Souphanouvong University Journal of Multidisciplinary Research and Development
2025, Vol. 11, No. 03, 107-117
https://doi.org/10.69692/SUJMRD1103107

Evaluating Mass Loss of Rubber Veneer after Thermal-Treatment and Rubber Laminated Veneer Lumber (LVL) Mechanical Properties

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Article Info:
***Submitted:** June 04, 2025*
***Revised:** July 30, 2025*
***Accepted:** August 13, 2025*

Abstract

This research aims to evaluate the mass loss of rubber wood veneer through thermal treatment and assess the bending strength of Laminated Veneer Lumber (LVL) produced from thermally treated rubber wood veneer. A 30-year-old rubber tree was cut into billets of 1300 mm in length, then peeled into veneers of 2.5 mm thickness using a spindleless lathe machine. The veneers were kiln-dried to a moisture content of 6–8%. Specimens measuring 2.5 × 400 × 400 mm were prepared for thermal treatment. The thermal treatment was carried out at three temperatures: 180°C, 200°C, and 220°C, each for three durations: 4, 12, and 20 minutes. After thermal treatment, the LVL panels were assembled using Urea-Formaldehyde (UF) adhesive. Specimens were cut for both edgewise and flatwise bending tests, and tested using a Universal Testing Machine (UTM) at a loading rate of 6 mm/s. Results indicated that both temperature and time significantly affected the mass loss of the veneer. As temperature and time increased, mass loss generally increased. The mass losses recorded were as follows:

- 180°C: 4 min – 9.21%, 12 min – 11.08%, 20 min – 9.92%
- 200°C: 4 min – 11.59%, 12 min – 11.29%, 20 min – 11.96%
- 220°C: 4 min – 13.01%, 12 min – 13.26%, 20 min – 14.22%

Mechanical testing showed varying trends in Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) underedgewise and flatwise conditions:

- Edgewise MOE: 180°C ≤ 200°C ≥ 220°C
- Flatwise MOE: 180°C ≥ 200°C ≥ 220°C
- Edgewise MOR: 180°C ≥ 200°C ≥ 220°C
- Flatwise MOR: 180°C ≤ 200°C ≥ 220°C

These results suggest that thermal treatment conditions significantly influence both the mass loss and mechanical properties of LVL made from rubber wood veneer.

Keywords: Rubberwood, Thermal, Mass loss, Modulus of Elasticity, Modulus of Rupture

1. Introduction

Rubber wood (*Hevea brasiliensis*) is a popular species that used to make high-quality wooden furniture, a wood with outstanding properties, medium density of the wood, beautiful color, small shrinkage and easy to paint. In addition, rubber wood is also an environmentally friendly wood, because rubber wood is used in different parts and effectively. Characteristics of the rubber tree: It is a tall tree, the trunk can be more than 30 meters in high, the resin is white and yellow in the bark, the process of tapping begins when the rubber tree is about 5-6 years old (Abitha et al., 2020)

In Lao PDR, rubber plantations are popularly planted which currently covers 58% or 276,131 hectares (Smith et al., 2020) Within this, some areas are 25-30 years old and nearing the end of producing latex, so the rubber trees will transfer to be the raw material of wood industries. To support the value addition in the use of wood to maximize its benefits, research on the thermal-treatment of rubber wood to produce a finished product is very necessary.

Laminated Veneer Lumber (LVL) is one of the engineered wood products (EWPs), it is popular for use in construction, furniture and general decoration products, especially LVL products that are used in building structures (Boupha et al., 2021). Therefore, rubber wood may be an option to research to create the potential for production in the wood processing industry in Lao PDR. However, in the past, the research to increase the value of rubber wood through thermal-treatment has not been popular and no experimental research has been carried out yet. Therefore, there is a lack of technical information to research and add value to thin wood products and LVL rubber plywood to help the business sector.

