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Comparison of the Shrinkage – Swelling Characteristics and Water Absorption of Group (I) Species

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Contents

List of Tables

List of Figures

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Abstract

This research examines shrinkage, swelling and water absorption behaviors of Group (I) timber species of Myanmar in order to suggest their efficient utilization. Swelling is less than shrinkage in transverse section of all tested timber species. This is due to the fact that shrinkage is tested from green to oven-dry condition whereas swelling is examined from air-dry condition to green condition. Like in other timber species, longitudinal shrinkage is negligible as it ranges from 0.3% to 0.6%. But radial shrinkage is from 3% to 6 % whereas tangential shrinkage ranges from about 6 % to 12%. Thus, radial shrinkage is about half of the tangential values in all tested timber species. With regard to shrinkage or swelling, Thitya with the lowest specific gravity shows the highest shrinkage or swelling. This could be due to presence of juvenile wood or reaction wood in test specimens. Water absorption is highest in Thingan (377 kgm^{-3}) and Thitya (240 kgm^{-3}), which might be accounted for by low specific gravities (0.597) and (0.592), respectively, representing thin cell wall and large cavities. Being high density timbers, Group (I) species are mostly suited to construction. If they are applied for furniture or cabinet making, careful drying and application of hydrophobic materials is recommened. Thingan and Thitya with low specific gravity will not be suited to heavy constructions.

Key words: Group I species, Shrinkage, Swelling, Water absorption

အုပ်စု (၁) သစ်မျိုးများ၏ ကျုံ့မှု၊ကြွမှုလက္ခဏာများနှင့် ရေစုပ်ယူမှုကို နှိုင်းယှဉ်ခြင်း

ဒေါက်တာချိုချိုမြင့်၊ လက်ထောက်သုတေသနအရာရှိ
ခရစ္စတီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
စုစုလှိုင်၊ လက်ထောက်သုတေသနအရာရှိ
ချောရူပါစိုး၊ သုတေသနလက်ထောက်-၂

စာတမ်းအကျဉ်း

ဤစာတမ်းတွင် မြန်မာနိုင်ငံရှိ အုပ်စု (၁) သစ်မျိုးများကို ထိရောက်စွာ အသုံးပြုနိုင်ရန် ယင်းတို့၏ ကျုံ့မှု၊ကြွမှုနှင့် ရေစုပ်ယူနိုင်မှုတို့ကို လေ့လာတင်ပြထားပါသည်။ စမ်းသပ်သည့် သစ်မျိုးအားလုံးတွင် လားရာဘက်အားလုံး၌ ကြွမှုသည် ကျုံ့မှုထက် နည်းနေသည်ကို တွေ့ရှိရပါသည်။ ဤသို့ဖြစ်ရခြင်းမှာ ကျုံ့ခြင်းကို အစိုမှအခြောက်အခြေအနေအထိ စမ်းသပ်ခဲ့ပြီး ကြွခြင်းကိုမူ လေဖြင့်အခြောက်ခံထားသည့် အခြေအနေမှ အစိုအခြေအနေအထိသာ စမ်းသပ်ခြင်းကြောင့် ဖြစ်ပါသည်။ အခြားသစ်များမှာကဲ့သို့ပင် အလျားလိုက်ကျုံ့မှုသည် ၀.၃% မှ ၀.၆ % အထိသာ ရှိသောကြောင့် မပြောပလောက်သဖြင့် လျစ်လျူရှုနိုင်ပါသည်။ သို့သော်လည်း နှစ်ကွင်းထောင့်မှန်ကျကျုံ့မှုသည် ၃% မှ ၆% အထိရှိပြီး နှစ်ကွင်းအပြိုင်ကျုံ့မှုသည် ၆% မှ ၁၂% အထိဖြစ်သည်။ ထို့ကြောင့် နှစ်ကွင်းထောင့်မှန်ကျကျုံ့မှုသည် နှစ်ကွင်းအပြိုင်ကျုံ့မှု၏ တစ်ဝက်ခန့်ဖြစ်သည်။ ကျုံ့/ကြွမှုနှင့်ပတ်သက်၍ ရေချိန်သိပ်သည်းဆအနည်းဆုံးဖြစ်သော သစ်ရာသည် အများဆုံး ကျုံ့ကြွနေသည်ကိုတွေ့ရသည်။ ဤသို့ဖြစ်ရခြင်းမှာ စမ်းသပ်သော တုံး များတွင် သက်နုသားများ သို့မဟုတ် တံ့ပြန်သားများ ပါဝင်ခြင်းကြောင့် ဖြစ်နိုင်ပါသည်။ ရေစုပ်ယူမှုသည် သင်္ကန်း (၃၇၇ kgm^{-3}) နှင့် သစ်ရာ (240 kgm^{-3})တို့တွင် အများဆုံးဖြစ်ပါသည်။ ဤသို့ဖြစ်ရခြင်းမှာ ယင်းတို့တွင် ရေချိန်သိပ်သည်းဆများ နည်းပါးပြီး ယင်းတို့၏ ဆဲလ်နံရံများ ပါးပြီး ဆဲလ်အခေါင်းကြီးမားခြင်းကြောင့် ဖြစ်နိုင်ပါသည်။ သိပ်သည်းမှုမြင့်မားသည့် သစ်များ ဖြစ်သည့် အားလျှော်စွာ ဆောက်လုပ် ရေးလုပ်ငန်းများတွင် သုံးစွဲရန်သင့်လျှော်ပါသည်။ ပရိဘောဂနှင့် ဘီရိုများ ပြုလုပ် အသုံးပြုလိုပါလျှင် အသုံးမပြုမီ စနစ်တကျ အခြောက်ခံ ရန် လိုအပ်ပြီး ရေမဝင်စေနိုင်သည့် ပစ္စည်းများဖြင့် သုတ်လိမ်းထားရန် လိုအပ်ပါသည်။ သစ်ရာနှင့် သင်္ကန်းမှာ ရေချိန်သိပ်သည်းဆနိမ့်သဖြင့် ကြီးမားသောဆောက်လုပ်ရေးတို့တွင် အသုံးပြုရန် မသင့်တော်ပါ။

