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Estimating Quantity of Water Contained in Different Timber Species from Myanmar

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မြန်မာနိုင်ငံမှသစ်ပင်အမျိုးမျိုးတွင်ရှိသောရေ၏ပမာဏကိုခန့်မှန်းခြင်း

ဒေါက်တာချိုချိုမြင့်- သုတေသနလက်ထောက်-၂၊ သစ်တောသုတေသနဌာန
ဒေါက်တာခင်မောင်ဆင့်- ညွှန်ကြားရေးမှူး၊စီမံကိန်းနှင့်စာရင်းအင်းဌာနခွဲ၊ပြည်ထောင်စုဝန်ကြီးရုံး
ပါမောက္ခ ဝင်းကြည် (အငြိမ်းစားပါမောက္ခချုပ်) သစ်တောတက္ကသိုလ်

စာတမ်းအကျဉ်း

သစ်သားကို အစိမ်းရောင် ဆောက်လုပ်ရေးပစ္စည်းအဖြစ် ပို၍ အသိအမှတ် ပြုလာကြပါသည်။ အကြောင်းမှာ အခြားသော ဆောက်လုပ်ရေးပစ္စည်းများနှင့် နှိုင်းယှဉ်လျှင် သစ်သားသည် ကုန်ချော ထုတ်လုပ်ရာတွင် စွမ်းအင်လိုအပ်မှု နည်းသောကြောင့်ဖြစ်သည်။ သစ်သားတွင် ပြန်ပြည့်နိုင်စွမ်း၊ ရေရှည်တည်တံ့နိုင်စွမ်း၊ ဆွေးမြေ့နိုင်စွမ်း၊ ပြန်လည်အသုံးပြုနိုင်စွမ်း စသည့် ပတ်ဝန်းကျင်ဆိုင်ရာ ကောင်းကျိုးများလည်း ရှိနေပါသည်။ အရောင်အသွေးစုံလင်ပြီး လှပသော ဒီဇိုင်းများရှိခြင်း၊ ပေါ့ပါးပြီးအင်အားကောင်းမွန်ခြင်း၊ ရုတ်ခြည်း ဒဏ်အားကို ခံနိုင်ခြင်း၊ လျှပ်ကာနိုင်ခြင်း၊ အပူစီးကူးမှုနည်းခြင်း၊ စသည်တို့ကြောင့် နယ်ပယ်စုံ လုပ်ငန်းစုံတွင် အသုံးပြု နိုင်ပါသည်။ သို့သော် တစ်ဘက်တွင်လည်း အချိန်ကာလ တစ်ခုအထိသာ ကြာရှည်ခံနိုင်ခြင်း၊ တည်ငြိမ်မှုမရှိခြင်း၊ သစ်တစ်ပင်တည်း၌ပင် ဂုဏ်သတ္တိများ မတူညီခြင်း၊ အသုံးပြုနေစဉ် ပြဿနာဖြစ်ပေါ်တတ်ခြင်း စသည့်အားနည်းချက်များ ရှိနေပါသည်။ အဆိုပါ အားနည်းချက်များ အားလုံးနီးပါးသည် သစ်သားတွင် ပါဝင်နေသည့် ရေကြောင့်သာ လျှင် ဖြစ်ပါသည်။ ထို့ကြောင့် သစ်သားတွင် ပါဝင်သည့် ရေပမာဏကို သိရှိပါက အဆိုပါ ပြဿနာများကို ဖြေရှင်းနိုင်မည်ဖြစ်ပါသည်။ ထို့ကြောင့် မြန်မာနိုင်ငံမှ သစ်မျိုး(၈၀)မျိုး၏ ရေပမာဏ အသီးသီးကို ယင်းသစ်မျိုး တစ်မျိုးချင်း၏ အစိုဓာတ်ပါဝင်မှုနှင့် အခြေခံ သိပ်သည်းခြင်း တို့ပေါ်တွင် မူတည်ကာ တွက်ချက် ခန့်မှန်း ထားပါသည်။ အစိုဓာတ်ပါဝင်မှုများသော သစ်မျိုး များတွင် ရေပါဝင်မှုများသည်ကို တွေ့ရှိရသကဲ့သို့ အစိုဓာတ်ပါဝင်မှု နည်းသည့် သစ်မျိုးများ တွင် ရေပါဝင်မှု ပမာဏနည်းသည်ကို တွေ့ရှိရပါသည်။ သို့ရာတွင် အစိုဓာတ်ပါဝင်မှု   အများဆုံး သစ်မျိုးများတွင် ရေပါဝင်မှုပမာဏ အများဆုံး မဟုတ်သကဲ့သို့ အစိုဓာတ်ပါဝင်မှု အနည်း ဆုံးသစ်မျိုးများ၌လည်း ရေပါဝင်မှုပမာဏ အနည်းဆုံး မဟုတ်သည်ကို တွေ့ရှိရပါသည်။ ထိုကဲ့သို့ဖြစ်ရခြင်းမှာ ရေပါဝင် မှုပမာဏသည် အစိုဓာတ်ပါဝင်မှုနှင့် အခြေခံသိပ်သည်းခြင်း နှစ်ခုလုံးပေါ်တွင် မူတည်နေသောကြောင့်ဖြစ်ပါသည်။ သို့ရာတွင် အစိုဓာတ် ပါဝင်မှုပေါ်တွင် ပို၍ မူတည်နေကြောင်း တွေ့ရှိရပါသည်။

