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Study on Water Related Properties of Some Myanma Timber Species

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ဒေါက်တာချိုချိုမြင့်- လက်ထောက်သုတေသနအရာရှိ
စုစုလှိုင်၊ လက်ထောက်သုတေသနအရာရှိ
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စာတမ်းအကျဉ်း

ဤစာတမ်းတွင် မြန်မာ့သစ်မျိုး(၁၅) မျိုး၏ရေနှင့်ဆက်စပ်နေသော ဂုဏ်သတ္တိများ ဖြစ်သည့် သိပ်သည်းခြင်း၊ ကြွမှု၊ အသားငြိမ်မှု၊ သစ်သားမျှင်များရေပြည့်ဝအမှတ်နှင့် ရေစုပ်ယူမှု တို့ကို စမ်းသပ် ထားပါသည်။ မြန်မာ့သစ်မျိုး (၁၅) မျိုးကို ပေ့ါသောသစ်၊ အသင့်အတင့် လေးသော သစ်၊ လေးသောသစ် နှင့် အလွန်လေးသောသစ်ဟု အုပ်စု (၄) ခုခွဲ၍ စမ်းသပ် ထားပါ သည်။ စမ်းသပ်ခဲ့သော သစ်မျိုးများတွင် ကြို့သစ်သည် သိပ်သည်းခြင်း အများဆုံးဖြစ်ပြီး ဘိုင်သစ် သည် အနည်းဆုံးဖြစ်သည်ကို တွေ့ရပါသည်။ အလွန်လေးသောအုပ်စုဝင်သစ်များသည် သိပ်သည်းခြင်း အများဆုံးဖြစ်ပါသည်။ ထို့နောက် လေးသော သစ်၊ အသင့်အတင့်လေး သော သစ်၊ ပေ့ါသော သစ်ဟူ၍ လျော့နည်းလာကြောင်း တွေ့ရပါသည်။ ကြွမှုတွင် ကြို့သစ် သည် အများဆုံးဖြစ်ပြီး လက်ပံသစ်သည် အနည်းဆုံးဖြစ်ပါသည်။ အုပ်စုများအကြားတွင်လည်း သိပ်သည်းခြင်းကဲ့သို့ပင် ပြောင်းလဲကြောင်းတွေ့ရှိရပါသည်။ သိပ်သည်းခြင်းများသော သစ်များသည် ပိုမိုကျုံ့ကြွသောကြောင့်ဖြစ်သည်။ သစ်သားမျှင်များရေပြည့်ဝအမှတ်တွင် စကားစိမ်း သစ်သည် အများဆုံးဖြစ်ပြီး သစ်မန်ကျည်း သစ်သည် အနည်းဆုံးဖြစ်ကြောင်း တွေ့ရပါသည်။ သစ်သားမျှင်များ ရေပြည့်ဝ အမှတ်ကို ဆဲနံရံအထူအပါး၊ ဆဲလ်ခေါင်းအတွင်းတွင် အနည်ထိုင်မှု တို့က လွှမ်းမိုးကြောင်း လေ့လာ တွေ့ရှိရပါသည်။ ရေစုပ်ယူမှုတွင် စကားစိမ်းသစ်သည် ရေစုပ် ယူမှု အများဆုံးဖြစ်ပြီး ကြို့သစ် သည် အနည်းဆုံးဖြစ်ပါသည်။ အလွန်လေးသော သစ်များတွင် ဆဲလ်နံရံထူခြင်းကြောင့် ရေနေနိုင်မည့် နေရာ ဆဲလ်ခေါင်း အနည်းငယ်သာရှိသဖြင့် ရေစုပ်ယူမှု နည်းခြင်း ဖြစ်ပါသည်။ အုပ်စုများကြား ရေစုပ်ယူမှုနှင့် သစ်သားမျှင်များ ရေပြည့်ဝ အမှတ်တို့ သည် သိပ်သည်းခြင်း၊ ကြွခြင်းတို့နှင့် ပြောင်းပြန်ဆက်သွယ်မှုရှိကြောင်း တွေ့ရပါ သည်။ ကုက္ကို၊ တောသရက်၊ ထောက်ကြံ့၊ ကြို့သစ်မျိုးများသည် အသားငြိမ်မှု ၂ အောက်ရှိပြီး ကျန်သစ်များ သည် ၂ ထက်ကြီးသည်ကို တွေ့ရပါသည်။ လေးသော သစ် များနှင့် အလွန်လေးသော သစ်မျိုး များ ကို အဆောက်အဦနှင့် ပရိဘောဂများပြုလုပ်ခြင်းတွင် အသုံးပြု နိုင်ပြီး အသင့် အတင့် လေးသောသစ်များနှင့် ပေ့ါသော သစ်မျိုးများကို မီးခြစ်၊ သေတ္တာနှင့် ခဲတံ ပြုလုပ် နိုင်ပါသည်။ ထို့ကြောင့် ရေစုပ်ယူမှုနှင့် ကြွမှုများသော သစ်မျိုးများကို သင့်လျော်သည့် နည်းလမ်းဖြင့် ပြုပြင်ပြီး မှ အသုံးပြုသင့်ပါသည်။

Study on Water Related Properties of Some Myanma Timber Species

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Abstract

In this research paper, water-related properties of fifteen Myanmar timber species were investigated, especially basic density, swelling, swelling anisotropy, fiber saturation point and water absorption. They were divided into four groups as light woods, moderately heavy woods, heavy woods and very heavy woods. Among the tested species, Gyo has the highest basic density whereas Letpan has the lowest. Among the groups, very heavy woods have the highest basic density, followed by heavy woods, moderately heavy woods and light woods, respectively. Swelling is the highest in Gyo and the lowest in Letpan. The variation among the groups is the same as in density. This is due to the fact that high density timbers shrink and swell more than less density timbers. With regard to fiber saturation point, Sagasein has the highest whereas Thitmagyi has the lowest. Fiber saturation points vary among species due to variations in cellwall thickness and deposits in cell lumina. Sagasein absorbs the highest whereas Gyo absorbs the lowest. Among the groups, water absorption and fiber saturation point are inversely correlated to density and swelling. Kokko, Tawthayet, Taukkyan and Gyo have a swelling anisotropy of less than 2 whereas the other tested ones have that of greater than 2. Those timbers in heavy and very heavy groups can be used for building and furniture making whereas those in moderately heavy and light groups are suitable for matches, boxes and pencil making. Those showing higher water absorption and swelling should be used after treated with suitable methods.

