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Investigation on Drying Behaviours, Appropriate Temperatures and Relative Humidities for Kiln Drying of Four Lesser Used Species

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ခရစ္စတီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
စုစုလှိုင်၊ သုတေသနလက်ထောက်-၂
ဘီလီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ
အောင်စိုး၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်းချုပ်

သစ်အခြောက်ခံခြင်းသည် သစ်အသုံးချမှုတွင် အရေးပါသော လုပ်ငန်းစဉ်တစ်ခုဖြစ်ပြီး ရှေးယခင်ကတည်းပင် အသိအမှတ်ပြုခဲ့ကြပြီး ဖြစ်ပါသည်။ သစ်အသုံးချမှုများအတွက် သစ်အခြောက်ခံခြင်းနှင့် ဆက်စပ်နေသော ဂုဏ်သတ္တိများသည် အသုံးပြုမည့် သစ်နှင့်သင့်လျော်သော အခြောက်ခံ ပေါင်းဖိုဇယားများ ဖော်ထုတ်ခြင်းတွင် အထောက်အကူဖြစ်စေပြီး ပေါင်းဖိုဖြင့် အခြောက်ခံခြင်း လုပ်ငန်းစဉ်သည် သစ်အရည်အသွေးကို မြင့်မားစေပါသည်။ ထို့ကြောင့် အခြောက်ခံရာတွင် ဖြစ်ပေါ်နိုင်သည့် သွင်ပြင်လက္ခဏာများကို စူးစမ်းရှာဖွေဖော်ထုတ်ရန်နှင့် အချိန်တိုအတွင်း အပြစ်အနာအဆာ နည်းပါးစွာဖြင့် အခြောက်ခံနိုင်ရန်အတွက် အဆိုပြုသင့်လျော်သည့် အပူချိန်နှင့်စိုထိုင်းဆများ ဖော်ထုတ်ရန်စသည့် ရည်ရွယ်ချက်များဖြင့် ဤသုတေသနလုပ်ငန်းကို စမ်းသပ် ဆောင်ရွက်ခဲ့ပါသည်။ Terazawa (1965) ၏ လျင်မြန်စွာ အခြောက်ခံစမ်းသပ်နည်းကို အသုံးပြု၍ သစ်ချို(*Sideroxylon tomentosum* Roxb.)၊ ကလော(*Taraktogenus kurzii* King)၊ အုံတုံ (*Litsaea glutinosa* (Lour)C.B.Rob.)၊ မဒမ(*Dalbergia ovata* Grah) သစ်မျိုးများအား စမ်းသပ်ဆောင်ရွက်ခဲ့ပါသည်။ တွေ့ရှိချက်များအရ- သစ်ချိုတွင် မျက်နှာပြင်နှင့်ထိပ်ကွဲအက်မှုများ၊ အတွင်းပိုင်း အက်ကွဲမှုများနှင့် ပုံပျက်မှုများ မဖြစ်ပေါ်သည်ကို တွေ့ရှိရပြီး၊ ပေါင်းဖိုဖြင့် အခြောက်ခံရန်အတွက် အပူချိန် ၆၀ ဒီဂရီစင်တီဂရိတ်နှင့် စိုထိုင်းဆ ၈၂ ရာခိုင်နှုန်းဖြင့် လည်းကောင်း၊ ကလောနှင့် အုံတုံသစ်တွင် မျက်နှာပြင်နှင့် ထိပ်ကွဲအက်မှုများ အနည်းငယ်မှ အတော်အတန် ဖြစ်ပေါ်ပြီး ပုံပျက်မှု အနည်းငယ်ရှိခြင်းနှင့် အတွင်းပိုင်းအက်ကွဲမှု မရှိသည်ကို တွေ့ရှိရပါသည်။ ပေါင်းဖိုဖြင့် အခြောက်ခံရာတွင် အပူချိန် ၅၅ ဒီဂရီစင်တီဂရိတ်နှင့် စိုထိုင်းဆ ၈၁ ရာခိုင်နှုန်းဖြင့် စတင် အခြောက်ခံသင့် ပါသည်။ မဒမသစ်သည် မျက်နှာပြင်နှင့် ထိပ်ကွဲအက်မှုများပြီး အတွင်းပိုင်းကွဲအက်မှုမှာ အတော်အတန် ရှိပါသည်။

ပုံပျက်မှုသည် အနည်းငယ်မှ အတော်အတန်ရှိပြီး ပေါင်းဖိုဖြင့် အခြောက်ခံ ပါ က အပူချိန် ၅၀ ဒီဂရီစင်တီဂရိတ်နှင့် စိုထိုင်းဆ ၈၉ ရာခိုင်နှုန်းဖြင့် စတင် အခြောက်ခံသင့်ပါသည်။ အဆိုပြုထားသော အပူချိန်နှင့် စိုထိုင်းဆများကို အခြေခံလျက် သစ်တစ်မျိုးစီအတွက် လက်တွေ့ အသုံးပြုသင့်သော အခြောက်ခံပေါင်းဖိုဇယားများကို လွယ်ကူစွာ ရှာဖွေနိုင်မည် ဖြစ်ပါသည်။ စမ်းသပ် ရရှိသော ရလဒ်များအရ ပေါင်းဖိုဖြင့် အခြောက်ခံရန် သစ်ချိုသည် မခက်ခဲသောသစ်မျိုး (ပေါင်းဖိုဇယား အဆင့် ၂)၊ ကလောနှင့် အုံတုံသည် အတော်အတန် ခက်ခဲသောသစ်မျိုး (ပေါင်းဖိုဇယားအဆင့် ၃) ဖြစ်ပြီး မဒမသည် ခက်ခဲသောသစ်မျိုး (ပေါင်းဖိုဇယားအဆင့်၅) ဖြစ်ကြောင်း တွေ့ရှိရ ပါသည်။

