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Influence of fiber ratios and resin contents on the properties of medium density fiberboard made from rubberwood and *Leucaena*

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Abstract*: This study presents the manufacturing of medium density fiberboard (MDF) produced from a mixture of Leucaena and rubberwood species. The evaluations are conducted to determine the physical and mechanical properties of MDF from the mixture of Leucaena and rubberwood and the effect of different wood ratios and resin content on fiberboard properties. The usage of urea formaldehyde (UF) as a particleboard binder and target board density of 700 kg/m^3 were studied. Medium density fiberboards were assessed for the properties of mechanical (bending and internal bonding) and physical (thickness swelling) according to European Standard (EN 622-5:2006). Results shows that fiberboard made from 80% Rubberwood and 20% Leucaena and 12% resin content has the highest Modulus of Rupture (MOR) value of 15.09 MPa. Whereas, fiberboard made from 20% Rubberwood and 80% Leucaena and 12% resin content has the highest Modulus of Elasticity (MOE) and Internal Bond (IB) values of 2005 Mpa and 0.7 Mpa, respectively. Fiberboard made from 80% Rubberwood and 20% Leucaena and 12% resin content has the best Thickness Swelling (TS) value of 21.59%. The results revealed that the variations in wood ratios and resin contents shows significant effect on MOR, MOE and TS values of fiberboard. However, there is no significant changes on IB values with the usage of different Leucaena and rubberwood ratios.

Index Terms*: Medium density fiberboard; rubberwood; Leucaena; resin content; fiber ratio.

I. INTRODUCTION

The performance of timber products sector in Malaysia has been slowing down over the years. According to Abdul Rahim [1] from 1990 to 2007, timber production from natural forest in Peninsular Malaysia, Sabah and Sarawak has been decreased due to the law enforcement of forest harvest control imposed by Malaysian government. Besides that, most of the forest plantation area in Malaysia had been turned to agricultural purposes such as oil palm plantation and for construction area [2]. This situation had negatively affected many wood-based entrepreneurs in Malaysia. The management of the wood-based production need to have a back-up plan to keep the raw material stable and sustainable. Based on Malaysian Timber Industry Board [3] eight species had already been identified as potential wood resources. This includes Rubber tree, Binuang tree, Kelempayan tree, Teak tree, Sentang tree, Batai tree, Laran tree and Acacia tree. Target is to ensure that raw materials of timber related production is always enough for products manufacture.

Nowadays, it has been difficult to acquired solid woods. To meet the standards required, wood-based materials (particleboard, oriented strand board and waferboard) seem to provide alternatives in construction materials. Composites items have the upside of utilizing the whole sign in an exceptionally productive way. Accordingly, bring down item costs might be more than balanced by lower handling costs and higher yields. However, when there is sure standard should be accomplish base on their application, the generation of wood composite is substantially harder, for instance, the determination of the materials itself and the control of their creation. Be that as it may, numerous wood composite items are constrained in their exhibitions. This is because of, their accomplishment did not satisfy the market request and the nature of the regular items that had been expressed by the maker is yet ambiguous. Research in the advantages of composite innovation for wood-based materials for auxiliary and non-basic use expanded to beat the specialized issues and enhanced the quality. One of the targets of composite innovation is to create an item with adequate execution attributes utilizing low quality crude materials consolidating advantageous parts of every constituent. New composites are created with the intend to diminish the expenses and to enhance exhibitions.

In Malaysia, Rubberwood is one of the popular species used in the wood industry such as in furniture industry, particleboard and medium density fiberboard (MDF). According to Blasiger [4] Rubberwood have natural light color, making it more desirable in making a product. Utilization of rubberwood timber into valuable products had proven the technological and economic potential of using small-diameter and low-grade material. Blasiger [4] reported, until 10 to 20 years ago, the cut trees of rubber were usually burned on site, used for fuel wood or used to make charcoal.

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The typical tree during harvesting is small in diameter, quite crooked, and highly susceptible to blue stain fungi and beetle attack. The maximum length of the useable log is about 6 feet since it was crooked. Besides, the logs also have a high juvenile and reaction wood content. After several problems had been overcome with the help of applied research, particularly in connection with wood seasoning and preservation but also related to the small size of logs, rubberwood developed as one of the most successful export timbers of Southeast Asia.

As of late, Rubberwood volume has been diminishing as, after felling, its ranch territory has been supplanted by Oil Palm [5]. A new fast-growing species must be discovered to sustain the demand from the wood industry. *Leucaena* or Petai belalang is one of the fast-growing species that has the potential to be one of the raw materials in wood industry [6]. *Leucaena* is a multipurpose species that have potential in the tropic region. It is a multi-purposes tree that can be adapted to various environments. It has gained a great attention for its utilization commercially as a precursor for pulp and paper as well as packaging industries [7]. *Leucaena* is a tree with vast branches. It delivers considerably less seeds and isn't viewed as intrusive. *Leucaena* can develop to wind up huge trees of up to ~20 m in tallness, or it tends to be developed as a vegetable feed by keeping up the plants as smaller person hedges through rehashed reap of foliage, up to ten times each year. The wood of *Leucaena* can be utilized for timber, paper mash, or biofuel generation. In the Hawaiian Islands, many disintegrated living spaces, for example, roadsides, slope inclines, and infertile terrains, are for the most part involved by normal *Leucaena*.This study resulted from the needs of the industry to find an alternative material at reasonable cost. This study aims at determining the physical and mechanical properties of MDF from Rubberwood and *Leucaena* at different resin content and wood ratio.

