International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Properties of Particleboard in Correlation with Mat Weight and Press Factor

Nor Yuziah Mohd Yunus, Muhammad Abdilah Ab. Rani, Nur Sakinah Mohamed Tamat, Wan Mohd Nazri Wan Abdul Rahman

***Abstract:** The influence of resin types on board properties and the correlation to mat weight and press factor on commercial production of particleboard were investigated. These factors could be used as the control mechanism for board making in order to predict final board properties. The resins used in this study were the lower emission resin E0, E1 and EC. Rubberwood and mix tropical species were used as raw material for manufacturing particleboard with thickness of 18mm. This research was done at Mieco Chipboard Bhd. The boards were tested for their mechanical properties which are modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding (IB) and screw withdrawal. Overall, the result shows that board made from E0 resin had better MOE, MOR and IB. Meanwhile the result of screw edge showed that board made from E1 resin is better with the value of 510N. The result also showed high correlation between mat weight and press factor (0.937) and contributed in particleboard manufacturing control*

***Keywords :** Mat Weight, Particleboard, Press Factor*

I. INTRODUCTION

Particleboard is comprised of lignocellulosic material primarily in the form of particles which has been compressed to a panel form under heat and pressure. The compressed board could be with or without a binder. A particleboard is defined as flat plated when the pressure is applied perpendicular to the faces as seen in regular multi-plate press or continuous press. Extruded particleboard is produced when the hot press pressure is parallel to the faces [1]. Particleboard is widely used in furniture, flooring board, cabinet, housebuilding, table tops, interior signs, kitchen counters, bookshelves and office furniture, to name a few [2].

Manuscript published on November 30, 2019.
* Correspondence Author
Nor Yuziah Mohd Yunus*, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. Email: noryuziah@uitm.edu.my
Muhammad Abdilah Ab. Rani, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. Email: aj.abdilah@gmial.com
Nur Sakinah Mohamed Tamat, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. Email: sakinah292@yahoo.com
Wan Mohd Nazri Wan Abdul Rahman*, Faculty of Applied Sciences, Universiti Teknologi MARA, Pahang, Malaysia. Email: wmdnazri@uitm.edu

The most expensive raw material in producing particleboard is resin. Resin plays an impressive role in the performance of wood-based panels, where the bonding quality and improvement of the properties of these materials depend mainly on the type and quality of the resin. Resin used in the wood industry could be grouped according to their chemical properties, physical properties or intended use in construction [3].

Formaldehyde is the simplest form of the aldehyde series. Formaldehyde is a reactive monomer, a colourless gas with an acrid odour at room temperature. It is a primary building block for chemicals such as hexamine and many polymers used for coating and binding. The wood-based industry used formaldehyde based resins in composites such as medium density fiberboard, particleboard, oriented strand board and plywood [4]. It is also used, combined with polyvinyl acetate widely in the furniture industry. Urea formaldehyde (UF) accounted for 80 % of formaldehyde based resin used in the wood composite industry [5].

The study of mat weight and press factor in manufacturing particleboard aims to improve the quality and strength of the particleboard. Hot press was the important process that involves compressing and curing the mat being formed. The particleboard core layer heating rate during hot-pressing need to be controlled as it will affect final board quality. It is sensitive to press temperature used and its profile, the pressure's quantum and cycle, duration in the press, the board layering and formation, moisture content and the resin formulation used [6].

The level of speed in mat forming process will also give effect to the physical properties on particleboard. In small factory with multi-daylight hot press, the batch mat forming will be at a slower speed. In larger factory, the continuous line used will allow faster mat forming term of speed when wood particle is distributed. This differential gives rise to various press factors.

Besides that, the mass of mat weight is also a factor that can be affecting the strength of particleboard formed. Usually, mat weight is related to the thickness and size of the particleboard to be produced. The mat weight value will have an impact on the density, compaction and performance of particleboard. Hence, this study was to investigate the effects of resin types and the correlation of mat weight and press factor on properties of commercially produced particleboard.

