Flexural influence on screw withdrawal behaviour of selected commercial particleboard

Nor Yuziah Mohd Yunus, Nur Wafa Amalina Amali, Nur Sakinah Mohamed Tamat, Wan Mohd Nazri Wan Abdul Rahman

Abstract**: *A study was conducted to evaluate the influenced of flexural strength toward screw withdrawal (SW) and surface soundness (SS) based on selected commercial particleboard. The SW and SS is an important criteria for utilization of boards in application involving board surface properties and board reaction towards usage of fastener. The material was collected from MIECO Manufacturing Sdn. Bhd. The selected commercial particleboard includes 3 different thickness of board (16mm, 18mm and 25mm) were tested. The particleboard ratio was 60% rubberwood and 40% mixed tropical wood with dimension of 60 cm x 120 cm x thickness of board. This study is to investigate the mechanical properties of board that determined internal bonding, flexural, SW and SS of board. The result shows there is correlation on flexural. Meanwhile for SS, the positive correlation was with value of 0.415 according to Pearson correlation analysis.***

Keywords : Flexural, Particleboard, Screw Withdrawal, Surface Soundness.

I. INTRODUCTION

Composite wood or engineered wood are manufactured by binding or fixing the strand, particle, fibre or veneer of wood together with adhesive to form composite material like particleboard, sandwich board, cement board and other. There are more than 16 mills manufacturing particleboard running in Malaysia. Particleboard have been accepted as an alternative way to replace solid wood, as particleboard or composite panel product is more durable, consistence, can be produced in precise thickness and is more affordable [1]. Particleboard for example comes in a variety of densities and strength groups, presents as a flat panela that could be laminated, coated and cut to sizes ready for use.

In Malaysian particleboard making, commonly rubberwood is the main raw material. Based on [2] study, rubberwood is major material of particleboard and MDF production in Malaysia but the supply of rubberwood has depleted. Unfortunately, the raw material supply has become limited in the future due to replacement of rubberwood with oil palm during replanting. Not only that, research by [3], agriculture waste material has become common alternative raw material for wood composite material or particleboard manufacturing. Non-wood material like hemp, bagasse and wheat straw or other crop residue are commercially in number of countries in the world. Non-structural purposes mostly can be seen on light or interior uses because particleboard is made from wood residue.

Particleboard is generally used as raw material of finished goods like ready-to-assemble furniture, counter top, storage facilities. Hence, particleboard furniture can substitute wooden furniture in market. It became more popular as particleboard has no natural defect like knot, grain defect or compression. Other than that, non-structural particleboard can be found in packaging like boxes or aesthetic product such as music instrument including piano, guitar or violin. It is also used as building construction part like floor, wall and ceiling panel. Utilization of particleboard is important not only for furniture and other industrial application as consumer, but also important for economy income. Added by [4] particleboard can be concluded as one of high demand on wood composite product that consumed a large part in wood composite industry.

Performance of fastening is crucial element on determine the stability of furniture structure. Composite material or wood mostly used screw as fastening tool rather than nail. The reason of screw recommendation is the ease of its removed once fastened compared to nail.

On furniture making, fastening is a critical process when combining the two or part together. Fastener is a tool typically used for affixing or joining used as temporary linking where fastener can be installed or removed repeatedly by hand or machine without damaging the component. Application of fastener mostly is design to transmit or support the two parts of attached component when externally load is applied. Performance of engineered structure depends on suitable connector. According to [5], in furniture making, the hardest part of choosing engineering design on wood is selecting an appropriate fastener (bolt, screw or nail) and raw material (types of material, geometry of material or size of material). According to [6], for easier connection and more practical mechanical connection, screw gave good results for both wood and wood composite material. Added by [7], the fiber structure might cause an impact on bending strength of board. Bending properties may affect screw withdrawal, surface soundness or IB of particleboard.

Previous studies on particleboard have shown some correlation between screw withdrawal strength with wood species, wood densities, coated and uncoated board, types of screw, depth of pilot hole, the handling of the screw when tightening, mechanical and

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physical properties of board and position of screw insertion when testing. As stated by [8], bending properties which include MOE and MOR have influence on the properties of board screw withholding strength. This study focused on determining the flexural influenced on screw withdrawal properties and surface soundness towards commercial particleboard.

