MECHANICAL AND THERMAL PROPERTIES OF COMPOSITE BOARD PREPARED BY USING POLYPROPYLENE AND CARDBOARD WITH ADDITION OF MALEIC ANHYDRIDE (MA) AS COUPLING AGENT

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Abstract— **Worldwide issues about solid paper waste are very typical these days. There is disposed of solid paper waste has reached 67 million tons that wound up in landfill. The solid paper waste such as cardboard will be mix with propylene to enhance the strength between the two component and with addition of MA (maleic anhydride) as the coupling agent to enhance the strength of composite board. The experiment started with the number of ratio of polypropylene as the matrix while cardboard as filler. The ratio starts with none of coupling agent present which are 40:60, 60:40, 50:50 and 75:25. The experiment continues with different ratio of matrix: filler: coupling agent. They are 40:50:10, 50:40:10, 60:30:10 and 75:15:10. The testing and analysis is includes tensile and bending testing. The research is about to indicate the effectiveness of the coupling agent that will be use and the suitable ratio of matrix and the filler with amount of the compatibilizer that will produce a good composite board. The result showed that there are increased of the bond within the polymer and cardboard resulted from mechanical testing and thermal analysis..**

Keywords— Composite Board, Polymer, Cardboard, Polypropylene, Maleic Anhydride (MA)

I. INTRODUCTION

Composite board comes with a variety of type and also shades that provide long lasting protection beyond wear and tear. Commonly, it has been used for a variety of furniture, domestic building projects, trimming, exterior shutters and other home products. It's an ideal material preference due to the many advantages. Composite board or additionally acknowledged as Wood plastic composites (WPC) have obtained great attention beyond industry in recent years (Zhang Xiaolin, Bo Xiangfeng, & Rumin, 2013). There are many demand of composite board production in order to produce a lot of type products from household to construction materials. The wide range of application give the composite board a wide acceptance by the global market due to conversion of the existing plastic processing techniques.

Cardboard, saw dust and rice husk are the example of the wood fibre that contained in the composite board. Composite board is the product from combination from two type of material which are thermoplastic and wood fibre. At specific temperature thermoplastics can be in mouldable condition where they cool down they will become in solid condition once again. Matrix and filler is the main component in the composite board. The adhesion between those two components need to be strong attached to each other that can produce a flexible composite board. In the composite board. Basically, the filler will fill with the wood fibre while the matrix contained of thermoplastics such as polyester, polypropylene, polyethylene, and polystyrene. The ratio of the between both components must be correct amount based on calculation and it is very important to make sure the composite board can last longer. based on natural fibres due to their low density and accurate cost and overall performance ratio, resins had been derived from the petrochemical industry that have promoted the development of composite substances(C.A. Kakou et al., 2014).

Fibres are evaluated as environmentally friendly materials because of their biodegradability and renewable characteristics regardless of the response to the challenges of sustainable development(C.A. Kakou et al., 2014). Based on the concept of the production itself are from agricultural residues and blend with polymers shows that the composite board was produced from recycled material based. So that manufacturers could discover a path to cheaply collect and reuse every that raw material, some of the major hurdles to affordable sustainable manufacturing would keep cleared.

Typically, the strength of regular composite board in market nowadays are not strong enough to adapt with current weather or temperature and also based on their mechanical properties. The composite board’s interface bond between matrix and filler can be enhanced with addition of coupling agent. The coupling agent works to make sure the bond between matrix and filler compact. In addition to produced stronger bond with the polymer, hydrogen bonding must be decreased between the fibres.

For example, alkalinisation relies upon on the breakdown on the hydrogen bond in cellulose and eliminates some regarding the lignin and wax covering the fibres Mohanty et al (as cited as (El-Sabbagh, 2014)) The coupling acts as compatibilizers to improve the interface of the matrix and hydrophilic lignocellulosic fibres as the filler. To produce a very good composite board with advance mechanical and thermal properties, coupling agent is used to control chemical modification in hydrophilic properties of lignocellulose materials.

II. METHODOLOGY

A. Materials

Cardboard and polypropylene (PP) are the compulsory in this study acts as a filler and matrix and maleic anhydride (MA) as coupling agent. The cardboard represents as the filler while polypropylene as matrix. Polypropylene basically used for packaging box, stationery, laboratory equipment and in automotive. It is resistant to a lot of chemical solvents, acids and bases. Cardboard was obtained from Mini Mart, Mawar College while the coupling agent MA and polyethylene were provided by the Faculty of Chemical Engineering UITM Shah Alam.