Key Words: Basic density, Fiber saturation point, Swelling and Swelling anisotropy, Water absorption.

Study on Water Related Properties of Some Myanma Timber Species

1. Introduction

Wood is hygroscopic; it takes on moisture from the surrounding environment. Moisture exchange between wood and air depends on the relative humidity and temperature of the air and the current amount of water in the wood. This moisture relationship has an important influence on wood properties and performance. Many of the challenges of using wood as an engineering material arise from changes in moisture content or an abundance of moisture within the wood. (Forest Products laboratory, 2010)

Variation in relative humidity (RH) causes wood to change in dimensions when its moisture content is below the fiber saturation point (FSP). Fiber saturation point is a term used in wood mechanics and especially wood drying, to denote the point in the drying process at which only water bound in the cell walls remains - all other water, called free water, having been removed from the cell cavities. (Hernandez, 2007)

Shrinkage is a reduction, and swelling is an increase of the dimensions of wood due to changes of its moisture content. Such dimensional changes occur when the moisture of wood fluctuates below the fiber saturation point. Swelling occurs when wood gains water vapor, while shrinkage takes place when it loses moisture. Shrinking and swelling occur as the wood changes moisture content in response to daily as well as seasonal changes in the relative humidity of the atmosphere, i.e., when the air is humid, wood adsorbs moisture and swells; when the air is dry, wood loses moisture and shrinks. (Tsoumis, 1991)

Dimensional changes associated with shrinkage and swelling may cause degradation of products. Degradation may result from a simple reduction or increase of dimensions, anisotropy, or differential shrinkage or swelling in the mass of wood under the influence of differences in the distribution of moisture or density. As a result, various defects may develop, such as opening or tightening of joints, change of cross-sectional shape, warping, casehardening, honeycombing, collapse, and loosened or raised grain (Forest Products Laboratory, 2010).

Therefore, it is quite important to know shrinkage and swelling behaviors of various wood species. Shrinkage of most Myanmar timber species has been tested and is available in most literature. However, swelling behavior is still unknown for most Myanmar timber species. If swelling data are available, those with minimal swelling can be used to keep away from swelling and shrinkage-related problems. Moreover, measures to minimize water absorption can also be investigated for those species with high swelling.

Wood species vary in wood anatomy and extractive content, thereby causing water absorption to vary among wood species (Dinwoodie, 2000). Thus, swelling due to water absorption can vary accordingly. Therefore, it is crucially important to study water absorption of some timber species.

2. Objectives

The objectives of this research are to investigate water-related properties of some Myanma timber species to compare these properties among them and to recommend their suitable uses.

3. Materials and Methods

3.1 Materials

Fifteen wood species such as Letpan, Bonmeza, Sagasein, Gwe, Thitkado, Baing, Kuthan, Dwabok, Kokko, Pyinma, Taungthayet, Tawthayet, Thitmagyi, Taukkyan and Gyo were studied in this research. Sagasein species was obtained from wood samples collected for Wood Anatomy Section. The other species were selected from wood samples collected for "Introducing Myanmar's Lesser Used Timber Species to the World Market" ITTO Project. The selected species were classified into four groups based on their basic specific gravities. Wood with basic specific gravity of 0.360 and less are considered to be light, 0.361 to 0.500 moderately heavy, 0.501 to 0.800 heavy and above 0.800, very heavy. One sample tree for each species was used to investigate water related properties. The scientific name, number and size of specimens were shown in Table 1. Size of specimens and testing procedures were in accordance with the procedures given in DIN 52184. The photos of selected samples and water absorption test were shown in Figures (1-16).

Table 1: The name of selected species, scientific name, size of specimen and number of specimens for each species

Sr. No	Species	Scientific Name	Size of specimen $(mm)^3$	Number of specimens per tree
1	Letpan	*Bombax ceiba*	30 x 30 x 10	30
2	Bonmeza	*Albizia chinensis*	30 x 30 x 10	30
3	Sagasein	*Cananga odorata*	30 x 30 x 10	30
4	Gwe	*Spondias pinnata*	30 x 30 x 10	30
5	Thitkado	*Toona ciliata*	30 x 30 x 10	30
6	Baing	*Tetrameles nudiflora*	30 x 30 x 10	30
7	Kuthan	*Hymenodictyon excelsum*	30 x 30 x 10	30
8	Dwabok	*Kydia calycina*	30 x 30 x 10	30
9	Kokko	*Albizia lebbek*	30 x 30 x 10	30
10	Pyinma	*Lagerstroemia speciosa*	30 x 30 x 10	30
11	Taungthayet	*Swintonia floribunda*	30 x 30 x 10	30
12	Tawthayet	*Mangifera spp.*	30 x 30 x 10	30
13	Thitmagyi	*Albizia odoratissima*	30 x 30 x 10	30
14	Taukkyan	*Terminalia tomentosa*	30 x 30 x 10	30
15	Gyo	*Schleichera oleosa*	30 x 30 x 10	30