II. MATERIALS

Raw materials for this particleboard are rubberwood and mixed tropical wood. The rubberwood were obtained from small holder and mixed tropical wood was supplied from sawmill waste. The particleboards are taken from production sampling taken at stabilized production interval of 2 hrs. A sample of 60 cm x 210 cm was cut from the production line. This board was then sampled to the required sizes for flexural, internal bonding and screw withdrawal. The test sample was conditions at 65% relative humidity and temperature of 25^{o}C for 24 hours prior to testing.

III. METHODS

The commercial particleboard used in this comparison was made up from a mixture of rubberwood (60%) and mixed tropical wood (40%) with Urea Formaldehyde E2 as resin. The density of board is between 640 to 670 kg per cubic meter based on commercial industry target. The process of particleboard involved mat forming where particleboard formation was with two face layers and one core layer (3 layer board). The flow process of making particleboard is shown in Fig. 1.

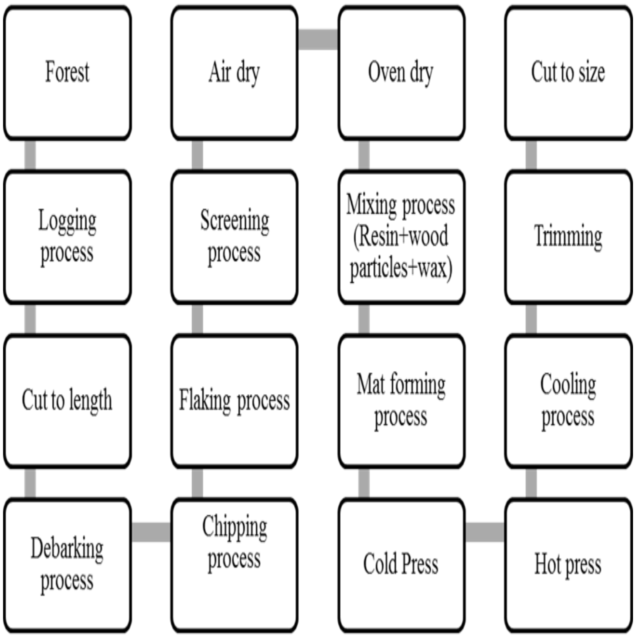

Fig. 1: The flow process of particleboard production.

A sample of 60 cm x 210 cm particleboard was collected at the end of hot press. No stacking after hot press was done on the collected samples. The board sample was then cut into specific sizes for internal bonding (IB), bending strength testing, screw withdrawal (SW) and surface soundness (SS) testing (Fig. 2). The testing was conducted according to European standards [9], [10]. The sample testing for IB, SS and SW was 50 mm x 50 mm x thickness in mm for 3 test specimens each. Meanwhile flexural testing dimension was 300 mm x 50 mm x thickness in mm dimension (5 specimens). All results were analyzed using ANOVA for statistical significance.

Fig. 2: Board cutting for test sample preparation.

IV. RESULTS AND DISCUSSION

A. Mechanical Properties

Table I shows the mean values of the Modulus of Elasticity (MOE), Modulus of Rupture (MOR), IB, SS and SW of the different thickness of particleboard from rubberwood and mix-tropical wood. The particleboard with 25mm thickness showed highest MOE (2350 MPa) followed by 16 mm (2112 MPa) and lastly 18 mm (207MPa). Modulus of Rupture showed similar results for all thicknesses with 16mm having a slight edge with MOR of 11.10 MPa. The boards are production are normally controlled by the MOR requirement of customers, thus the targeted MOR will be as required by standard [9]. The same could be said for IB, with a target of 0.4 MPa. The values for all three boards are slightly lower than the target. It should also be noted that these test samples area taken immediately after the hot-press and are for in-line quality testing control. The value after hot stacking of boards produced in a production line is normally increase by 20%. Boards at end of hot press line collected for quality control are normally aimed for 80 to 85 % curing. Theoretically the boards will have a final IB of about 0.45 MPa.