Investigation on Drying Behaviours, Appropriate Temperatures and Relative Humidities for Kiln Drying of Four Lesser Used Species

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Abstract

Wood drying is important for efficient and rational utilization of wood and the necessity of drying wood before using it to manufacture various objects was early recognized, in the antiquity. Measurement of technological properties relevant to the drying of wood are also aimed at developing appropriate drying schedules for specific end-uses, and consequently leading to improvement in the kiln drying process, and in the quality of lumber. Therefore, the objectives of this study are to investigate the drying behaviours, appropriate temperatures and relative humidities for kiln drying by diminishing drying defects within the shortest time. It was developed based on the results of Quick Drying Test elaborated in accordance with Terazawa's method. The tested species were Ondon (*Litsea glutinosa* (Lour.) C.B.Rob.), Kalaw (*Taraktogenus kurzii* King.), Madama (*Dalbergia ovata* Grah.) and Thitcho (*Sideroxylon tomentosum* Roxb.). The study revealed that there were no initial checks (surface and end checks), honeycombing (internal checks), spool-like deformation in Thitcho. Kiln drying for Thitcho should be started at 60˚C drying temperature and 82% relative humidity (RH) at the early stage of drying. The woods of Kalaw and, Ondon were small to medium in initial checks (surface and end checks), no honeycombing (internal checks), little to mild in spool-like deformation. Kiln drying for these woods should be started at 55˚C and 81% relative humidity (RH) at the early stage of drying. Madama was large in initial checks (surface and end checks), medium to large check of honeycombing, little to mild of spool-like deformation, and should use 50˚C and 89% relative humidity (RH) at the early stage of drying. Further kiln drying test to get the "Optimum Kiln Schedules" of the tested species could be done without any difficulties based on the results given in this paper. According to results, four tested wood species could be classified: Thitcho is non-refractory timber (Kiln Schedule Type B), Kalaw and Ondon are moderately-refractory timbers (Kiln Schedule Type C) whilst Madama is refractory-timber (Kiln Schedule Type E), respectively.

Key Words: initial check, honeycomb, spool-like deformation, proposed temperatures and relative humidities

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1. Introduction

In the forest of Myanmar, there exists about a thousand and five hundred tree species of which forty to fifty are in use commercially throughout the country. The remaining species are little used or Lesser Used Species (Cho Cho Myint, el.al., 2000).

It is hoped that these little-used or Lesser Used Species may be placed into appropriated end-uses if their technical properties were known. Wood drying which is one of the technical properties improves wood quality and maximum value-addition. So, the necessity of drying wood before using it to manufacture various objects was early recognized, in the antiquity.

Wood is a hygroscopic material which is one of the most important properties of wood. In other words, when wood is put in an environment, it takes up or repels the moisture until finally the moisture of wood and the surrounding atmosphere approaches equilibrium. Fresh cut lumber contains a great deal of water. If the water is not removed or lumber is not dried under controlled conditions, it is prone to undesirable drying defects and other degrades that diminishes its selling price and workability and can't be used to produce a high quality finished product.

When lumber is dried right, it machines better, glues better, and finishes better. Drying also improves the strength of the lumber, increases of dimensional stability, kills infestations, preserves color, reduces weight and controls shrinkage. Therefore, wood drying is considered to be important for efficient and rational utilization of wood.

During the drying process, drying defects including end check, surface check, honeycombing (internal check), collapse and deformation/warping (bow, cup or twist) (Win Chit,2007) are flaws that develop in the wood and decrease its value (Simpson, 1991). Of all those defects, honeycomb (internal check) and deformation are considered to be the two most important for the wood based industries. Whilst end check and surface checks will normally close as the moisture continues decreasing, internal check behaves differently once it develops. It is, therefore, important that the susceptibility of the wood species to these drying defects which are related to its interaction with moisture be studied to provide important information on the ability of particular species to be utilized for specific purposes and to enhance its future utilization.

Drying cannot be omitted in the wood industrial processing, and the good drying quality comes from the perfect drying schedules which involve a set of wet and dry bulb temperatures that characterize the kiln's temperature and relative humidity (RH). So, it needs to study on drying defects first, then predict the drying schedules based on the relationships between drying defects and drying conditions, and then adjust the schedules to the optimum situation through kiln drying experiments. After fininshing these procedures, the optimized drying schedules can be provided for practical production.

Dry kiln schedules for fifty-four Lesser Used Species have been investigated during ITTO Project (1997-2000). No work has been done on drying behaviours of Lesser Used Species in Shan State. According to FFPRI Project Survey, it was reported that there are about 181 species in Taung Kya village, Pinglaung Township, Southern Shan State. Many species of the village are still left for testing the utilization-oriented properties. Thitcho (*Sideroxylon tomentosum* Roxb.), Kalaw (*Taraktogenus kurzii* King.), Ondon (*Litsea glutinosa* (Lour.) C.B.Rob.) and Madama (*Dalbergia ovata* Grah.) are among those species.

According to interview, selected timbers are widely used by local people in Taung Kya village, Pinglaung Township, Southern Shan State, and also known to be good for making a variety of products such as furniture, housing, building, ploughing materials and domestic items. Therefore, with the intention of exploring a better and efficient use of those timber species, drying behaviors were investigated.

The objectives of this study are:

(a) to investigate the drying behaviours of four timber species, and

(b) to find out appropriate temperatures and relative humidities for kiln drying by diminishing drying defects within the shortest time.

2. Literature review

Quick Drying Test, which is already widely known and very popular today as a simple and effective method, was originally designed and developed at Forestry and Forest Products Research Institute of Japan, to estimate the first kiln drying schedules of an unknown species of timber by Terazawa (1965,1976). Thirty seven wood species from Japan were tested by this method and the initial kiln drying schedules of each species were given in their paper.

