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Investigation on Anisotropy, Fiber Saturation Point, Swelling and Periodical Water Uptake of Plantation Teak at Different Ages

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သက်တမ်းအမျိုးမျိုးရှိစိုက်ခင်းကျွန်း၏ပုံသဏ္ဌာန်မတည်မြဲမှု၊သစ်သားမျှင်များရေပြည့်ဝအမှတ်၊ကြွခြင်းနှင့် ရေစုပ်ယူနိုင်မှုများကိုလေ့လာစမ်းသပ်ခြင်း

ချိုချိုမြင့်၊သုတေသနလက်ထောက်-၂
နွယ်နွယ်ဝင်း၊သုတေသနလက်ထောက်-၃
ဝင်းဦးနိုင်၊လက်ထောက်သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန၊ရေဆင်း

စာတမ်းအကျဉ်း

ကျွန်းသည် တော်ဝင်သစ်ဖြစ်ပြီး အသုံးပြုမှု အမျိုးမျိုးအတွက် တန်ဖိုးထားကြသည်။ သဘာဝအတိုင်းပေါက်ရောက်သည့် ကျွန်းသည် ကြာရှည်ခံခြင်း၊ အသားတည်ငြိမ်ခြင်း၊ အင်အားကောင်း ခြင်း၊ အရောင်အသွေး၊ သစ်ကြော၊ အသွင်အပြင်တို့ဖြင့် ဆွဲဆောင်မှု ရှိခြင်းတို့ကြောင့် ကမ္ဘာနှင့်အဝှမ်း လူသိများ ကျော်ကြားလှသည်။ သို့သော် သက်တမ်း အမျိုးမျိုးရှိ စိုက်ခင်းကျွန်းကိုမူ အသားတည်ငြိမ်မှု နည်းပြီး ကြာရှည်ခံမှုလည်း နည်းသည်ဟု မကောင်း သတင်း ကျော်ကြားနေသည်။ ထို့ကြောင့် သက်တမ်းအမျိုးမျိုးရှိ စိုက်ခင်းကျွန်းများ၏ ကြွမှု၊ အသားတည်ငြိမ်မှု(ကြွခြင်းကွဲလွဲမှု)၊ သစ်သားမျှင်များရေပြည့်ဝအမှတ်နှင့် ရေစုပ်ယူနိုင်မှု တို့ ကို စမ်းသပ် ခဲ့ပါ သည်။ သိပ်သည်းခြင်းများ သည့် စိုက်ခင်း ကျွန်းသည် ကြွမှု ပိုများပြီး ရေစုပ်ယူမှု နည်းသည်ကို တွေ့ရသည်။ စမ်းသပ်ခဲ့သည့် စိုက်ခင်းကျွန်း အားလုံးသည် သစ်သားမျှင်များရေပြည့်ဝအမှတ် ၁၃% ခန့်မျှသာတွေ့ရသည်။ ယင်းတန်ဖိုးသည် သစ်မျိုးအများစု၏ သစ်သားမျှင်များ ရေပြည့်ဝအမှတ်ထက် နည်းသည်ကို တွေ့ရသည်။ ယင်းသို့ဖြစ်ရခြင်းသည် ဆဲလ်ခန်းများအတွင်းတွင် တည်ရှိနေသည့် အနယ်အနှစ် များ ကြောင့်ဖြစ်နိုင်သည်။ ကြွခြင်းကွဲလွဲမှုသည် သစ်သား၏အသားတည်ငြိမ်မှုကို ပြဆိုသည့် ညွှန်းကိန်း ဖြစ် သည်။ စမ်းသပ်ခဲ့သည့် စိုက်ခင်းကျွန်းများအနက် အသက် ၂၅ နှစ်ရှိ လယ်ဝေးစိုက်ခင်းကျွန်းသည် ကြွခြင်းကွဲလွဲမှု ၁.၉ ရှိခြင်းကြောင့် အသားအငြိမ်ဆုံး ဖြစ်သည်။ ထို့နောက် အသက် ၂၀ နှစ်ရှိ အုတ်တွင်း စိုက်ခင်းကျွန်း၊ ယင်းနောက် အသက် ၃၀ နှစ်ရှိ သံတွဲစိုက်ခင်းကျွန်း တို့ဖြစ်ပြီး အသက် ၁၄ နှစ်ရှိ ရေတာရှည် စိုက်ခင်းကျွန်းသည် အသားတည်ငြိမ်မှု အနည်း ဆုံးဖြစ်သည်။