Wood thermal-treatment is a technique that can increase the strength properties of *Tectona grandis* (Teak), and reduce the attacking by molds and fungi (Bupha, 2002). Thermo treatment on veneer has been recognized as environmentally friendly and can modify wood properties. The objectives of this study were to investigate mass loss of thermo-teak veneer, to assess the density changes, and to examine shrinkage based on different levels of temperature at different time lengths. The temperatures were 180, 200, 220, and 240 °C applied at three different lengths of time, i.e., 4, 8, and 12 min on teak veneer sheets. The results showed that the mass loss at the temperature of 180, 200, 220, and 240 °C were not significantly different. Density changes were significant depending on the level of temperatures. Percentage of density decrease changed from 3.85% to 15.69% at temperatures ranging from 180 to 240 °C but the length of time (4, 8, and 12 min of thermal treatment) did not have a significant effect. The mass loss ranged from 5.90% to 17.66%. (Bouaphavong et al., 2022)

Syvongsouk (2021) evaluated the mass loss of veneer from heating. The research was reviewing existing studies on available different species of wood through varied experiments. For instance, level of temperatures, pressure, and length of heating time in experiments for 14 species of wood: Beech, Birch, Pine, Poplar, Teak, Rubber, Black locust, Oak, Ash, Cherry, Spruce, Fir and Larch. Through the review, there are total of 9 formulas that indicated the level of Significant confidence for veneer treatment and 1 formula that for plywood. It can be seen that the heating period, temperature and air pressure affected changes in mass loss of wood. The level of confidence (R^2 = 0.95) for Alder and Birch. Therefore, it was recommended that the formula is considered suitable for rubber due to these two species have approximate density.

Testing the mechanical properties of LVL and plywood from Burapha Agro-Forest Co., Ltd., with the use of different test sizes: plywood size 8 x 100 x 600 mm and LVL size 12 x 100 x 600 mm^2). the 4-point bending test using the Universal test machine was conducted for the edgewise and flatwise. The test results showed LVL wood has a value of MOE = 15,272 MPa and Bending Strength = 126.1 MPa, the edgewise test of LVL wood has a value of MOE = 15,532 MPa and Bending Strength = 85.2 MPa, the Flatwise test of LVL wood, MOE = 15,340 MPa and Bending Strength = 222 MPa (Faircloth, 2020)

The application of laminated veneer lumber (LVL) has long been limited to non-structural elements in Malaysia. LVL is commonly fabricated with veneer from low to medium density (290 to 630 kg/m3) softwood or temperate hardwood. The data on the properties of LVL made from medium to high density (567 to 687 kg/m3) tropical hardwood species is very limited. Therefore, this study investigated the mechanical properties of LVL fabricated from Malaysian hardwood species namely Kasai (Pometia spp.), Mengkulang (Heritiera spp.) and Kedondong (Canarium spp.). Different variables were studied: i) wood species; ii) loading direction (flatwise or edgewise), iii) grain direction (parallel and perpendicular), iv) treatment condition. The bending and compression test was carried out in accordance with EN 408:2012, while the block shear test was conducted based on EN14374:2004 and EN 314-1:2004. The results show that the grain direction has the most significant effect ($P \leq 0.01$) on bending, compressive and bonding properties of the samples tested. The treatment conditions for block shear test also displayed significant effect on its shear strength. The samples loaded parallelly displayed 320-450% higher bending values than the samples loaded perpendicularly. The compressive strength and compressive modulus were 323-365% and 523-2530% higher respectively when loaded parallelly. LVL performed the best mechanically when loaded parallelly and when subjected to Treatment A which was the least extreme treatment condition (Mohamad et al., 2023)

This research arms to evaluate mass loss of rubber veneer through thermal-treatment and evaluate the bending strength of Laminated Veneer Lumber produced from rubber wood veneer through thermal-treatment.

2. Research methods

In this research study, each work step has been well planned to achieve the set goals, which will be divided into 2 stages: office and field, including 5 tasks:

- Rubber tree cutting task
- Rubber wood sawdust production task
- Thermal wood treatment task and mass loss test
- Rubber LVL plywood production task
- MOE-MOR mechanical properties testing task

2.1 Materials

The 30 years old of rubber plantation was used in this study is 20°57 ´15.07´´N and 101°25 ´50.78´´E. the rubber trees have average diameter of 150 mm. It was cut in to billets of 1300 mm of log length, the logs have transported to Wood Science and Wood Products Research Center at Faculty of Forest Sciences, National University of Laos.

2.2 Rubber wood sawdust production task

The preparation of the sample wood before being taken for peeling is done by measuring the width and length of the log, calculating the volume of the wood, the length of the wood is 1.30 centimeters, the log must be in good condition, without defects such as: bent, eyes larger than 5 centimeters, rotten wood or bare heartwood, no embedded solid objects (iron), no cracks or holes in the wood.