Estimating quantity of water contained in different timber species from Myanmar

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Abstract

Wood is increasingly recognized as a green building material because it requires lower amount of energy in production of finished products compared to other building materials. Wood also has many other environmental benefits: renewability and sustainability, biological degradability and recyclability. Its technological properties are also applauding, making it versatile for a quite range of end uses: high strengths compared to its weight, good shock resistance, attractive grain patterns and colors and insulating properties. Despite these approving properties, it also has some shortcomings: limited durability, dimensional instability, performance problems, and heterogeneity of properties within the same tree. Almost all shortcomings are due to the water the wood contains. If we know the quantity of the water of the wood, then it is possible to fix the problems associated with it. Thus, the amounts of water of green wood of (80) timber species from Myanmar were estimated on the basis of their green moisture contents and basic densities. Species with higher moisture contents are found to have higher amounts of water whereas those with lower moisture contents tend to have lower amount. However, the species with the highest moisture content does not have the highest amount of water. Neither does the species with the lowest moisture content have the least amount of water. This is due to the fact that the amount of water contained in green wood is dependent both on its moisture content and basic density, but to a larger extent on the former than the later.

Keywords: Species, Moisture content, Basic density, Amount of water

Estimating quantity of water contained in different timber species from Myanmar

1. Introduction

Today, wood is increasingly recognized as a green building material as it has a low level of embodied energy relative to many other building materials such as steel, concrete, aluminum or plastic. Substitution of other building materials by wood will help us fight climate change. Wood is also renewable in contrast to metals and fossil fuel-based products as it comes from forest resources. If sustainable forest management and harvesting practices are followed, wood is sustainably available (Forest Products Laboratory, 2010). In addition, wood is recyclable. The simplest and earliest recycling is the burning of used wood. Moreover, it is also biologically degradable. It is an advantage of wood. The world would be completely covered by wood debris unless wood is biologically degradable as plastic (Risbrudt, 2005).

Wood is a natural material used in our modern living environment nearly everywhere due to its applauding technological properties and aesthetical value. It is used for home and other structures, tools, vehicles and other decorative (Forest Products Laboratory 1999). After being harvested from the forest, it is converted into a number of products through different processing techniques such as sawing, slicing, gluing, chipping, pulping, etc. In chemical products, the change is so drastic that their wood origin cannot be recognized (Tsoumis, 1991). The unique physical properties associated with different timber species and the engineering properties of wood make it versatile for a quite range of end uses (Eaton, 1993). It has a high strength to weight ratio, thereby performing well as a construction material. It has also good shock resistance, a variety of grain patterns and colors and good insulating properties (Milton, 1995). For these reasons, wood is fitted to most applications from toys and household utensils to heavy constructions.

Despite its suitability to enormous applications, wood also possesses some weak points: limited natural durability, hygroscopicity, dimensional instability, variability in properties, etc. All these drawbacks of wood has led to its competition with other construction materials such as plastics, metals, glass, concrete, etc. Most of the shortcomings of wood are closely related to its moisture content. Fungi cannot attack wood of moisture content less than 19% (Milton, 1995). Due to its hygroscopicity, wood can absorb moisture from the surrounding and can lose its moisture to the surrounding, which causes changes in dimensions and other properties below fiber saturation point (Forest Products Laboratory 2010). It is estimated that over 80% of the in- service problems of wood are in some way related to the moisture content (Anon 2011). In fact, wood structure is formed in a water-saturated environment in a living tree (Rowell, 2005). Thus, wood from freshly cut logs contains a considerable amount of water, normally more than 30%, but depending on species. Wood with this amount of moisture cannot be put into uses because it will have many problems: dimensional instability, susceptibility to biological attacks, twisting, bowing, etc. Thus, we have to dry the green wood before putting it into uses in order to gain many benefits such as better dimensional stability, reduced shipping cost, less likelihood of stain and decay, increased strength, better hold, better finishing, increased insulation, enhanced durability and added value (Reeb, 1997). Moreover, it also increases the weight of logs and green lumber. Therefore, moisture content is of concern to those who design harvesting and transport equipment, purchase wood on a weight basis or ship or transport green wood (Schmulsky and Jones 2011). As almost all of wood and wood products are affected by water, it is of quite importance to have information on water that the green wood of Myanmar timber species contains.