Investigation on Anisotropy, Fiber Saturation Point, Swelling and Periodical Water Uptake of Plantation Teak at Different Ages

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Abstract

Teak is a Royal Tree which is prized for many versatile applications. The natural grown teak is worldwide well known for its durability, stability, high strength, attractiveness in colour and grain and good appearance. But, plantation teaks of young ages are reputed to possess low dimensional stability and lower durability. Thus, swelling, swelling anisotropy, fiber saturation point and water absorption of plantation teak of different ages were determined to assess their swelling behaviors in response to water soaking. Among different plantation teaks, those with higher densities showed higher swelling and lower water absorption. Almost all plantation teaks have almost the same value of fiber saturation point at about 13%, which is lower than the usual value of most timber species. This could be attributed to some extractives deposited in the cell lumina. Swelling anisotropy is the index of dimensional stability of timber. Among the tested plantation teaks, 25 years old Lewe plantation teak is found to have the best dimensional stability at the ratio of 1.9, followed by 20 years old Oktwin teak, Thandwe teak and Yetashe teak, respectively. The youngest Yetashe teak has the highest swelling anisotropy, meaning that it is least dimensionally stable.

Keywords: Plantation teak, swelling, swelling anisotropy, fiber saturation point and water absorption

Contents

Investigation on Anisotropy, Fiber Saturation Point, Swelling and Periodical Water Uptake of Plantation Teak at Different Ages

1. Introduction

Teak is a Royal Tree which is prized for many versatile applications. The natural grown teak is worldwide well known for itsdurability,stability,high strength, attractiveness in colour and grain andgood appearance.It is very suitablefor ship and boat building. It can also be used for various furniture, window frames, doors and floors. Nowadays, due to increasing scarcity ofthe natural grown teak production as well as the intensified establishment of teak plantation,juvenileplantation teak will find increasing acceptance in the market in future.So,the utilization potential of plantation teak has obtained enormous attention of many wood technologists.

Some physical and mechanical properties of plantation teak have been tested and published worldwide.In Myanmar, plantation teak of different ages has been investigated for their physical and mechanical properties. But,there is no research on anisotropy, fiber saturation point, swellingand periodical water absorptionproperties of these plantation teak timbers, which are very important in practice. All woods including teak can absorb moisture from the environment and desorb moisture to the environment as a result of changes in moisture content of the ambient atmosphere. Swelling is caused by absorbing moisture and shrinkage by desorbing moisture. This shrinkage and swelling can cause bending, twisting, holing and performance problems in timber. Fiber saturation point is also worth knowing as it is the moisture content where physical, mechanical and durability properties begin to change.

For some Myanma timber species, shrinkage has been studied but swelling has not been done yet.Swelling is a common problem of drywood when it is used in moist environment. In rainy season, the difficulties of closingdoors and windows are general problems of wood swelling as drywood absorb moisture from the environmentand gets swollen.Thus, swelling of different timbers including plantation teak should be studied.