In the year of 1998, Hiroshi Sumi, et.al carried out kiln drying properties and kiln drying test on nine species of Sarawak Timbers by using "Quick Drying Test" method. Based on the drying defects obtained from each test, their suitable kiln drying schedules of 1 inch thick lumber were estimated in their paper.

U Aung Kyaw and U Win Kyi (1999) carried out "Proposed kiln schedules for thirty lesser used timber species of Myanmar" by using "Quick Drying Test". According to the drying defects, thirty lesser used timber species are classified into four groups, namely non-refractory timbers, moderately refractory, refractory timbers , and very refractory timbers. They were mentioned that further kiln drying test to get the “Optimum Kiln Schedules” of the tested species could be done without any difficulties based on the results given in their paper.

Drying properties and basic drying schedule of three wood species from Indonesia;i.e. kuda (*Lannea coromandelica* Merr.), waru (*Hibiscus tiliaceus* L) and mindibesar (*Meliadubia*

Cav.) were investigated using "Quick Drying Test" method by Efrida Basri, et.al.(2005). It was reported that each of the drying schedule needs to be modified and adjusted to kiln condition, initial moisture content and the dimension.

U Aung Soe et.al (2013), studied on proposed kiln schedule of some commercial hardwood species from Tanintharyi Region. It was noted that the tested species were categorized into four classes as non-refractory timbers, moderately refractory, refractory timbers, and very refractory timbers based on the drying defects developed during the "Quick Drying Test".

Bernard Effah (2014) studied the susceptibility of two lesser known species; *Cola nitida* and *Funtumiae lastica* to some drying defects. "Quick Drying Test" was carried out to determine the susceptibility of some drying defects as the basis for determining the potential uses that may encourage the utilization and promotion of these two lesser known species. It was described that two rounds of drying tests were conducted for each species.

Wood Drying Working Party suggested to develop drying schedule to improve better drying quality (Vermaas, 1983) especially in tropical countries, which have many species variations (Simpson, 1992). One of the rapid methods to develop drying schedules was initiated by Terazawa (1965), which showed the satisfaction results to develop proper drying schedule (Ilic and Hillis, 1986; Jankowsky, 1992).

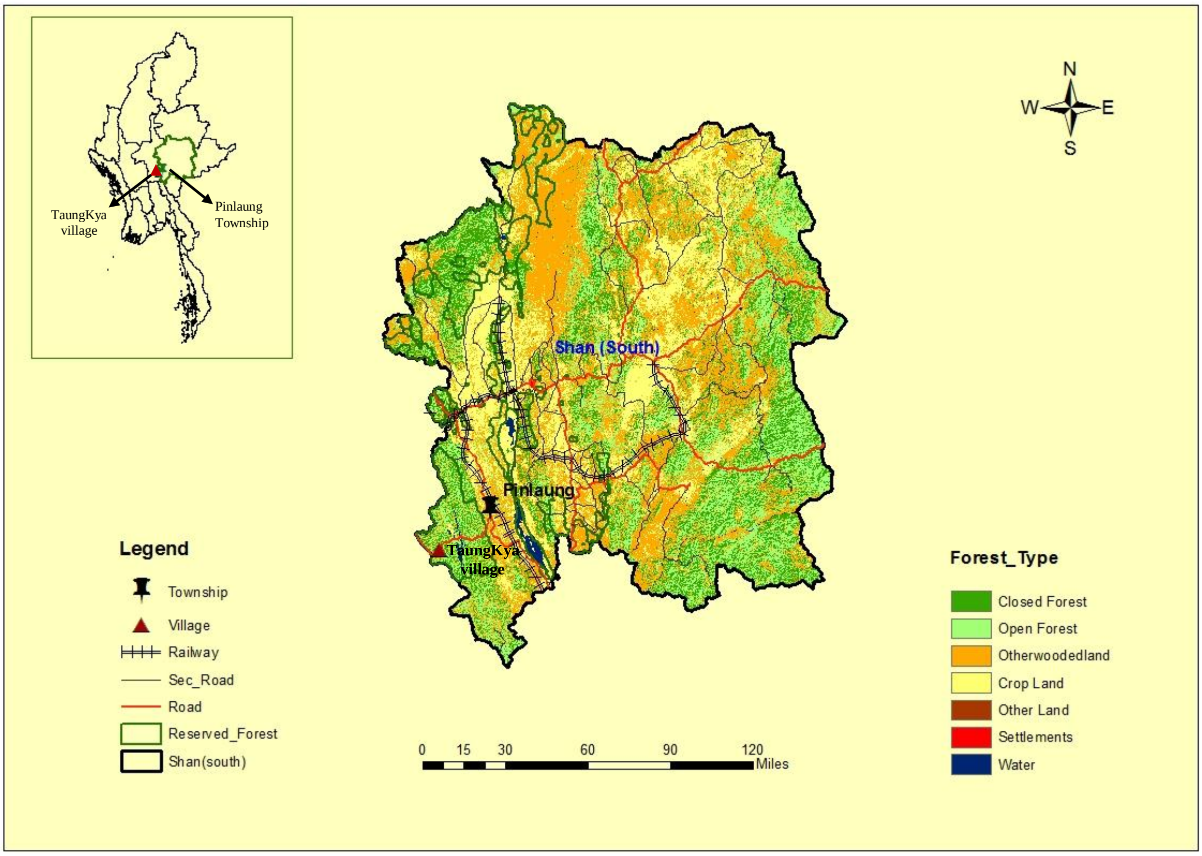
Kiln drying schedules for eleven timber species from Sarawak, Malaysia were determined using "The Quick Drying Test" method (Sulaiman, 1996). Based on the drying defects obtained from each test, initial drying schedules for each species were developed. Those proposed schedules were later improved to get the optimum drying schedules. According to that study, it was found that the initial kiln drying schedule for an unknown species can be determined within a couple of days and new optimum schedules were more refined than those currently recommended.

