Australian Government
Australian Centre for
International Agricultural Research

ADVANCING ENHANCED WOOD MANUFACTURING INDUSTRIES IN LAOS AND AUSTRALIA

A PRELIMINARY EVALUATING THE EFFECT OF PRESSING TEMPERATURE AND PRESSURE ON WOOD DENSIFICATION OF RUBBER WOOD

Research Team:

Dr. Oudone Sichalern

Louxiong SIAKOR

Khanxay Khammanivong

Khonethong Souphaxay

November, 2021

VALTIP 3

Acknowledgement

Authors would like to thank VALTIP3- ACIAR for providing this grant to conduct the project. Thanks to VALTIP3 research fellow that contributed in this hands-on research project, Mr Louxiong SIAKOR. We also thank Mr Khanxay Khammanichan providing transportation of the logs from field to the laboratory. Thanks to the final year bachelor program student who provided his labor Mr. Thinnakone Inthachack. Thanks to many other people who provided their opinions on this wood densification experimental.

Citation: Sichalern O., Siakor L., Khammanivong K. and Soukphaxay K. for ACIAR project FST/2016/151 - Advancing enhanced wood manufacturing industries in Laos and Australia.

Content

Abstract

The preliminary study on conditions for wood densification for the three rubber trees from Thaphabard District, Borikhamxay Province with the aims of investigating the best pressing condition for rubber wood densification and to test for the ability of water absorption and dimensional changes from soaking in water of the densified and control wood.

Results of the study showed that the three rubber trees bear moisture content with no different between tree by 0.05 of statistic significant. It also found that there is a different in density between the three trees. For the shrinkage, it is found that the greatest shrinkage is tangential direction at 4.96 % follows by radial and longitudinal stand at 2.16 and 0.56 % respectively.

Wood densification (by pressing) with 8 different conditions showed that the 2nd condition with (30 mm of thickness of the board, 130 degree of Celsius of temperature, 60 % MC and increasing the pressure by 10 MPa in every 3-5 minutes) is able to press and reduced timber dimension the most at 38.73 %t, follows by the 3rd condition with (30 mm of thickness of the board, 155 degree of Celsius of temperature, 12 % MC and increasing the pressure by 10 MPa in every 3-5 minutes) reduced the thickness of the boards for 37.63 % and the condition produced the least is the 8th condition with (50 mm of thickness of the board, cold press, 12 % MC and increasing the pressure continuously) which is able to reduce the thickness by 14.19 percent. The research also showed that densified timber has greater density than the control rubber wood at 0.81 mg/mm^3 and 0.53 mg/mm^3 respectively.

It also found that the rate of swelling of soaking in water for 2 hours and 24 hours of the densified and control rubber wood is different by 0.05 of statistic significant. However, there is a notably that tangential dimension of the densified wood become smaller, both after soaking in water, for 2 hours and 24 hours. While the control wood become larger (swelling) and the densified always make better in water absorption than the control wood. This is because when the board is pressed from the top and bottom, the wood was pressed and caused to some wood spread out on horizontal direction and the board look wider. When we cut that board for smaller samples and soak in water. The sample sacked water in and it spring back to the natural shape. While it is spring back, it pulled the spread out back too.

Introduction

Rubber (*Hevea brasiliensis*) trees have been imported and planted in Lao PDR at scale since the early 1990s (Alberny E. 2009) for the production of natural latex, with around 90 percent of the current area, estimated to be around 275,000 ha, planted between 2000-2010. Rubber trees have been planted by farmers on their own land (smallholders), companies on state land (concessions), and through contracts between farmers and companies (contract farming) (Smith, Lu and To 2020). When grown under optimal conditions rubber trees can produce natural latex for 25 to 30 years (Aekkasai Pheuk-amphai, 2004) after which it is typically harvested, and the wood processed for non-structure timber.