1.1 Literature Review

Teak is recognized as one of the most valuable timbers in international trade and an important species for tropical forestry (Miranda et. al. 2011). According to Dietrich Brandis, it will be the most valuable timber in the world as he said, "Among timbers, teak holds the place which diamond maintains among precious stones and gold among metals". Due to its unrivalled durability and ease of workability, it has become one of the most sought after timbers in the world, and high prices are paid for teak and teak products,which result in heavy logging and decline in its growing stock. Thus, the limited availability of natural teak in the international trade, coupled with high prices, has prompted in the establishment of a large teak plantation across the tropics (Oteng-Omoako, 2004). It holds true for Myanmar where teak plantation establishment by *Taungya* method has begun since 1856, and it has been later planted on a special program with annual rate of 8100 ha (Dah, 2004). The total teak plantation has amounted to 390000 ha in Myanmar (Kollert and Cherubini, 2012).It has been reported that private sector is being allowed to establish teak plantation on a commercial scale. The heartwood of adult teak is considered the most valuable tropical hardwood on the market because of a combination of favorable wood characteristics: decay resistance, strength, high dimensional stability and an attractive colour and appearance (Lamin and van der Zee, 2007). Even six years old plantation teak in Queensland was found to have sufficient material properties to be used in typical teak products such as garden furniture and yacht decking, with the older ones having higher log values (Anon, 2011) whereas plantation teak of older ages like 50 to 70 years have higher specific gravities, strengths and higher percentages of heartwoods (Miranda et al. 2011). However, plantation teak is not as durable as mature teak (Bhat et. al. 2003). Moreover, it is characterized by wider rings, shorter fibers, smaller diameters, wide microfibrillar angles, and relatively lower or similar mechanical properties and the percentage of juvenile wood is 80-100% at age 20 and 25% at age 60 (Bhat et. al. 2001; Oteng-Omoako, 2004). These characteristics are especially important for uses of teak wood as furniture, stability demanding cabinets, door and window frames. This study is intended to determine water related properties of plantation teak of different ages grown in Myanmar.

Thus, the objective of this research paper is to present the test results of the properties which are quite important in practical application of wood such as anisotropy, fiber saturation point,swelling and periodical water absorption of plantation teak at different agesforimproving the utilization potential of plantation teak.

2. Materials and Methods

Five teak trees were randomly selectedforeach of different ages 14,20,25 and 30 years as shown in Table 1. The base portion of each sample tree was used to investigate anisotropy, fiber saturation point, swelling and periodical water absorption. Size of specimens and testing procedures were in accordance with the procedures given in DIN 52184.

Table 1: The number and size of specimen of plantation teak atdifferent ages

Sr.No	Locality	Ages(years)	Size of specimen (mm^3)	Number of specimens per tree
1	Yetashe	14	30 x 30 x 10	30
2	Oktwin	20	30 x 30 x 10	30
3	Lewe	25	30 x 30 x 10	30
4	Thandwe	30	30 x 30 x 10	30

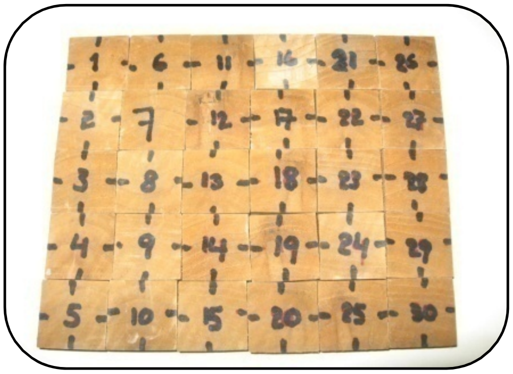

Figure 1: Photo showing plantation teak samples

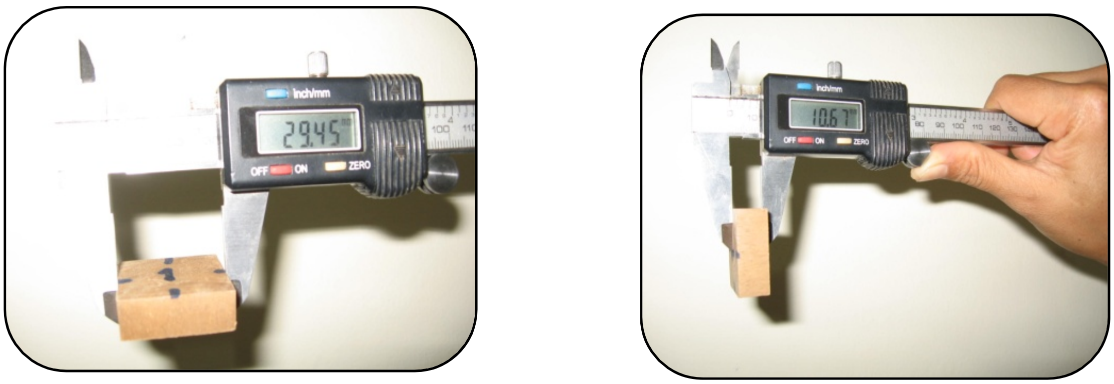

Figure 2: Photos showing measurement of dimensions before and after soaking for determination of shrinkage and swelling