3. Materials and Methods

3.1. Materials

3.1.1. Sample collection

Four species were tested in this study, namely, Thitcho (*Sideroxylon tomentosum* Roxb.), Kalaw (*Taraktogenus kurzii* King.), Ondon (*Litsea glutinosa* (Lour.) C.B.Rob.) and Madama (*Dalbergia ovata* Grah). Each sample tree for tested species was collected from Taung Kya Village in Pinlaung Township, Southern Shan State. After felling the trees, the trunks were cross-cut into three-meter (9ft) logs, and the base portions were used for the determination of drying behaviours and the appropriate temperature and relative humidities for kiln drying. Selected base portions were sawn along tangential direction to get flat sawn boards with the band saw.



Location Map of Sample collected area

3.1.2. Sample preparation

Eighteen flat-sawn green samples were sawn into specific sizes of 20 mm x 100 mm x 200 mm in thickness, width and length respectively for each species. All samples were taken from the heartwood portion of the log, and all are free from defects such as knot and decay.

The collected species were identified and authenticated at the Wood Anatomy Section of Forest Research Institute, Yezin. The tests were carried out at wood drying laboratory of the Forest Research Institute. The equipments used are band saw, electric balance, laboratory oven and digital caliper.

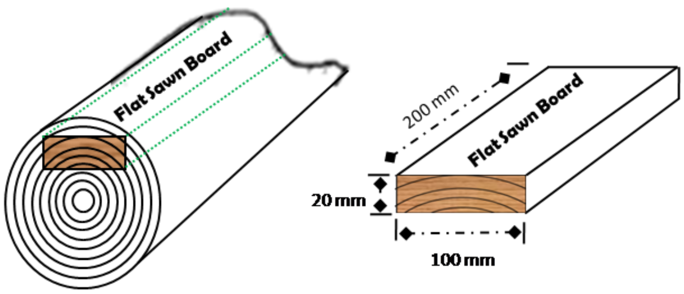


Figure 1. Size and grain of specimens

3.2.Methods

3.2.1.The Quick Drying Test

The Quick Drying Test method was used to determine the basic drying defects. According to Terazawa, this method is used as a starting point in developing drying schedule which illustrate the temperature and relative humidity and to determine the basic drying defects; end checks, surface checks, deformation and honeycomb for any timber species.

3.2.2. Testing Procedures

After preparation the required size, sawdust adhering to them was removed and specimens were labeled on the surface and kept within each plastic container of water to maintain green moisture content.

Before drying in an oven, each tested specimens was weighed for the initial green weight and the data was recorded. This was used in calculation the initial moisture content of the samples. The dimension of each specimen was measured using the digital caliper for thickness, width and length respectively and recorded. One end face of each specimen was marked and selected for end-checking observation. The test was run in a set of six samples, and the samples were placed edge-wise at more than 75 mm apart each in oven which was maintained at 103 ± 2°C for free air circulation until oven-dry condition was reached.

3.2.3. Degree of initial check (D_1)

During the test was running, at the first eight hours, the samples were weighed and critically observed for drying defects (end and surface-checks) occurrences every hour. The checks were measured and the data were recorded carefully at the same time. The purpose was to ascertain the maximum end checks and the surface checks that were appearing in the initial stages of drying.

Afterwards, two observations were made and re-weighing twice daily on the second and subsequent days until constant weight was achieved. During the drying and monitoring processes, checks occurred, movements of maximum check and check closing occurred were observed. The class of 1 to 8 was used to evaluate the degree of initial checks based on the criteria set by Terazawa as shown in Table 1.

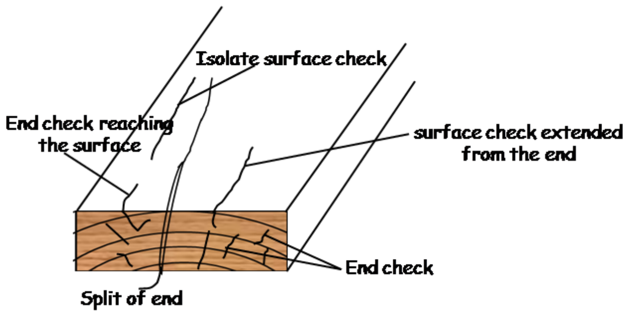


Figure 2 . Various checks appearing on the early stage of drying

Table 1. Classification of defects based on Terazawa and modified by Jankowski.

Level of defects	Checks	
	End checks (mm)	Surface check (mm)
1	No check	No check
2	Small checks L < 10 , W< 0,8	Small checks L<50 W<0.5
3	Small checks L >10 W< 0,8	Small to medium checks L<100 W>5 W<1 W>1
4	Medium Check L < 10 W>0.8, W<1.5	Medium to large checks L<150 W<1.5
5	Medium to large checks L > 10 W>0.8, W<1.5	large Checks L>150 W>1.5
6	large checks L > 10 W< 1.5	large Checks L>150 W>1.5
7	large checks L > 10 W< 1.5	large checks L>150 W>1.5
8	large checks L > 10 W< 1.5	large checks L>150 W>1.5

L= Check length, W = Check width

3.2.4. Degree of honeycombing (Internal Check – D_3)

At the end of the drying process, i.e. after attaining the constant weight, the test samples were cross-cut in the middle part to measure the degree of honeycombing. The sizes and number of honeycombs on newly exposed faces were recorded and the class of 1 to 6 in Table 2 provided by Terazawa's method was used to classify the degree of honeycombing.