II. MATERIALS AND METHODS

A. Preparation of Rubberwood and Mix Tropical Species Particles

Rubberwood and mix tropical species or sawmill wastes were obtained from Mieco Manufacturing Sdn. Bhd. Gebeng, Pahang, Malaysia. Rubberwood was supplied by plantation owner who are undergoing replanting exercise. The sawmill wastes comprised of wood off cuts, shaving and wood slabs, which are normally either thrown away or burnt by timber factories and log yards. Raw material in logs form were debarked and then sawn into smaller logs for easier chipping. Chips were flaked into smaller particles and stored in a "Wet Silo" before being fed into dryer drum for drying. Later, the particles were screened. At Mieco, screening machine divides the wood particles into 0.25 mm, 0.8 mm and 1.25 mm sizes. The smallest size will be transferred to dust silo and burned to generate heat which would be used for drying of chips. The 0.8 mm and 1.25 mm sizes will be used as surface and core layer respectively. Any larger sizes such as 8-10 mm measurement were transferred to the hammer mill in order to reduce it into smaller size. These particles will then be screened and treated as described earlier.

B. Board Making

A calculated amount of dried particles, resin, wax and hardener were blended. Resinated particles were then transported into mat former. The resins used were E1, EC and E0. The free formaldehyde level for these resin are ranked as E1>EC>E0. The ranking of the molar ratio of the resin will be E1>EC>E0. The mats were then pre-pressed. Mat weight was calculated during pre-pressed. Mat weight is the mass of board per meter square. Each board has different mat weight based on their resin. For example, E0 has higher material composition on board per meter square than other resin. The pre-pressed resin-coated mats were then hot pressed to cure the resins and to bind the particles together. At Mieco, there are 28 hot press frames with different function (Table I) and temperature (Table II). Press factor reported in second, is the time taken for a specified board length to pass through the hot pressing process. The mechanical properties decreased with decreasing press factor and increasing speed. Besides high temperature, the adequate press factor speed line is needed to achieve proper cure of the adhesive and provide the necessary compaction. After being hot pressed, the boards were trimmed and cut into various sizes for property evaluation.

Table I: Function of hot press frame

Press Frame	Pressing Area	Function
1-10	Maximum press	Strength and bending
11-17	Normal press	Remove gas
11-28	Minimal press	Thickness

Table II: Temperature at hot press frame

Frame	Temperature (˚C)
1-2	175
3-8	200
9-13	218
14-18	210
19-28	200

C. Board Evaluation

Particleboards were cut into required sizes for testing flexural strength, modulus of elasticity (MOE) and modulus of rupture (MOR), internal bond (IB) and screw withdrawal (SW) following [7], [8] requirements. The test samples for each test were 5 specimens. Modulus of elasticity, MOR and IB tests were conducted using an Instron Universal Testing Machine. The materials used for SW tests were commercially produced specimens of conventional particleboard (PB). The tests were carried out on 18 board samples. The screws used were 55 mm in length with pilot hole of 30 mm depth.

III. RESULTS AND DISCUSSION

A. Mechanical Properties of Particleboard

Table III shows the value of mechanical and physical properties of particleboard by the types of resin. The result of testing shows that samples with E0 resin is better in bending strength and IB than other resin types. Meanwhile samples with E1 give a lower press factor than samples with EC and E0 resins. Press factor is highest for E0 boards showing that E0 needs longer time to cure. The table also shows that samples with E0 resin have the highest mat weight.