2.1 Swelling and Swelling Anisotropy

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

$$S_R = \frac{L_s - L_o}{L_0} x100 \quad (\%) \tag{1}$$

$$S_T = \frac{L_s - L_o}{L_0} x100 \quad (\%) \tag{2}$$

$$S_L = \frac{L_s - L_o}{L_0} x100 \quad (\%) \tag{3}$$

$$SwellingAnisotropy = \frac{S_T}{S_R} \tag{4}$$

Where S_R, S_T and S_L are radial, tangential and longitudinal 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.

2.2 Fiber Saturation Point

Fiber saturation point was estimated by the common relationship as follows:

$$FSP = \frac{V_{Sat} - V_{dry}}{W_{dry}} x \ density \ of \ water \ x \ 100 (\%) \tag{5}$$

Where FSP is fiber saturation point (%) of a specimen, V_{sat} and V_{dry} volume of the specimen at fully swollen and oven-dry conditions (cm^3), and W_{dry} oven-dry weight of the same specimen measured in gram (g). Two assumptions must be met in regard to estimating the fiber saturation point from the relationship (5). After saturation, the specimens must be in a fully swollen state so that the cell wall cannot swell any more. The volume of cell lumina of the specimens must remain constant at both fully swollen saturated and completely oven-dried states.

2.3 Water absorption

Water absorption was determined as follows:

$$US = \frac{W_{end} - W_{start}}{V} \; (kg/m^3) \qquad (6)$$

Where US 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.), V volume of the specimen through which water diffuses.

3. Results and Discussion

3.1 Swelling of plantation teak at different ages

Table 2: Swelling from oven dry to saturated state

No.	Locality	Density (kg/m^3)	Direction	Mean (%)	Standard error	-95% swelling	+95% swelling	N
1	Lewe (25 yrs)	597	R	2.69	0.061	2.57	2.81	148
			T	5.08	0.061	4.96	5.20	148
			L	0.63	0.061	0.51	0.75	148
2	Oktwin (20 yrs)	595	R	2.15	0.061	2.03	2.27	150
			T	4.99	0.061	4.87	5.11	150
			L	0.70	0.061	0.58	0.82	150
3	Thandwe (30 yrs)	549	R	1.97	0.061	1.85	2.09	149
			T	4.77	0.061	4.65	4.89	149
			L	0.54	0.061	0.42	0.66	149
4	Yetashe (14 yrs)	533	R	1.96	0.061	1.84	2.08	150
			T	4.84	0.061	4.72	4.96	150
			L	0.42	0.061	0.30	0.54	150

The swelling of plantation teak at different ages is as shown in Fig 3 and Table 2. It can be found that tangential swelling is the largest and radial swelling is the second largest whereas longitudinal swelling is the lowest as in swelling of all the timber species. Radial swelling ranges from 1.96% in 14 years old Yetashe plantation teak to 2.69% in 25 year old Lewe teak whereas tangential swelling varies from 4.77% in 30 years old Thandwe teak to 5.08% in Lewe teak. It is found that swelling relates to densities. Lewe teak possesses the highest basic density, which has also the highest radial and tangential swelling. Similarly, Yetasheand Thandwe teak have the lowest density, and thus show the least swelling. Wood with higher density shows higher swelling(USDA, 2010). Longitudinal swelling is between 0.1% and 0.2% (USDA 2010). Longitudinal swelling of the tested material is found to higher than this range, which could be attributed to higher percentage of juvenile wood. However, longitudinal shrinkage and swelling of normal wood from green to over dry condition ranges between 0.1% and 0.9% (Kollmann and Cote 1968).