Rubber wood has pros such as light color, beautiful grain, even properties, low shrinkage rate, and good dimensional stability for use in manufacturing and is widely used for flooring and furniture production. However, the wood has some cons due to its chemical components and properties that make it susceptible to fungal decay and insect attack requiring early treatment soon after harvest and its ability to absorb water and to re-dry when used in variable environments resulting in splitting, twisting and warping. Rubber wood also has low density at 450-550 kg/m^3, and the air-dry density is 560-640 kg/m^3 and can be difficult to process due to the presence of latex (Yongdong Z. et al., 2007).

Research undertaken by ACIAR project investigated the potential for rubberwood value chains (see Smith, Lu and To 2020). The study found that some of the earliest rubber plantations are already being harvested, and this rate will likely increase as trees mature, with rubberwood becoming available to industry at scale in around 2030-2035. It is expected, therefore, that there is potential for a significant volume of rubberwood to be available for the wood processing sector in the future. This study also found that the actual volume of rubberwood supply will be difficult to predict due to a range of factors associated with planting conditions, plantation management and the clones used, and latex markets and competition for land impacts impacting the potential for early harvesting and conversion to other land uses.

The project also assessed the peeling potential of rubber trees past the prime latex-producing age (Belleville et al. 2020). The results demonstrated that rubber trees past their latex-producing prime from un-thinned and unpruned stands have qualities and desirable traits to potentially produce certain high-value engineered wood products. Senile rubber trees in Laos could represent significant additional revenue to growers and a source of raw material to the industry which, theoretically, could be converted into high-value products if other factors can be overcome.

Nevertheless, it is likely that over time, a large area of rubber plantation will be harvested and either replanted with rubber or for other agricultural purpose. Using hypothetical parameters of an estimated 666 trees per ha, where the planting line is 3 x 5 meters in average and there could be in the order of 183 million harvestable trees over the next 20-30 years – representing a significant opportunity for plantation owners and the wood processing industry in Lao PDR. To enable this opportunity research is needed to investigate the qualities and properties of Lao rubber wood.

The basic disadvantage are evident in Rubberwood, (1) fast biodegradation and susceptibility to insect infestation after felling, the rubber wood logs must be sawn as soon as possible or preservation. (2) Rubberwood could be low density and low strengthen quality of bending and it is quite difficult for sawing due to the presence of latex. (Yongdong Z. et al., 2007).

Objectives

This preliminary experiment used three Rubber trees of after the age of giving latex for samples preparation for the experiement of wood densification with the aims of :

1. Investigate the most appropriate ccondition (temperature, sample size and moisture content, pressure ratios and time of increasing the pressure) for Rubber wood densification and
2. Study about physical properties of (the ability of water absorption and dimension changes) of the densified Rubber wood.

   The reason why we selected a water absorption and thickness swelling test is that we would like to know how much and how fast the densified rubberwood is able to suck water in and we would like to know how much the dimensions changes due to the water absorption. The densified products shall be consideration for both furniture (non-structural parts) and non-structural engineering products like flooring and ceiling.

Research Methodology

Preparation samples for physical properties assessment :

Three post-latex producing rubber trees (planted in 1996 from Thaphabard District, Borikhamxay Province were selected for the experiment. Each tree was harvested and cut into three logs for 100 cm length (bottom log, middle log and top log). The logs were processed (a backsawn is applied for the logs sawing) to lumber (Figure 1) for physical properties study (moisture content, density and dimensional changing from drying) based on Boupha L.,2002, ISO 3130 and ASTM D143, and other boards were used for densification. Sixty-three small samples (20x20x20 mm) were used for physical properties (moisture content, density, shrinkage) calculation. The offcut lumber was divided into two samples for green densification (60% of MC) and dried densification (12 percent of moisture content (MC)) (Figure 2). Drying of samples was undertaken using a solar kiln (Figure 3, see Phonetip et al 2021).

Figure 01: Log breakdown designing and sawing

The experimnet use a total 63 samples from the three trees for wood physical properties testing, 24 samples from tree number 1, 23 samples from tree number 2 and 16 samples from tree number 3. All the sample were identified by giving its an individual number and then clean the samples by removing the lift grains and saw dust before weighing.

