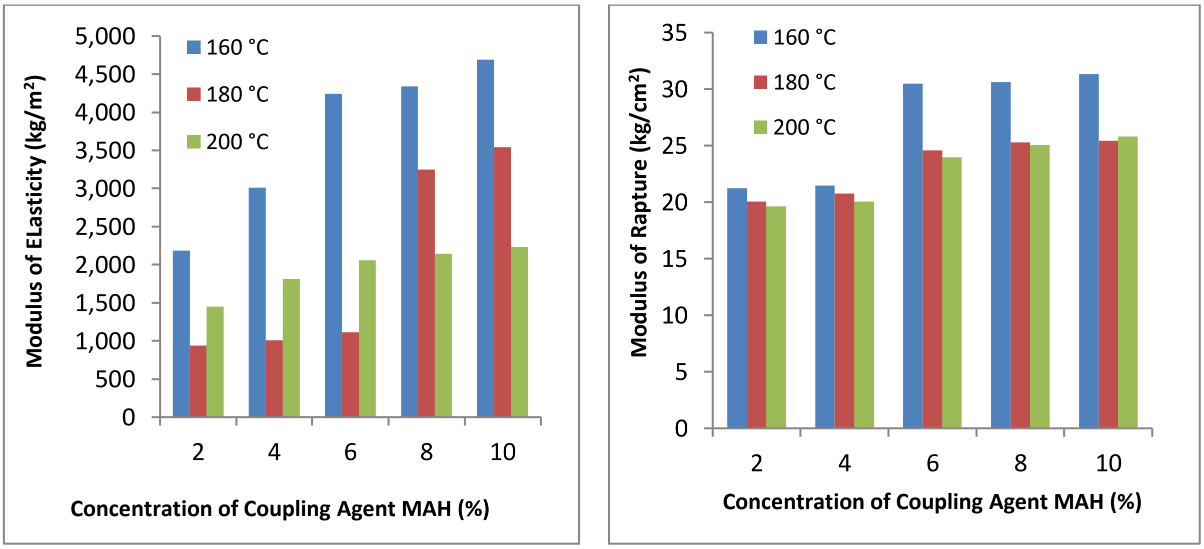

Figure 3. The effects of temperature and concentration of coupling agent on MOE and MOR

In general, the comparison between the values of physical and mechanical properties tested in this work and the standard of SNI 03-2105-1996 is given in Table 1.

Table 1. The Comparison of Physical and Mechanical Properties

Parameters	**SNI 03-2105-1996**	**This Work**
MOE (Mpa)	min 0,15	92,188 – 459,901
MOR (Mpa)	min 9,881	1,927 – 3,073
DSC (kj/g)	-	5,30 - 23,52
Density (kg/m^3)	250 – 450	342,18 – 560,49
Thickness Expansion (%)	Max 12	0,002 – 0,015
Water Absorbing Capacity (%)	-	0,067 – 0,640

Melting point and amount of energy needed to melt the bagasse-waste-based HDPE composite are given in Table 2. The amount of coupling agent affects enthalpy and melting point. Higher amount of it will need more enthalpy since the resulting composite will be more compact. However, due to its higher plastic content, the melting point will be lower.

Table 2. Enthalpy and Melting Point of The Composite

Hot Press Temp. (^{o}C)	Coupling Agent Conc. (%)	Enthalpy (kJ/g)	Melting Point (^{o}C)
160	2	5,300	325,440
	10	23,520	244,570

4. Conclusion

The optimum condition of the composite board based on physical and mechanical properties in this research is obtained at hot press temperature of 160 ^{0}C and coupling agent concentration of 10%. The capacity of water absorption obtained ranges from 0.067 to 0.640%, the thickness expansion from 0.002 to 0.015%, and density from 342.175 to 560.488 kg/m^3. In terms of MOE, the composite board resulting from this work fulfills the standard of SNI 03-2105-1996 but MOR does not meet the standard.

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