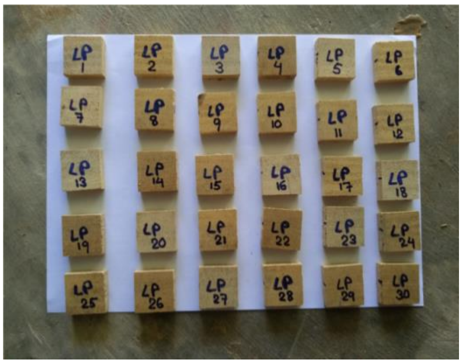

Figure 1: Photo showing Letpan wood sample

Figure 2: Photo showing Bonmeza wood sample

Figure 3: Photo showing Sagasein wood sample

Figure 4: Photo showing Gwe wood sample

Figure 5: Photo showing Thitkado wood sample

Figure 6: Photo showing Baing wood sample

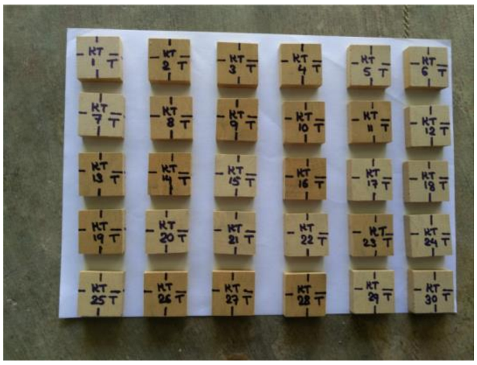

Figure 7: Photo showing Kuthan wood sample

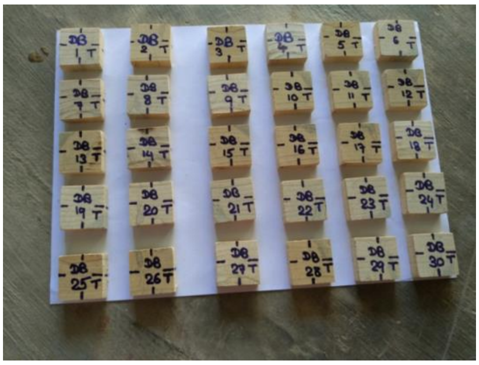

Figure 8: Photo showing Dwabok wood sample

Figure 11: Photo showing Taungthayet wood sample

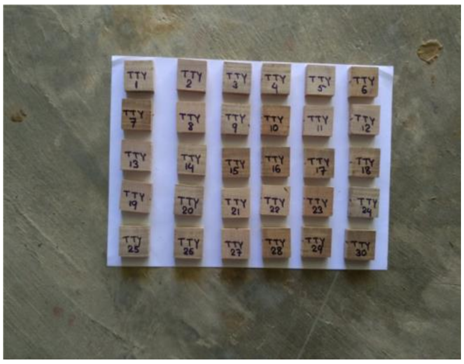

Figure 12: Photo showing Tawthayet wood sample

Figure 13: Photo showing Thitmagyi wood sample

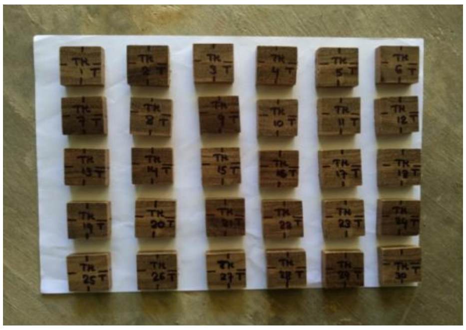

Figure 14: Photo showing Taukkyan wood sample

Figure 15: Photo showing Gyo wood sample

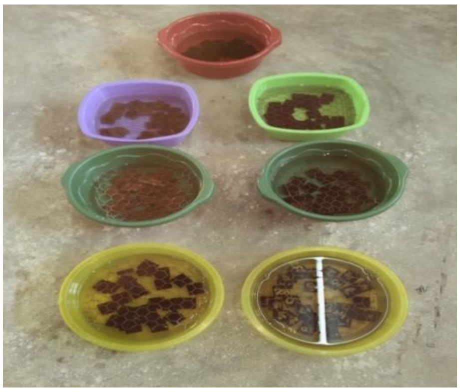

Figure 16: Photo showing Water absorption testing of wood sample

3.2 Methods

3.2.1 Basic density

The density of wood is defined as the ratio of its weight to its volume (Schmulsky and Jones, 2011; Forest Products Laboratory, 2010; Dinwoodie, 2000). Basic density is the ratio of oven-dry weight of wood to its green volume. The volume and the weight cannot be affected by moisture content. It is the best index for comparison of different timber species. Thus, the basic density of wood is calculated as follows:

$$\boldsymbol{Basic\ density} = \frac{\boldsymbol{Oven - dry\ weight}}{\boldsymbol{Green\ volume}}\ \boldsymbol{x\ 1000}\ (\boldsymbol{kg/m}3)$$

3.2.2 Swelling and Swelling Anisotropy

Radial, tangential, Longitudinal and volumetric swelling and swelling anisotropy were determined according to DIN 52184 as follows:

$$S_R = \frac{L_s - L_o}{L_0}\ x\ 100 \quad (\%)$$

$$S_T = \frac{L_s - L_o}{L_0}\ x\ 100 \quad (\%)$$

$$S_L = \frac{L_s - L_o}{L_0}\ x\ 100 \quad (\%)$$

$$S_v = \frac{V_s - V_o}{V_0}\ x\ 100 \quad (\%)$$

$$\textbf{Swelling Anisotropy} = \frac{S_T}{S_R}$$

where S_R, S_T, S_L and S_V are radial, tangential, longitudinal and volumetric swelling of a specimen, respectively. L_s and L_o represent radial or tangential or longitudinal dimensions of the specimen in saturated and oven-dry conditions and V_S and V_O volume of the specimen in saturated and oven- dry conditions. The dimensions of specimens before and after soaking in water were measured using a digital caliper. Volume of the specimen in saturated and oven- dry conditions was determined by multiplying radial, tangential, longitudinal dimensions of the specimen in saturated and oven-dry conditions.

3.2.3 Fiber saturation point

Fiber saturation point was determined as follows:

$$FSP = \frac{V_{sat} - V_{dry}}{W_{dry}}\ x\ density\ of\ water\ x\ 100 \quad (\%)$$

Where

FSP = fiber saturation point of a specimen (%)

V_{sat} = Volume of the specimen at fully swollen condition (cm^3)

V_{dry} = Volume of the specimen at oven- dry condition (cm^3)

W_{dry} = oven- dry weight of the specimen (g)

3.2.4 Water absorption

Water absorption was determined as follows:

$$WA = \frac{W_{end} - W_{start}}{V}\ (kg/m^3)$$

where ***WA*** is water absorption by a specimen, W_{start} and W_{end} weights of the specimen at the start and after a specific time (after 1, 2, 3, 4 hour, etc.), and ***V*** volume of the specimen through which water diffuses.

