Degradation of Medium Density Fibreboard and Particleboard Mechanical Performance after Exposed to Different Environmental Condition

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Abstract*: Wood or natural-based products will continue to be susceptible to degradation. However, this degradation process can be slow-down by introducing additives or certain treatment. The properties (i.e. mechanical, physical, bonding etc.) of wood-based panel such as Medium Density Fiberboard (MDF) and Particleboard (PB) degrades in function with period of usage or exposure due to factors in surrounding conditions. This work focuses on the study of mechanical performance deterioration for MDF and PB after condition in the air-conditioned room and ambient for three months. Through this study, comparisons of various board variables (board types, exposure conditions, board thicknesses, resin types) influences the board performance degradation process. The project also studied the effects of cold-water immersion (12, 24 and 72 hours) to the mechanical properties of the board. The mechanical performance of boards was evaluated based on static bending (Modulus of Elasticity and Modulus of Rupture) and internal bonding tests after exposed for 3 months. All boards (MDF and PB) used in this study were obtained from local commercial panel manufacturer and test according to JIS A 5908-1994. The findings show that all the variables studied: exposure conditions, resin type, board thickness and board type respectively, have a significant effect on the diminished strength of panel strengths. The conditioning method and board type found to influence foremost compared with resin type. Exposing both of panels in air-conditioned room found to delay the degradation compared with ambient exposure for tested properties; MOE, MOR and IB respectively. The board thickness seems influenced the degradation of the board in any exposure conditions; air-conditioned, ambient or cold-water soaking. The thicker of the board, the greater the degradation occurred.

***Index Terms*: Medium density fibreboard, Melamine urea formaldehyde, Particleboard, Urea formaldehyde**

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I. INTRODUCTION

Currently, most panel manufacturers are trying to produce products with better performance, longer service life and environmentally friendly etc. On that note, great efforts have been done from finding new alternative raw materials up to new binder system. For instance, in term of raw materials, various sources have been studied includes sunflower stalks (Mati-Baouche et al., 2014), hemp (Almusawi et al., 2016), flax stalk (Mahieu et al. 2019), palm oil (Lee et al, 2017), Kenaf (Paridah et al, 2018), rice straw (Wei et al., 2015), wheat straw (Halvarsson et al., 2009), corn pith (Wang and Sun, 2002) or sugarcane bagasse (Panyakaew and Fotios, 2011). However, there is still no substance from these sources that able to compete holistically for the manufacturing of panel boards from existing timber sources. On top of that, many works have also been conducted in finding a new binder system such as tannin, lignin, protein, plant oil (Solta et al., 2019). However, in many ways' degradation of the products especially lignocellulosic based products cannot stop but only can be delayed by adding other material to maximize the usage. Degradation can occur in various ways, for example degradation by termites, flood, extreme humidity, drought etc. These factors will affect to some extent the usage of the products. In a normal condition, however, degradation caused by climatic does occur, parallel to the period of usage. For wood composites products such as MDF and PB, degradation can be from lignocellulosic material or from the adhesives used. In tropical climate, glue bond strength is pronged to degradation caused by the changes in climatic conditions (dry season, wet season, drought, flooding, rain). This may give a big impact to performance of wood composite after certain duration. Due to the hydrophilicity nature of lignocellulosic materials, the moisture absorption in wood-based composite is high which lead to week interfacial bonding between wood and adhesives (Paridah, 2013). The effects will be on glue bond quality, strength of panel products, which influenced the service life of the product. For a long-term application of wood composites, it is important to ensure that the degradation is minimized. If the extent of the degradation can be quantified the service life of the composite products can be estimated and applications of wood composite products become universally applicable. Hence, the usage of wood composite can be more efficient and suitable in every stage of application. Therefore, the objective of this study was to estimate the degradation of board mechanical performance of MDF and PB after being condition in an air-conditioned room and at ambient.