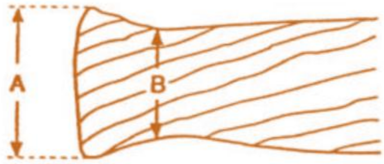
Figure 3. Honeycomb (internal checks) in the cross section of wood

Table 2. Classification of degree of honeycomb (internal checks)

Class	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Degree of internal check	No check	1 wide or 2 narrow checks	2-3 wide checks; 4-5 narrow check; 1 wide and 3 narrow	4-5 wide; 7-9 narrow;1 wide and 4-6 narrow	6-8 wide; 15 narrow; 4 wide and 6-8 narrow	15-17 wide or continuous checks

3.2.5. Degree of spool-like deformation (D_2)

To evaluate the degree of deformation, the two ends at the cut edge for each half was labeled (A), and a reduced thickness was also labeled as (B).



A: The thickness at the edge,
B: the thinnest 1-2 cm apart from the edge

Fig 4 . Method for evaluating spool-like deformation on the section

Thickness at points A and B at the four edges of the two halves (newly exposed faces) were measured using the digital caliper. Differences between the thickest (A) and the thinnest (B) for each of the four was then determined. An average value for the four differences, thickness and thinnest (A-B) for the edge of each sample was evaluated and classified as the cross-sectional spool-like deformation according to Table 3.

Table 3. Method for evaluating spool-like deformation on the section

Degree	1	2	3	4	5	6	7	8
A-B (mm)	0-0.3	0.3-0.5	0.5-0.8	0.8-1.2	1.2-1.8	1.8-2.5	2.5-3.5	Over 3.5

For each species, three rounds of drying tests were conducted.

Based on these drying characteristics in 103±2˚C test, the estimated drying condition of this species was obtained by the relationships of drying defects and drying conditions shown in Table 4, which are very helpful to predict the drying schedules.

Table 4. Drying condition based on degree of each defects (Tarazawa,1965).

Variety of defect	Drying condition	Defect degrees							
		1	2	3	4	5	6	7	8
I. Surface check	Initial temp. (ºC)	70	65	60	55	53	50	47	45
	W.B.depression (Initial)(ºC)	6.5	5.5	4.3	3.6	3.0	2.3	2.0	1.8
	Final temp. (ºC)	95	90	85	80	80	80	80	80
II. Deformation	Initial temp. (ºC)	70	66	58	54	50	49	48	47
	W.B.depr.(Initial)(ºC)	6.5	6.0	4.7	4.0	3.6	3.3	2.8	2.5
	Final temp. (ºC)	95	88	83	80	77	75	73	70
III. Honeycomb	Initial temp. (ºC)	70	55	50	49	48	45	43	40
	W.B.depr.(Initial)(ºC)	6.5	4.5	3.8	3.3	3.0	2.5	2.2	2.0
	Final temp. (ºC)	95	83	77	73	71	70	68	67

By using above table, based on the highest degree of these three defects, initial and final temperatures as well as the wet bulb depression were estimated for each species.

3.2.6. Estimation of Drying Time

The relationship between the time needed to reduce from green to constant moisture content and the actual kiln drying period is as shown in Figure 5. The relationship between the actual kiln drying time and initial DBT and WBD determined in Table 4 is also presented in Figure 5.

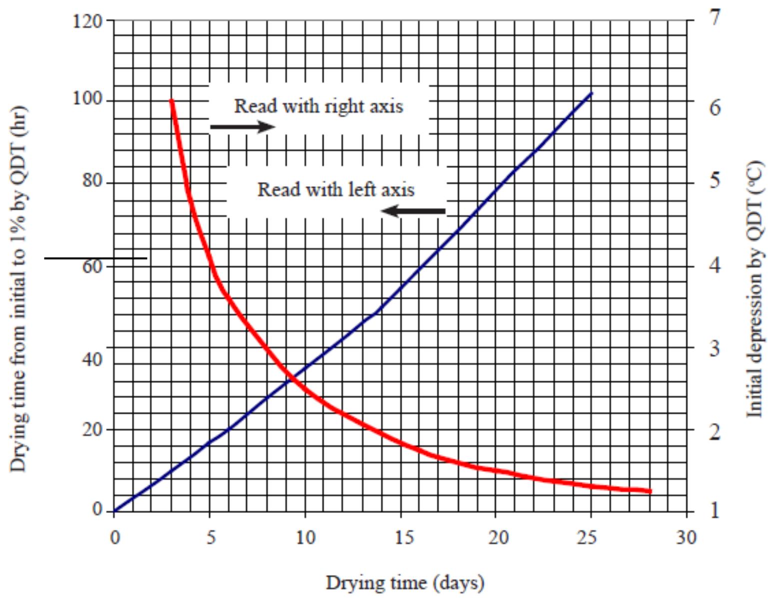


Figure 5. Estimation of drying time for 25-mm thick lumber from green to constant moisture content by conventional steam kiln

3.2.7. Determination of the patternized kiln schedule code number

A pair of patternized kiln schedule codes of Dry Bulb Temperature (DBT) and Wet Bulb Depression (WBD) for each species was determined based on the intersection of two straight lines drawn using a combination of the initial check-D_1, deformation-D_2, honeycombing-D_3, and initial moisture content U_a by using Figure 6 and 7.

As a final step, the value of dry bulb temperature (DBT) and wet bulb depression (WBD) were found by using moisture content as indicator from Table 5, 6 and the values of relative humidity (RH) were determined from Appendix II.