II. MATERIALS AND METHODS

The *Leucaena* tree was harvested from Sabah Softwood Forest reserved. The tree age is approximately 5 years old. The tree was felled, cut to 1.5 m length logs and transferred to the UiTM wood industry workshop. Sawmill sawdust was used from wood shaving, wood sawing and wood cutting, from surface planning machine, thickness planning and straight-line ripe saw. Both *Leucaena* and sawmill waste were sent to FRIM for fiber making. The Rubberwood was obtained from Dongwa Merbok Sdn Bhd. The resin used was commercial urea formaldehyde (UF) with ammonium chloride (NH_4Cl) as hardener. The fibers were air-dried for duration of 7-9 days and then oven-dried for 24 hours at 80ºC to achieve moisture content of below 5 %. The MDF dimensions were 340 mm x 340 mm x 12 mm with a target density of 700 kg/m^3.

The fibers were sprayed with UF resin in a particleboard mixer at three resin dosages of 8%, 10% or 12%. Hardener of 3% was added to all formulations. Air pressure at hydraulic pressure 0.4 MPa atomized the resin into mixer until the fiber was completely blended. Hands forming were used to lay the fibers in a forming box and pre-press done at pressure of 300-500 psi for 30 seconds before being hot pressed for 6 minutes at 165ºC. All boards were conditioned in a conditioning room maintained at 20 ± 2ºC and relative humidity (65 ± 5) %.

The test pieces were prepared according to EN 622-5:2006 to determine the modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding (IB) and thickness swelling (TS). The effect of variables on the properties of the board was assessed by Analysis of Variance (ANOVA) and Duncan Multiple Range test was used for comparison of the average values.

III. RESULTS AND DISCUSSION

Summary of physical and mechanical of properties of MDF from *Leucaena* and Rubberwood are presented in Table 1.

Table 1: Mechanical and physical properties of LW And RW MDF

RATIO	RC	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
RW80:LW20	8	14.23	1944	0.31	43.22
RW80:LW20	10	15.05	1976	0.55	23.26
RW80:LW20	12	15.09	1980	0.67	21.59
RW50:LW50	8	8.89	1510	0.28	44.21
RW50:LW50	10	11.97	1908	0.48	30.02
RW50:LW50	12	13.37	1855	0.59	22.93
RW20:LW80	8	6.70	1011	0.39	34.72
RW20:LW80	10	10.84	1531	0.42	34.46
RW20:LW80	12	14.59	2005	0.70	26.88
EN 622-5:2006		22	2500	0.60	<15

Notes: RC: Resin Content, MOR: Modulus of Rupture, MOE: Modulus of Elasticity, IB: Internal bonding, TS: Thickness swelling, RW: Rubberwood and LW: Leucaena, GP: General Purpose

Apart from the IB value (0.67 MPa) for RW80:LW20 and RW20:LW80 (0.7 MPa) with 12 % resin all other board treatments did not achieve the requirement of MOR, MOE, IB and TS for general purpose, dry EN 622-5 2006. As such further discussions will look at the ratio trends and behavior for the MDFs made. Meanwhile, the interaction between ratio and resin has significant effect.

A. Effects of resin contents

The comparison for effect of resin contents on MDF panel MOR, MOE and IB on are shown in Figure 1. The results show that MOR a trend for MDF with 12% resin content (14.35 MPa) being higher than 10% resin content (12.62 MPa), and both dosages higher than 8% resin content (9.94 MPa). The increase of resin content in MDF also increased the MOR significantly. The increase in resin content enable better resin distribution as the glue to substrate contact can be enhanced. The hybrid MDF with 12 % resin content exhibited highest MOE value of 1946 MPa when compared to hybrid MDF from 10 % resin content (1805 MPa) and 8 % resin content (1488 MPa). All values differences are highly significant.

The IB strength shows MDF with 12% resin exhibit the highest value (0.65 MPa, passed EN general purpose - dry). The results were 35 % and 100 % higher than the 10 % and 8 % resin dosages respectively. The results were significant at $P<0.05$. This might be due to increase of the resin content in the board which gave more intimate contact for bonding. Nourbakhsh [8] reported increased MOR, MOE and IB with increasing of resin content. Similarly, Jahanshahi [9] found that the mechanical properties of panel increase were influenced by the resin content and board has more strength when more resin is added.