Table III: Mechanical Properties of Particleboard and selected process parameters

Resin	MOR (MPa)	MOE (MPa)	IB (MPa)	SW (N)	Mat Weight (kg m^2)	Press Factor (s)
E0	13.5	2641	1.07	500	13.9	10.5
E0	13.1	2598	1.05	497	14.2	10.0
E0	13.3	2471	1.09	499	14.2	10.8
E0	13.3	2548	0.69	486	14.3	10.5
E0	13.2	2483	0.71	488	14.1	10.3
E0	13.2	2671	0.87	450	14.1	10.8
E1	11.0	2077	0.38	488	13.6	6.7
E1	10.8	2282	0.36	471	13.4	7.0
E1	10.9	2008	0.39	466	13.6	7.0
E1	10.7	1824	0.37	470	13.4	6.8
E1	11.0	1954	0.79	456	13.4	6.7
E1	13.6	2291	0.90	466	13.6	7.0
EC	11.6	2103	0.40	502	13.6	7.5
EC	11.3	2143	0.37	511	13.6	7.4
EC	11.5	1997	0.39	528	13.7	7.5
EC	11.4	2310	0.40	487	13.7	7.5
EC	11.2	2094	0.37	528	13.6	7.4
EC	11.3	2025	0.39	503	13.6	7.5

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture , IB-Internal Bond, SW-Screw Withdrawal

B. Statistical Significance

Resin type was observed to have significant effect on mat weight and press factor. This was shown in Table IV, where the analysis of variance (ANOVA) on the effect of MOR, MOE, IB, SW, mat weight, press factor and their interaction on the resin was summarized. The resins of E1, EC and E0 have significant effect on the particleboard.

Table IV: Summary of the ANOVA on Board Properties

SOV	df	Bending Strength		IB	SW	Mat Weight	Press Factor
		MOE	MOR				
Resin Type	2	16.99*	25.65*	14.19*	10.17*	60.70*	568.25 *

Note: MOE-Modulus of Elasticity, MOR-Modulus of Rupture , IB-Internal Bond, SW-Screw Withdrawal, SOV= Source of variance, df=degree of freedom, *significant at p<0.05

C. Effects of Resin Type

Fig. 1 shows the effect of resin type on MOE. Boards made from resin types E0 had significantly higher MOE compare to the board made from resin type EC and E1. Meanwhile, the MOE values for boards made from resin EC and E1 were insignificantly different to each other. This might be due to boards made from E0 resin have good properties of elasticity on combination with wood particle.

According to [9] the MOE or MOR values of the boards are highly dependent on the quality of the board face layers. These results are related to in the resins cure state when used in the face layers. This result appears to indicate that improvement of board strength to some extent could be done by making changes to the resin formulation.

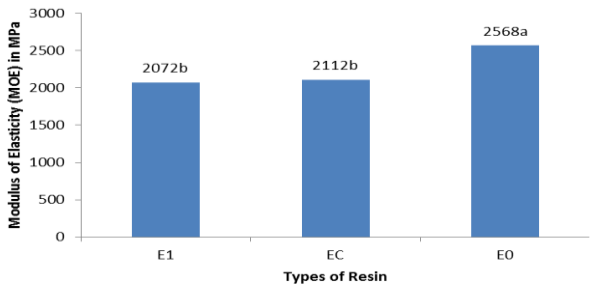

Fig. 1: Effects of resin type on MOE. Letters a and b indicate values in cluster to be significantly different at p < 0.05

Fig. 2 shows the effect of resin type on MOR. It can be seen that the MOR was significantly higher when the board manufactured from E0 resin. Meanwhile for resin EC and E1 there are not significant different. The E0 board has slower speed as seen by the higher press factor. The slower speed caused the resin on the board surface to cure better creating a more rigid structure [10].

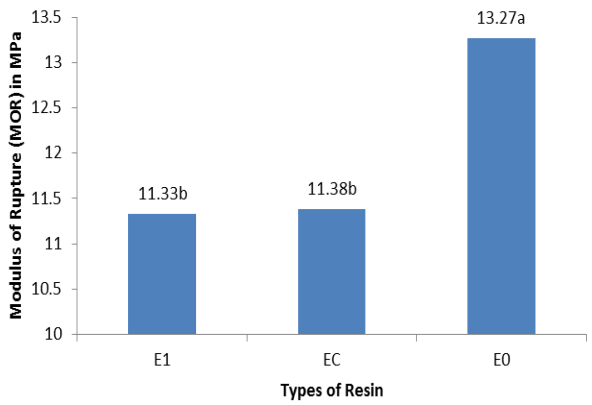

Fig. 2: Effects of resin type on MOR. Letters a and b indicate values in cluster to be significantly different at p < 0.05

Fig. 3 shows the effect of resin type on internal bonding of particleboard. Particleboard made from E0 resin shows significantly higher IB. This is because resin E0 has a good mechanical property for the combination of wood particle.