Thus, the objective of this paper is to estimate the weight of water contained in green wood of some Myanmar timber species.

2. Material and Methods

Basic densities and moisture contents of 80 timber species were used to analyze the correlation between the two variables. These data were collected from literature and articles already published.

Moisture content (MC) of wood is calculated as follows:

$$\text{MC (\%)} = \frac{\text{Weight of water contained in a piece of wood (WW)}}{\text{Ovendry weight of the piece of wood (ODW)}} x\ 100 \quad \text{---------- (1)}$$

From equation (1), the dry weight of a piece of wood (ODW) can be derived as follows:

$$ODW = \frac{WW}{MC} \text{ x } 100 \text{ -------- (2)}$$

Basic density (BD) of wood is estimated from the oven dry weight of wood and the green volume of the wood as follows:

$$BD = \frac{Ovendry\ Weight\ of\ a\ piece\ of\ wood\ (ODW)}{Green\ volume\ of\ the\ piece\ of\ wood\ (GV)} \text{ ---------- (3)}$$

From equation (3), ovendry weight of a piece of wood (ODW) can be derived as follows:

$$ODW = BD\ x\ GV \text{-------- (4)}$$

From equations (2) and (4), we can write as follows:

$$\text{BD x GV} = \frac{\text{WW}}{\text{MC}} \text{ x } 100 \text{ ------- (5)}$$

From equation 5, the weight of water can be derived as follows:

$$\text{WW} = \frac{MC\ x\ BD\ x\ GV}{100} \text{ -------- (6)}$$

From the equation (6), we can see that the weight of water contained in a volume of wood can be estimated from its moisture content and its basic density. Thus, equation (6) was used to estimate the weight of water of a tree if we know its volume, moisture content and density. As the volume of the tree can vary from one tree to another within the same species, thus the quantity of water contained in one cubic meter was determined for every timber species. When we know the volume of a whole tree, then this volume is to be multiplied by the quantity of water contained in one cubic meter to obtain the quantity of water of a whole tree.

3. Results and Discussion

3.1. Quantity of water present in green wood of different Myanmar timber species

The quantities of water contained in one cubic meter of green wood of 80 Myanmar timber species are shown in Table 1. They were estimated from their moisture contents and basic densities. According to Table 1, Yemane is found to contain the largest amount of water of 633.5 kg in one cubic meter of green wood whereas Thitkha contains the lowest amount of water of 206.5 kg in the same volume.

Table 1: Amount of water contained in 1 m^3 of different wood species

No	Species	Scientific name	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	kg
1	Baing	*Tetrameles nudiflora*	Taungoo	113.2	376	425.6
2	Binga	*Mitragyna rotundifolia*	Taungoo	67.0	554	371.2
	Binga	*Mitragyna rotundifolia*	Myanmar	58.4	553	323.0
3	Bonmeza	*Albizzia chinensis*	Taungoo	171.1	291	497.9
4	Cherry-Bo	*Betula alnoides*	Muse	49.6	568	281.7
5	Chinyoke	*Garuga pinnata*	Taungoo	101.1	601	607.6
6	Didu	*Salmalia insignis*	Taungoo	143.9	363	522.4
7	Dwabok	*Kydia calycina*	Taungoo	96.9	429	415.7
8	Dwani	*Eriolaena candollei*	Taungoo	66.2	719	476.0
9	Eucalypt	*Eucalyptus camaldulensis*	Kyauk-padaung	76.7	713	546.9
	Eucalypt	*Eucalyptus camaldulensis*	Yetashe	51.1	870	444.6
	Eucalypt	*Eucalyptus camaldulensis*	Tharzi	52.3	820	428.9
	Eucalypt	*Eucalyptus camaldulensis*	Magway	47.6	900	428.4
10	Gangaw	*Mesua ferrea*	Gangaw	36.4	809	294.5
11	Gwe	*Spondias pinnata*	Taungoo	196.4	280	549.9
12	Gyo	*Schleichera oleosa*	Taungoo	34.0	938	318.9
13	Hmyaseik	*Antiaris toxicaria*	Taungoo	123.2	335	412.7
14	Hnaw	*Adina cordifolia*	Taungoo	60.2	601	361.8
15	In	*Dipterocarpus tuberculatus*	Myanmar	50.3	726	365.2
16	Ingyin	*Pentacme siamensis*	Myanmar	54.3	779	423.0