- The moisture content was calculated according to Boupha L., 2002.

$$^{0}/_{0}\,MC = \frac{Wg - W_d}{w_d}$$

Where: MC = Moisture content (%)

Wg = Green weight (mg)

Wd = Dried weight (mg)

- Density calculation: Density refers to the amount of wood in a unit, per volume of wood. The ratio of dry weight and green volume of the given wood is the basic wood density. More wood content in a specific volume means it has a high density. Density can be obtained from the form below:

$$D = \frac{Md}{Vg} \text{ (mg/mm}^3\text{)}$$

Where: D = Density (mg/mm^3)

Md = dried weight (mg)

Vg = green volume (mm^3)

- Shrinkage calculation: according to Boupha L., 2020. The shrinkage can be obtained by the following formular:

$$shr = \frac{(Vi - Vf)}{Vi} \text{ x100 (\%)}$$

Where: Shr = Shrinkage (%)

Vi = initial volume (m^3)

Vf = final volume (m^3)

Figure 02: Sample cleaning and drying

Figure 03: Drying Rubber wood by Solar kiln

Preparation samples for wood densification

Both the green (60 % of moisture content) and dried boards (12 % of moisture content) were processed to three categories dimension (1): 20x50x400 mm; (2): 30x50x400 mm and (3) 50x50x400 mm, used for densification with the 8 designed conditions (Table 1). Densification involves of measuring dimension (three points for both the width and thickness) of the green and dried boards, then placed the board on stage of the hot press machine (at the determined temperature that the condition is using, see Table 1) which was prepared, one board at the time. After that, a heating is started for 30 minutes in order to allow heat immersed the board. Next, started the pressing (according to the condition: increasing the pressure 10 MPa in every 3-5 minutes or increasing the pressure continuously). The pressing is stopped when the board collapsed. Then, left the timber on the stage for 15 minutes to make sure that it isn't spring back after the pressing. Finally, removed the board from the machine and kept it in the room for 10 minutes to cool before measuring its width and thickness again.

Table 01: Densification condistion

No.	**condition**	**Detail of condition**			
		Thickness (mm)	**Temperature (Celsius)**	**MC %**	**Pressure increasing method**
1	C1	20	130	60	continuously
2	C2	30	130	60	Increase in 3-5 minutes
3	C3	30	155	12	Increase in 3-5 minutes
4	C4	30	180	60	Increase in 3-5 minutes
5	C5	15	130	12	Increase in 3-5 minutes
6	C6	15	Cold press	12	continuously
7	C7	50	130	12	continuously
8	C8	50	Cool press	12	continuously

Figure 04: Wood densifying by a hot press machine

Figure 05: Comparison the dimension of the control wood and densified lumbers

- Water absorption of the samples was measured and calculated by the formular:

$$Wa = \frac{(Wf - Wi)}{Wi} x100\ (\%)$$

Where: Wa = water absorption (%)

Wf = final weight (mg)

Wi = Initial weight (mg)

- Swelling amount was measured and calculated by the form:

$$shr = \frac{(Vi - Vf)}{Vi}\ \text{x100 (\%)}$$

Where: Shr = Shrinkage (%)

Vi = initial volume (m^3)

Vf = final volume (m^3)

Figure 06: Water absorption and dimensional changing experiment.

Result of study

Moisture Content:

Results of the study showed that moisture content of the three rubber trees stand at 63.23 % in average. In specific, the tree number 3 has the highest level of moisture content at 64.97 %, while tree number 2 is at 64.42 % and tree number 1 has the lowest amount of moisture content at 60.31 % (figure 07). Result from One-Way ANOVA showed that moisture content of the three trees is not different by 0.05 of statistic significant.