The peeling of the log into a thin wood product (Veneer) The machine used is a DEBARKER, the method is to use two people to lift the log and place it on the wood support of the machine and wait for the order from another person who is the commander of the machine. When all the logs are ready, the commander of the machine will give the order to the two people who lift the log to slowly place the log in the gap of the blade to prepare for peeling. Then, the log is controlled by the two ends of the machine, while the blade to be used for peeling is stationary.

The diameter of each log before and after peeling was measured to calculate the utilization rate of the logs that went through the peeling process. The logs that were peeled this time were large logs with round or slightly curved edges.

After going through the peeling process, the next step was to peel the logs into thin wood products through a thin wood peeling machine that set the thickness of the wood to 2 millimeters. The thickness of each thin wood sheet was measured at 2 points: the end and the middle of the thin wood sheet about 20 millimeters from the edge of the wood sheet, and the length and width of each thin wood sheet were measured and recorded.

The Veneer was dried using a steam oven of the Wood Science and Wood Products Research Center, the temperature setting was 60 degrees Celsius, and the heat treatment time was 1-2 hours.

The method is to prepare the veneer, arrange it in a drying rack and then put it in a steam oven to get a moisture content of 6-8 percent before heat-treating the wood (THERMAL). To calculate the moisture content of the wood, cut a sample of 5x5 centimeters. One sample is taken to weigh the wood before and after being put into the steam oven with the wood in the drying rack. After 15-20 minutes, take the sample and measure it to calculate the moisture content of the wood. If the moisture content is not yet 6-8 percent, it is put back into the oven and wait for 1-2 hours to get the desired moisture content. After the wood has been dried to the desired temperature, cut the wood into 45 x 45 centimeters pieces and then heat-treat (Thermal).

2.3 Thermal wood treatment task and mass loss test

The method is to turn on the machine and set the temperature as desired, namely 180 degrees Celsius, 200 degrees Celsius, 220 degrees Celsius (respectively) for about 20-30 minutes, then place the sample board between the upper and lower heating plates, and adjust the sample board to fit the heating plate. Then, press the lever to bring the two heating plates into contact using a pressure of 5MPa until the specified time of 4 minutes, 12 minutes, 20 minutes respectively, then remove the sample board by releasing the pressure slightly and insert a new sample until complete.

The temperatures used in this research were 180 degrees Celsius, 200 degrees Celsius, and 220 degrees Celsius, using a temperature measuring instrument (TES) as a reference to help determine the temperature used in heat treating wood more accurately.

- Find the mass of wood after heat treatment

$$\text{Mass} = \frac{(W2-W1)}{W1} * 100\ \% \qquad (1)$$

Mass = mass loss

W1 = Green Weight (g)

W2 = Dry Weight (g)

2.4 Rubber LVL plywood product and mechanical properties testing

LVL plywood production is to glue 5 layers of LVL wood/sheet, thickness 10 millimeters, width 40x40 centimeters, glue application rate is 30-35 g / total area, hot pressing rate for LVL wood products is 1 millimeter per 1 minute, pressure force is 2.5 MPa/square millimeter.

Before applying glue, the wood sheets are cleaned, dust and debris are removed to maximize the adhesion of the glue.

The method of gluing is to arrange the plywood in the same direction, with the first layer of plywood with the fine side down and the rough side of the plywood applied, the second, third, and fourth layers with the rough side down and the fine side of the plywood applied, and the last layer is not glued, with the rough side down and the fine side up. The data is recorded in a table, the glue mixing ratio (PF) is 100:15 (glue: accelerator).

Cold pressing: The LVL plywood, which has been glued and laid to the desired thickness, is cold pressed using a pressure of 19 MPa, taking about 19 minutes to ensure good adhesion of the glue (TDIC, 2011).

Hot pressing: LVL plywood that has been cold pressed is pressed in a hot press machine consisting of a metal plate that is a good conductor of heat, which is pressed for about 10 minutes, at a temperature of 148 degrees Celsius (TDIC, 2011).