Table 1: Continued

No	Species	*Scientific name*	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	kg
17	Kaban-thangyin	*Shorea sericiflora*	Tanintharyi	82.06	598	490.7
18	Kadut	*Shorea cinerea*	Tanintharyi	71.84	561	403.0
19	Kanyaung	*Shorea argentea*	Myanmar	56.9	706	401.7
20	Kanyin-byu	*Dipterocarpus alatus*	Myanmar	73.4	574	421.3
21	Kanyin-ni	*Dipterocarpus turbinatus*	Myanmar	65.7	655	430.3
22	Kaung-hmu	*Anisoptera scaphula*	Myanmar	117.8	475	559.6
23	Kokko	*Albizzia lebbek*	Taungoo	68.6	538	369.1
24	Kuthan	*Hymenodictyon excelsum*	Taungoo	131.4	404	530.9
	Kuthan	*Hymenodictyon excelsum*	Myanmar	126.5	376	475.6
25	Kyana	*Xylocarpus moluccensis*	Myanmar	45.0	670	301.5
26	Kyetyo	*Vitex peduncularis*	Taungoo	50.1	761	381.3
27	Lein	*Terminalia pyrifolia*	Myanmar	85.2	625	532.5
	Lein	*Terminalia pyrifolia*	Taungoo	72.2	644	465.0
28	Letpan	*Salmalia malabarica*	Taungoo	119	260	309.4
29	Leza	*Lagerstroemia tomentosa*	Tatkone	94.0	550	517.0
	Leza	*Lagerstroemia tomentosa*	Taungoo	59.8	583	348.6
30	Ma-u-lettan-she	*Anthocephalus cadamba*	Taungoo	94.3	436	411.1
31	Myauk-chaw	*Homalium tomentosum*	Myanmar	40.4	755	305.0
	Myauk-chaw	*Homalium tomentosum*	Taungoo	30.5	776	236.7

Table 1: Continued

No	Species	Scientific name	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	kg
32	Myaukngo	*Duabanga grandiflora*	Taungoo	114.5	464	531.3
	Myaukngo	*Duabanga grandiflora*	Myanmar	110.0	429	471.9
33	Myauk-thwegyi	*Myristica spp*	Taungoo	129.1	339	437.6
34	Myauk-thwethe	*Myristica angustifolia*	Taungoo	56.3	549	309.1
35	Nabe	*Lennea grandis*	Taungoo	78.7	672	528.9
36	Nyan	*Quercus serrata*	Southern Shan State	74.7	650	485.6
	Nyan	*Quercus serrata*	Pyin Oo Lwin	53.5	690	369.2
37	Padauk (natural)	*Pterocarpus macrocarpus*	Myanmar	43.8	752	329.4
	Padauk (Plantation)	*Pterocarpus macrocarpus*	Pyinmana	58.6	706	413.7
38	Panga	*Terminalia chebula*	Taungoo	62.2	779	484.5
39	Petthan	*Haplophrogma aderophyllum*	Myanmar	50.5	726	366.6
	Petthan	*Haplophrogma aderophyllum*	Taungoo	41.5	745	309.2
40	Pinle-kanazo	*Heritiera fomes*	Myanmar	56.3	792	445.9
41	Pyaukseik	*Holoptelea integrifolia*	Tatkone	67.5	580	391.5
	Pyaukseik	*Holoptelea integrifolia*	Taungoo	64.9	567	368.0
42	Pyinkado	*Xylia dolabriformis*	Myanmar	48.6	779	378.6
43	Pyinma	*Lagerstroemia speciosa*	Taungoo	71.6	529	378.8
44	Seikchi	*Bridelia retusa*	Taungoo	98.2	583	572.5
45	Shaw	*Sterculia versicolor*	Taungoo	86.5	352	304.5