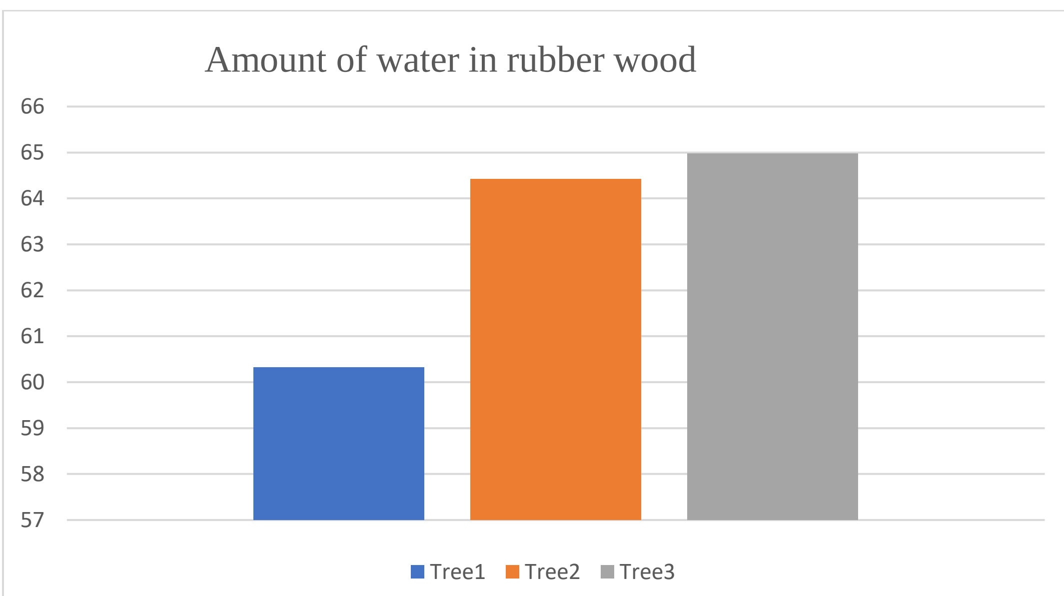

Figure 07: Moisture content of the three rubber Trees

Table 02: One-Way ANOVA result of moisture content.

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	273.0108	2	136.5054	2.968747	0.059224	3.155932
Within Groups	2666.887	58	45.98081			
Total	2939.898	60				

<u>Wood Density Properties:</u>

Result from descriptive statical analysis showed that the density of the three-rubber trees in average stands at 0.62 mg/mm^3. In specific, it is found that the tree number two has the highest of density at 0.64 $mg.mm^3$ when compare to tree number 1 and number 3 which stand at 0.615 mg/mm^3 and 0.611 mg/mm^3 respectively (in figure 08).

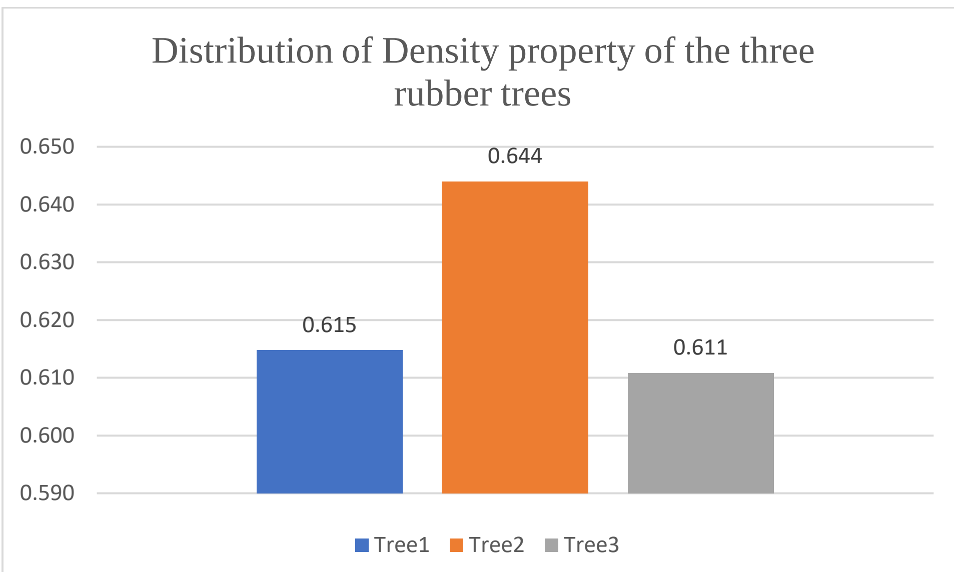

Figure 08: The distribution of density property of the three rubber trees

<u>Dimensional Changes from drying:</u>

Result of the analysis showed that there is a high level of shrinkage in dimension in tangential direction which stands at 4.54 percent, followed by the shrinkage in radial direction and longitudinal which are at 2.36 and 0.74 percent respectively as shown in figure 09.