- How to calculate the time and temperature for pressing veneer

The time and temperature for pressing LVL wood are determined according to the standard (TDIC.2011). For rubber plywood with a thickness of 2.1-3.0 millimeters, the cold pressing time is 16-19 minutes and the hot press time is 10 minutes, at a temperature of 148 degrees Celsius.

The heat press is based on the size of the wood with a base time of 130 degrees Celsius for a 3-minute press time, so 1 thin wood panel is 2.1 millimeters thick multiplied by 5 panels (5-layer LVL wood) with a thickness of 10.5 millimeters multiplied by 1.3 will equal 13.65 minutes divided by 2 (the heat press machine has two heating panels, top and bottom) equals 6.8 + 3 (base time of 130 degrees Celsius / 3 minutes) equals 10 minutes (TDIC, 2011).

The method of testing the elongation coefficient and the modulus of rupture (MOE-MOR) is to use a universal testing machine to test the wood samples by setting the speed of the machine to hit the wood at 6 millimeters/minute, and then observe the bending and breaking distance of the wood of each sample. After completing one sample, a new sample must be replaced until 30 samples are completed. The testing machine will have a value reader and record the required data such as the load force (P1, P2), (P max), and the breaking time.

2.5 Data analysis

Then, the data is analyzed to obtain the Modulus of Elastic and Modulus of Rupture (MOE-MOR) using the SPSS program and Microsoft Excel as an assistant.

3. Results

The mass loss of rubber veneer with thermal-treatment in different lengths of time: 4 minutes, 12 minutes, and 20 minutes and different levels of temperature: 180 degrees Celsius, 200 degrees Celsius, 220 degrees Celsius were found that the rubber veneer mass loss were related between the length of time and level of temperature of thermal-treatment are significant different. In Table1.

Form table1:

- Temperature 180°C, there is a significant difference in mass loss between 4 minutes and 12 minutes (P-value = 0.02) and between 4 minutes and 20 minutes (P-value = 0.02). However, there is no significant difference between 12 minutes and 20 minutes (P-value = 0.97).

- Temperature 200°C, none of the time comparisons show significant differences (all P-values > 0.05).

- Temperature 220°C, there is a significant difference between 4 minutes and 20 minutes (P-value = 0.04), but not between other time points.

From the strength test of LVL plywood products through heat treatment (Thermal):

Edgewise test, the modulus of elasticity (MOE) of 180 degrees Celsius - 4 minutes is 20071.25 N/mm^2, 12 minutes is 19244.44 N/mm^2, 20 minutes is 21063.67 N/mm^2, the modulus of elasticity (MOE) of 200 degrees Celsius - 4 minutes is 20022.88 N /mm2, time 12 minutes is 20195.85 N/mm^2, time 20 minutes is 20786.98 N/mm^2, the modulus of elasticity (MOE) of 220 degrees Celsius - time 4 minutes is 17950.82 N/mm^2, time 12 minutes is 19382.42 N/mm^2, time 20 minutes is 16734.20 N/mm^2. It can be seen that the MOE strength load test of temperature 180 ≤200 ≥220 degrees Celsius (Figure 4).

Flatwise test: the modulus of elasticity (MOE) of 180 degrees Celsius - 4 minutes is 10380.72 N/mm2, 12 minutes (11133.29 N/mm^2), 20 minutes (11478.87 N/mm^2), the modulus of elasticity (MOE) of 200 degrees - 4 minutes is 10517.82 N/mm^2, 12 minutes (10916.49 N/mm^2), 20 minutes (11366.22 N/mm^2), the modulus of elasticity (MOE) for the specimen of 220 degrees Celsius by 4 minutes is 10194.10 N/mm^2, 12 minutes (10402.02 N/mm^2), 20 minutes (9035.81 N/mm^2). It can be seen that the MOE strength load test of temperature 180 ≥200 ≥220 degrees Celsius (table2).

Edgewise test, the modulus of rupture (MOR) of 180 degrees Celsius by4 minutes is 7950.468 N/mm^2, 12 minutes is 8622.781 N/mm^2, 20 minutes is 8792.922 N/mm^2, the modulus of rupture (MOR) of 200 degrees Celsius-4 minutes is 7712.237 N /mm2, time 12 minutes is 7680.553 N/mm^2, time 20 minutes is 8365.981 N/mm^2, the modulus of rupture (MOR) of 220 degrees Celsius - time 4 minutes is 7215.557 N/mm^2, time 12 minutes is 5701.181 N/mm^2, time 20 minutes is 4391.496 N/mm^2. It can be seen that the MOE tensile strength load test of temperature 180 ≥200 ≥220 degrees Celsius (Figure 3).