Comparison of the Shrinkage - Swelling Characteristics and Water Absorption of Group (I) Species

1. Introduction

Dry wood can absorb water from the surrounding environment. The entry of water into cell cavities cannot result in swelling. Only when the adsorbed water gets into the cell wall, does swelling start to occur. Wood used in different kinds of buildings, other structural applications and furniture is normally dry timber. Thus, it will absorb water and swell when in contact with water due to various reasons such as contact with rainwater or relative humidity becoming high. The resultant swelling of the cell wall can be assumed to be equivalent to the volume of adsorbed water (Kuklik, 2008).

In a similar way, green wood can also lose its moisture to the surrounding environment. When removing water from the cell cavities of wood, it does not shrink. But when its bound water is removed from the cell wall, shrinking of the cell wall occurs. The amount of shrinkage that occurs is proportional to the amount of water removed from the cell wall (Shmulsky and Jones, 2011).

Wood is an anisotropic material and shrinking or swelling is different in three structural dimensions. Whereas longitudinal shrinkage of normal wood is negligible, tangential shrinkage is greater than radial shrinkage by a factor of 1.5 to 3 (Shmulky and Jones, 2011). This difference in shrinking in the radial and tangential direction causes splits to develop in the ends of lumber or logs and distortion of flats, squares and rounds.

This shrinking and swelling can result in warping, checking, splitting and loosening of tool handles, gap in wooden applications or performance problems that detract from the usefulness of wood products (Jain and Kurhekar, 2015). Difficulties to close or open wood windows and doors, problems with wood drawers due to tightening or sticking, and raising of wood grains in rainy seasons are the consequences of wood swelling after taking up moisture from the surrounding air. Similarly, the problems like automatic opening of windows or doors instead of keeping them tight if bar locks are not used, loosening of nails and fastenings, loosening of mortise and tenon joints, gaps in wood floors, etc. in dry seasons of low relative humidity are due to shrinking of wood members after desorbing moisture to the surrounding air. Thus, it is of utmost importance to understand shrinkage and swelling of wood. Although the shrinkage, swelling and water absorption of some Myanma timber species have been tested, the swelling and water absorption of group (I) timber species commonly used in residential buildings and furniture have not been tested yet. Therefore, it needs to test them so that their swelling and water absorption behaviors are well understood.

2. Objectives

The objectives of this research are:

(1) to study the shrinkage-swelling characteristics and water absorption of Group (I) species

(2) to suggest efficient utilization of Group (I) species based on the findings, and

(3) to use the data for wood entrepreneurs and scientific researchers.

3. Literature Review

Wood is a hygroscopic material, continually giving off or taking on moisture in accordance with the relative humidity and temperature to which it is exposed (Forest Products Laboratory, 1951). Wood changes dimensions as it gains or loses moisture from the cell walls. It swells when gaining moisture in the cell wall and shrinks when losing moisture from the cell wall. It swells when exposed to a humid condition and shrinks non-uniformly into a smaller dimension when subjected to a condition of lower humidity.

As orthotropic material, wood shrinks most in the direction of the annual growth ring (tangentially), about half as much across the rings (radially), and only slightly along the grain (longitudinally) (Forest Product Laboratory, 1999). The difference between radial and tangential shrinkage may also be accounted for on the basis of the strands in the fiber walls being bent around the pits that predominate in the radial walls of the fibers, rather than being parallel to the long axis of the fiber. This arrangement of the strands permits maximum tangential shrinkage but lessens radial shrinkage (Forest Product Labratory, 1957).

Differential dimensional changes are of utmost importance in seasoning which has a direct effect on the production of furniture and joinery. When wood comes in contact with water, dimensional changes occur and might not work as designed (Usta and Guray, 2000). To stop water getting into the wood, various kinds of paints and varnishes are applied. Millions of dollars are spent each year as shrinkage and swelling cause many problems (Rahman et al., 2010). In fact, both shrinkage and swelling can interfere with the most efficient utilization of wood. Therefore, it is necessary in the utilization of wood to consider the primary cause of shrinking and swelling, and the shrinking and swelling characteristics of different species (Peck, 1957).

Water absorption measurement is important for the structural uses of wood. Wood components in residential buildings and industrial applications are periodically exposed to liquid water in the form of rain or water vapour and will pick up some moisture. An increase in 2% or 3% of water vapour can cause reduction in strength properties of timber structures (Emmanuel, 2014).

Thus, this study deals with the anisotropy of swelling and shrinkage in the longitudinal, tangential and radial directions and water absorption behaviors of some Myanmar commercially important timber species.

4. Materials and Methods

4.1 Materials

In this research, Group (I) timber species were selected which are used for a variety of purposes at various levels and well known commercial species. The selected Group (I) species were: Pyinkado (*Xylia xylocarpa* Benth), Padauk (*Pterocarpus macrocarpus* Kurz), Thingan (*Hopea odorata* Roxb), Thitya (*Shorea obtusa* Wall), Ingyin (*Shorea siamensis* (Kurz) Miq.) and Tamalan (*Dalbergia oliveri* Gamble). Thingan, Thitya, Padauk and Tamalan wood samples were obtained from Forest Research Institute. The other wood samples were collected from different saw mills in Mandalay. These species were identified in Wood Anatomy Section from Forest Research Institute. Air-dried defect-free (i.e no knots or decay) specimens were prepared for the selected timber species and tested for shrinkage-swelling characteristics and water absorption. The photos of Group (I) species wood samples and water absorption testing were shown in Figures (1 and 2). The number and size of specimens for the tested properties were shown in Table 1. The digital caliper, oven and electric balance were used in this study.