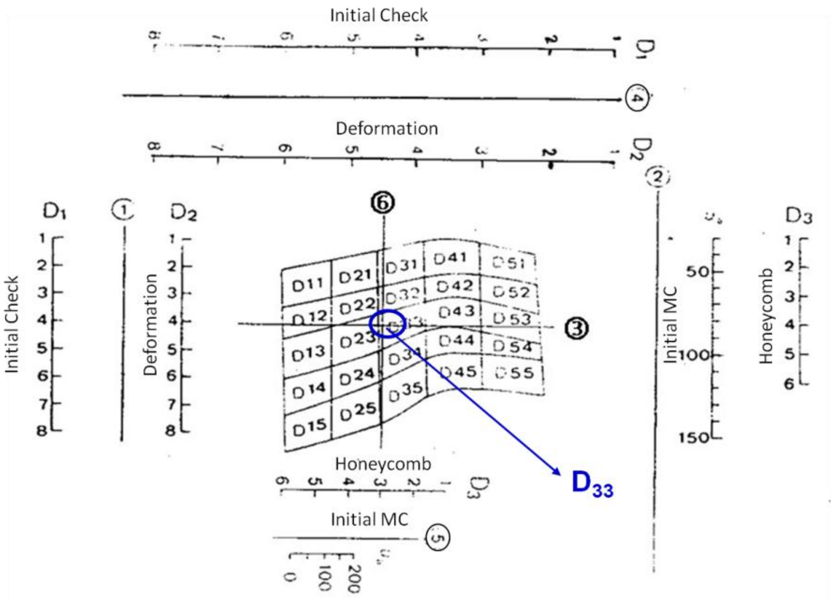


Figure 6. Chart for estimation of the code number of patternized dry bulb temperature schedule (Terazawa, 1965)

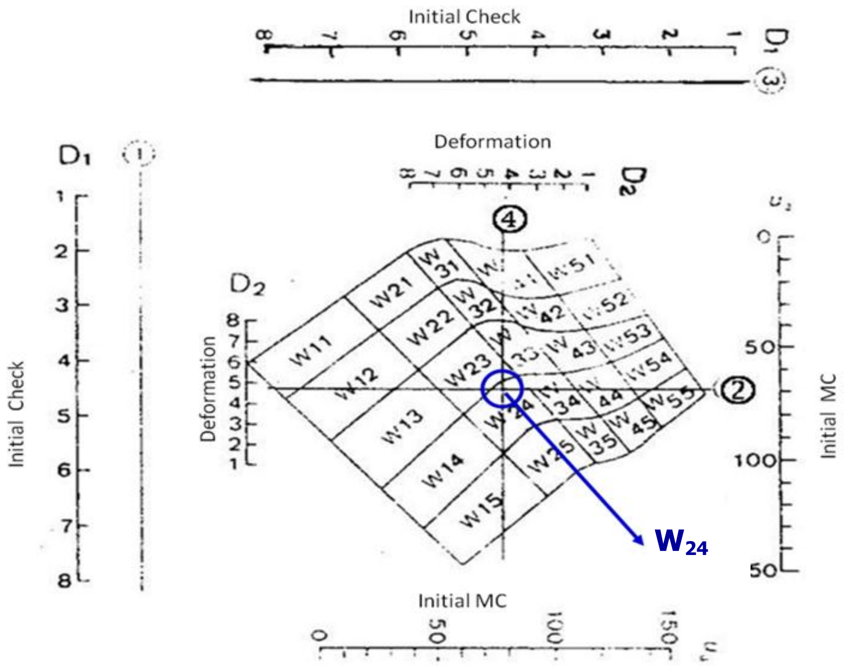


Figure7. Chart for estimation of the code number of patternized wet -bulb depression schedule (Terazawa , 1965)

Table 5. Patternized dry bulb temperature schedule

Moisture content (%): 60, 50, 40, 30, 20, 10

Schedule type	Dry bulb temperature for each schedule type (°C)					
D 11	45	50	55	60	70	
D 12	45	50	55	60	65	70
D 13	45	50	55	60	65	70
D 14	45	50	55	60	65	70
D 15	45	50	55	60	65	70
D 21	50	55	60	65	75	
D 22	50	55	60	65	70	75
D 23	50	55	60	65	70	75
D 24	50	55	60	65	70	75
D 25	50	55	60	65	70	75
D 31	55	60	65	70	80	
D 32	55	60	65	70	75	80
D 33	55	60	65	70	75	80
D 34	55	60	65	70	75	80
D 35	55	60	65	70	75	80
D 41	60	65	70	75	85	
D 42	60	65	70	75	80	85
D 43	60	65	70	75	80	85
D 44	60	65	70	75	80	85
D 45	60	65	70	75	80	85
D 51	70	75	80	85	90	
D 52	70	75	80	85	90	
D 53	70	75	80	85	90	
D 54	70	75	80	85	90	
D 55	70	75	80	85	90	

Table 6.Patternized wet bulb depression schedule

MC (%): 80, 70, 60, 50, 45, 40, 35, 30, 25, 20, 15, 10

Schedule type	Wet bulb depression for each schedule type (°C)							
W 11	2	3	4	5	7	10	17	20
W 12	2	3	6	9	15	25		
W 13	2	3	5	7	10	16	25	
W 14	2	3	4	6	8	11	16	25
W 15	2	3	5	8	12	18	25	
W 21	3	5	8	13	21	30		
W 22	3	4	6	10	15	22	30	
W 23	3	4	6	8	11	16	22	30
W 24	3	4.5	7	9	12	16	21	30
W 25	3	4	6	9	14	20	30	
W 31	4	6	9	13	20	30		
W 32	4	5	7	10	15	21	30	
W 33	4	5	7	9	12	16	21	30
W 34	4	5	8	12	18	25	30	
W 35	4	5	7	10	13	18	23	30
W 41	5	7	10	14	20	25	30	
W 42	5	7	9	12	15	20	25	30
W 43	5	7	10	13	16	20	25	30
W 44	5	7	9	13	18	24	30	
W 45	5	6	8	11	14	19	25	30
W 51	7	9	12	16	20	25	30	
W 52	7	10	15	20	25	30		
W 53	7	9	13	19	25	30		
W 54	7	9	12	15	20	25	30	
W 55	7	8	10	13	16	20	25	30