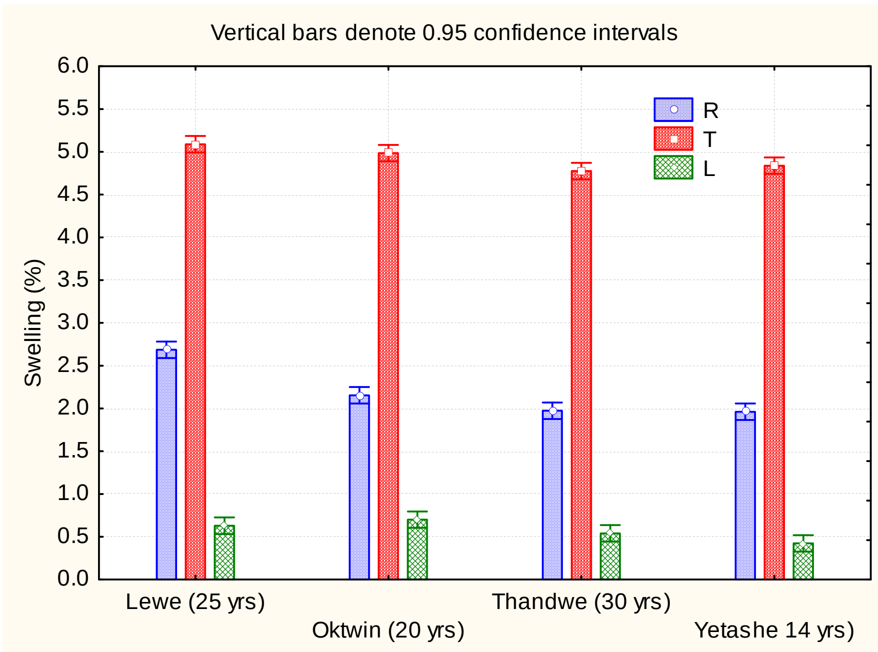

Figure 3: Graph showing swelling anisotropy of plantation teak at different ages

Table 3: ANOVA on swelling of plantation teak at different ages

Effect	SS	Degree Of freedom	MS	F	p
Locality	45.25	3	15.08	42.02	0.000000
Tree	73.05	4	18.26	50.88	0.000000
Direction	5765.47	2	2882.74	8031.70	0.000000
Locality*Tree	109.62	12	9.14	25.45	0.000000
Locality*Direction	21.64	6	3.61	10.05	0.000000
Tree*Direction	73.27	8	9.16	25.52	0.000000
Locality*Tree*Direction	117.64	24	4.90	13.66	0.000000
Error	621.29	1731	0.36		

Swelling of the tested plantation teak is found to vary significantly between locality or age, among trees of the same locality, and within the same tree. Trees are influenced by many factors suchas insects, wildlife, climate, soil conditions, and land management. Each of these lends to a great variability in the properties of a particular wood (USDA, 1999). Different ecological conditions and anthropogenic intervention can induce the development of varied forms of trees, varied leaf size and thickness, and varied bark colour. They can also influence the durability as well asother physical and mechanical properties of the wood (Hapla et. al. 2000).

3.2 Swelling anisotropy

Table 4: Swelling anisotropy of plantation teak at different ages

No	Locality	Swelling anisotropy
1	Lewe (25 yrs)	1.9
2	Oktwin (20 yrs)	2.3
3	Thandwe (30 yrs)	2.4
4	Yetashe (14 yrs)	2.5

According to Table 4, Lewe teak has the best dimensional stability while Yetashe teak has the leastdimensional stability. Higher anisotropy results from higher radial and tangential swelling or higher difference between them. Higher radial and tangential swelling is related to higher density while higher difference between the two is due to higher percentage of juvenile wood. Thus, higher swelling anisotropy is due to higher juvenile wood as it is the youngest plantation teak.The wood having a low anisotropy is best suited for use (Panshin& de Zeeuw, 1980).

This anisotropy is related to the alteration of late and early wood increments within the annual ring, the influence of wood rays, the features of the wall structure and the chemical composition of the middle lamella (Kollmann and Cote 1968).

3.3 Fiber saturation point

The fiber saturation point of all ages is about 13% on average, which is relatively less than the fiber saturation point 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). Thirty year old Togo plantation teak has a fiber saturation point at 20% (Kokutose et. al. 2010). Fiber saturation point is negatively correlated with wood density, acetone extracted fraction, interlocked grain and ash content (Hernandez 2007). These factors could be attributed to the low values of fiber saturation point of the tested material.