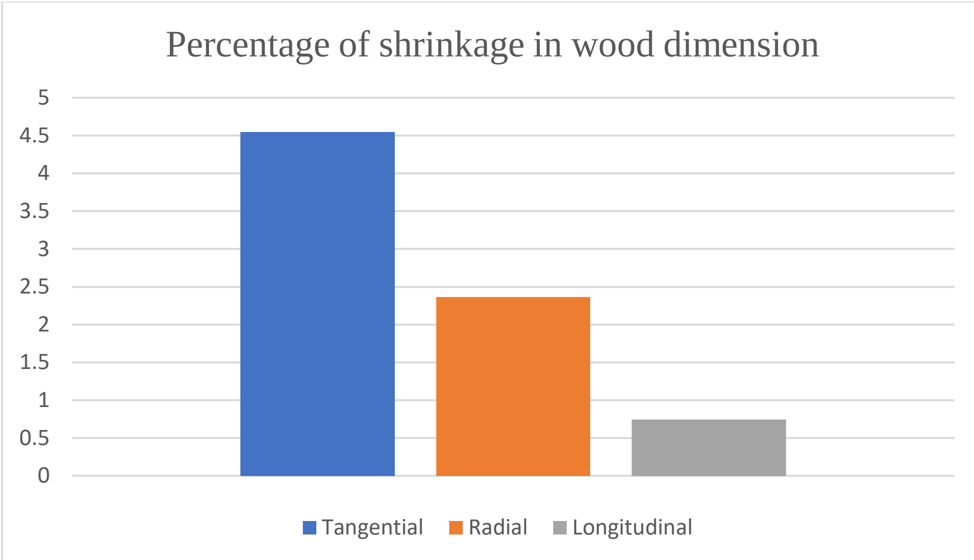

Figure 09: Percentage of shrinkage in wood dimensional

Result of Wood densification:

Result of Wood densification by 8 different conditions, found that every condition is able to press and reduced the thickness of the boards to different levels. It is shown that the second condition (green wood, size 30x50 mm, temperature 130 degrees of Celsius and increase pressure in every 5 minutes after the heating started for 30 minutes) is able to press the timber to the longest compression ratio at 38.73 %. Following by the third condition (timber with 12 % of MC, size 30 x50 mm, 155 degrees of Celsius and increase pressure in every 5 minutes after the heating started for 30 minutes) made the compression ratio for 37.63 percent; and the densification condition that reduce the least amount of compression ratio is condition 8 which is able to make the compression ratio for 14.19 percent as shown in figure 10.