II. MATERIALS AND METHODOLOGY

A. Materials summary

The MDF and PB used in this study were obtained from local commercial board manufacturers. The thickness of the MDF samples were 6, 12, 18 and 25 mm. As for PB, only 12 mm thickness was used. All the samples were bonded with urea formaldehyde (UF) resin except for 6 and 12 mm thickness of MDF which bonded with melamine urea formaldehyde (MUF) resin. Basically, this study divided into four parts.

Part 1: Effect of board thickness and exposure condition on the bending and internal bond properties of UF-bonded MDF.

- all samples were exposed in different conditions over a period of 3 months. The thicknesses of MDF used were 6, 12, 18 and 25 mm.

Part 2: Effect of exposure condition on the bending and internal bond properties of UF and MUF bonded MDF of different thickness; 6 and 12 mm respectively.

- Both UF and MUF bonded boards were exposed in different conditions over a period of 3 months. The thicknesses of MDF used were 6 and 12 mm.

Part 3: Effect of exposure condition on the bending and internal bond properties of 12 mm thickness UF-bonded boards; MDF and PB

- Both UF - bonded MDF and PB boards were exposed in different conditions over a period of 3 months. Only 12 mm board was used.

Part 4: Effect of cold-water on bending and internal bond properties of UF and MUF bonded MDF.

- Both UF and MUF bonded MDF with different thicknesses were soaked in cold water for 12 hours, 24 hours and 72 hours.

B. Preparation of Specimen

The specimens were cut into size of static bending sample and internal bond testing according to JIS A 5905 and 5908 specification. For dry experiment, the samples were exposed in different conditions over a period of 3 months. For wet experiment, the specimens were soaked in the cold water for 12 hours, 24 hours and 72 hours. Both types of boards used rubberwood species.

C. Specimen Exposure

Two exposure conditions were applied for dry experiment in this study; a) an air-conditioned room (a temperature of 20˚C and relative humidity 65%), b) at ambient room (a temperature of 29˚C and relative humidity 78%). The unconditioned samples were used as control. The specimens were tested after exposed for 0 (control) and 3 months. For wet experiment, the specimens were tested after 0 hour (control), 12 hours, 24 hours and 72 hours of soaking.

D. Evaluation of MDF and PB performance

The boards were evaluated for bending and internal bonding properties according to the Japanese Industrial Standard, JIS A 5905 (Fiberboards) and JIS A 5908 (Particleboard). The bending test; modulus of rupture (MOR), modulus of elasticity (MOE) respectively and internal bond (IB) strength test of the boards were conducted using Instron Universal Testing Machine Model 4204.

III. RESULTS AND DISCUSSION

A. Part 1: Effect of board thickness and exposure condition on the bending and internal bond properties of UF-bonded MDF.

The ANOVA of the effect of exposure condition and board thickness revealed that there were no interaction effects between both variables in terms of MOE and MOR except for IB that shown in Table 1 with highly significant effect.

Table 1: Summary of ANOVA

Variables	*df*	Significance level		
		MOE	MOR	IB
Exposure condition (C)	2	***	***	***
Board thickness (TS)	3	***	***	***
C * TS	6	*	*	***

* Significant at $P < 0.1$, *** Significant at $P < 0.01$

Both exposure conditions and board thickness significantly affected the strength of MDF. Exposing the MDF in air-conditioned room could retain 92% its stiffness compared to only 85% if stored in ambient (room condition). Similar with IB strength, more than 13% higher retention were found in MDF stored in an air-conditioned room (Table 2). The strength (MOR) of the MDF, however, did not vary much between the exposure conditions. Board thickness significantly influenced the MOE, MOR and IB of the board that of 25mm thick. Amongst the board thickness studied, 18 mm apparently exhibited a much superior performance (Table 3)

Table 2: Effect of exposure condition on the bending properties of MDF after exposed for 3 months

Exposure condition	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
Control	2617^a	46.6^a	0.65^a
Ambient	2222^c	42.4^c	0.48^c
(% retention)	(85)	(91)	(74)
Air-Conditioned	2420^b	44.0^b	0.56^b
(% retention)	(92)	(94)	(87)