Table 5: Fiber saturation point of plantation teak at different ages

No	Locality	Fiber saturation point (FSP) (%)	Number	Standard deviation	Oven-dry volume (cm^3)	Saturated volume (cm^3)	Ove-dry weight(g)
1	Lewe	13.83	148	2.4	8.57	9.34	5.57
2	Oktwin	12.89	150	2.3	6.80	7.37	4.39
3	Thandwe	13.09	149	2.2	5.44	5.86	3.24
4	Yetashe	13.39	150	3.0	4.27	4.59	2.45
	All Grps	13.30	597	2.5	6.26	6.78	3.91

3.4 Water absorption of plantation teak

Table 6: Water absorption of plantation teak at different ages

No.	Locality	Duration (h)	Mean (kg/m^3)	Standard error	-95%	+95%	N
1	Lewe (25 yrs)	1	57	2.58	51	62	148
		2	80	2.58	75	85	148
		3	97	2.59	92	102	147
		4	119	2.58	114	124	148
		8	148	2.58	143	153	148
2	Oktwin (20 yrs)	1	27	2.53	22	32	154
		2	78	2.56	73	83	150
		3	105	2.56	100	110	150
		4	124	2.56	119	129	150
		8	157	2.56	152	162	150
3	Thandwe (30 yrs)	1	71	2.57	66	76	149
		2	99	2.57	94	104	149
		3	114	2.57	109	119	149
		4	127	2.57	122	132	149
		8	156	2.57	151	161	149
4	Yetashe (14 yrs)	1	96	2.56	91	101	150
		2	118	2.56	113	123	150
		3	136	2.56	131	141	150
		4	144	2.56	139	149	150
		8	174	2.56	169	180	150

Fourteen year old Yetashe plantation teak absorbs water more readily than other plantation teak whereas 30 year old Thandwe teak stands at second place. Lewe and Oktwin plantation teaks are found to absorb water at the least. This could be attributed to their densities. Yetashe and Thandwe teak have the lowest densities and thus absorb water at the highest amount. Sint and Hapla (2009) found that timbers with higher densities absorb less water or solution than those with lower densities. Again, among timbers of the same density, those with deposits in cell lumina showed lower absorption than those without deposits (Sint 2010; Sint et. al. 2011). Moreover, the absorption is also influenced by anatomical structure of timber species (Sint et. al. 2013; Sint et. al. 2012).

As shown in Figure 4, moisture content increases with increasing soaking time and will continue to increase until it is fully saturated.