B. Equipment

The required equipment in this study in order to produce composite board such as digital scale, oven, hot press, co-rotating twin extruder (HAAKE-Rheomex-PTW16), cutting mill and sieve with shaker. For mechanical properties analysis equipment are Tensile testing (Servotec Fully Automatic Universal Tensile Machine 10kN (NL 6000 X / 019)), Bending testing (ASTM D790).

C. Preparation of Composite

1. Preparation of Filler

Cardboard is strong and resists punctures. So to smoothen the cardboard, it was soaked and stirred at medium speed in hot water at temperature 100ºC soften it physical condition for 1 to 2 hours. This is how to make it tends to get soggier and disintegrate. Before grind and sieved the cardboard, it had been dried up for 24 hours to remove moisture content. After grinding and sieved, cardboard once again need to dry up to eliminate all the excess moisture content. The cardboard was milled with a rotatory mill prior to the sample preparations. It was sieved to pass mesh 120 to 500 microns.

At the first testing, the ratio of the coupling agent will be fixed at 10 % but in the four different ratio of percentage of matrix and filler. This first testing aim is to get the best ratio of the PP and cardboard that would be tested in the next testing. The total weight is constant at 40 grams. The melting temperature of PP is at 180ºC. The PP oven dried wood flour (cardboard) and MA were then weighted and bagged according to ratio calculated. Then they were properly mixed with the coupling agent and poured into the funnel of the co-rotating twin extruder (HAAKE-Rheomex-PTW16) at the Polymer Laboratory, UITM SHAH ALAM. The screw speed was set at 40 rpm. The temperature of its barrel zone was adjusted at 180ºC to 190ºC.

The materials were subsequently grounded using grinder. Then, resulting product or granules were dried at 110ºC for 24 hours. Next is hot press. The press was employed to press samples and cast them at 190ºC starting at pressure 25 MPa for five minutes.

D. Testing and Analysis

1. Tensile Testing

Tensile testing (Servotec Fully Automatic Universal Tensile Machine 10kN (NL 6000 X / 019)) can record the maximum of the composite board can be stretch. It also can include the test pressure, and fracture. ASTM D790 is one of the most commonly used specifications in the plastics industry. The Young modulus is obtained from this testing. The presence of WP and increase in WP content resulted in a continuous increase in Young’s modulus of the composites [5].

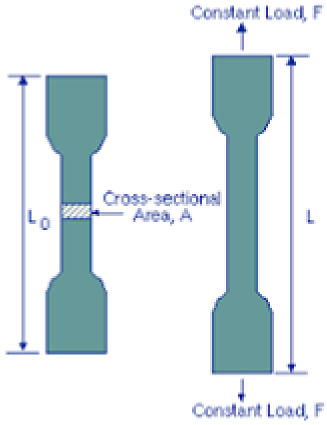

Figure 1 Illustration tensile specimen.

2. Bending Testing

There are few types of bending such as 3 point and 4 point of bending. This research used bending testing based on 3 point bending. ASTM D790 Flexure is the method that had been used for the bending testing.

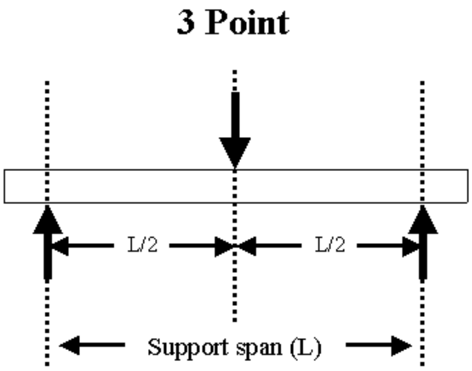

Figure 2 Illustration 3 point bending testing.

III. RESULTS AND DISCUSSION

A. The effect of polypropylene and cardboard without coupling agent and with addition of coupling agent.

The amount of ratio were used to form composite board. Before proceed to addition of MA as coupling agent, first and foremost there are some experiment to make composite board without coupling agent. From this result will be compared with the ratios of composite board with coupling agent.

Figure 3 Sample of specimen for tensile

Figure 4 Sample of specimen for flexure of bending

Table 2.1 Difference Ratio of Matrix and Filler.

Ratio Matrix : Filler (%)	Matrix (g)	Filler (g)
40:60	16	24
60:40	24	16
50:50	20	20
75:25	30	10
Total weight (g)	90	70

The research continued with addition of MA as coupling agent. The addition of coupling agent acts to increase adhension between matrix and filler. Some amount of ratio was decided to use in this experiment. With constant of MA was to determine the consistency of effect of coupling agent to the amount of ratios.