Table 1: Continued

No	Species	Scientific name	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	kg
46	Sit	*Albizzia procera*	Taungoo	69.4	720	499.7
47	Taukkyan	*Terminalia tomentosa*	Taungoo	44.8	815	365.1
48	Taung-meok	*Alstonia scholaris*	Taungoo	96.9	388	376.0
49	Taungok-shit	*Elaeocarpus spp*	Taungoo	46.5	691	321.3
50	Taung-peinne	*Artocarpus chaplasha*	Taungoo	106.3	435	462.4
51	Taungpetwun	*Pterospermum acerifolium*	Taungoo	79.9	483	385.9
52	Taung-thayet	*Swintonia floribunda*	Myanmar	58.5	551	322.3
	Taung-thayet	*Swintonia floribunda*	Taungoo	84.2	558	469.8
53	Tawthayet	*Mangifera spp*	Taungoo	75.6	582	440.0
54	Tayouk-khaung-bin	*Taiwania cryptomerioides*	Waingmaw	143.08	358	512.2
55	Teak (natural)	*Tectona grandis*	Myanmar	51.8	596	308.7
	Teak (14 years plantation)	*Tectona grandis*	Yetashe	92.2	518	477.6
	Teak (20 years plantation)	*Tectona grandis*	Oktwin	95.3	591	563.2
	Teak (25years plantation)	*Tectona grandis*	Lewe	61.5	578	355.5
	Teak (30 years plantation)	*Tectona grandis*	Thandwe	78.2	544	425.4
56	Thande	*Stereospermum personatum*	Taungoo	53.0	725	384.3
57	Thaphan	*Ficus spp.*	Taungoo	121.5	344	418.0
58	Thingadu	*Parashorea stellata*	Myanmar	70.7	589	416.4
	Thingadu	*Parashorea stellata*	Taungoo	59.2	561	332.1

Table 1: Continued

No	Species	Scientific name	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	Kg
59	Thingan	*Hopea odorata*	Myanmar	73.9	637	470.7
	Thingan	*Hopea odorata*	Tanintharyi	53.97	684	369.2
60	Thingan-net	*Hopea helferi*	Tanintharyi	36.52	922	336.7
61	Thinwin	*Millettia pendula*	Pyinmana	44.3	850	376.6
62	Thitkado	*Cedrela toona*	Taungoo	75.8	410	310.8
	Thitkado	*Cedrela toona*	Myanmar	65.1	474	308.6
63	Thitkha	*Pentace burmanica*	Myanmar	37.0	558	206.5
64	Thitmagyi	*Albizzia odoratissima*	Taungoo	43.2	803	346.9
65	Thitmin	*Podocar puswallichianu s*	Myanmar	45.5	462	210.2
66	Thitpagan	*Millettia brandisiana*	Pyinmana	133.8	440	588.7
67	Thitpa-yaung	*Nauclea sessilifilia*	Taungoo	61.6	720	443.5
68	Thitsein	*Terminalia bellerica*	Taungoo	53.5	717	383.6
69	Thitswele	*Schrebera swietenioides*	Taungoo	48.7	710	345.8
70	Thitya	*Shore oblongifolia*	Myanmar	46.3	858	397.3
71	Tinyu (hna-khwa)	*Pinusmerkusii*	Taungyi	65.7	470	308.8
72	Tinyu (thone – khwa)	*Pinus insularis*	Kalaw	61.9	460	284.7
73	Uban	*Shorea farinosa*	Tanintharyi	141.49	422	597.1
74	Yemane	*Gmelina arborea*	Myanmar	151.2	419	633.5
	Yemane	*Gmelina arborea*	Taungoo	125.6	469	589.1

Table 1: Concluded

No	Species	Scientific name	Locality	Moisture content	Basic density	Weight of water contained 1 m^3
				%	kg/m^3	Kg
75	Yindaik	*Dalbergia cultrata*	Taungoo	39.6	792	313.6
76	Yinma	*Chukrasia tabularis*	Taungoo	59.2	781	462.4
77	Yinma	Chukrasia velutina	Yezin	67.0	661	442.9
78	Yinzat	*Dalbergia fusca*	Taungoo	45.9	704	323.1
79	Yon	*Anogeissus acuminata*	Taungoo	40.6	762	309.4
	Yon	*Anogeissus acuminata*	Myanmar	34.8	739	257.2
80	Zaungbale	*Lagerstroemia villosa*	Taungoo	66	597	394.0
	Zaungbale	*Lagerstroemia villosa*	Myanmar	39.1	610	238.5

As already stated, the quantity of water of a wood species was calculated from its basic density and moisture content. Theoretically, species with high basic densities tend to have lower moisture contents because high density species have thick cell wall, and thus small room is available for free water. Gyo is the species with the highest basic density in this study, but it is not the species with the lowest amount of water in a given volume. Similarly, species with low basic densities tend to have higher moisture contents. It is because such low density species have thin cell wall, and thus large room is available for free water. Letpan is the species with the lowest basic density in this study, but it is not the species with the highest moisture content in a given volume. Thus, moisture content and basic density are to some extent inversely related to each other.

According to Table 1, it is generally true that timber species with higher moisture contents have higher amounts of water whereas those with lower moisture contents have lesser amounts of water in a given volume of wood. This can be clearly seen in Figure 1. The figure explains that the moisture content of a species is directly related to its amount of water with R^2 value of 0.4238 whereas density is inversely related to its quantity of water with R^2 value of 0.07. The density of wood has a very small effect on its quantity of water as R^2 is quite small and negligible. Therefore, the moisture content of a green wood has a more pronounced effect on the quantity of the water contained in the wood than its basic density.

