The Republic of the Union of Myanmar
Ministry of Environmental Conservation and Forestry
Forest Department
Forest Research Institute

# Study on Proposed Kiln Schedule of Some Commercial Hardwood Species from Tanintharyi Region

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# တနင်္သာရီတိုင်းဒေသကြီးရှိ စီးပွားရေးဈေးကွက်ဝင် သစ်မျိုးအချို့၏ ပေါင်းဖိုဖြင့် အခြောက်ခံရာတွင် အသုံးပြုသင့်သည့် သစ်ပေါင်းဖိုဇယားအား ဖော်ထုတ်လေ့လာခြင်း

အောင်စိုး၊ လက်ထောက်သုတေသနအရာရှိ
ခရစ္စတီနေဝင်း၊ သုတေသနလက်ထောက်-၂
စုစုလှိုင်၊ သုတေသနလက်ထောက်-၃

## စာတမ်းအကျဉ်း

အဆောက်အအုံဆောက်လုပ်ခြင်းနှင့် ပရိဘောဂပစ္စည်းအမျိုးမျိုး ပြုလုပ်ရန်အတွက် သစ်ကို တွင်ကျယ်စွာအသုံးပြုလျက်ရှိပါသည်။ ယာယီလုပ်ငန်းများအတွက်သော်လည်းကောင်း၊ အမြဲတမ်းလုပ်ငန်းများအတွက်သော်လည်းကောင်း၊ စီးပွားရေးအရ လိုက်လျောညီထွေမှုရှိပါသည်။ မြန်မာနိုင်ငံတွင် အဖိုးတန် သစ်မျိုးများစွာ ပေါက်ရောက်လျက်ရှိရာ ကျွန်း၊ ပျဉ်ကတိုး၊ ပိတောက် သစ်မျိုးများသည် ကမ္ဘာကျော်သကဲ့သို့ အခြားသစ်မာမျိုးစုံသည်လည်း ပြည်နယ်နှင့်တိုင်း ဒေသအသီးသီးတွင် ပေါက်ရောက်ရှင်သန်လျက်ရှိပါသည်။ အဆိုပါ သစ်မျိုးများသည် ကျွန်း၊ ပျဉ်ကတိုး၊ ပိတောက်ကဲ့သို့ နေရာစုံအသုံးမပြုနိုင်သော်လည်း သူ့နေရာနှင့်သူအကျိုးရှိစွာ အသုံးချလျက်ရှိရာ အဆိုပါသစ်မျိုးများသည် တစ်စတစ်စ မျိုးတုန်းပျောက်ကွယ်တော့မည့် အခြေအနေဖြစ်ပေါ်လျက်ရှိပါသည်။ အိမ်နီးချင်းနိုင်ငံနှင့် ထိစပ်လျက်ရှိသော ပြည်နယ်တိုင်းဒေသများမှ သစ်မာမျိုးများသည် ကောင်းမွန်မှုရှိသော်လည်း အကြောင်း အမျိုးမျိုးကြောင့် ပြည်တွင်း၌သုံးစွဲမှု အနည်းငယ်သာရှိပြီး မိမိတို့နိုင်ငံနှင့် ထိစပ်လျက်ရှိသော ပြည်ပနိုင်ငံများသည် မိမိတို့၏သစ်မာမျိုးများစွာကို တွင်ကျယ်စွာ အသုံးပြုလျက်ရှိပါသည်။ ဤသုတေသန စာတမ်းတွင် တနင်္သာရီတိုင်းဒေသကြီးရှိ သစ်မျိုးများထဲမှ စီးပွားရေးဈေးကွက်ဝင် သစ်မာ(၁၆)မျိုး ဖြစ်သော အောက်ချင်းစာနီ၊ စကားဝါ၊ ကောင်းမှူ၊ ကရစ် (ခေါ်) ရှစ်ခါး (ခေါ်) သစ်ခါး၊ ကန့်ဇော်၊ ဥဘန်၊ သရဖီ၊ သစ်မင်း၊ သက်န်း၊ ကညင်နီ၊ ကတွတ်၊ ကဒူ၊ သစ်တို၊ ပင်လယ်အုန်း၊ တောင်ပရုန်းနှင့် လိပ်သဲ သစ်မျိုးတို့၏ ရေငွေ့ပေါင်းဖိုဖြင့် အခြောက်ခံရာတွင် အသုံးပြုသင့်သည့် သစ်ပေါင်းဖို ဇယားအား ဖော်ထုတ် လေ့လာရာတွင် သက်န်း၊ ဥဘန်၊ စကားဝါ၊ ကတွတ်၊ သရဖီနှင့် ပင်လယ်အုန်း သစ်(၆)မျိုးသည် ပေါင်းဖိုဇယားအဆင့်(၁)၌လည်းကောင်း၊ ကန့်ဇော်၊ ကောင်းမှူ၊ ကရစ် (ခေါ်) ရှစ်ခါး (ခေါ်) သစ်ခါး၊ သစ်မင်း၊ သစ်တို၊ တောင်ပရုန်း သစ်(၆)မျိုးသည် ပေါင်းဖိုဇယားအဆင့်(၂)၌လည်းကောင်း၊ အောက်ချင်းစာနီ၊ ကဒူ၊ လိပ်သဲ သစ်(၃)မျိုးသည် ပေါင်းဖိုဇယားအဆင့်(၃)၌လည်းကောင်း၊ ကညင်နီသစ်သည် ပေါင်းဖိုဇယား အဆင့်(၄)၌ ပါဝင်ကြောင်း စမ်းသပ်တွေ့ရှိပါသည်။