4. Results and Discussions

4.1. Status and classification of defects

4.1.1. Checks in the early stages of drying (initial checks)

In early drying process of Quick Drying Test, it is observed that samples of Kalaw and Madama were began end checks after 3 hours, and Ondon was began to check in 5 hours. The main reason for the end checks is their high growth stress and another reason is the high temperatures which make them lose more water in a short time at the early stage of the test. As the test goes on, the end checks become stronger and some of them stretch to the surface becoming to end-to surface checks and at this time the surface checks arise also. It was found that all these initial checks stop stretching and closed in the samples of Ondon and Kalaw in 55 hours while Madama species closed within 72 hours, and a general appearance is that the end checks closed first.

Most severe (or) large initial checks appeared on the wide surface and end-grain surface in samples of Madama and small to medium checks were found in both samples of Kalaw and Ondon but there was no initial checks in samples of Thitcho. Based on initial checks, Madama was the highest scoring level of initial check (class 6), whilst Kalaw and Ondon were in the second rank with the same scoring level of (class 3) and Thitcho owned the lowest level (class 1) by Terazawa's method (1965).

4.1.2 Honeycombing (internal checks)

Honeycombing (internal check) in lumber is the separation of the fibers in the interior of the piece, usually occurs along the rays. The failures can be the extended result from surface and end checks. According to Johanson (2005), the presence of honeycomb defect is affected by the initial moisture content of the board, the wood mass loss, the presence of pith and the speed of drying process.

The results observed that there was no honeycombing (internal checks) in samples of Kalaw, Ondon and Thitcho species. Medium to large checks of honeycombing were found in Madama. Thus, Madama was the highest scoring level of honeycomb (class 5) whilst Kalaw, Ondon and Thitcho species were the same scoring level of honeycomb (class 1) as shown in Figure 8.

Madama(*Dalbergiaovata* Grah) Ondon (*Litsaeaglutinosa* Lour) Kalaw (*Taraktogenuskurzii* King) Thit-cho (*Sideroxylontomentosum* Roxb)

Figure 8. Honeycombing was found in Madama and not in Ondon, Kalaw, and Thitcho

4.1.3. Cross - sectional spool-like deformation

It was found that there was no spool-like deformation in Thitcho species and deformation was little to mild in Kalaw, Ondon and Madama species. According to finding results, Thitcho was classified as class 1, and class 3 for Kalaw, Ondon and Madama species, respectively.

The results of the type and class of defects obtained from the samples of each of the four species are presented in Table 7.

Table 7. Type and class of drying defects

Type of defects	Class of drying defects			
	Kalaw	Ondon	Madama	Thitcho
Class of initial Checks(D_1)	3	3	6	1
Class of Cross section deformation(D_2)	3	3	3	1
Class of Honeycombing (D_3)	1	1	5	1

4.2. Estimating the drying condition (initial temperature and relative humidity)

Table 7 shows the drying defects grades of four species, and Table 4 shows the drying condition based on class of each defects. From these two tables, the results of estimated drying conditions were presented with the types and classes of drying defects of each species.

The estimated drying conditions, the mildest conditions (viz. overall lowest initial temperature, overall smallest initial wet bulb depression, and final temperature) were selected because the drying condition is inferred from the most severe class of defects. By this reason, the estimated initial temperature and relative humidity were 58˚C, and 81% for Kalaw and Ondon, 48˚C and 89% for Madama and 70˚C and 76% for Thit-cho, respectively as shown in Table 8.

Table 8.Summary of adopted classification of defect types and estimated drying conditions

Species	Adopted classification of defect type			Estimated drying conditions	
	Initial Checks	Honey combing	Deformation	Initial temperature (˚C)	Relative humidity %
Kalaw	3	3	1	58	81
Ondon	3	3	1	58	81
Madama	6	3	5	48	89
Thitcho	1	1	1	70	76

4.3. Estimation of Drying Time

The drying times for 25 mm-thick lumbers from green to 10 % moisture content in conventional steam kiln were estimated as (5~8) days for Thitcho, (7~10) days for Ondon, (8~12) days for Kalaw, and (10~14) days for Madama.

4.4. Determination of patternized kiln schedule codes

According to Figure 6 and 7 provided by Terazawa (1965), based on the combination of three drying defects and initial moisture content of each species, the patternized kiln schedule code for each tested species were Kalaw ($D_{34}W_{34}$), Ondon ($D_{35}W_{35}$), Thitcho (D_{45} W_{35}) and Madama ($D_{22}W_{14}$) and are given in Table 9.

Table (9): Summary of initial moisture content and adopted classification of defect types used in estimating drying conditions

Species	Initial MC	Adopted classification of defect type			Estimated drying conditions		Patternized Schedue Code	Estimated drying time Kiln drying (days)
		Initial Checks	Honey combing	Defor mation	Initial temperature (C)	Relative humidity %		
Kalaw	88.0	3	3	1	58	81	D_{34} W_{34}	8~12
Ondon	109.4	3	3	1	58	81	D_{35} W_{35}	7 ~10
Madama	77.6	6	3	5	48	89	D_{22} W_{14}	10~14
Thitcho	192.61	1	1	1	70	76	D_{45} W_{35}	5~8

4.5. Formulation of appropriate temperatures and relative humidities

A series of temperatures and relative humidities that are applied at various stages of drying is called a kiln drying schedule. According to "Quick Drying Test", there are six kinds of kiln schedule types A to F: A and B for non-refractory timbers (i.e. easy to dry), C and D for moderately-refractory timbers (i.e. moderately difficult to dry), E for refractory timber (i.e. difficult to dry), F for very refractory timber (i.e. very difficult to dry).