Figure 1. Photo shows Group I species wood samples

Figure 2. Photo shows water absorption testing

Table 1. Tested properties, size of specimen and number of specimens for Group(I) Species

Sr. No	Properties	Size of specimen (mm)	Number of specimens
1	Shrinkage (Radial, Tangential, longitudinal)	20mm x 20mm x10 mm	30
2	Swelling (Radial, Tangential, Longitudinal)	20mm x 20mm x 10mm	30
3	Water absorption	20mm x 20mm x 10mm	30

4.2 Methods

4.2.1 Swelling

For the swelling determination, the first measurement was made of the dimensional lengths of air-dried wood specimens. Then the specimens were completely immersed in water during which readings were taken every 10 minutes for 1 hour and then every 30 minutes for 4 hours. Thereafter, readings were taken every hour for 5 hours and then every 5 hours for 20 hours. Measurements were made until a steady weight was recorded. The percentage of swelling was then calculated according to the following equation:

$S_w = [(D_s – D_g)/ D_g] \times 100$

where, S_w = percentage of the swelling,

D_s = swelling dimension of the specimen (mm)

Dg = green (original) dimension of the specimen (mm)

4.2.2 Shrinkage

For the shrinkage determination, dimensional measurements were made in green condition for radial, tangential and longitudinal direction and each specimen was then weighed and recorded as green weight. Then, all the specimens were dried in an oven at 103 ± 2 ℃ to make the specimens shrink. Readings from the oven were taken as in the swelling study. Each experimental specimen was consequently removed from the oven according to the set time and immediately put back in the oven after weighing on a scale and dimensional measuring by a digital caliper, and this continued until a steady weight was recorded. The percentage of shrinkage was calculated by the following formula:

$S_h = [(D_g – D_{od})/ D_g] \times 100$

where , S_h = percentage of the shrinkage,

D_g = green (original) dimension of the specimen (mm)

D_{od} = oven dry dimension of the specimen (mm)

4.2.3 Specific Gravity

Specific gravity is the density of wood relative to the density of water, and for this reason the terms *relative density* is sometimes used. Specific gravity is used as a basis to standardize comparisons among species and products (Forest Product Laboratory, 1999).

Specific gravity was calculated as oven-dry weight divided by green volume. In this case, volume was determined by multiplying radial, tangential and longitudinal dimensions of wood samples.

4.2.4 Water absorption

For water absorption, the first measurement was made of the dimensional lengths of air-dried wood specimens. Then the wood specimens were completely immersed in water, and the readings were also taken as in the swelling study. Water absorption was calculated by using the following equation:

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

Where, **WA** = water absorption by a specimen

W_{start} = weights of the specimen at the start

W_{end} = weights of the specimen after a specific time as the swelling study

V = volume of the specimen through which water diffuses.

4.3 Data analysis

Minimum, maximum, mean and standard deviation were calculated for swelling, shrinkage and water absorption study by using Microsoft excel 2010.

5. Results and Discussion

5.1 Swelling and shrinkage

Shrinkage values from green to oven dried conditions and swelling values from air-dried to green conditions are shown in Table 2. And then, the percentages of swelling and shrinkage at varying time intervals in different directions of the Group (I) Species are shown in Table 3 and Figures 3, 4, 5, 6, 7 and 8, respectively.

Table 2. Shrinkage and swelling of Group (I) species

Species		Shrinkage from green to oven dry			Swelling from air-dried to green		
		Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
Pyinkado	Min	2.57	5.80	0.09	1.05	2.12	0.09
	Max	4.19	8.06	0.92	3.42	6.67	0.84

	Mean	3.23	6.79	0.54	1.42	3.17	0.45
	STD	0.37	0.59	0.22	0.43	0.75	0.23
Padauk	Min	2.14	6.04	0.09	1.44	2.94	0.10
	Max	4.07	7.82	0.94	2.40	4.47	0.94
	Mean	3.41	6.82	0.35	1.90	3.69	0.44
	STD	0.38	0.39	0.26	0.25	0.41	0.22
Thingan	Min	2.96	6.79	0.09	1.63	4.04	0.18
	Max	4.24	9.00	0.92	3.69	7.25	0.94
	Mean	3.51	7.89	0.56	2.63	6.07	0.63
	STD	0.35	0.47	0.23	0.52	0.67	0.28

Table 2. Continued:

Species		Shrinkage from green to oven dry			Swelling from air-dried to green		
		Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
Thitya	Min	5.05	10.96	0.10	1.04	3.16	0.10
	Max	9.20	13.56	0.98	8.15	12.38	0.98
	Mean	6.52	12.17	0.65	6.26	8.92	0.44
	STD	0.86	0.69	0.26	2.11	2.43	0.32
Ingyin	Min	5.00	8.97	0.10	2.03	3.81	0.19
	Max	6.02	12.36	0.95	3.67	6.56	0.96
	Mean	5.68	9.91	0.56	2.88	5.18	0.43
	STD	0.27	0.66	0.24	0.35	0.59	0.22
Tamalan	Min	3.38	7.53	0.10	1.24	2.44	0.10
	Max	5.73	9.18	0.98	2.25	4.06	0.98
	Mean	4.80	8.28	0.41	1.60	3.58	0.50
	STD	0.50	0.44	0.26	0.23	0.34	0.27

Table 3. Mean Percentages of swelling and shrinkage at varying time interval in different directions of Group (I) Species