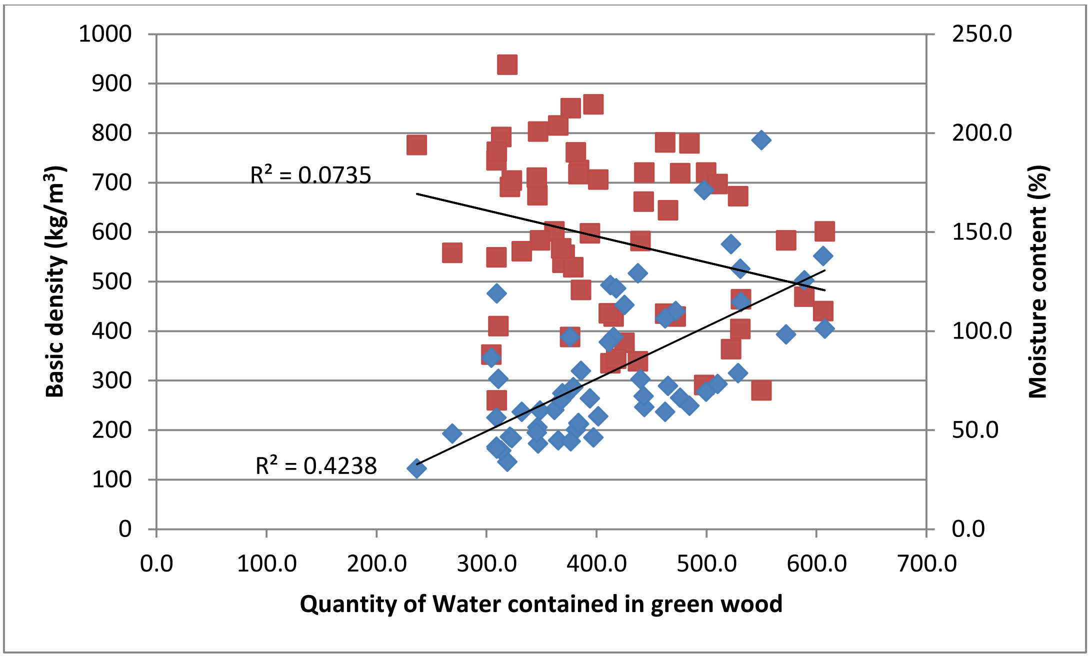

Figure 1: Relationships among water quantity, basic density and moisture content

Therefore, Thitkha (558 kg/m^3) is not as high as Gyo (938 kg/m^3) in basic density, but its moisture content of 37% is higher than that of Gyo, which is 34%. Although both basic density and moisture content influence the quantity of water contained in a given green volume, the moisture has a more pronounced effect than basic density. Thus, Thitkha is calculated to have the lowest quantity of water in 1 m^3 of green volume among the tested Myanmar timber species.

Yemane (419 kg/m^3) is not as low as Letpan (260 kg/m^3) in basic density, but its moisture content of 151% is much higher than that of Letpan, which is 119%. Therefore, Yemane has higher quantity of water in the same volume.

Ten timber species with the lowest moisture contents are Myaukchaw, Gyo, Yon, Gangaw, Thingan-net, Thitkha, Zaungbale, Yindaik, Petthan and Thitmagi. They also have the least amount of waters among the tested timber species. In other words, they include Thitka, the species with the lowest amount of water. Similarly, ten timber species with the highest moisture contents include Gwe, Bonmeza, Yemane, Didu, Tayoukkhaungbin, Uban, Thitpagan, Kuthan, Myaukthwegyi and Hmyaseik. They also include Yemane, the species with the highest amount of water.

Ten species with the highest basic densities include Gyo, Thingannet, Eucalypt, Thitya, Thinwin, Taukkyan, Gangaw, Thitmagyi, Pinlekanazo and Yindaik. They also tend to have lower amounts of water, but do not include Thitkha, the species with the lowest amount of water. Ten species with the lowest basic densities are Letpan, Gwe, Bonmeza, Hmyaseik, Myaukthwegyi, Thapan, Shaw, Tayoukkhaungbin, Didu and Baing. They also tend to have higher amounts of water, but do not include Yemane, the species with the highest amount of water.

Thus, it can generally be found that timber species with the lowest moisture contents are those with the highest basic densities whereas those with the highest moisture contents are those with the lowest basic densities. This finding is consistent with earlier results (Zobel and Jett, 1995), which stated that higher density trees have lower moisture content. It can also be found that the ten species with the lowest or highest moisture contents include the species with the lowest or the highest amount of water. But ten species with highest or lowest basic densities do not include the species with the lowest or the highest amount of water. Thus, moisture content has a more pronounced effect on the amount of water than the density.