Finally, in formulation of appropriate temperatures and relative humidities of each wood species, in the early stage of drying, minimum temperature (DBT) 50˚C and maximum relative humidity (RH) 89%, and maximum temperature 75˚C and minimum relative humidity 28% in final stage should be used for Madama. Minimum temperature (DBT) 60˚C and maximum relative humidity (RH) 82% in the early stage of drying, and maximum temperature 85˚C and minimum relative humidity (RH) 23% in the final stage should be used for Thitcho, whereas in the early stage of drying, minimum temperature (DBT) 55˚C and maximum relative humidity (RH) 81%, and maximum temperature 80˚C and minimum relative humidity 22% in final stage should be used for Kalaw and Ondon and are given in Table 10 to Table 13.

In this paper, based on the drying defects developed during the "Quick Drying Test", four tested species could be classified as Thitcho species is non-refractory timber (Kiln Schedule Type B), and it is similar to Baing, Dwabok, Thitkado, Bomeza, etc. Kalaw and

Ondon are moderately-refractory timbers (Kiln Schedule Type C). They are similar to Teak, Padauk, Thitya, Ingyin, Leza, Thingadu, Myaukngo, etc. Madama species is refractory timber (Kiln Schedule Type E) like Hnaw, Thabye, Pyinkado, etc.

Table 10 . Proposed drying schedule for Thitcho (*Sideroxylontomentosum* Roxb.)

MC (%)	DBT(˚C)	WBD(˚C)	R.H(%)
Above 70	60	4	82
70 - 60	60	5	77
60 -50	60	7	69
50 - 40	65	10	60
40 - 30	70	13	53
30 - 20	75	18	42
20 - 15	80	23	33
Below 15	85	30	23

Table 11. Proposed drying schedule for Kalaw (*Taraktogenus Kurzii.* King)

MC (%)	DBT(˚C)	WBD(˚C)	R.H(%)
Above 60	55	4	81
60 - 50	55	5	76
50 - 40	60	8	66
40 - 30	65	12	54
30 - 20	70	18	40
20 -15	75	25	28
Below15	80	30	22

Table 12. Proposed drying schedule for Ondon (*Litsaeaglutinosa* (Lour) C.B.Rob.)

MC (%)	DBT(˚C)	WBD(˚C)	R.H(%)
Above 70	55	4	81
70 - 60	55	5	76
60 -50	60	7	70
50 - 40	60	10	59
40 - 30	65	13	51
30 - 20	70	18	40
20 -15	75	23	31
Below 15	80	30	22

Table 13. Proposed drying schedule for Madama (*Dalbergia ovata*Grah.)

MC (%)	DBT(˚C)	WBD(˚C)	R.H(%)
Above 45	50	2	89
45 - 40	50	3	85
40 -35	50	4	80
35 - 30	55	6	72
30 - 25	60	8	66
25 - 20	65	11	57
20 - 15	70	16	45
Below15	75	25	28

5. Conclusions

The study revealed that there were no initial checks, honeycombing and spool-like deformation in Thitcho. Kiln drying for Thitcho should be started at 60˚C drying temperature and 82% relative humidity (RH) in the early stage of drying.

There were small to medium in initial checks, no honeycombing, little to mild in spool-like deformation in Kalaw and Ondon. For kiln drying of these woods should be started at 55˚C drying temperature and 81% relative humidity (RH) in the early stage of drying.

Madama wood was large in initial checks, medium to large check of honeycombing, little to mild of spool-like deformation and 50˚C drying temperature and 89% relative humidity (RH) should be used in the early stage of drying.

Based on the results, kiln drying schedules for four tested species are proposed as follows: Thitcho (*Sideroxylon tomentosum* Roxb.) species should be kiln dried in Type B, Kalaw (*Taraktogenus kurzii* King.) and Ondon (*Litsea glutinosa* (Lour.) C.B.Rob.) in Type C, Madama (*Dalbergia ovata* Grah.) species in Type E.

These proposed kiln drying schedules are need to be adjusted through practical experiment to get the "Optimum Kiln Schedules" of the tested species without any difficulties based on the results given in this paper.

These research findings are useful not only for knowledge of wood properties related to drying but also for wood based industries to make the efficient uses of Lesser Used Species. Although drying defects is an essential requirement to assess the end use of the species, other technological knowledge on physical and mechanical properties, durability, anatomical properties should also be considered.

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Appendix I

Recommended Kiln Schedules

Schedule A

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	70	5	79
75	70	6	75
65	70	8	69
55	70	11	58
45	75	14	52
35	80	19	42
25	85	25	40
15	90	30	32

Schedule B

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	60	4	82
60	60	5	77
50	65	8	68
40	70	12	55
30	75	18	43
20	80	25	30
15	85	30	23

Schedule C

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	55	3	86
60	55	4	81
50	60	6	73
40	65	9	64
30	70	14	50
20	75	20	38
15	80	30	26

Schedule D

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	50	3	85
45	50	4	80
40	50	6	69
35	55	8	64
30	60	11	54
25	65	16	42
20	70	22	31
15	75	30	21

Schedule E

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	50	2	88
45	50	3	85
40	50	4	80
35	55	6	71
30	60	8	66
25	65	11	57
20	70	16	44
15	75	25	28

Schedule F

Moisture Content (%)	Dry Bulb Temperature (°C)	Wet Bulb Depression (°C)	Relative Humidity (%)
Green	45	3	85
60	45	4	79
50	45	6	68
40	50	8	62
35	55	11	52
30	60	16	40
25	65	22	28
20	70	30	21

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