4. Data analysis

In this research, minimum, maximum, mean and standard deviation were calculated by using Statistica Software.

5. Results and Discussion

5.1 Basic density

Table 2: Basic density of tested timber species

Sr. No	Species	Basic density (kgm^{-3})	Number	Standard deviation	Minimum	Maximum
Light wood species						
1	Letpan	345	30	16.52	321	372
2	Bonmeza	357	30	23.23	320	388
3	Sagasein	327	30	8.32	312	345
4	Gwe	322	30	13.25	305	339
Moderately heavy wood species						
5	Thitkado	420	30	39.91	356	462
6	Baing	317	30	16.93	302	348
7	Kuthan	475	30	13.39	451	494
8	Dwabok	459	30	15.89	445	494
Heavy wood species						
9	Kokko	642	30	35.48	588	685
10	Pyinma	552	30	13.30	528	569
11	Tawthayet	563	30	13.14	541	583
12	Taungthayet	623	30	9.36	599	636
Very heavy wood species						
13	Thit-magyi	692	30	11.20	677	718
14	Taukkyan	786	30	21.63	745	845
15	Gyo	919	30	9.16	901	946

The basic densities of tested timber species are shown in Table 2. They range from 317 kg m^{-3} to 919 kg m^{-3}. Gyo has the highest basic density whereas Baing has the lowest basic density among them. According to Tsoumis (1991), variation of density exists within a tree, between trees of the same species, and between species. In Table 3 and figure 17, the basic density is found to differ significantly among the tested timber species and between groups. According to figure 17, very heavy wood species possess the highest basic density whereas light wood species possess the least one between groups. The density of wood is influenced by moisture, structure of wood, chemical composition and extractable substances (USDA, 1991).

Table 3: ANOVA of basic density

Analysis of Variance (Basic Density.sta) Marked effects are significant at p < .05000								
	SS	**df**	**MS**	**SS**	**df**	**MS**	**F**	**p**
Basic density (kg/m3)	10485870	14	748990.7	90553.6	255	355.1	2109.2	0.00

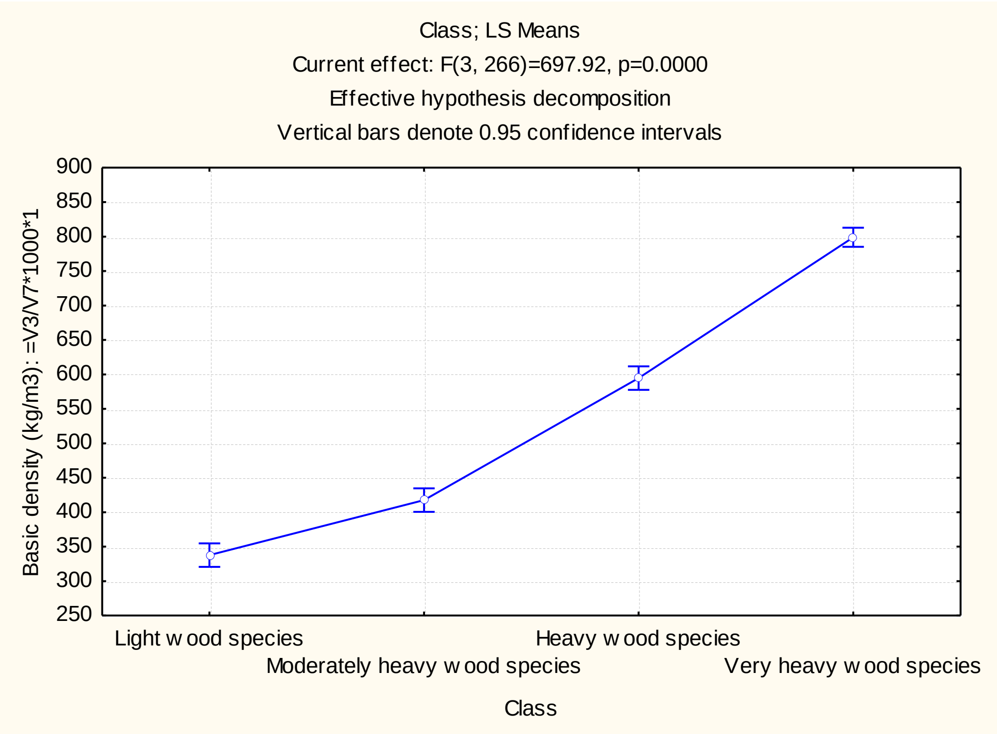

Figure 17: Comparison of basic density of tested timber species between groups

5.2 Swelling and swelling anisotropy

Table 4: Swelling and swelling anisotropy of tested timber species

Sr. No	Species	Scientific name	Radial Swelling %	Tangential Swelling %	Longitudinal Swelling %	Volumetric Swelling %	Swelling Anisotropy
Light wood species							
1	Letpan	*Bombax ceiba*	2.01	4.83	0.72	6.19	2.57
2	Bonmeza	*Albizia chinensis*	2.67	5.31	0.38	6.98	2.10

3	Sagasein	*Cananga odorata*	2.43	6.63	0.19	9.23	2.77
4	Gwe	*Spondias pinnata*	2.57	6.79	0.33	9.90	2.85
Moderately heavy wood species							
5	Thitkado	*Toona ciliata*	2.47	5.29	0.12	8.02	2.18
6	Baing	*Tetrameles nudiflora*	3.05	6.38	0.19	8.76	2.10
7	Kuthan	*Hymenodictyon excelsum*	3.18	7.15	0.24	10.41	2.28
8	Dwabok	*Kydia calycina*	3.06	8.61	0.33	11.69	2.89
Heavy wood species							
9	Kokko	*Albizia lebbek*	2.62	4.85	0.59	7.24	1.91
10	Pyinma	*Lagerstroemia speciosa*	2.92	7.08	0.58	9.82	2.44
11	Tawthayet	*Mangifera spp*	3.08	5.24	0.94	8.54	1.72
12	Taungthayet	*Swintonia floribunda*	2.63	6.08	0.98	9.94	2.36
Very heavy wood species							
13	Thit-magyi	*Albizia odoratissima*	2.67	6.79	0.29	9.96	2.57
14	Taukkyan	*Terminalia tomentosa*	6.64	9.63	0.45	17.44	1.46
15	Gyo	*Schleichera oleosa*	7.68	14.04	0.47	23.38	1.85