Table I: Mechanical properties of particleboard

Thickness of board (mm)	Bending strength (MPa)		IB (MPa)	SW (N)	SS (N/mm$^{2)}$
	MOE	MOR			
16	2112	11.10	0.37	510	1.19
18	2007	11.05	0.38	471	1.25
25	2350	11.03	0.37	488	1.17
BS EN Standard	2300	11	0.40	-	-

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture, IB-Internal Bond, SW-Screw withdrawal, SS-Surface soundness

Meanwhile, the highest SW value is 510 N for 16 mm thickness of particleboard. This augurs well with theory where thinner board tends to have higher compaction ratio. However, the values of 18 mm and 25 mm negate this. The SS reading also present an interesting variation as it does not follow a specific trend against the thickness.

The 18 mm board is more resilient in SS compared to the 16 mm and 25 mm boards.

B. Statistical Significance

The ANOVA results for the effect of the thickness of particleboard on the mechanical properties are given in Table II. The data obtained in this research showed thickness of particleboard is not significantly affecting the MOR, IB and SW. For MOE and SS the board thickness playa an important role as the effect significant is at $p<0.05$.

Table II: Summary of the ANOVA of the mechanical properties

SOV	df	Bending strength		IB (MPa)	SW (N)	SS (N/mm^2)
		MOE	MOR			
Board thickness	2	3.81*	0.34 ns	1.63 ns	0.97 ns	6.47*

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture, IB-Internal Bond, SW-Screw withdrawal, SS-Surface soundness

C. Effects of Particleboard Thickness

Fig. 3 compares the effect of the thickness of particleboard on the MOE and MOR. The DMRT results showed that the MOR values of all thickness is not significantly different. The target specification for MIECO's production is 11 to 11.5 MPa as required by standard and their customer. For MOE values, there was a significant difference between the 25mm against 16mm and 18mm thickness of particleboard. The difference indicated the different degree of flexibility of boards. The standard requirement of 2300 MPa by [9] is likely to be achieved by the 16 mm and 18 mm board after the batch tested has undergone hot stacking during storage.

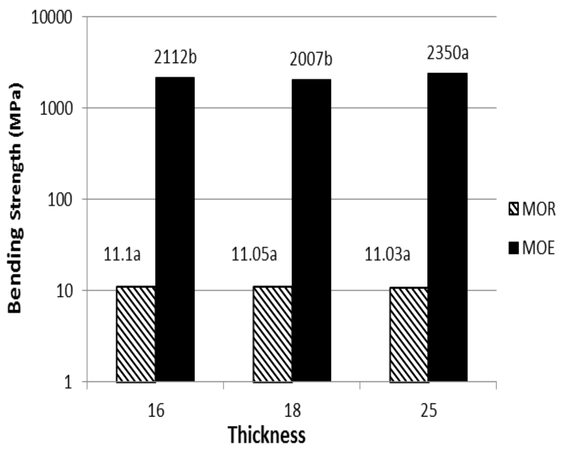

Fig. 3: DMRT results of the MOR and MOE for the different thickness of particleboard (MPa).Letters a, and b indicate values in cluster to be significantly different at p<0.05

According to [11], even when the density of board is same on different thickness of board, the higher compression ratio between particles affected the MOE of board. All three thicknesses were produced with densities between 640 to 670 kg per cubic meter. The different thicknesses were produced at different rate, thus giving different closing speed for the hot press. This could account for the better performance in MOE for 25 mm board as the slower speed will allow the surface of the board to cure faster.

For IB, according to data, all thickness showed similar result of 0.37 to 0.38 MPa (see Table I). There is no significant difference between the three board thicknesses used. As expected, commercial made boards aimed for a specific range for IB value and this proved the consistency and stability of production. In term of IB, normally the edge screw withdrawal will be proportional to the IB as reported by [12]. As stated earlier the production online control parameters will give a further 20% increment to the IB value.