Pyinkado						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	0.87	1.80	0.54	1.84	4.49	0.54
5	1.43	2.94	0.60	2.76	6.57	0.51
10	2.02	3.99	0.50	2.94	7.21	0.50
20	2.54	4.94	0.51	3.13	7.72	0.52
Padauk						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	0.85	1.34	0.51	1.78	3.59	0.55
5	1.60	2.63	0.46	3.38	6.67	0.50
10	2.15	3.58	0.56	3.46	6.84	0.42
20	2.68	4.57	0.58	3.84	7.44	0.38
Thingan						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	1.59	3.24	0.49	1.50	3.08	0.37
5	2.53	5.06	0.92	3.39	7.40	0.45

10	2.86	5.71	0.56	3.42	7.91	0.88
20	3.51	6.76	0.69	3.50	7.99	0.56
Thitya						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	4.97	7.70	0.51	3.95	7.57	0.53
5	5.90	9.46	0.53	6.78	11.97	0.63
10	6.44	10.46	0.46	6.09	11.24	0.49
20	6.18	8.66	0.62	6.73	12.08	0.48

Table 3. Continued:

Ingyin						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	0.83	1.42	0.51	1.92	2.37	0.59
5	1.50	2.95	0.52	4.88	8.56	0.45
10	2.53	4.58	0.53	5.22	9.02	0.43
20	2.55	4.44	0.54	5.36	9.34	0.39
Tamalan						
Time (h)	Swelling			Shrinkage		
	Radial	Tangential	Longitudinal	Radial	Tangential	Longitudinal
1	0.48	0.98	0.46	2.36	3.73	0.51
5	1.78	3.12	0.51	4.36	7.85	0.46
10	2.23	3.96	0.51	4.45	7.45	0.42
20	2.25	4.20	0.51	5.05	8.25	0.53

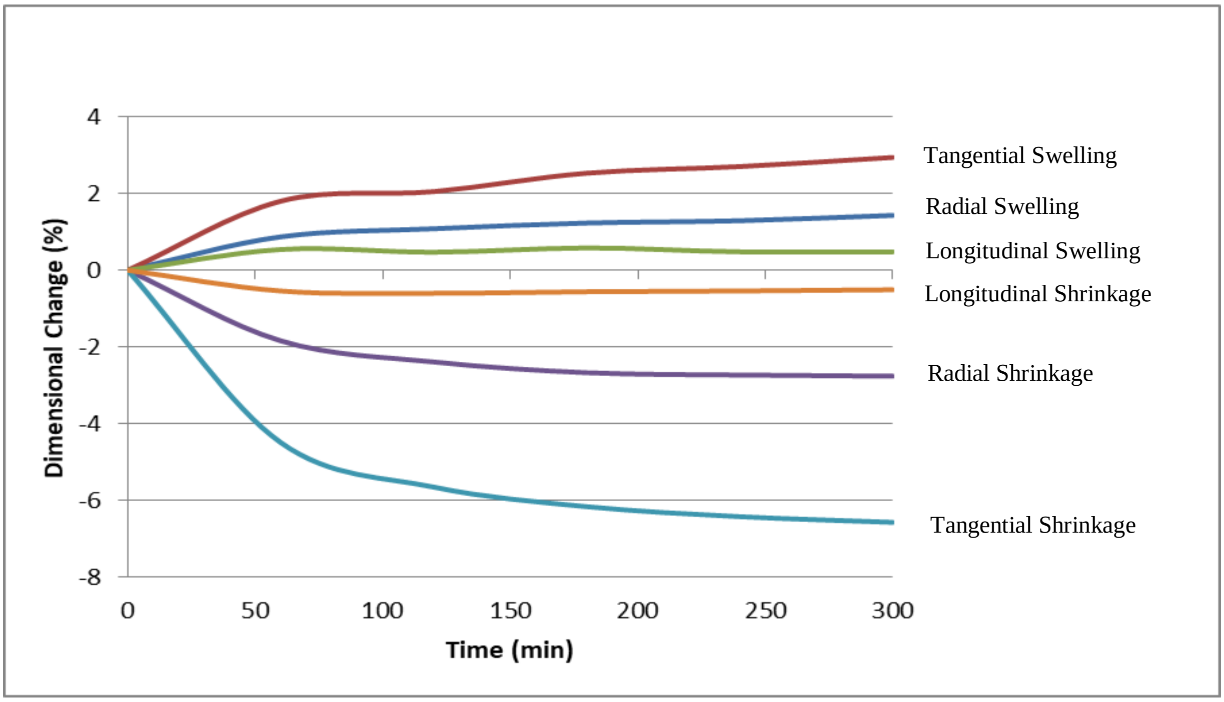

Figure 3: Swelling and shrinkage at varying time intervals in different directions of Pyinkado

The percentages of swelling and shrinkage in the three directions of Pyinkado are shown in Figure 3, Table 2 and Table 3, respectively. The swelling and shrinkage values show considerable differences among different directions. It is shown that shrinkage is greater than swelling for all directions. It is due to the fact that shrinkage is tested from green to oven-drying condition whereas swelling is examined from air-dry state to green state. It is clear that tangential swelling/shrinkage is always greater than radial swelling/shrinkage and longitudinal swelling/shrinkage can be considered negligible. According to Figure 3 and Table 2, the mean shrinkage/swelling value of Pyinkado in tangential direction is nearly twice the mean shrinkage /swelling value in radial direction.