Swelling and swelling anisotropy of tested timber species are shown in Table 4. According to the results, radial swelling ranges from about 2.01% to 7.68%, tangential swelling from about 4.83 to 14.04% and longitudinal swelling from 0.12 to 0.98%. It can be found that tangential swelling is the largest and radial swelling is the second largest whereas longitudinal swelling is the lowest. In general, radial shrinkage/ swelling is about half of tangential shrinkage / swelling of the same species. This also holds true for the tested timber species. There are many reasons explaining this phenomenon: the restricting effect of the ray on the radial plane, the increased thickness of middle lamella on the tangential plane, the difference in the degree of lignification between radial and tangential cell walls, the small difference in microfibrallar angles between the two walls and earlywood-latewood interaction (Dinwoodie 2000; Forest Products Laboratory 1957; Peck 1957; Clarke 1930 and Time, 1998). Longitudinal shrinkage and swelling of normal wood from green to oven dry condition ranges between 0.1% to 0.9% (Kollmann and Cote 1968). Volumetric swelling ranges from 6.19% to 23.38%. In this research, volumetric swelling is nearly the same to the sum of radial, tangential and longitudinal swelling. Among the tested species, Gyo is found to swell the highest and Letpan swells the lowest. It is found that swelling relates to densities. Wood with higher density shows higher swelling (USDA, 2010). The magnitude of shrinkage and swelling is higher with higher density due to the larger amount of wood substance (greater cell-wall thickness). According to Table 4, swelling anisotropy ranges from 1.46 to 2.85. The value of swelling anisotropy of Kokko, Tawthayet, Taukkyan and Gyo are less than 2. But, others are greater than 2. The wood having a low anisotropy is best suited for use (Panshin & de Zeeuw, 1980). This means that shrinkage or swelling problems can occur when putting species with higher anisotropies into use, but if they are properly dried before they are used, these problems can be controlled.

5.3 Fiber saturation point (FSP)

Table 5: Fiber saturation point of tested timber species

Sr. No	Species	Scientific name	FSP (%)	Std. Dev	Min	Max
Light wood species						
1	Letpan	*Bombax ceiba*	26.52	5.34	21.58	32.81
2	Bonmeza	*Albizia chinensis*	22.43	1.87	20.12	25.27
3	Sagasein	*Cananga odorata*	33.70	2.3	29.83	35.60
4	Gwe	*Spondias pinnata*	29.44	0.85	28.29	30.60
Moderately heavy wood species						
5	Thitkado	*Toona ciliata*	28.82	2.05	25.77	31.39
6	Baing	*Tetrameles nudiflora*	25.20	4.63	19.71	33.92
7	Kuthan	*Hymenodictyon excelsum*	19.86	1.66	16.79	22.19
8	Dwabok	*Kydia calycina*	22.76	1.77	19.16	26.34
Heavy wood species						
9	Kokko	*Albizia lebbek*	14.78	1.09	13.45	16.43
10	Pyinma	*Lagerstroemia speciosa*	23.51	2.57	22.03	28.08
11	Tawthayet	*Mangifera spp*	22.07	2.03	20.15	25.24
12	Taungthayet	*Swintonia floribunda*	15.31	1.34	13.87	16.86
Very heavy wood species						
13	Thit-magyi	*Albizia odoratissima*	14.57	1.14	12.96	15.62
14	Taukkyan	*Terminalia tomentosa*	20.68	2.47	18.58	24.53
15	Gyo	*Schleichera oleosa*	21.37	0.35	20.86	21.84

The fiber saturation point (FSP) is defined as the condition where the cell cavities are empty (no free water), but the cell walls are fully saturated. The moisture content at FSP is generally in the range of 25 to 30% (avg. ~ 28% often assumed) depending on the species.

The fiber saturation points of tested timber species are shown in Table 5. According to the results, Sagasein- *Cananga odorata* has the highest fiber saturation point while Thit-magyi- *Albizia odoratissima* has the least fiber saturation point. The fiber saturation points of Kokko- *Albizia,* Taungthayet- *Swintonia floribunda* and Thitmagyi- *Albizia odoratissima* are 14.78%, 15.31% and 14.57%, respectively, and are less than those of most timber species. Generally, fiber saturation point is assumed to be at about 28%, but varies with timber species depending on the amount of deposits on cell lumina (USDA 2010).

According to ANOVA as shown in Table 6 and figure 18, the fiber saturation point of tested timber species is found to differ significantly among the tested species and between the groups of tested timber species. Fiber saturation point is negatively correlated with wood density, interlocked grain and ash content (Hernandez 2007). These factors could be attributed to the low values of fiber saturation point of the tested timber species.

Table 6: Analysis of variance of fiber saturation point

Analysis of Variance (FSP.sta) Marked effects are significant at p < .05000								
	SS	**df**	**MS**	**SS**	**df**	**MS**	**F**	**p**
FSP	2258.499	14	161.3213	638.3518	90	7.092798	22.74438	0.000000