Percent (%) retention is over the control samples. Mean values followed by different letters are significantly different at $P < 0.05$

Table 3: Effect of board

thickness on the bending and IB properties of MDF

Board thickness (mm)	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
6	2211^{c}	44.2^{b}	0.57^{a}
12	2237^{bc}	42.1^{c}	0.41^{b}
18	2943^{a}	52.9^{a}	0.16^{c}
25	2289^{b}	38.0^{d}	0.10^{d}

Mean values followed by different letters are significantly different at P < 0.05

B. Part 2: Effect of exposure condition on the bending and internal bond properties of UF and MUF bonded MDF of different thickness; 6 and 12 mm respectively.

The summary of ANOVA of the effects of exposure condition, board thickness and resin type are shown in Table 4. Very high significant ($p<0.01$) differences were observed among all the variables studied.

Table 4: Summary of ANOVA

Variables	*df*	Significance level		
		MOE	MOR	IB
Exposure condition	2	***	***	***
Resin Type	1	***	***	***
Board Thickness	1	***	***	***

*** Significant at P < 0.01

Generally, the effects of exposure condition on the bending properties of MDF bonded with UF and MUF resins as shown in Table 5 were similar to those observed in Part 1. MUF-bonded MDF showed significantly higher strength (42% in MOE, 29% in MOR and 34% in IB) than the UF-bonded MDF (Table 6). The performances of both UF-bonded and MUF-bonded MDF differ greatly after being exposed under different condition. Between both samples, the UF-bonded MDF reduced its strength approximately 8% faster that did compare to MUF boards (MOE 2967 N/mm^2, MOR 53.5 N/mm^2, IB 1.09 N/mm^2) in ambient. As shown in Table 7 the effect of exposure condition is more prominent in UF boards with strength retention of MOE 83%, MOR 89%, and IB 71%.

Table 5: Effect of 3 months exposure condition on the bending and internal bond properties of MDF

Exposure condition	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
Control	2885^{a}	52.5^{a}	1.33^{a}
Ambient	2486^{c}	47.1^{c}	0.98^{c}
(% retention)	(86)	(90)	(74)
Air-Conditioned	2698^{b}	48.9^{b}	1.17^{b}
(% retention)	(94)	(93)	(88)

Percent (%) retention is over the control samples. Mean values followed by different letters are significantly different at P < 0.05

The resin types play and important role in glue bonding. MUF is the adhesive commonly used for exterior and semi exterior wood panels such as MDF. This is because, MUF have low ability to absorbed moisture and these will enhance its properties compared to UF resin. Even though MUF commonly used for outdoor, in this study the MDF that using MUF is placed in indoor just for comparison purposed. From the Table 6, the value of MOE, MOR and IB of the MUF resin are 3156 N/mm^2, 55.9 N/mm^2 and 1.33 N/mm^2, respectively. All these values are higher than UF-bonded samples. Higher resistant to water attack is the main distinguish characteristic of MUF compared to UF resin (Khairun, 2000). The major disadvantages of UF resin is its defect in low water resistance and hence could not withstand exterior uses. Consequently, the products make with UF resins have been restricted to interior application.

Table 6: Effect of resin type on the bending and internal bonding properties of MDF

Resin Type	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
MUF	3156^{a}	55.9^{a}	1.33^{a}
UF	2223^{b}	43.2^{b}	0.99^{b}

Mean values followed by different letters are significantly different at P < 0.05

Table 7: Effects of exposure condition and resin type on the bending and internal bonding retention of MDF.

Exposure condition	Properties	UF	MUF
		(% retention)	
Ambient	MOE	83	89
	MOR	89	91
	IB	71	77
Air-Conditioned	MOE	92	94
	MOR	93	93
	IB	87	89

Percent (%) retention is over the control samples

C. Part 3: Effect of exposure condition on the bending and internal bond properties of 12 mm thickness UF-bonded boards; MDF and PB.