Table 2.2 Difference Ratio of Matrix, Filler and Coupling Agent.

Ratio Matrix: Filler: Coupling Agent (%)	**Matrix (%)**	**Filler (%)**	**Coupling Agent(g)**
75:15:10	75	15	10
60:30:10	60	30	10
50:40:10	50	40	10
40:50:10	40	50	10

1. Bending strength

Bending strength testing is conducted by using the ratio of matrix at 40%, 60%, 50% and 75%. There were the ratio without using MA as coupling agent. The width and thickness of the specimen 13 mm and 3 mm respectively. From the testing, the result obtain in figure. The figure of Stress (MPa) Vs. Strain (%) were plotted that showed that the strength of the composite board which the composite will bend until maximum value.

Table 2.3 Ultimate Bending with MA and Without MA at different of ratios.

Ratios of Percentage,%	**Ultimate of Bending, MPa**	
	Without MA	With MA
40%PP,60%CB	21.8	22.4
50%PP,50%CB	24.2	26.6
60%PP,40%CB	25.8	27.2
75%PP,25%CB	26.4	28.9

Table 2.4 Modulus Bending with MA and Without MA at different of ratios.

Ratios of Percentage,%	**Modulus Bending, MPa**	
	Without MA	With MA
40%PP,60%CB	1210	1300
50%PP,50%CB	1240	1760
60%PP,40%CB	1260	1820
75%PP,25%CB	1290	3060

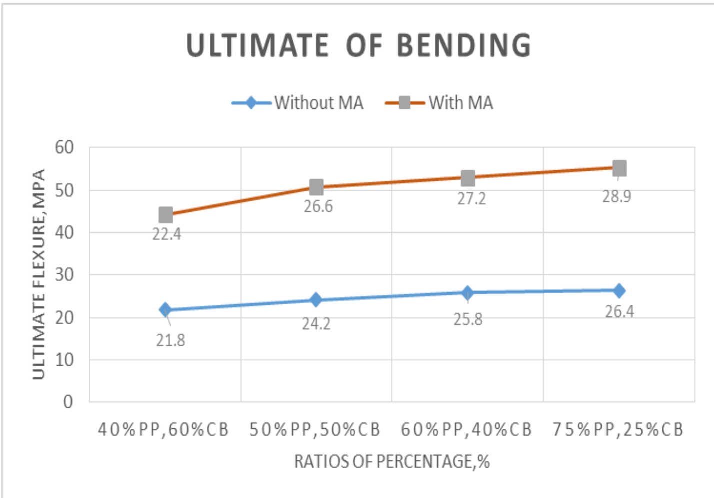

Figure 5 Ultimate Bending with MA and Without MA at different of ratio.

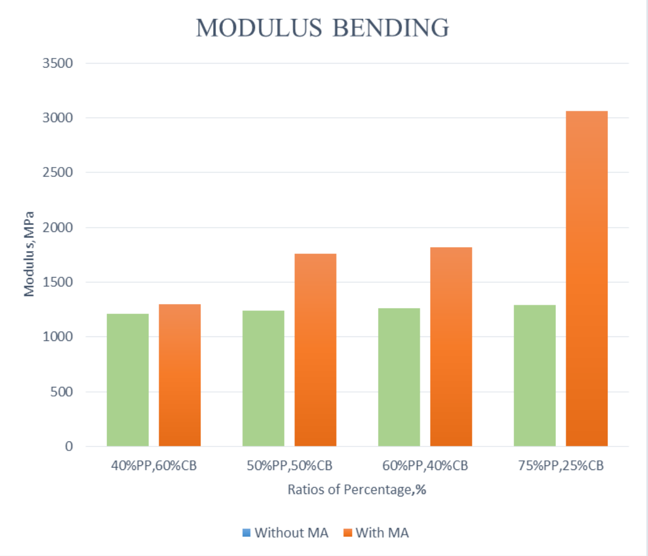

Figure 6 Modulus Bending with MA and Without MA at different of ratios.