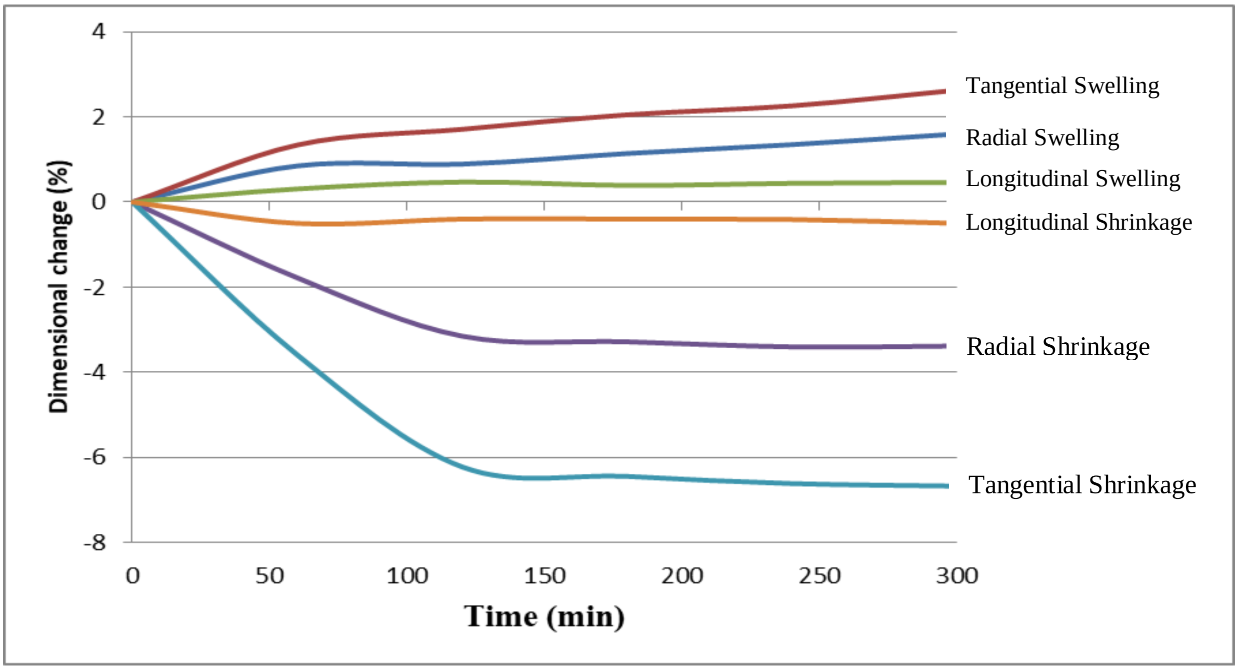

Figure: 4 Swelling and shrinkage at varying time intervals in different directions of Padauk

The percentages of swelling and shrinkage in different directions of Padauk are shown in Table 2 and 3, and Figure 4. Swelling/shrinkage values show considerable differences among different directions. It is shown that shrinkage is greater than swelling in radial and tangential directions. Shrinkage/swelling in tangential direction was greater than shrinkage/ swelling in radial direction. Swelling/shrinkage occurs in longitudinal direction was the lowest, medium in radial direction and the highest in tangential direction. According to Figure 4 and Table 2, shrinkage/swelling values of Padauk in tangential direction are twice the mean shrinkage /swelling values in radial direction.

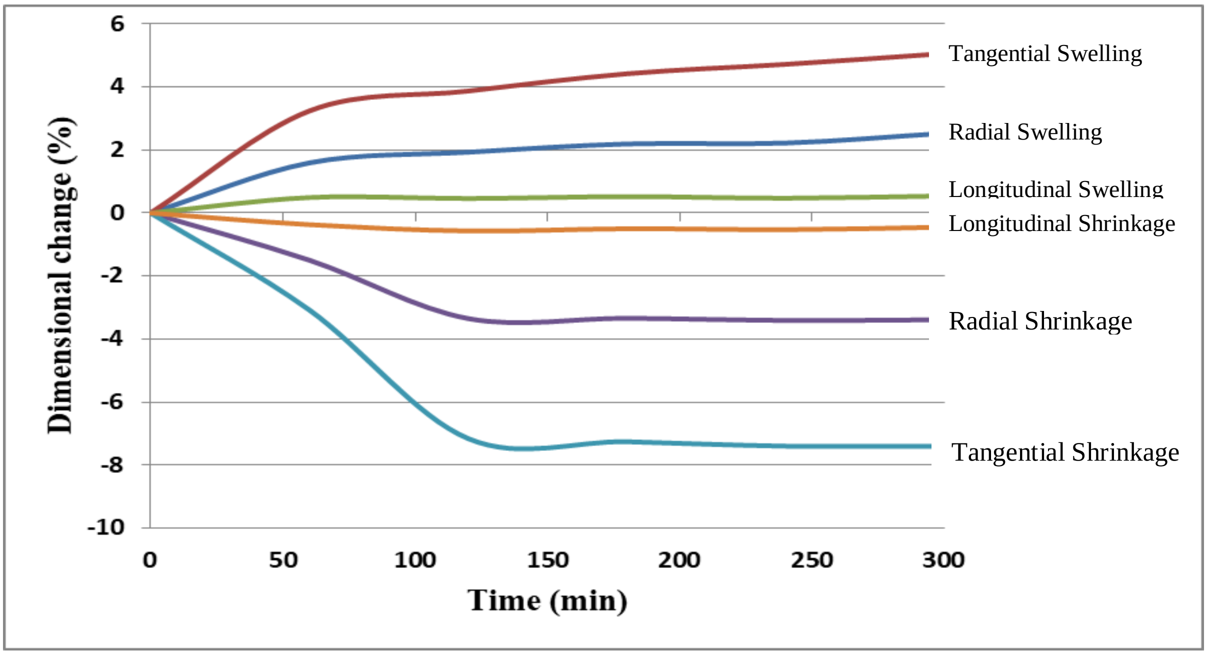

Figure 5: Swelling and shrinkage at varying time intervals in different directions of Thingan

Swelling and shrinkage values of Thingan are shown in Table 2 and 3, and Figure 5. Referring to Table 2 and 3, and Figure 5, it is clear that shrinkage was greater than swelling in radial and tangential directions of Thingan. It can be found that tangential swelling/shrinkage is the largest and radial swelling/shrinkage is the second largest whereas longitudinal swelling/shrinkage is the lowest. Shrinkage or swelling values in tangential direction are slightly higher than two times shrinkage or swelling values in radial direction.