Fig. 4 shows the effect of thickness of particleboard on screw withdrawal. According to the result, 16mm thickness of board shows the highest screw withdrawal strength with 510N followed by 25mm thickness of board with 488N. It was found that the 18mm thickness of board shows the lowest strength compared to others. If the compaction factor is taken into account, thicker board will have lower density at core while thinner board will have higher core density. The higher density will present more resistance against screw resistance as less voids is present in the mid-point of core.

According to [8], the MOE strength is found to be inversely proportional to screw withdrawal with the presence of high stiffness on board. This phenomenon was observed with the 16mm thick board versus the 25mm board. Pearson correlation analysis also supports the negative relationship of SW and MOE (Value -0.497).

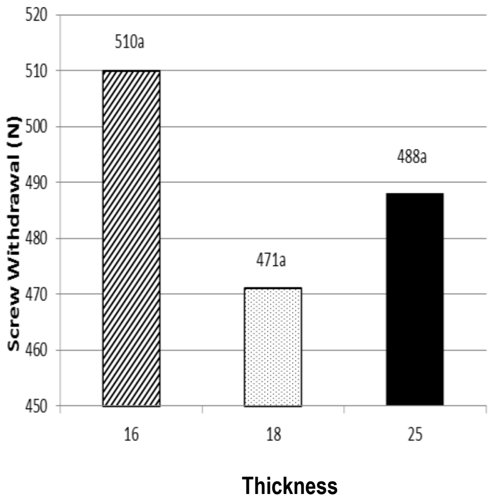

Fig. 4: DMRT results of the screw withdrawal for the different thickness of particleboard (N). Letter a indicate values in cluster to be not significantly different at p<0.05.

In Fig. 5, the highest to lowest value of surface soundness arrangement follows 18mm, 16mm and 25mm thickness of board with 1.25 N/mm^2, 1.19 N/mm^2 and 1.17 N/mm^2, respectively. According to [7] there is correlation between surface soundness and MOE. The SS behaviour is inversely proportional MOE, where it's increased when the values of MOE are decreased. However, Pearson correlation check showed a positive value with 0.415.

This opposing result could be due to the extreme high result of 18 mm board compared to 25 mm board. Other factors such as board process parameters during formation need to be further analysed and considered to account for this differential.

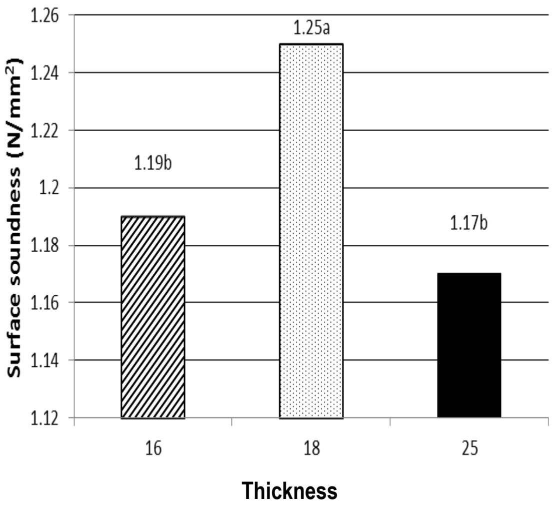

Fig. 5: DMRT results of the surface soundness for the different thickness of particleboard (N/mm^2). Letters a, and b indicate values in cluster to be significantly different at $p \leq 0.05$.

V. CONCLUSION

This study investigated the flexural properties on selected control board samples during commercial production of particleboard. The material collected at the press-line has not undergone post hot press stacking thus giving a borderline value against board acceptance criteria. The three different thicknesses of particleboards were tested on bending strength, IB, SW and SS. According to the results:

1. Immediately after hot-press, only particleboard with thickness of 25 mm immediately met the requirement of standard.
2. The result shows an inversely proportional correlation between flexural and SS (-0.497).
3. For SS, a positive correlation was with value of 0.415 according to Pearson correlation analysis.

VI. ACKNOWLEDGMENT

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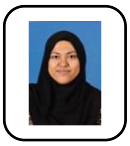

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