Flatwise test, the modulus of rupture (MOR) of 180 degrees Celsius - 4 minutes is 4299.116 N/mm^2, 12 minutes is 8743.338 N/mm^2, 20 minutes is 1048.052 N/mm^2, the modulus of rupture (MOR) of 200 degrees Celsius - 4 minutes is 8322.151 N/mm^2, at 12 minutes is 9149.981 N/mm^2, at 20 minutes is 8182.713 N/mm^2, the modulus of rupture (MOR) of 220 degrees Celsius - at 4 minutes is 8279.289 N/mm^2, at 12 minutes is 7678.47 N/mm^2, at 20 minutes is 7371.064 N/mm^2. It can be seen that the MOE tensile strength load test of temperature 180 ≤200 ≥220 degrees Celsius (Figure 5).

4. Discussion

Mass loss of 180 degrees Celsius by4 minutes was 9.21 %, 12 minutes was 11.08 %, 20 minutes was 9.92 %. Mass loss of 200 degrees Celsius-4 minutes was 11.59 %, 12 minutes, 11.29 %, 20 minutes was 11.96 %. Mass loss of 220 degrees Celsius-4 minutes was 13.01 %, 12 minutes was 13.26 %, 20 minutes is 14.22 %. It can be seen that time and temperature have a difference in the mass loss of wood, if the temperature and time increase, then the mass loss increases accordingly. Comparison with (Anna et al., 2016): the results show significantly higher mass loss percentages at shorter exposure times (4, 12, and 20 minutes) compared to the mass loss reported by Anna et al. (2016) at 66 minutes. Temperature 180°C is 9-11% mass loss at shorter times, compared to 0.8% at 66 minutes. Temperature 220°C is 13-14% mass loss at shorter times, compared to 7.8% at 66 minutes.

This study highlights the rapid and significant mass loss of rubber wood during the initial stages of thermal exposure, particularly at higher temperatures. This contrasts with Anna et al. (2016), who observed lower mass loss over longer exposure times, suggesting that the majority of mass loss occurs early in the process. The findings emphasize the importance of controlling temperature and exposure time in applications involving rubber wood, such as wood processing and fire safety. Understanding these thermal degradation behaviors can help in developing strategies to improve the thermal stability and safety of rubber wood in various applications.

The modulus of elasticity (MOE) of LVL (Laminated Veneer Lumber) plywood products after heat treatment, tested under two conditions: edgewise and flatwise. Edgewise Test Results (MOE): 180°C - 4 minutes: 10380.72 N/mm², 180°C - 12 minutes: 11133.29 N/mm², 180°C - 20 minutes: 11,478.87 N/mm², Comparison with (Faircloth, 2020) MOE value is 15532 N/mm², which is significantly higher than the values in this study.

Flatwise Test Results (MOE): 180°C - 4 minutes: 20071.25 N/mm², 180°C - 12 minutes: 19244.44 N/mm², 180°C - 20 minutes: 21063.67 N/mm², Comparison with (Faircloth, 2020) MOE value is 15340 N/mm², which is lower than the values in this study.

Comparison with (Faircloth, 2020) Edgewise Test: this results show lower MOE values compared to their study. This could be due to differences in: Material composition: The type of wood or adhesive used in the LVL plywood, Heat treatment process: Differences in temperature control, heating rate, or cooling methods, testing conditions: Variations in sample preparation, loading rate, or testing environment.

5. Conclusion

Research results show that time and temperature have different effects on the loss of mass of some wood, if the temperature and time increase then the loss of mass increases. Mass loss with increasing temperature Mass loss 180 degrees Celsius, 200 degrees Celsius, 220 degrees Celsius and mass loss with increasing time Mass loss time 4 minutes, time 12 minutes, time 20 minutes. Compare the mass loss group:

The temperature 180°C: There is a difference between 4 minutes vs 12 minutes and 4 minutes vs 20 minutes, but no difference between 12 minutes vs 20 minutes.