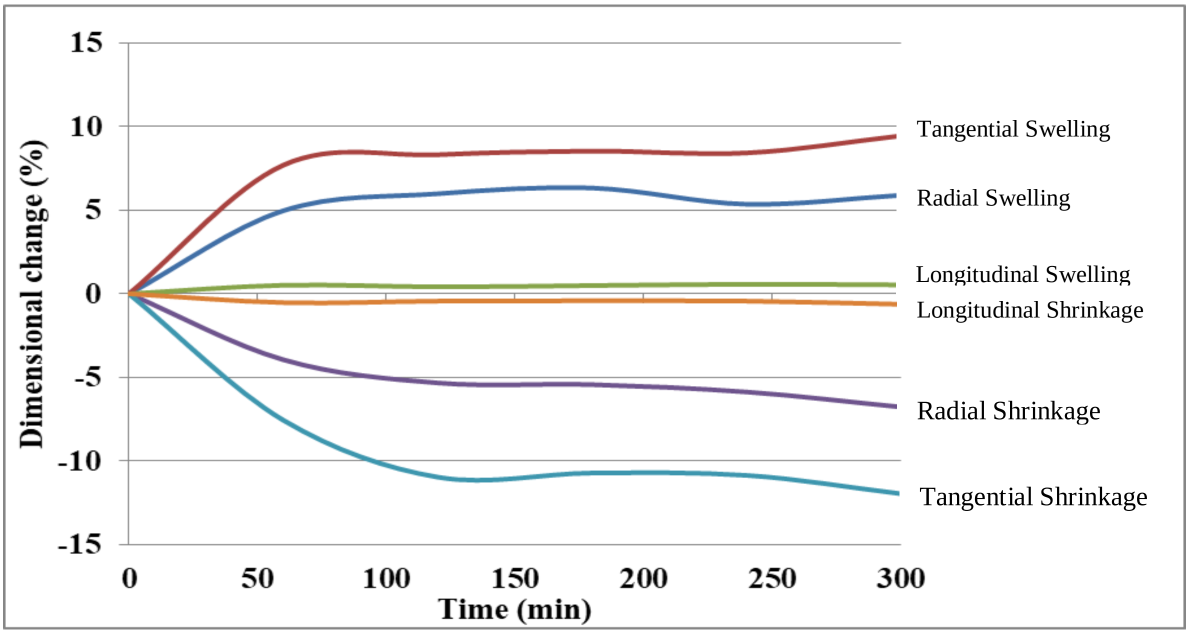

Figure 6: Swelling and shrinkage at varying time intervals in different directions of Thitya

Shrinkage and swelling values of Thitya are shown in Figure 6. Swelling occurs in longitudinal direction was the lowest, medium in radial direction and the highest in tangential direction. It holds true for shrinkage i.e. lowest in longitudinal direction, medium in radial direction and highest in tangential direction. Tangential shrinkage or swelling values are about twice radial shrinkage or swelling values.

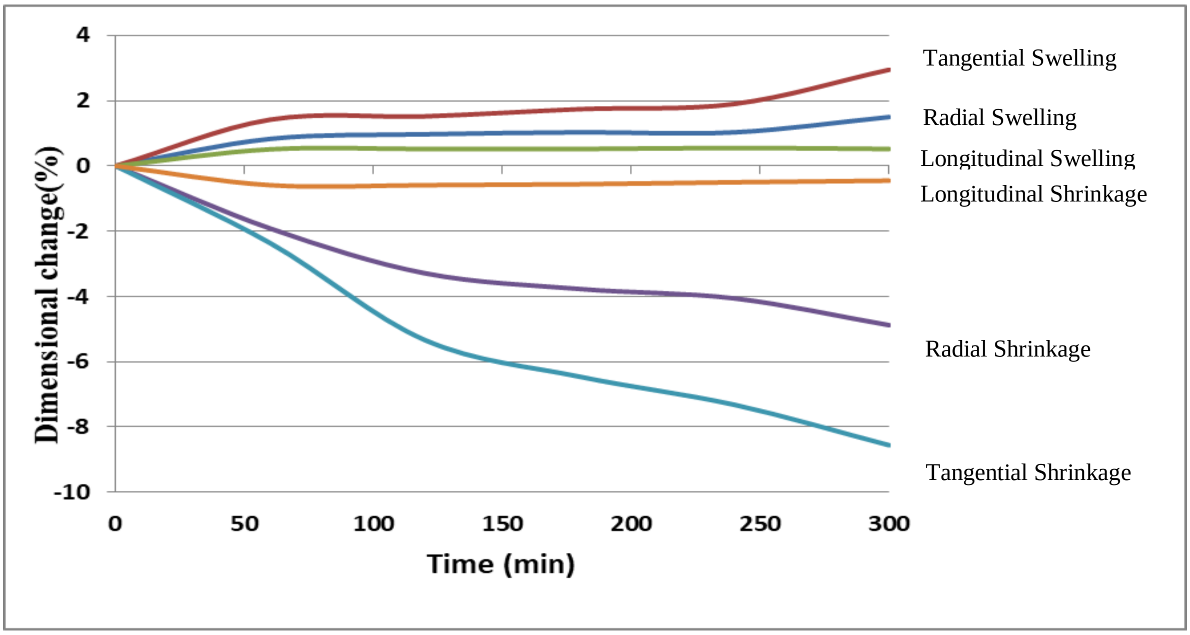

Figure 7: Swelling and shrinkage at varying time interval in different directions of Ingyin

Table 2 and 3, and Figure 7 show shrinkage and swelling of Ingyin. Shrinkage is greater than swelling for all directions. Shrinkage/swelling in radial direction is about half of the shrinkage/swelling in tangential direction. Longitudinal shrinkage/swelling is the lowest in three directions. Tangential shrinkage or swelling is about twice radial shrinkage or swelling.