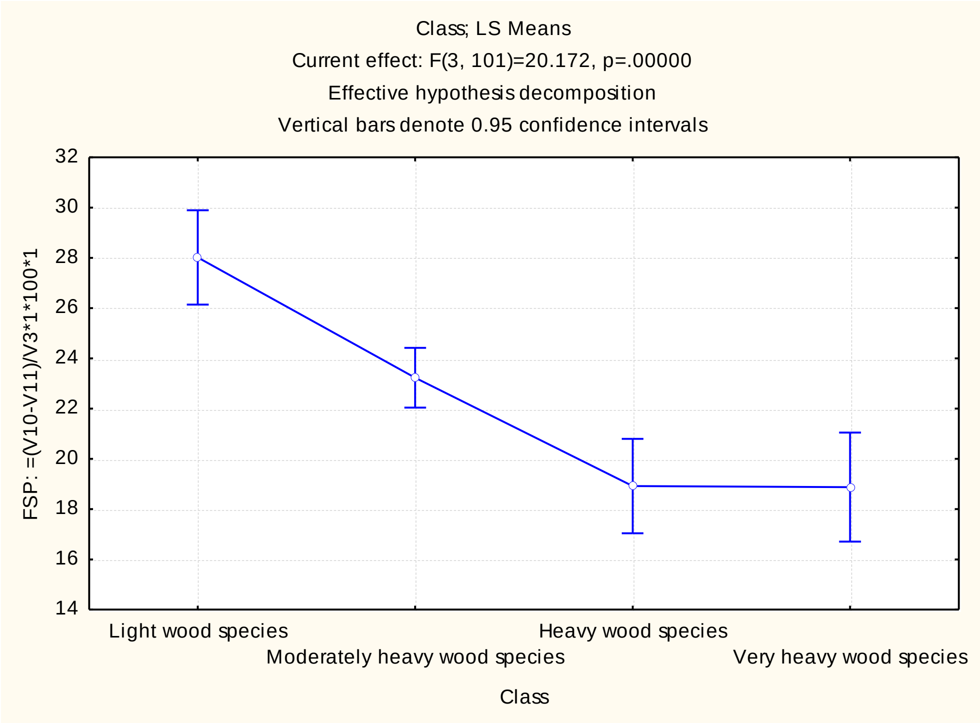

Figure 18: Analysis of variance of fiber saturation point between groups

5.4 Water absorption

Table 7: Maximum water absorption of tested timber species

Sr. No	Species	Scientific name	Maximum water absorption (kgm^{-3})
1	Letpan	*Bombax ceiba*	827.41
2	Bonmeza	*Albizia chinensis*	838.76
3	Sagasein	*Cananga odorata*	843.84
4	Gwe	*Spondias pinnata*	839.07
5	Thitkado	*Toona ciliata*	785.24
6	Baing	*Tetrameles nudiflora*	835.25
7	Kuthan	*Hymenodictyon excelsum*	700.88
8	Dwabok	*Kydia calycina*	737.17
9	Kokko	*Albizia lebbek*	600.66
10	Pyinma	*Lagerstroemia speciosa*	619.84

11	Tawthayet	*Mangifera spp*	665.11
12	Taungthayet	*Swintonia floribunda*	617.08
13	Thit-magyi	*Albizia odoratissima*	539.22
14	Taukkyan	*Terminalia tomentosa*	461.59
15	Gyo	*Schleichera oleosa*	393.98

The maximum water absorption values of tested timber species are shown in Table 7. Among the tested species, Sagasein has the highest water absorption which reached 843.84 kg/m^3. Gyo has the lowest water absorption which reached 393.98 kg/m^3. Figure 19 to 22 show the results of water absorption (WA) of wood samples of tested timber species for the whole test period. Comparison of maximum water absorption between groups is shown in figure 23 where light wood species are found to absorb the highest amount of water but very heavy wood species the least amount of water.

Water absorption is generally influenced by wood types (sapwood or heartwood), extractives, density or specific gravity and wood directions (Maclean 1935). The main influencing factor is extractive. In this research, Gyo with the highest basic density absorbed the least amount. This is due to its thick cell wall, small lumens, and extractives compared to other tested timber species, thus small space available for water. Sagasein is not with the lowest basic density absorbed the largest amount. This might be due to its thin cell wall and large lumens, thus large space available for water.