Fig. 4 shows the SW of particleboard manufactured using different resin type. Boards from EC had significantly higher SW than the boards from E1 and E0 resins. The SW values for boards from E1 and E0 were insignificantly different to each other even though the resin differs in their molar ratio. Normally the properties of IB and SW will be related to resin molar ratio, in which resin with higher ratio will exhibit better performance [11].

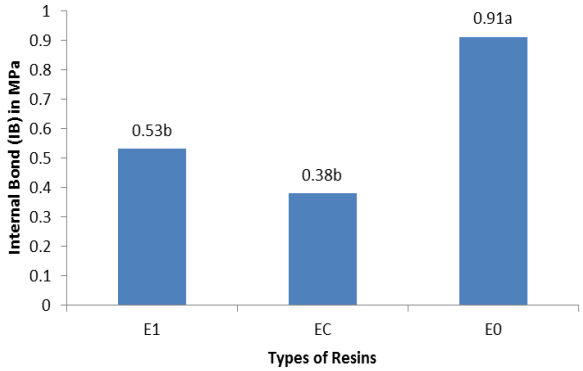

Fig. 3: Effects of resin type on IB. Letters a and b indicate values in cluster to be significantly different at p < 0.05

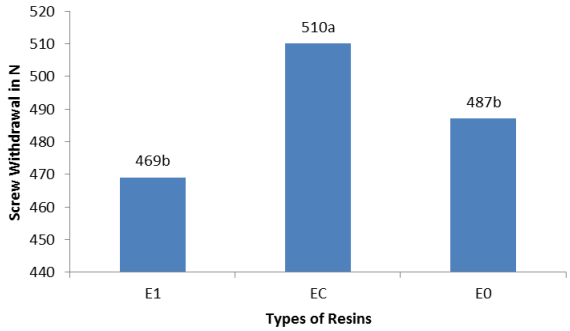

Fig. 4: Effects of resin type on screw withdrawal. Letters a and b indicate values in cluster to be significantly different at p < 0.05

Fig. 5 shows the effect of resin type on mat weight of the particleboard per meter square. The mat weight was significantly higher when the boards were manufactured with E0 resin. This could be contributed by higher resin composition on board per meter square than others. With E0, lower emission resin is necessary, lower emission resin normally require higher dosage in order to attain requirement in board properties.

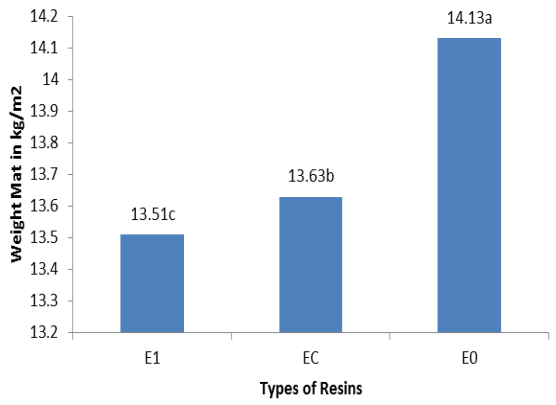

Fig. 5: Effects of resin type on mat weight. Letters a, b and c indicate values in cluster to be significantly different at p < 0.05

Fig. 6 shows the effects of resin type on press factor of the board. It can be seen that the press factor was significantly higher when the boards made from E0 resin. This might be due to board made from resin E0 need longer press time than other. According to [12] in wood-based composites, bonding of thermosetting adhesives plays an important role. During hot pressing the temperature will cause water to convert to vapour. The vapour pressure will constantly change govern by the moisture content and temperature in the board. The changes will affect the adhesion process and bond strength development. This will be translated to the final product's properties, the required hot-pressure time and energy consumption. The E0 resin is likely to have lower formaldehyde content which translate to slower curing rate. The changed of curing enthalpy for low emission urea formaldehyde at various formulation modifications was highlighted by [10] which translate to different curing rate.