The temperature 200°C: There is a difference between 4 minutes vs 20 minutes, but no difference between 4 minutes vs 12 minutes and 12 minutes vs 20 minutes.

The temperature 220°C: There is a difference between 4 minutes vs 20 minutes, but no difference between 4 minutes vs 12 minutes and 12 minutes vs 20 minutes.

The strength test results of LVL plywood products in the Edgewise test show that the modulus of elasticity (MOE) and modulus of rupture (MOR) at a temperature of 180 degrees Celsius, 200 degrees Celsius, the load value is increased according to the time of 4 minutes, 12 minutes, 20 minutes (respectively), at a temperature of 220 degrees Celsius, the load value is decreased according to the time conditions of 4 minutes, 12 minutes, 20 minutes. (In order).

Compare the temperature group:

- The temperature 180°C: There is a difference between 4 minutes with 12 minutes and 4 minutes with 20 minutes, but no difference between 12 minutes with 20 minutes.

- The temperature 200°C: There is a difference between 4 minutes with 20 minutes and 12 minutes with 20 minutes, but no difference between 4 minutes with 12 minutes.

- The temperature 220°C: There is a difference between 4 minutes with 20 minutes and 12 minutes with 20 minutes, but no difference between 4 minutes with 12 minutes.

From the flatwise test, it will be seen that the modulus of elasticity (MOE) at the temperature of 180 degrees Celsius, 200 degrees Celsius, a load of 4 minutes, 12 minutes, and 20 minutes (respectively), at a temperature of 220 degrees Celsius, a load of 4 minutes, 12 minutes increase and decrease at 20 minutes. modulus of rupture (MOR) at 180 degrees Celsius, the load value increased by 4 minutes, 12 minutes, and 20 minutes (respectively), at 220 degrees Celsius the load value decreased by 4 minutes, 12 minutes, and 20 minutes (respectively).

Compare the temperature group:

- The temperature 180°C: There was a difference between 4 minutes with 20 minutes and 12 minutes with 20 minutes, but no difference between 4 minutes with 12 minutes.

- The temperature 200°C: No significant difference in all tests.

- The temperature 220°C: There was a difference in all tests.

6. Conflict of Interest

I, as a scientific researcher, swear that all the information contained in this technical article does not have a conflict of interest with any party and does not favor any party.

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Table 1: Compare the difference between temperatures and times of the Mass loss

Temperature (°C)	Time (I)	Time (J)	Difference (I-J)	Std. Error	P-Values
180	4 min	12 min	-0.71	0.30	0.02
		20 min	-0.70	0.30	0.02
	12 min	20 min	0.01	0.30	0.97
200	4 min	12 min	0.29	0.35	0.41
		20 min	-0.37	0.35	0.29
	12 min	20 min	-0.66	0.35	0.06

220	4 min	12 min	-0.17	0.41	0.67
		20 min	-0.85	0.41	0.04
	12 min	20 min	-0.68	0.41	0.10

Table 2: Summary of the data obtained from this study

Temperature (°C)	Time (minutes)	Mass loss (%)	Edgewise		Flatwise	
			(MOE) (N/mm²)	MOR) (N/mm²)	(MOE) (N/mm²)	MOR) (N/mm²)
180	4	9.21	20071.25	7950.46	10380.72	4299.52
180	12	9.92	19244.44	8622.78	11133.29	8743.23
180	20	11.08	21063.67	8792.92	11478.87	1048.40
200	4	11.59	20022.88	7712.23	10517.82	8322.15
200	12	11.29	20195.85	7680.55	10916.49	9149.98
200	20	11.96	20786.98	8365.98	11366.22	8182.71
220	4	13.01	17950.82	7217.33	10194.10	8279.06
220	12	13.26	19382.42	5781.33	10402.02	7675.2
220	20	14.22	16734.20	4394.96	9035.81	7374.53