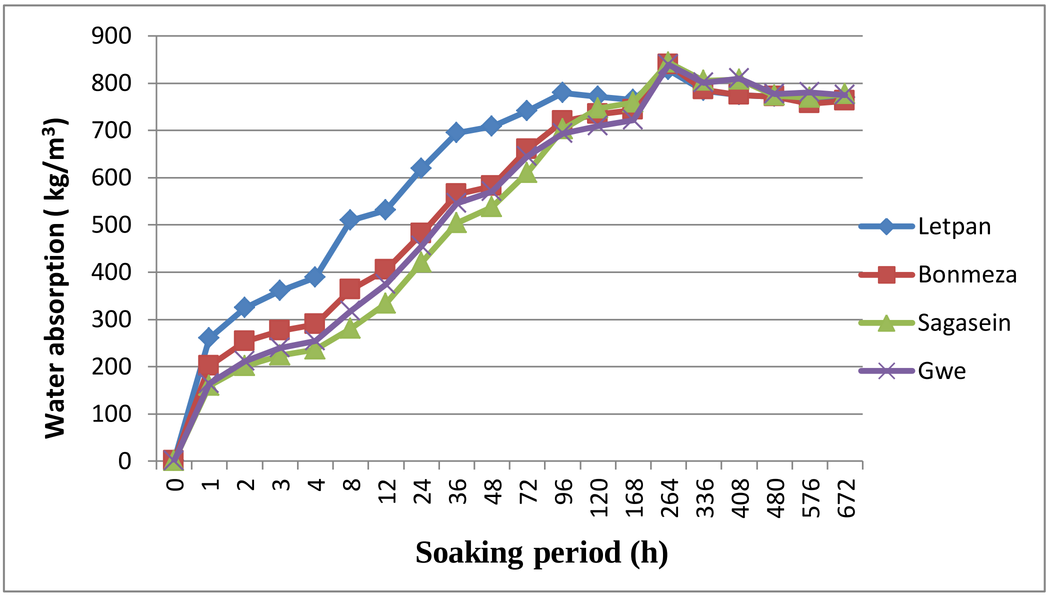

Figure 19: Water absorption of tested light wood species during the whole period

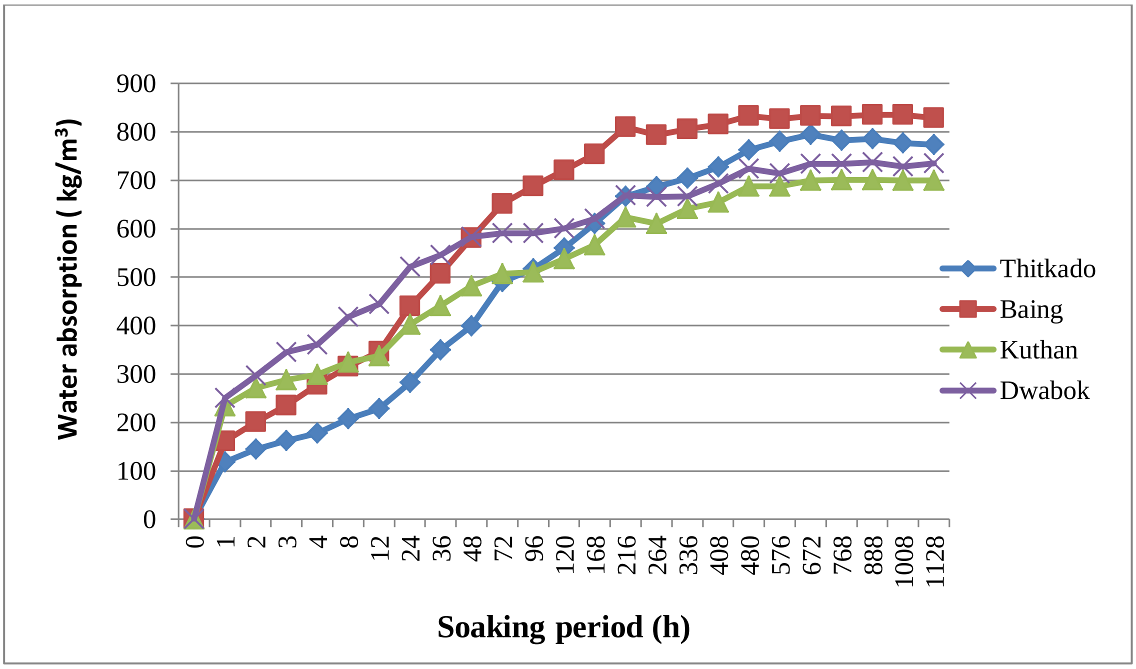

Figure 20: Water absorption of tested moderately heavy wood species during the whole period