The observation of ultimate bending and modulus bending in bending testing were very important to determine the resistance of the specimens with the forces. The maximum value of forces will be stated to be compared. The ultimate bending strength was very significant if the material were homogeneous. Effectively causing a localized weakness as act to concentrate the stresses locally whereas most materials have small or large defects in them. A condition where the material was bend only when the extreme fibers were the largest stress so the flexural strength will be controlled by the strength of those intact of fibers when there were those fibers were free defects,. The modulus bending or also known as Young's modulus was one of the mechanical property of linear elastic materials [32]. It was evaluated the elasticity of rigid or solid material, which was the relation between the deformation of a material and the forces which needed for the deformation of the specimens [32].

The figure 6, showed that the percentage of the ultimate bending was increased with the increasing of the percentage of polypropylene. The value of ultimate bending (MPa) with addition of MA was increased with increasing of PP at 22.4, 26.6, 27.2 and 28.9 MPa. While for ultimate bending without addition of coupling agent also increased at 21.8, 24.2, 25.8, and 26.4 MPa but the differences of the value represented that the addition of coupling agent enhanced the interfacial condition between the polypropylene and cardboard. The highest percentage of the ultimate bending with MA was at 75% of PP and 25% of cardboard at 28.9 MPa while the lowest of was at 40% of PP and 60% of cardboard which at 22.4 MPa. The highest percentage of PP was the highest ultimate bending pressure because of the polymer 75% of PP is suitable ratio that mixed with 25% of cardboard and tend to have a good interaction between them rather than the 40% of PP that has more percentage of cardboard that possible to easily cracked and need low amount of pressure and low of value ultimate tensile. According to [15], the composite that low amount of polymer has less elongated.

After that, the effect of the coupling agent testing to the bending with differ ratios continued. The increasing of percentage of PP gave the increasing of bending strength outcome based on figure 6. According to [5], the presence of WP and increase in WP content resulted in a continuous increase in value of modulus of the composites. But in this case the addition of the coupling agent produced compact composite board of the specimen to increase the bond between the matrix and filler. Although, the modulus with addition of MA were increased at 1370, 1820, 1760 and 3060 MPa. The value modulus without coupling agent also increased 1210, 1240, 1260 and 1290 MPa but the increment did not high as the value of modulus with addition of MA. The highest amount of PP was reacted with the coupling agent that resulted modulus as 3060 MPa. These condition showed that the coupling agent, MA attracted most bond between matrix and filler at 75% of PP. As stated in [14] interfacial de-bonding was crucial to allow the deformation of the polymer matrix proved that at high deformation rate as resulted in bending testing. Good compatibilizing agent contributed to such a purpose since it improves interfacial adhesion but initial de-cohesion at the interphase should be avoided as mentioned [14]. Same result as [20] showed an increase in flexural modulus when fiber and compatibilizer content increased as the result obtained. Modulus of bending was obtained when the specimen went flexed and the surface was submitted with the greatest value of stress. This is because when the specimen achieved the maximum of bending that would result the value ultimate bending.

2. Tensile strength

Servotec Fully Automatic Universal Tensile Machine 50kn was used in testing tensile properties. The specimen with dumbbell shape that has same width and thickness at 9 mm and 3 mm. they have same width and thickness because of they had been moulded by using same mould pallet. The figure of stress vs. strain was plotted to determine the tensile strength of the specimen.

Table 2.5 Ultimate Tensile with MA and Without MA at different of ratios.

Ratios of Percentage	Ultimate Of Tensile, MPa	
	With MA	Without MA
40:50:10	1.81	9.95
50:40:10	1.666	8.36
60:30:10	1.33	2.23
75:15:10	0.835	1.18

Table 2.6 Break Stress Tensile with MA and Without MA at different of ratios.

Ratios of Percentage	Break Stress Tensile, MPa	
	With MA	Without MA
40:50:10	0.744	1.05
50:40:10	1.18	2.00
60:30:10	1.48	8.19
75:15:10	1.62	9.68

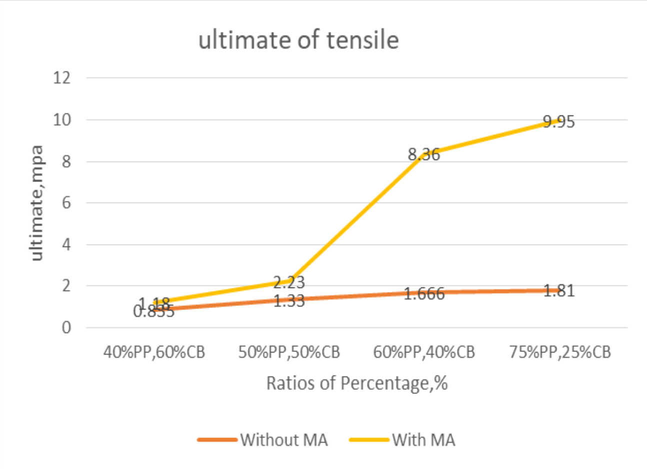

Figure 7 Ultimate Tensile with MA and Without MA at different of ratios.