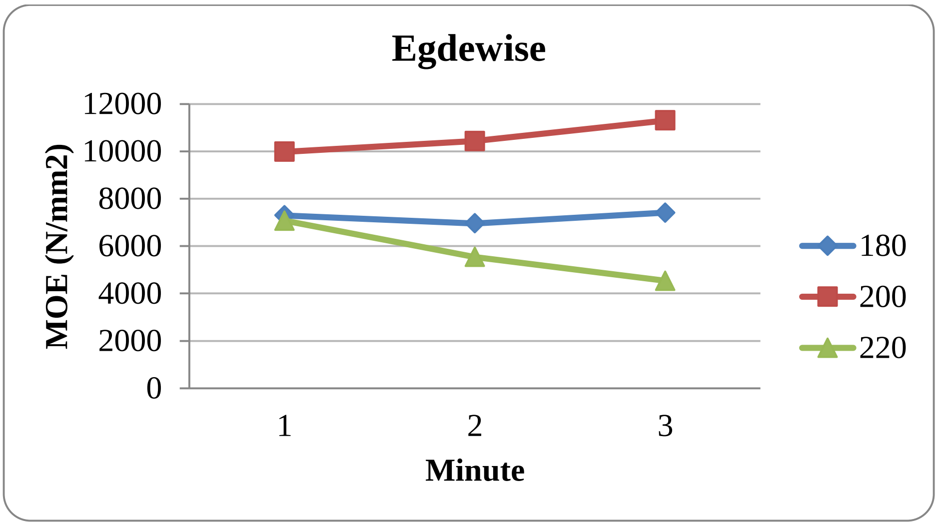
Table 3: formulas of research

fomulas	R2	a	b	c	t	spicies	reference
ML=a+b*T+c*t	0.18	4.6333	0.0241	0.0135	2	Teak	(Bouaphavong, Jarusombiti et al., 2022)
ML=a+b*T+c*t	0.74	-47.21	0.259	-0.00095	2.5	Poplar	(Ramkuma, 2023)
ML=a+b*T+c*t	0.92	-19.32	0.120	0.059	1.5	Birch	(Khasanshin et al., 2016)
ML=a+b*T+c*t	0.85	-22.29	0.134	0.113	2		
ML=a+b*T+c*t	0.95	-3.43	0.043	0.0042	1.5	Alder	(Bekhta, 2016)
ML=a+b*T+c*t	0.92	-2.73	0.041	0.570	1.5	Beech	(Khoo et al., 2021)
ML=a+b*T+c*t	0.95	-1.267	0.0007	0.570	1.5	Birch	
ML=a+b*T+c*t	0.94	-1.194	0.0003	0.645	1.5	Pine	
ML=(a*EXP (T/d)+b)*t(c+t)		0.147	-5.04	3.29	32	Black Locust	(Ferrari, 2013)
		0.0023	-0.38	2.07	32	Oak	
		0.0024	-0.53	1.71	32	Ask	
		0.0001	0.29	2.85	32	Beech	
		0.0003	-0.04	2.68	32	cherry	
		0.0059	-0.21	1.85	32	Spruce	
		0.0010	0.14	2.13	32	Fir	
		0.4666	-0.33	0.93	32	Larch	

Where, ML is mass loss, T is Thickness of sample test, a is Coefficient, b is Coefficient, c is Coefficient, t is thickness.

(*Khonexai Syvongsouk, Khamtan Phonetip, and Khonethong Soukphaxay, 2023*)

Figure 1: Percentage of Mass loss (ML%) at different temperatures and time



(*Khonexai Syvongsouk, Khamtan Phonetip, and Khonethong Soukphaxay, 2023*)

Figure 2. The modulus of elasticity (MOE) for edgewise at different temperatures and time