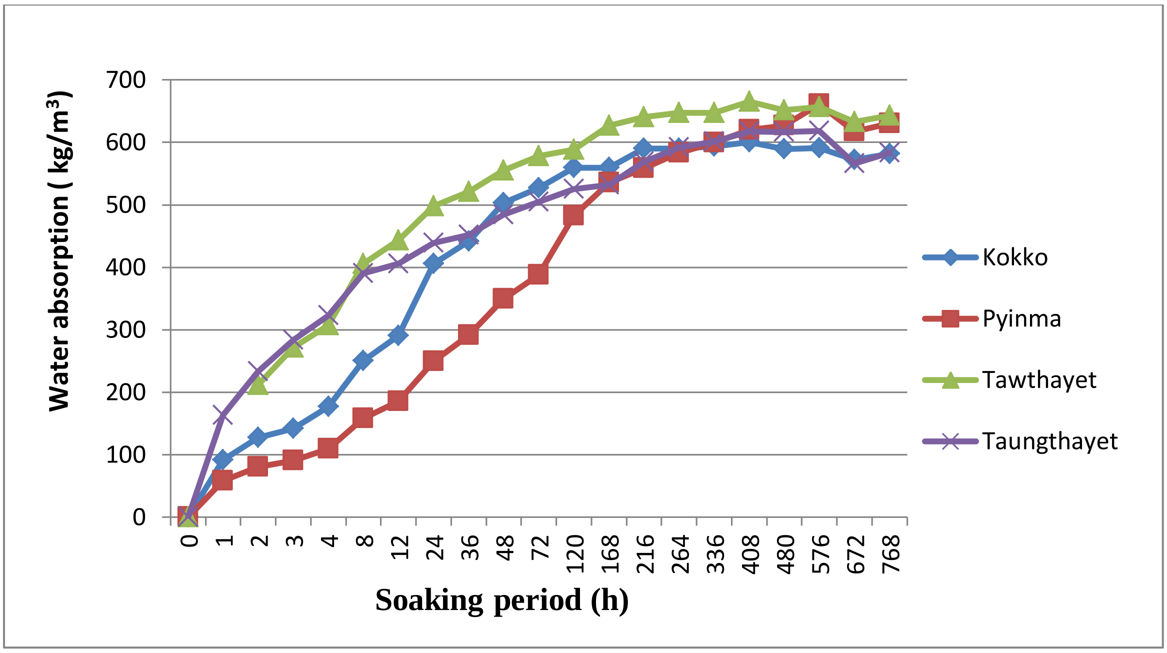

Figure 21: Water absorption of tested heavy wood species during the whole period

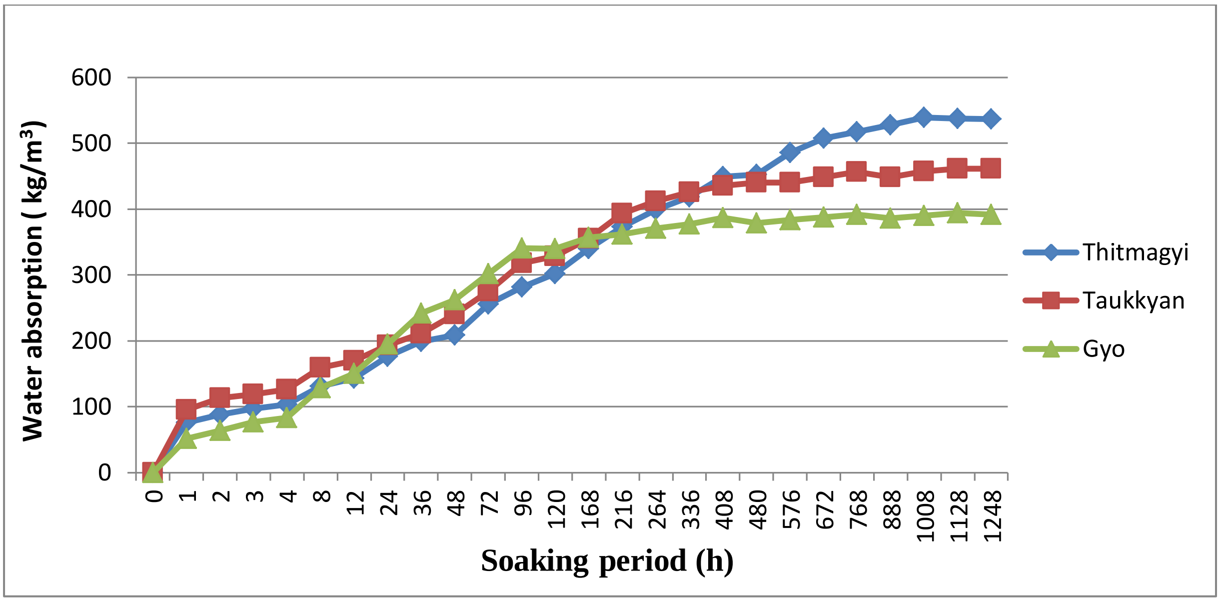

Figure 22: Water absorption of tested very heavy wood species during the whole period

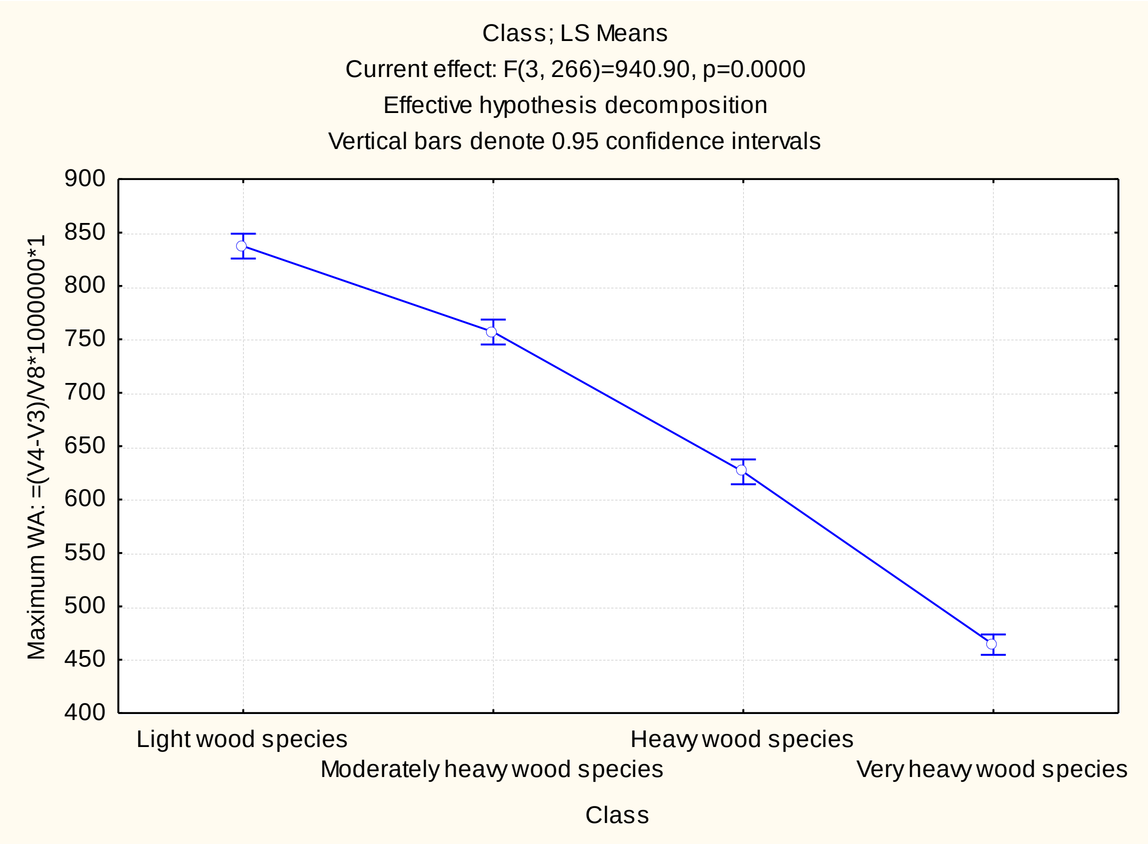

Figure 23: Comparison of maximum water absorption of tested timber species between groups

6. Conclusion

Water related properties such as basic density, swelling, swelling anisotropy and water absorption of fifteen hardwood species were determined after water soaking. Among tested species, Gyo has the highest basic density and Baing the lowest among them. Among the groups, those in very heavy group have the highest basic density, followed by those in heavy group, moderately heavy group and light group.

Swelling is affected by density and thus, the species with higher density swell higher. Baing has the lowest density but does not swell the lowest. Letpan swells the lowest. There are also other factors affecting shrinkage and swelling like size and shape of specimen and the rate of drying. Thus, the variation among the groups is the same as in basic density.

With regard to fiber saturation point, Sagasein has the highest whereas Thitmagyi has the lowest. Fiber saturation point is dependent on its cell wall thickness and deposits in cell wall and cell lumina. Among the groups, the light woods show higher fiber saturation points and high or very high density woods have lower fiber saturation points.

Gyo absorbed the least amount of water. This is due to its higher density caused by its thick cell wall, small lumens and extractives, thus small space available for water. Sagasein absorbed the highest amount of water.

Swelling anisotropy is the index of dimensional stability of timber. All other tested species are found to have a higher tangential to radial swelling ratio of greater than 2 except Kokko, Tawthayet, Taukkyan and Gyo.

According to the findings in this research, Kokko, Tawthayet, Taukkyan and Gyo can be used in furniture due to its low swelling anisotropy. Other timber species are not suitable for uses where dimensional stability is required. With regard to density, all species in heavy and very heavy groups can be used for building and furniture making. All species in moderately heavy and light groups are suitable for pencil making, matches and boxes. All species with higher water absorption and higher swelling should be used after treatment.

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