Let us consider the amount of a tree 30 ft. long with its mid girth of 6 ft. for Letpan, Eucalypt (Magway) and Gyo species. All the three species have the same volume of 86 cubic ft. or 2.44 cubic meters each. Therefore, the amount of water will be 754.9 kg, 1035.5 kg and 778.1 kg for Letpan, Eucalypt and Gyo species, respectively. From this example, we can see that Letpan and Gyo contain almost the same amount of water in the same volume, having without a distinct difference between the two species although they are quite different in their basic densities.

Binga was tested for two different localities: Myanmar and Taungoo. Basic densities are quite similar to each other: 553 and 554 kg/m^3. However, moisture contents vary to some extent from one locality to another: 58.4 and 67%. Taungoo sample has greater moisture content than Myanmar sample. Thus, Taungoo sample has a greater amount of water than Myanmar in a green volume of 1 m^3 of wood.

Eucalyptus was also tested for four different localities: Kyaukpadaung, Yetashe, Tharzi and Magway. It is found that samples from Kyaukpadaung locality have the highest moisture content and the lowest basic density, thus rendering it to possess the highest amount of water whereas those from Magway locality have the lowest moisture and highest basic density and thus tend to have the lowest amount of water.

Kuthan was also tested for two localities: Taungoo and Pyinmana. Taungoo samples have higher moisture content and basic density, thus higher amount of water than Pyinmana samples.

Similarly, Lein, Leza, Myaukchaw, Myaukngo, Nyan, Padauk, Petthan, Phyaukseik, Taungthayet, teak, Thingadu, Thingan, Thitgado, Yemane, Yon and Zaungbale were also tested for different localities. In case of Lein, the difference in the amount of water between the two localities is not great as moisture content and basic density do not vary a lot.

The difference in the amount of water is great in Leza between the two localities: Tatkone and Taungoo. Its basic densities are quite similar to each other: 550 and 583 kg/m^3. However, its moisture contents vary greatly from one locality to another. This is the reason why the amounts of water quite different. In this research, samples from Tatkone have greater moisture contents than those from Taungoo. The specimens from Tatkone were soaked until those sank in the water before moisture testing. This soaking could have a great impact on the green moisture content, but no effect on the basic density as it is based on green volume and dry weight.

In the same way, densities are quite similar between the two localities in Myaukchaw. Samples from Taungoo and Myanmar are found to have 776 and 755 kg/m^3, respectively. Myanmar has higher moisture content than Taungoo and thus contains more amount of water. In case of Myaukngo, moisture contents and basic densities are quite similar from two localities: Taungoo and Myanmar. However, samples from Taungoo have to some extent higher moisture content and higher basic density than those from Myanmar, and thus accordingly have higher amount of water.

Plantation Padauk is found to have a higher amount of water than natural Padauk. This is because it has higher moisture content and lower basic density.

Petthan has similar basic density in both localities, but differences in moisture content lead to differences in amount of water. Taungoo sample having lower moisture content contains lower amount of water.

Natural teak has lower moisture content and higher basic density than plantation teak. Thus, it has lower water content than plantation teak.

In Pyaukseik, both localities have almost the same basic density and moisture content, thus making it contain nearly the same amount of water in both localities.

In other species, localities having higher moisture contents tend to have higher amount of water than the other if basic density is similar.

Density and moisture content vary among species. It is due to environmental factors from one locality to another and genetic variation among trees within the same species (Tsoumis, 1991). Other factors are also responsible for this variation such as site, climate, geographical location, growth stresses, anatomical structures, etc.

The moisture contents of the tested timber species were not investigated as soon after the sample trees were felled. Thus, the specimens were tested for their moisture content only after they were soaked until they sank in the water. This means that the moisture contents can be less to some extent from their true green moisture contents. Therefore, the calculated quantities of water contained in one cubic meter of green volume can accordingly vary. This is a possible explanation about why moisture content has a more pronounced effect on the quantity of water than basic density. Moisture content is calculated from the weight of water and oven-dry weight and thus depends much on the amount of free water. Water can enter cell lumina as free water in soaking samples and increase the weight of water. However, basic density is calculated from oven-dry weight and green volume. Oven-dry weight is always constant for a given sample and never changes due to soaking. Similarly, green volume is also constant and not affected by the amount of free water due to soaking. Thus, in order to get the exact green moisture content of a timber species, it is necessary to do testing as soon after felling sample trees and preparation of samples as possible.