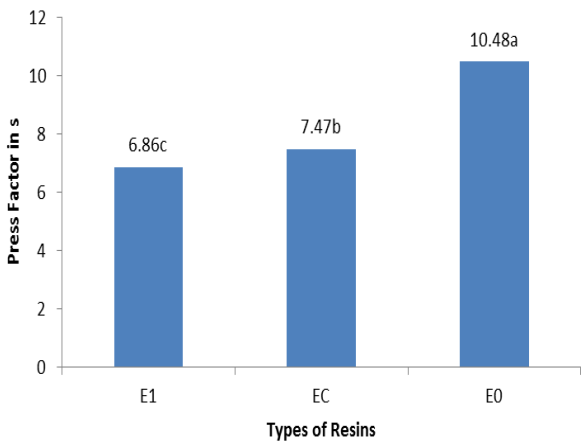

Fig. 6: Effects of resin type on press factor. Letters a, b and c indicate values in cluster to be significantly different at p < 0.05

D. Correlation with Mat Weight and Press Factor on Commercial Particleboard

Table V shows the correlation coefficients of the effects of resin type on MOE, MOR, IB, SW, mat weight and press factor. There is a significant negative correlation between the resin type with MOE (r = -0.791*) and MOR (-0.732*). The correlation analysis also indicated that the IB have a significant negative correlation with resin type (r = -0.567*) while SW had insignificant negative correlation with resin type (r = -0.322ns). The correlation analysis also confirmed that resin type had significant negative correlation with mat weight (-0.894*) and press factor (-0.927*).

Table V: Correlation Coefficients of the Effects of Resin Type on Board Properties

Variable	MOE	MOR	IB	Screw Edge	Mat Weight	Press Factor
Resin Type	-0.791 *	-0.732 *	-0.567 *	-0.322n s	-0.894 *	-0.927 *

Note MOE-Modulus of Elasticity, MOR-Modulus of Rupture , IB-Internal Bond, SW-Screw Withdrawal,: ns = no significant correlation, *correlation is significant at the 0.05 level

The increasing press factor will cause slower compaction of mat that has been formed. This lead to different in behaviour and relationship of board mechanical properties as observed by [10] when different speed, slow and fast compaction of mat was done. Faster speed has a tendency to cause springback as the pressure removal during hot pressing is faster. This lead to lower MOE when particleboard made with different resins used was compared.

IV. CONCLUSION

It can be concluded that resin type was influential to the performance in mechanical properties of particleboard. Resin type also had correlated with the mat weight and press factor in commercial particleboard. Particleboard from resin types E0 showed better bending strength and internal bonding. Further observation showed that boards from resin types E1 had the lowest screw withdrawal as compared to other resins.

ACKNOWLEDGMENT

Acknowledgment given to Mieco Manufacturing Sdn. Bhd. at Gebeng, Pahang Malaysia for providing raw materials use of facilities for the experimental work.