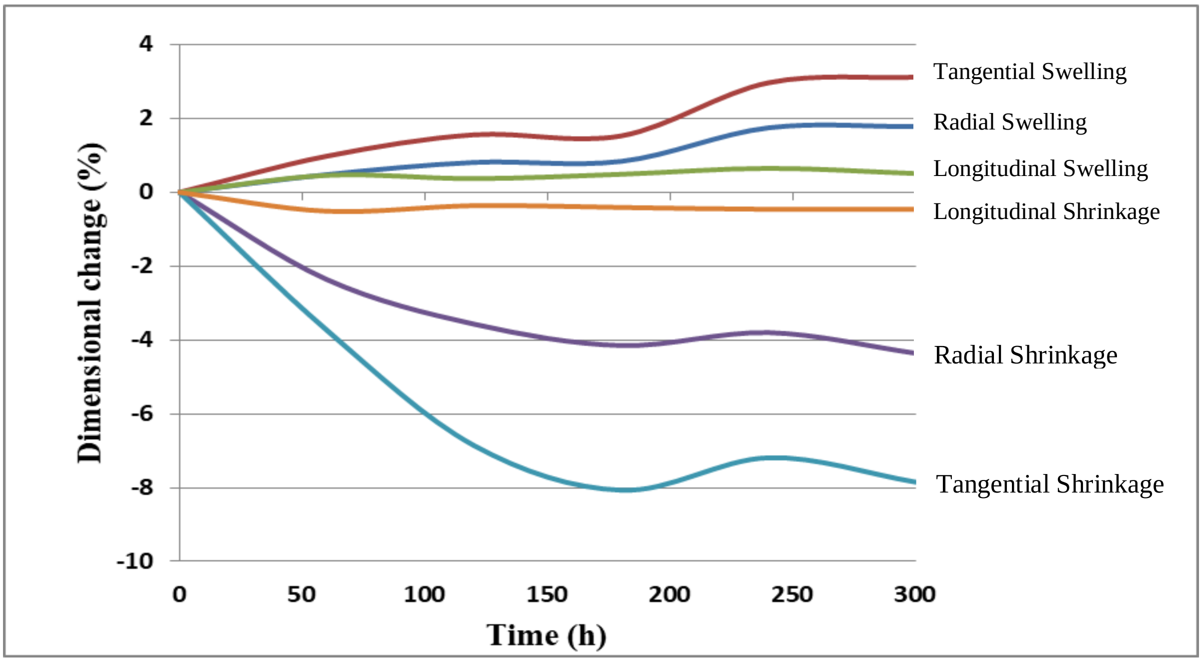

Figure 8: Swelling and shrinkage at varying time intervals in different directions of Tamalan

The percentages of dimensional change in different directions of Tamalan are shown in Table 2 and 3, and Figure 8. According to the results, shrinkage is greater than swelling in radial and tangential directions. The same trend is also observed for swelling, i.e. it exhibits the lowest value in longitudinal direction, medium in radial direction and the highest in the tangential direction. Tangential shrinkage or swelling is nearly twice radial shrinkage or swelling.

According to the results in Table 2, the mean radial shrinkage values of Pyinkado, Padauk, Thingan, Thitya, Ingyin and Tamalan from green to oven-dry condition are 3.23%, 3.41%, 3.51%, 6.52%, 5.68% and 4.80%, respectively. According to Skaar (1988), the order of magnitude of total shrinkage in "normal" wood is 3 to 6% in radial direction. Thus, the radial shrinkage values of Pyinkado, Padauk, Thingan, Thitya, Ingyin and Tamalan are found within the range. The mean tangential shrinkage values of Pyinkado, Padauk, Thingan, Thitya, Ingyin and Tamalan from green to oven-dry condition are 6.79%, 6.82%, 7.89%, 12.17%, 9.91% and 8.28%, respectively. The total tangential shrinkage in "normal" wood is 6 % to 12% (Skaar, 1988). Thus, Tangential shrinkage of Group (I) species is in line with those findings. The mean longitudinal shrinkage values of Pyinkado, Padauk, Thingan, Thitya, Ingyin and Tamalan from green to oven-dry condition are 0.54%, 0.35%, 0.56%, 0.65%, 0.56% and 0.41%, respectively. Longitudinal shrinkage and swelling of normal wood from green to oven dry condition ranges between 0.1% to 0.9% (Kollmann and Cote 1968). Thus, the longitudinal shrinkage values of Group (I) species are found within this range. Rowell (2005) states that most radial and tangential shrinkage values are less than 6% and 10%, respectively. All Group (I) species are found to swell less than 6% in radial direction and less than 10% in tangential direction, and thus are within the limits. The lesser radial shrinkage as compared with the tangential shrinkage was attributed to several anatomical traits: the presence of ray tissues, frequent pitting on the radial wall, domination of summerwood in driving moisture-induced shrinking and swelling in the tangential direction, and the differences in the amounts of cell wall material radially versus tangentially (Shmulsky and Jones, 2019)

Among the Group (I) species, Thitya has the highest shrinkage/swelling value, followed by Ingyin, Tamalan, Thingan, Padauk and Pyinkado. Generally, species with higher densities shrink more than those with lower densities. But there are some other exceptions such as juvenile woods and reaction wood which have excessive shrinkage or swelling (Forest Products Laboratory, 2010). Thitya shrinks higher than others although its density is the lowest, which could be explained by the presence of juvenile wood or reaction wood.