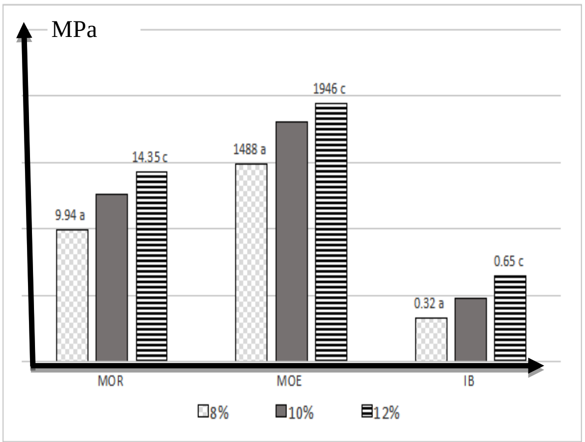

Fig. 1: Effect of resin content on mechanical properties

Value of TS and effect of significant of MDF for resin content is shown in Table 2. The MDF produced with 8 % resin gave the highest TS followed by 10 % and 12 % resin. The relationship of TS to resin content is inversely proportional and is significantly different. This might be due to insufficient UF resin for fiber in the composite. According to Jenkins [10], the "spring back" increases when the amount of resin used is not enough. "Spring back" occurs either when bonding contact area is low or when raw material used has low density and can lead to expansion of board, thus higher TS.

Table 2: Effect of resin content on physical properties

RESIN CONTENT (%)	TS (%)
8	40.72 b
10	29.24 a
12	23.8 a

B. Effects of wood ratio

Figure 2 shows the value of MOR, MOE and IB of hybrid MDF produced from RW80:LW20, RW50:LW50, and RW20:LW80. The value of MOR for MDF from RW80:LW20 (14.79 MPa) is higher than RW50:LW50 and RW20:LW80 (11.41 and 10.71 MPa respectively). While, hybrid MDF from RW80:LW20 exhibit the highest value of MOE (1967 MPa) as compared to hybrid MDF from RW50:LW50 (1758 MPa) and RW20:LW80 (1516 MPa).

The higher MOR and MOE by hybrid MDF produced from RW80:LW20 is due to the enough stress transferred from fiber to enable fiber to be ultimately fractured, thus giving higher bending properties. According to Khalil [11], Rubberwood fiber can withstand heavy load and this lead to higher results for composite with higher Rubberwood ratio. MOR of RW50:LW50 and RW20:LW80 are not significantly different. This might occur due to poor fiber refining quality. According to Mannheim [12], fiber processed by thermo mechanical pressure give higher potential for bonding between fiber and adhesive.

MDF of RW80:LW20 exhibited the highest value of IB strength (0.51 MPa) when compared to RW50:LW50 (0.45MPa) and RW20:LW80 (0.50 MPa). This might be due to the difference of wood ratio as reported by Paridah, [13] for fibers from heterogeneous MDF having different properties. The IB results is however not difference significantly.

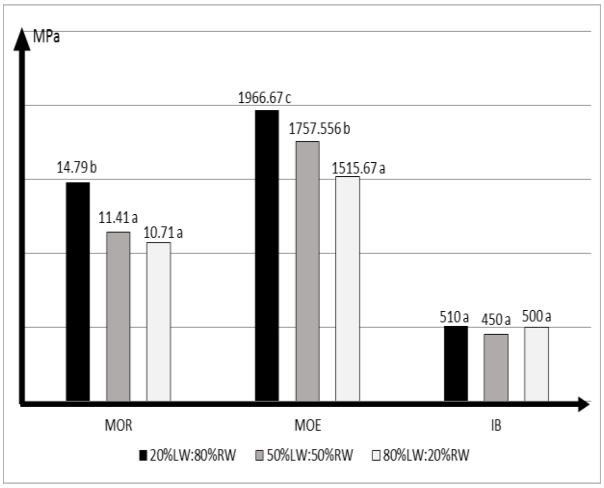

Fig. 2: Effect of ratio on mechanical properties

Results of TS of MDF produced from Rubberwood and *Leucaena* is shown in Table 3. MDF produced from RW50:LW50 showed the highest TS as compared to the other two combinations. Distribution of UF resin and fiber in the composite which results in the formation of fiber lump may cause this. Besides that, this phenomenon could be due to the properties of rubberwood fiber. According to Khalil (2010), rubberwood fiber had the lower content of the free hydroxyl group in the fiber. Therefore, RW80:LW20 has low TS because Rubberwood fiber is more stable towards water.

Table 3: Effects of ratio on physical properties

RATIO	TS (%)
RW80:LW20	29.35 a
RW20:LW80	32.02 b
RW50:LW50	32.39 b

Notes: a = lowest significant, and b = highest significant)

IV. CONCLUSION

The mechanical and physical properties of MDF made from Rubberwood and *Leucaena* at various wood ratios and resin content were studied. There is slightly enhancement on the fiberboard strength made from Rubberwood and *Leucaena* using 12% resin content compared to 10% resin content. Mixture of 80% Rubberwood and 20% *Leucaena* wood ratio gives the best properties of MOR (915.09 MPa) and TS (21.59 %). Fiberboard made of 20% Rubberwood and 80% *Leucaena* wood ratio gave the highest MOE and IB value of 2005 MPa and 0.70 MPa, respectively. Lastly, the effects of resin content and wood ratio for all properties gave significant impact except for IB value. Further work involving resin formulation, optimization of fiber formation and board making parameters are needed for this hybrid MDF before any combination can be recommended.

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