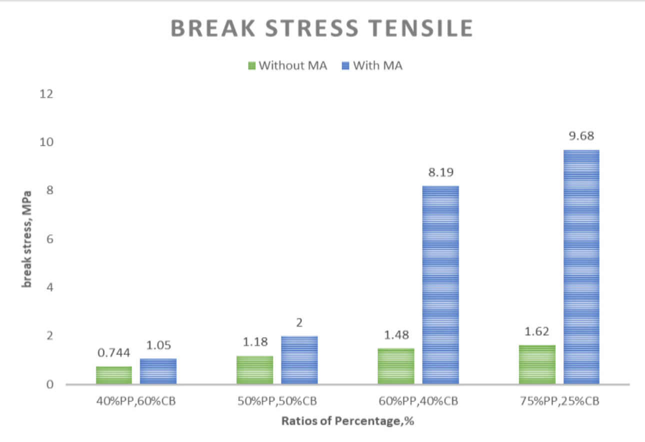

Figure 8 Break stress tensile with MA and Without MA at different of ratios.

Based on the ultimate tensile, figure 7 and break stress, figure 8 analysis were showed that the significant in studied to know the amount of limit value that maximum value was recorded as to notify the maximum forces or pressure that the specimens could be withstand. Theoretically considered the stress ultimate stress was maximum stress a material can withstand beyond which necking starts [33]. While breaking stress simply fracture stress where material breaks. The stress observation initial dimension would cause the breaking stress was less than ultimate stress. According to figure 7, showed that the ultimate tensile strength of the specimen. The highest percentage of the ultimate tensile strength is 75% of PP and 25% of cardboard. The specimen of 75% of PP was pulled to maximum as resulted at 9.95 MPa.

Next was the specimen of 40% of PP only can be pulled at 1.81 MPa which has low interaction between PP, CB and without using coupling agent. The ultimate tensile were increased by the increasing of percentage of matrices. This is showed that the coupling agent was reacted to polymer and well blended with the polymer. This condition caused the increasing of interaction of matrices and filler. When the interaction became higher the ultimate tensile also will become higher. According to [1], the tensile strength was depended the tensile modulus. Here, the tensile modulus was increased as same as the increment of the tensile strength.

For breaking tensile testing figure 8, the graph showed the highest of break stress tensile were at 9.68 MPa at 75% of PP with addition of MA where the harder specimen tend to split while for 40% of PP without addition of MA is the lowest at 1.05 MPa and 1.18 MPa. Breaking strength is the ability of a material to resist a pulling or tensile pressure. As similar result in [33] the breaking of the specimen led to decreased forces was detected because of low strength of the specimen blends. It is typically measured in units of pressure consistent with cross-sectional region. That is a crucial idea in engineering, specifically in the fields of material technology, mechanical engineering and structural engineering. As stated [8] the further addition of PP-MA led to a slight change in the tensile strength as same as the obtained result the increasing of the ratios of PP resulted the elongation at break possessed a noticeably higher value in high value of value PP.

Compatibilizing agents addition increased slightly the elongation at break of the binary blend, particularly when the high grafting level compatibilizing agent was employed this condition were led by the behaviour to a delamination process that was a consequence of the poor interfacial adhesion [14]. Experimental resulted the tensile strength of specimen would be matched with the tendon tensile strength at the same time this could conclude that by increasing the fraction of it increases the strength of the specimen and from this [17]. So the higher the value of breaking stress was determined when the maximum forces applied on specimen in such a way that the material unable to withstand any additional amount of stress before breaking. The breaking stress result showed that the tendency of the specimen to hold the amount of pressure to be break.

IV. Conclusion

The bending and the tensile testing give a differ result but the referred to the result, the highest of percentage ratio of PP was proven to become the high percentage of strain. The bending strength with coupling agent need to be enhanced the amount of the coupling agent but at percentage PP at 75% showed that the effect of coupling agent while for the tensile testing gave a good result that proved the MA as coupling agent was a good to make the bond of the matrix and filler. Next, the best ratio of the result from tensile and bending should be tested by using different amount of MA as coupling agent to be compared to each other. The experiment was successfully obtain the result the effect of the coupling agent to the matrix and filler which in between polymer and cardboard.

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