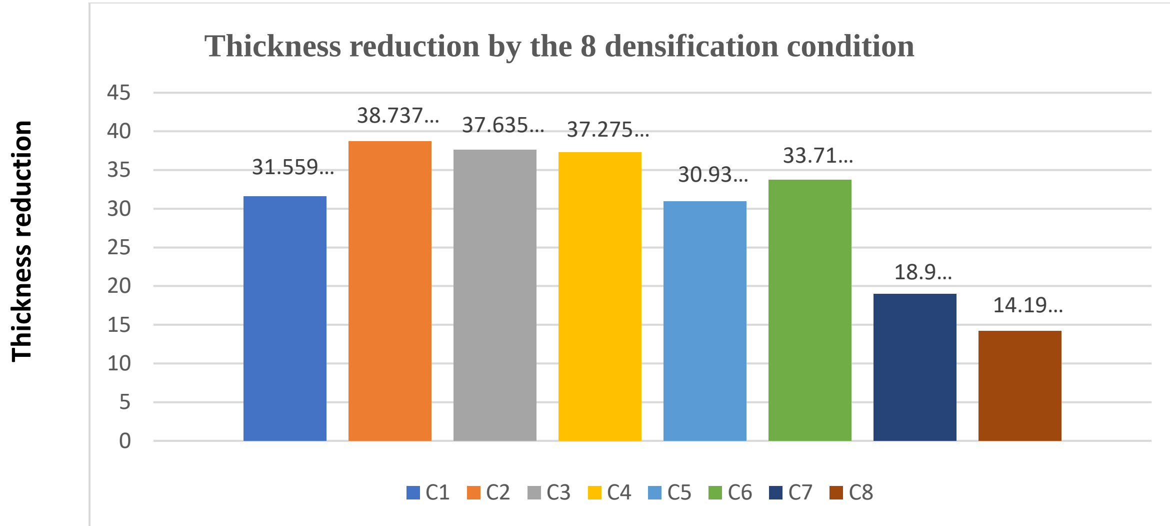

Figure 10: Thickness percentage reduction by the 8 densification conditions

A comparison of density property between the densified and control wood

From result of the wood densification testing, the third condition (Thickness of the board 30 cm, temperature 155 Celsius, at 12% MC and increasing 10 MPa of pressure in every 3-5 minutes) is selected for densifying the boards because this condition produced the greatest compression ratio.

The results of descriptive statistical analysis found that the density if densified wood is higher than the control wood which stand at 0.81 g/cm3 and 0.54 g/cm3 respectively. Result from t-Test showed that the densified and control wood are different in density by 0.05 of statistic significant and p-value < 0.001; as shown in table 03.

Table 03: Result of t-Test about the density of the densified and control wood.

	Densified wood	Control wood
Mean	0.81117	0.539282
Variance	0.006405	0.000491
Observations	36	25
Hypothesized Mean Difference	0	
df	42	
t Stat	19.34396	
P(T<=t) one-tail	7.8E-23	
t Critical one-tail	1.681952	
P(T<=t) two-tail	1.56E-22	
t Critical two-tail	2.018082	

Longitudinal direction changes of the densified and control wood for soaking in water for 2 hours and 24 hours:

Result of t-Test showed that the densified and control wood soaked in water for 2 hours have a different in longitudinal direction swelling by 0.05 of statistic significant and p-value <0.001; and It accepted the hypothesis that "different densification condition resulted to different swelling in longitudinal direction. While the result of t-Test for soaking in water for 24 hours indicated that there is no different in longitudinal direction swelling by 0.05 of statistic significant and p-value = 0.176; and it reject hypothesis (see table 04).

Table 04: Result of t-Test for longitudinal direction changing of the densified and control wood for soaking in water for 2 hours and 24 hours.

	Soak in water for 2 hours		**Soak in water for 24 hours**	
	Densified	**Control**	**Densified**	**Control**
Mean	0.943036	0.507124	0.828956	0.681338
Variance	0.277774	0.126611	0.31559	0.088735
Observations	39	25	39	25
Hypothesized Mean Difference	0		0	
df	62		60	
t Stat	3.948689		1.368157	
P(T<=t) one-tail	0.000102		0.088182	
t Critical one-tail	1.998972		1.670649	
P(T<=t) two-tail	0.000203		0.176365	
t Critical two-tail	2.297142		2.000298	

Radial direction changes of the densified and control wood for soaking both in 2 hours and 24 hours:

Result of t-Test of soaking in water for both 2 hours and 24 hours showed that the densified and control wood are different in radial direction swelling by 0.05 of statistic significant and p-value <0.001 (see table 05); and It accepted the hypothesis that "different densification condition resulted to different swelling in radial direction.

Table 05: Result of t-Test for radial direction changing of the densified and control wood for soaking in water for 2 hours and 24 hours.

	Soak in water for 2 hours		**Soak in water for 24 hours**	
	Densified	**Control**	**Densified**	**Control**
Mean	24.02328177	1.094199	27.08174921	1.769834
Variance	27.71747661	0.04688	12.49087515	0.286028
Observations	39	25	39	25
Hypothesized Mean Difference	0		0	
df	38		41	
t Stat	27.16251384		43.94800752	
P(T<=t) one-tail	8.49433E-27		2.04534E-36	
t Critical one-tail	1.68595446		1.682878002	
P(T<=t) two-tail	1.70E-26		4.09E-36	
t Critical two-tail	2.024394164		2.01954097	

Tangential direction changes of the densified and control wood for soaking in water for both 2 hours and 24 hours:

Result from the analysis found that there is an important point to note that the densified wood which was soaked in water for both 2 hours and 24 hours made a great thickness reduction in tangential direction at -0.368 percent for soaking in water for 2 hours and -0.87 percent for soaking in water for 24 hours. While the control wood is swelling for soaked both in 2 hours and 24 hours at 1.99 and 3.39 percent respectively.