Sometimes, it is quite difficult to guess how much water will be in 1 kilogram of wood. In this research, the species with the highest amount of water is Yemane. It contains 633.5 kg of water in 1 m^3 of green wood. As 1 kg of water occupies 1 liter of volume, Yemane has 633.5 liters of water in 1 m^3 of green wood. In other words, it can be said that the amount of water it contains is about 32 twenty liter bottles. Gyo contains about 16 twenty liter bottles whereas natural teak contains about 15 twenty liter bottles.

3.2 Relationship between moisture content and basic density

According to Figure 2, it can be found that the moisture content of a wood is inversely correlated to its basic density. This means that as the basic density of the wood increases, its moisture content decreases. This is due to the fact that as the basic density increases, the volume of the lumina decreases, thereby decreasing the moisture content (Forest Products Laboratory, 2010). In this research, the moisture content is strongly correlated to the basic density in a reciprocal way as R^2 value is about 0.6. This finding is also consistent with those of earlier works (Al-Sagheer and Prasad 2010)

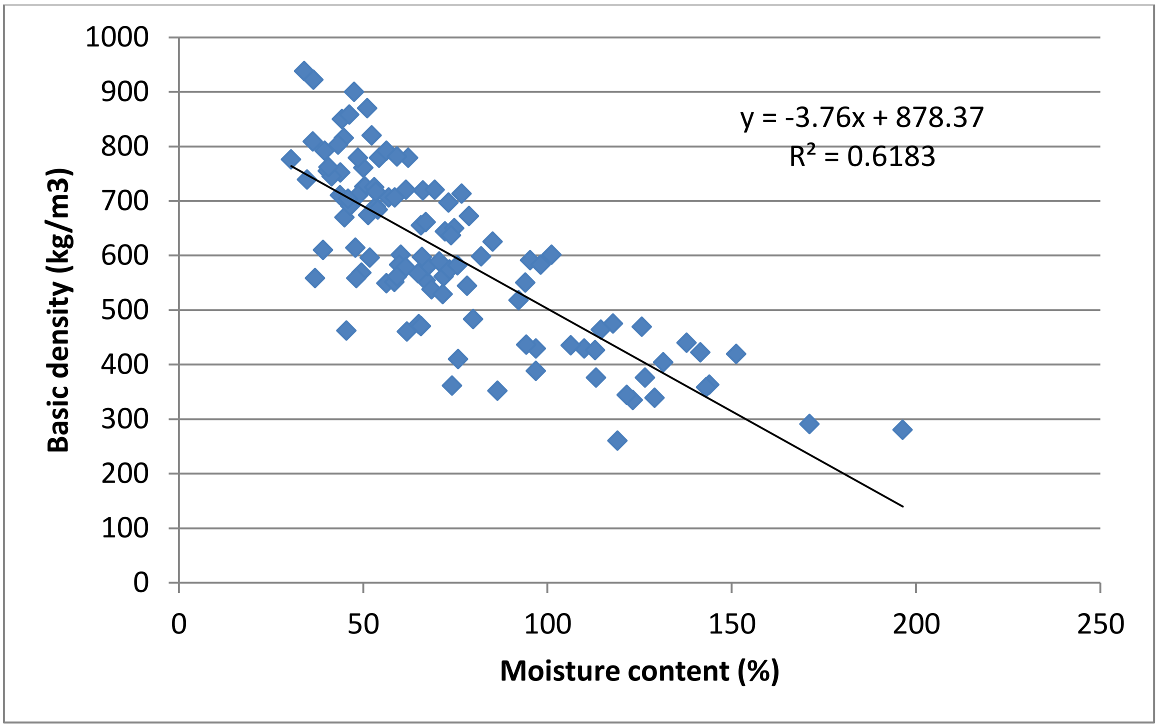

Figure 2: Relationship between basic density and moisture content

4. Conclusion

Green wood contains a considerable amount of water. Thus, it cannot be used as a construction material before proper drying because green timber will pose many problems in service such as dimensional change, biological attacks, and performance problems. Moreover, the amount of water contained in wood can affect its weight, strength and workability. If we can remove the water from the wood, the advantages are enormous: prolonging of service life, avoiding shrinkage in service, reducing transportation cost, improving workability and machining, etc. Thus, we have to know the amount of water contained in green wood so that we can determine how much water has to be removed. Therefore, the quantities of water contained in green wood of some timber species from Myanmar were calculated in this research paper. Generally, the water contained in green wood of a species depends on its moisture. The general trend is that species with higher moisture contents are found to have higher amount of water whereas species with lower moisture contents tend to have lesser amount of water. However, the species with the highest moisture content do not contain the highest amount of water. The species with the lowest moisture content do not contain the least amount of water, either. It is not because the amount of water does not depend only on moisture content, but because it depends on both moisture content and basic density.

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