REFERENCES

1. T.M. Maloney, "Modern Particleboard & Dry-Process Fiberboard Manufacturing," 1989, Miller Freeman Publications, San Francisco
2. L. Prasittisopin, and L. Kaichang, "A New Method of Making Particleboard with a Formaldehyde-Free Soy-Based Adhesive," Composites Part A: Applied Science and Manufacturing, 2010, pp. 1447-1453
3. Gindl-Altmutter, Wolfgang, O. Michael, V. Stefan, and L. Falk, "Compatibility between Cellulose and Hydrophobic Polymer Provided by Microfibrillated Lignocellulose," ChemSusChem, Vol 8(1), 2015, pp. 87-91
4. M. Abdollahi, and A. Hosseini, "Formaldehyde - In Encyclopedia of Toxicology," Elsevier, 2014, pp653-656
5. S. Boran, M. Usta, and E. Gümükaya, "Decreasing Formaldehyde Emission from Medium Density Fiberboard Panels Produced by Adding Different Amine Compounds to Urea Formaldehyde Resin," International Journal of Adhesion and Adhesives, 31, 2011, pp. 674–678
6. H. Li, C. Li, C. Hui, Z. Derong, Z. Shifeng, and L. Jianzhang, "Effects of Hot-Pressing Parameters on Shear Strength of Plywood Bonded with Modified Soy Protein Adhesives," BioResources, 9(4), 2014, pp. 5858-5870,
7. BS EN 310, "Wood-based Panels- Determination of Modulus of Elasticity in Bending and of Bending Strength, London, UK: British Standard Institution, 1993

8. BS EN 319, "Particleboards anf Fiberboards Determination of Tensile Strength Perpendicular to the Plane of the Board, London, UK: British Standard Institution, 1993
9. Hassan, E. Barbary, K. Moon, and W. Hui, "Phenol-Formaldehyde-Type Resins Made from Phenol-Liquefied Wood for the Bonding of Particleboard," Journal of Applied Polymer Science, 112(3), 2009, pp. 1436 - 1443
10. T. L. Han, R. N. Kumar, H. D. Rozman and W.D. Wan Rosli, "Influence of Process Variables on the Reactivity of Low Formaldehyde Emission Urea-Formaldehyde Resin" Plastics Technology and Engineering, 47:6, 2008, pp. 551-557
11. Z. Que, T, Furuno, S. Katoh, and Y. Nishino, "Effects of urea–formaldehyde resin mole ratio on the properties of particleboard". Building and Environment. 42, 2007, 1257-1263
12. Çetin, S. Nihat S, and O. Nilgül, "Use of Organosolv Lignin in Phenol-Formaldehyde Resins for Particleboard Production: II. Particleboard Production and Properties," International Journal of Adhesion and Adhesives, 22(6), 2002, pp. 481-486

AUTHORS PROFILE

Nor Yuziah Mohd Yunus is an associate professor at Department of Wood Industry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Jengka Campus, Pahang. She started at UiTM since 2014. Before joining academic profession, she was R&D manager and Director for Malayan Adhesives & Chemicals Sdn. Bhd for 26 years. She is a chemist by profession and her research fields in adhesive and wood composite and also holds an MBA. Her Philosophy Degree in 2005 from Universiti Putra Malaysia is in the field of wood plastic composite – conventional versus radiation treatment.

Muhammad Abdilah bin Ab.Rani obtained his Degree in Science (Furniture Technology) in 2019 from Universiti Teknologi MARA (UiTM). His thesis involved evaluation on Properties of Commercial Particleboard in Correlation with Mat Weight and Press Factor.

Nur Sakinah Mohamed Tamat obtained her Degree in Science (Furniture Technology) in 2010 from Universiti Teknologi MARA (UiTM). Her PhD in Wood Science and Technology was done also in UiTM. Her thesis involved evaluation on the effects of particle size, board density, resin content, hot press temperature and alkaline concentration on properties of Kelempayan (*Neolamarckia cadamba*) particleboard. She published her work in Scopus-Index Journals, Open-Access Journals, Book Chapter and International Conference Proceedings.

Wan Mohd Nazri Wan Abdul Rahman is an associate professor at the Department of Wood Industry, Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Jengka Campus, Pahang, Malaysia. He started teaching at UiTM since 2000. He obtained his Bachelor of Science (Forestry) Degree in 1998 and Master Degree of Science (Wood Utilization) in 2000 at Universiti Putra Malaysia (UPM). He holds a Philosophy Degree in 2009 from UiTM. His research fields in forest plantation, biomass and wood composite