Result of t-Test of soaking in water for both 2 hours and 24 hours showed that the densified and control wood are different in tangential direction swelling by 0.05 of statistic significant and p-value <0.001; and It accepted hypothesis that "different densification condition resulted to different swelling in tangential direction. (See table 06).

Table 06: Result of t-Test for tangential direction changing of the densified and control wood for soaking in water for 2 hours and 24 hours.

	Soak in water for 2 hours		Soak in water for 24 hours	
	Densified	**control**	**Densified**	**Control**
Mean	-0.36838	1.997316	-0.870087921	3.395558
Variance	1.319837	1.350407	1.918960408	0.877527
Observations	39	25	39	25
Hypothesized Mean Difference	0		0	
df	51		62	
t Stat	-7.98119		-14.69121021	
P(T<=t) one-tail	7.77E-11		3.65407E-22	
t Critical one-tail	1.675285		1.669804163	
P(T<=t) two-tail	1.55E-10		7.30813E-22	
t Critical two-tail	2.007584		1.998971517	

Rate of water absorption of the densified and control wood for soaking in water for both 2 hours and 24 hours:

Result from the analysis found that he densified wood is better in water absorption than the control wood by the weigh in average of 37.61 percent for the densified and 16.99 for control wood. In the same case, the densified wood soaked in water for 24 hours is also suck more water than the control wood which are at 51.55 and 42.77 percent respectively.

Result of t-Test of soaking in water for both 2 hours and 24 hours showed that the densified and control wood are different in water absorption by 0.05 of statistic significant and p-value <0.001; and It accepted hypothesis that "different densification condition resulted to different ability in water absorption. (See table 07).

Table 07: Result of t-Test of rate of water absorption of the densified and control wood for soaking in water for both 2 hours and 24 hours**.**

t-Test: Two-Sample Assuming Unequal Variances

	Soak in water for 2 hours		**Soak in water for 24 hours**	
	Densified	**Un-densified**	**Densified**	**Control**
Mean	37.6084	16.98948	51.53301786	42.27229
Variance	44.95346	23.54807	7.499087079	17.07018
Observations	39	25	39	25
Hypothesized Mean Difference	0		0	
df	61		38	
t Stat	14.24682		9.899616995	
P(T<=t) one-tail	2.27E-21		2.25788E-12	
t Critical one-tail	1.670219		1.68595446	
P(T<=t) two-tail	4.55E-21		4.51576E-12	
t Critical two-tail	1.999624		2.024394164	

Conclusion and recommendation

From the implementation of the experiment with the three rubber trees from Thaphabard District, Borikhamxay Province found that the average of moisture content of the logs on reception at National University of Laos stands at 63.23 %. It is also found that the density of the trees is at 0.6 mg/mm^3 and found that there is a high changing in tangential direction for drying.

The experiment also showed that the 2^{nd} condition for wood densification was able to make a great compression ratio of the boards while the 8^{th} densification condition made the least on compression ratio of the boards. In comparison to the control wood, found that the densified wood gained higher density than the control wood.

We also found that there is a different between the densified and control wood on water absorption and swelling for soaking in water for both 2 hours and 24 hours.

It is recommended that further studies should only use the dried wood (12 %MC) for densification, in order to reduce the amount of spring back after relieved from the press or a cooling period leaving the samples under pressure inside the press without temperature (lower than 60 Celsius for 10-15 minutes).

The next researcher should never overlook the temperature and pressing time, this is to ensure that the densified board will never spring back.

It is also recommended that the users of the densified for rubber species should make a consideration about the spring back to its natural shape because it will cause to dimension of the boards change when placing to an appropriate environment condition.

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