The summary of ANOVA of the effects of conditioning method, and board type is shown in Table 8. Very high significant ($p<0.01$) differences were observed among all the variables studied.

Table 8: Summary of ANOVA

Variables	*df*	Significance level		
		MOE	MOR	IB
Condition method	2	***	***	***
Board Type	1	***	***	***

*** Significant at P < 0.01

The effect of the exposure condition on bending and internal bonding properties of different board types is highly significant which achieved $p<0.01$ (Table 8). Both variables, exposure condition method and board types gave a big effect to strength properties of the board that includes MOE, MOR and IB.

Table 9: Effect of exposure condition on the strength properties of the board after

exposed for 3 months

Exposure condition	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
Control	2326[a]	30.7[a]	0.43[a]
Ambient	1864[c]	26.4[c]	0.22[c]
(% retention)	(80)	(86)	(50)
Air-Conditioned	2149[b]	27.9[b]	0.30[b]
(% retention)	(92)	(91)	(70)

Percent (%) retention is over the control samples. Mean values followed by different letters are significantly different at $P < 0.05$

As seen in previous parts, same trend was also observed as shown Table 9 whereby exposing the boards in air-conditioned condition reduce the degradation of the board properties. From the observations, MDF gave the better performance after exposed which shown in Table 10 and 11. The used of fibres with higher aspect ratio compared to particles contribute to superior strength properties of MDF. Between both of samples, particleboard reduced its strength almost 6% faster than MDF.

Table 10: Effect of conditioning method on the bending and internal bonding properties of different board type

Resin Type	MOE (N/mm^2)	MOR (N/mm^2)	IB (N/mm^2)
MDF	2237[a]	42.1[a]	0.41[a]
Particleboard	1989[b]	14.5[b]	0.22[b]

Means values followed by different letters are significantly different at $P < 0.05$

Table 11: Effects of exposure condition on bending and IB properties of MDF and PB.

Condition	Properties	MDF (% retention)	PB (% retention)
Ambient	MOE	82	78
	MOR	86	83
	IB	57	38
Air-Conditioned	MOE	92	92
	MOR	92	88
	IB	76	60

Percent (%) retention is over the control samples.

D. Part 4: Effect of cold-water on bending and internal bond properties of UF and MUF bonded MDF

Soaking the MDF's in cold water for 12, 24 and 72 hour significantly reduced the properties of the board. The 6 mm board shows superior board throughout the soaking duration compared to other thicker boards. The thicker the board, the higher is the reduction of bending properties for both MOE and MOR. (Fig. 1 and 2). As seen in previous parts, thicker boards have lower IB strength as it become less compact towards middle part of board thickness. Hence, water molecule easily penetrated. This will initiate the degradation of the board's strength resulting in a much lower strength in the first 12 hours. However, the bending properties was maintained after this period even up 72 hours of soaking.