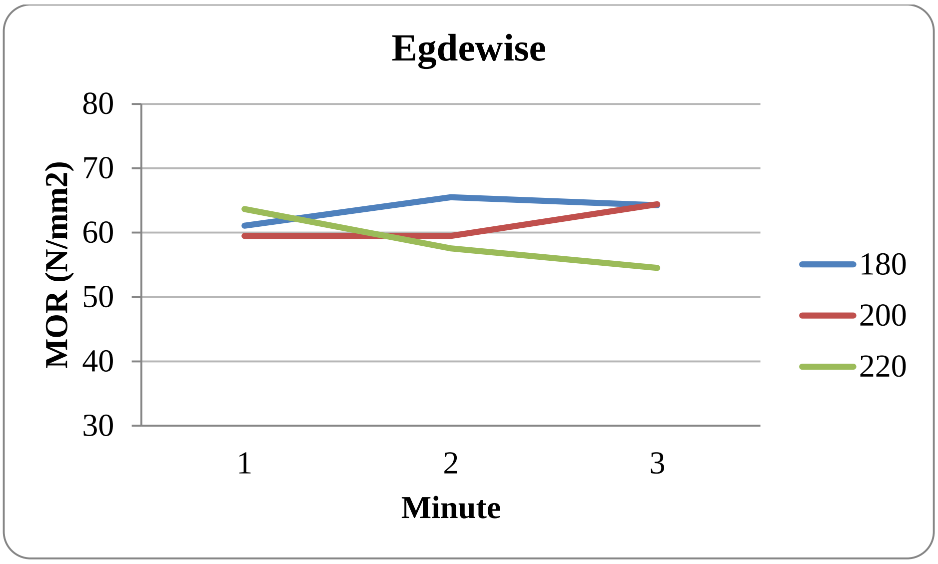


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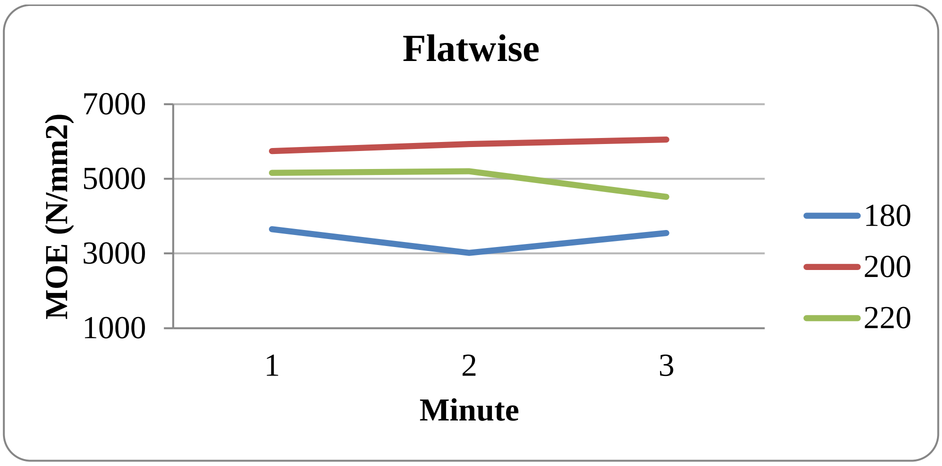
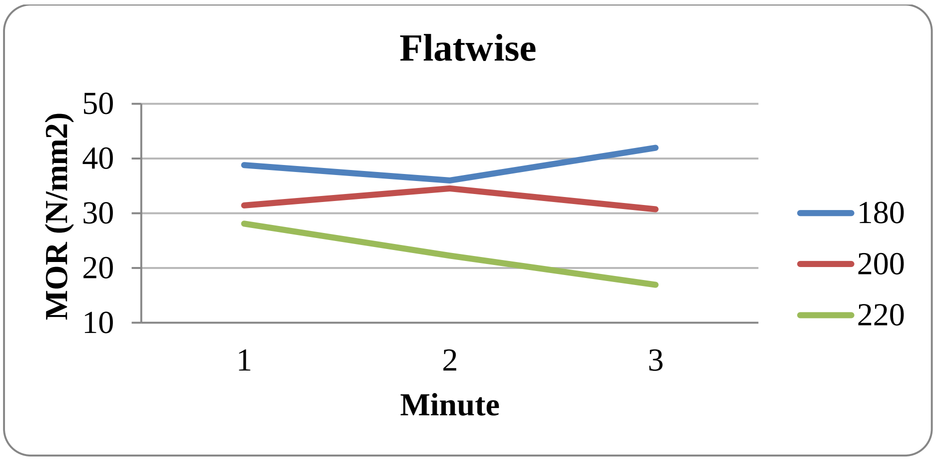
Figure 3. The modulus of rupture (MOR) for flatwise different temperatures and time



(*Khonexai Syvongsouk, Khamtan Phonetip, and Khonethong Soukphaxay, 2023*)

Figure 4: the modulus of elasticity (MOE) for edgewise at different temperatures and time



(*Khonexai Syvongsouk, Khamtan Phonetip, and Khonethong Soukphaxay, 2023*)

Figure 5. The modulus of rupture (MOR) for flatwise at different temperatures and