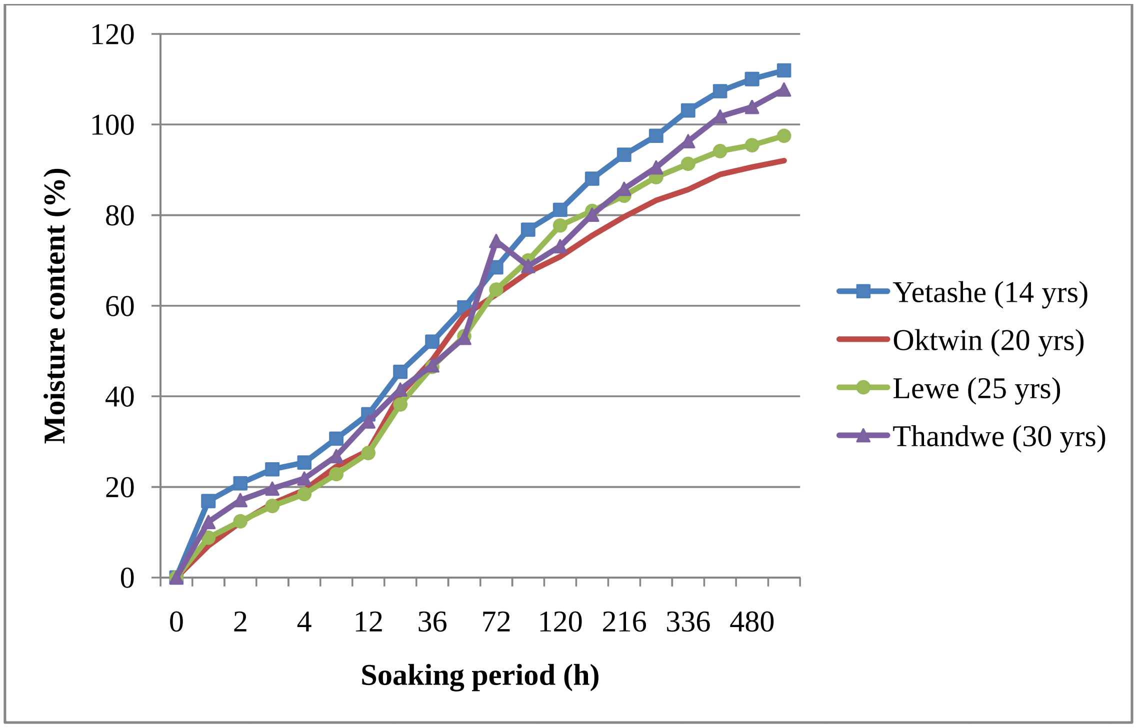

Figure 4: Soaking time versus moisture content

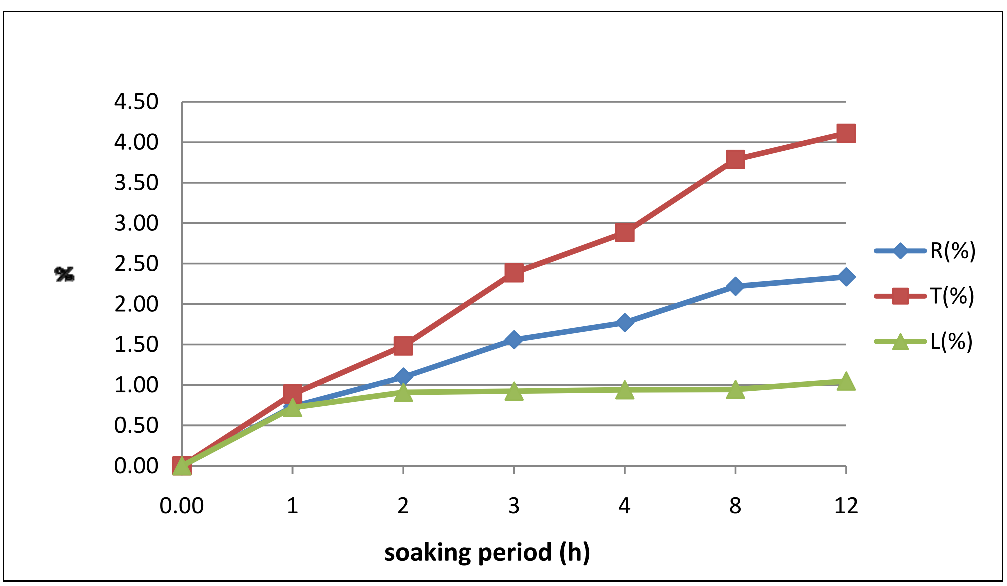

Figure 5: Graph showing swelling anisotropy of 25 years old plantation teak

4. Conclusions

The wood below fiber saturation point will absorb water if it is in contact with it and thus swells. As a result, the different swelling in three structural directions will cause collision in the structure, making it tilt and doors and windows difficult to shut or open. Moreover, the attack of fungi, bacteria and other microbiological organisms will appear, which reduces structural integrity of the buildings. Thus, swelling, fiber saturation point and water absorption of plantation teak of different ages were determined to assess their swelling behaviors in response to water soaking.

Among different plantation teaks, those with higher densities showed higher swelling and lower water absorption. Almost all plantation teaks have almost the same value of fiber saturation point at about 13%, which is lower than the usual value of most timber species. This could be attributed to some extractives deposited in the cell lumina.

Swelling anisotropy is the index of dimensional stability of timber. Among the tested plantation teaks, 25 years old Lewe plantation teak is found to have the best dimensional stability at the ratio of 1.9, followed by 20 years old Oktwin teak, Thandwe teak and Yetashe teak. The youngest Yetashe teak has the highest swelling anisotropy, meaning that it is least dimensionally stable.

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