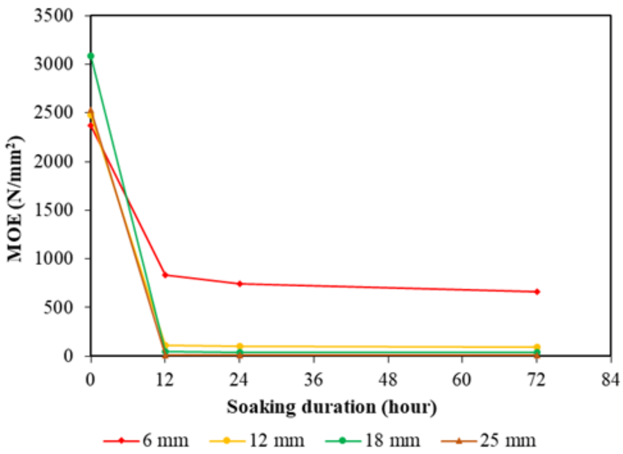

Fig. 1: Effect of soaking duration on the MOE of MDF at various board thickness

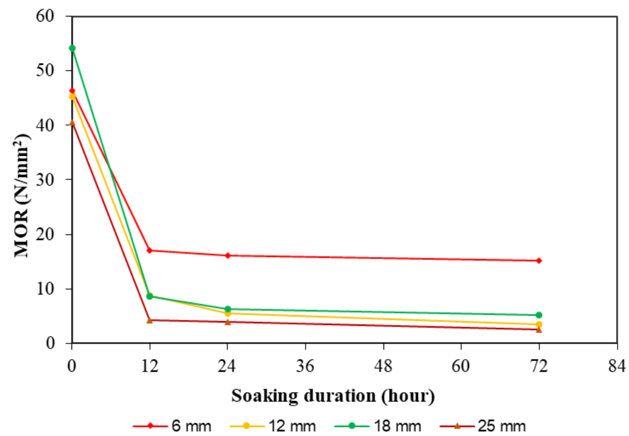

Fig. 2: Effect of soaking duration on the MOR of MDF at various board thickness

In term of resin effect, MUF-bonded MDF was a slightly more resistant towards water in terms MOR and MOE. For 6 mm thick MDF, the performance was apparently about the same regardless type of resin. The reductions of the both bending properties (MOE and MOR) were shown in Figs. 3 and 4.

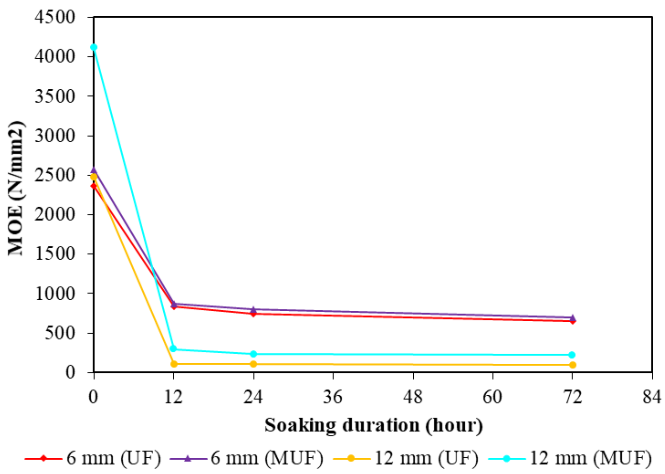

Fig. 3: Effect of soaking duration on the MOE of MDF bonded with different resin.

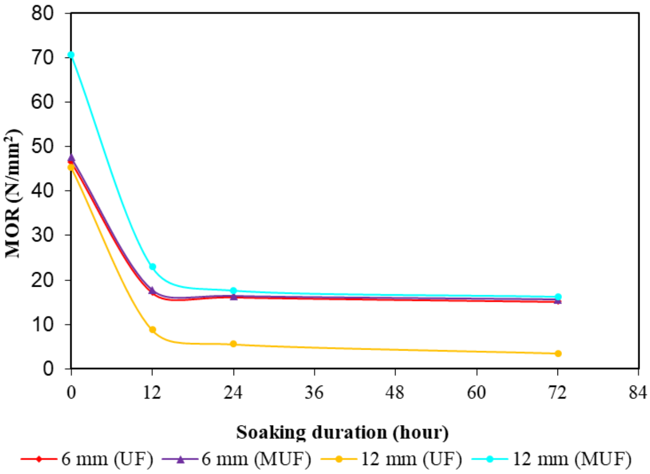

Fig. 4: Effect of soaking duration on the MOR of MDF bonded with UF and MUF resin.

IV. CONCLUSIONS

From the results, it can be concluded that the board mechanical performance significantly affected by all of variable studied especially board variables and conditioning method compared to resin type. Generally, exposing the panels in air-conditioned room delayed the degradation than expose in ambient especially for MOE and IB performance. The board thickness found significantly influences board degradation. The higher board thickness the greater the degradation. All MDF boards degraded after 12 hours of cold soaking but no further degradation occurs after this period.

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