The radial and tangential shrinkage of Group (I) species are compared with those of the same species tested by other authors as shown in Table 4.Thitya and Ingyin have greater shrinkage value in this research than in other research.

Table 4: Comparison of Shrinkage of Group (I) species with those of the same species tested by other authors

Species	This Paper		Kyi, (1993)		Naing, et al., (2016)		Aye, et al., (2007)		Wood database	
	R.S%	T.S%	R.S%	T.S%	R.S%	T.S%	R.S%	T.S%	R.S%	T.S%
Pyinkado	3.2	6.8	3.3	6.7	-	-	-	-	-	-
Padauk	3.4	6.8	3.4	5.1	-	-	3.8	5.6	-	-
Thingan	3.5	7.9	3.4	6.5	3.9	7.4	-	-	-	-
Thitya	6.5	12.2	5.4	9.7	-	-	-	-	-	-
Ingyin	5.7	9.9	4.8	8.9	-	-	-	-	-	-
Tamalan	4.8	8.3	-	-	-	-	-	-	~2	~5

5.2 Specific Gravity

The basic specific gravities of Group (I) species are shown in Table 5. They range from 0.592 to 0.923. Tamalan has the highest whereas Thitya has the lowest among them. Species with higher specific gravity tend to have higher amount of wood substances in the same amount of volume (Zobel and Jett, 1995).

Table 5: Specific gravity of Group (I) timber species

Sr. No	Species	Specific gravity	Min	Max	Standard Deviation
1.	Pyinkado	0.804	0.745	0.859	0.026
2.	Padauk	0.760	0.735	0.788	0.012
3.	Thingan	0.597	0.551	0.645	0.026
4.	Thitya	0.592	0.559	0.628	0.019
5.	Ingyin	0.865	0.836	0.899	0.016
6.	Tamalan	0.923	0.909	0.944	0.008

According to Negi (1997), wood can be classified into six groups based on their basic specific gravity (based on oven-dry weight and green volume). Woods with basic specific gravity of 0.28 and less are considered to be very light, 0.28 to 0.42 light, 0.42 to 0.56 moderately heavy, 0.56 to 0.70 heavy, 0.70 to 0.85 very heavy and above 0.85, extremely heavy. In accordance with this classification system, Pyinkado and Padauk will be in "Very Heavy" Group whereas Thingan and Thitya in "Heavy" Group. Ingyin and Tamalan will be in "Extremely Heavy" Group .

The basic specific gravities of Group (I) species are compared with those of the same species tested by other authors as shown in Table 6. Thingan has lower basic specific gravity in this research than in other research. But, Padauk has higher basic specific gravity in this research than in other research.

Table 6: Comparison of basic specific gravities of Group (I) species with those of the same species tested by other authors

Species	This Paper	Kyi, (1993)	Naing, et al., (2016)	Aye, et al., (2007)	Wood database
Pyinkado	0.804	0.779	-	-	-
Padauk	0.760	0.752	-	0.706	-
Thingan	0.597	0.637	0.684	-	-

Thitya	0.592	0.858	-	-	-
Ingyin	0.865	0.779	-	-	-
Tamalan	0.923	-	-	-	0.78

5.3. Water absorption

The maximum water absorption values of Group (I) species are shown in Table 7. Among the Group (I) species, Thingan has the highest water absorption which reached (377.14 kg/m^3) followed by Thitya (240.15 kg/m^3), Padauk (226.70 kg/m^3), Tamalan (165.23 kg/m^3) , Pyinkado (156.23 kg/m^3) and Ingyin (132.41 kg/m^3) , respectively.

Table 7. Comparison of Maximum water absorption of group (I) species (kgm^{-3})

Sr. No	Species	Water absorption	Min	Max	Standard Deviation
1.	Pyinkado	156.23	131.07	192.57	15.36
2.	Padauk	226.70	215.94	246.24	7.23
3.	Thingan	377.14	324.67	427.98	32.89
4.	Thitya	240.15	182.84	295.92	37.82
5.	Ingyin	132.41	120.24	143.64	7.10
6.	Tamalan	165.23	153.41	173.94	5.31

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, specific gravity of Tamalan is the highest among the Group (I) species, but its water absorption is not the least. It might be due to the fact that it has less extractive than Ingyin and Pyinkado which absorb less water although they have lower specific gravities. Ingyin with the second highest specific gravity absorbed the lowest amount of water. This might be due to its more extractives, thick cell wall and small lumens compared to other species. Thingan, although it is not with the lowest specific gravity, absorbed the highest amount of water. This might be due to its thin cell wall and large lumens, thus large space available for water.

6. Conclusion

Shrinkage, swelling and water absorption of Group (I) species were studied in this research. From the results of this study it could be concluded that Thitya exhibits the highest shrinkage/swelling value and Pyinkado shows the lowest shrinkage/swelling value in radial and tangential direction. Shrinkage value was greater than swelling value for all species. A greater swelling/shrinkage was observed in tangential direction compared to radial direction. Longitudinal shrinkage/swelling value was the lowest in all direction for all species. Among the group (I) species, Thingan has the highest maximum water absorption while water absorption of Ingyin is the lowest. Among Group (I) species, those with higher specific gravity showed higher shrinkage/swelling and lower water absorption. Among the Group (I) species, Pyinkado has shown the best performance in accordance with the shrinkage and swelling properties.

With regard to shrinkage or swelling, Group (I) species are found to be high or very high density timber species with a radial shrinkage of 3-6% and a tangential shrinkage of 6-12 %. While some species with low shrinkage can be used for furniture making, they are most suited to construction due to their high specific gravities. If they are used for furniture and cabinet making, they should be carefully dried and some coats of paints, shellac, lacquers, vanish, and enamel or water resisting materials should be used to check the change in dimension of wood. Thitya has the lowest density but a highest shrinkage, and thus it might contain some juvenile wood or reaction wood.

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