# Study on Proposed Kiln Schedule of Some Commercial Hardwood Species from Tanintharyi Region

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**Abstract**

Timber has always been widely used for structural and furniture purposes. It is economical important for both temporary and permanent structure. Myanmar is a place where many precious species of timber are plentiful. Teak, Pyinkado and Padauk were famous in the world. Moreover, there are other hardwood species growing in all States and Regions. Although some timbers such as teak, Pyinkado and Padauk cannot be used in all fields, they are very useful in their respective utilization. But now, there is a condition where these species can be scarce more and more. Although timbers especially from the States and Regions near the border are in good quality, there was little use in local due to many reasons, and then the neighboring countries had been using these woods. There are six grades of recommended kiln schedule based on wrinkling, honeycombing, and collapse, end and surface checks. According to the proposed kiln schedule results, Thingan, Kadauk, Pinle-on, Sagawa, U-Ban and Tharapi species are in Grade I because of the least probability in wrinkling and checks. Kaunghmu, Kashit or Shit-Ka or Thit-kha, Kant Zaw, Thit Min, Thitto and Taungpayone species are in Grade II. Auk Chin Sa Ni, Kadu and Leikthe species are in Grade III and Kanyin-Ni species are in Grade IV, respectively.

Key Words: Proposed Kiln Schedule, some commercially (16) Hardwood Species from Tanintharyi Region

**Contents**

## 1. Introduction

Timber has always been widely used for structural and furniture purposes. It is economical important for both temporary and permanent structure.

Myanmar is a place where many precious species of timber are plentiful. Teak, Pyinkado and Padauk were famous in the world. Moreover, there are other species of hard wood growing in all States and Regions. Although some timbers such as teak, Pyinkado and Padauk cannot be used in all fields, they are very useful in their respective utilization. But now, there is a condition where these species can be scarce more and more.

Although timbers especially from the States and Regions near the border are in good quality, there was little use in local due to many reasons, and then the neighboring countries had been using these woods.

Although Tanintharyi Region some species are not well known for its properties, they are really not only very useful but also economically accepted, from the marketing point of view.

In some developing countries, hardwood species could be promoted for use in construction both for the local market and for export to other developing countries where the raw material base may be inadequate. This strategy would first and foremost require a good local industrial base for secondary processing of hardwood species, based on standardized products and prefabricated component. The advantage with such as strategy is that the exporting countries have the advantage of satisfying domestic needs and at the same time gaining foreign exchange earnings. Most developing countries where strategies for promotion of hardwood species are feasible would by definition already have an existing timber construction practice based on popular timber species. Thus there in already an existing basis for promoting the use of timber in construction (L. Jayanetti (2000)).

Timber has a good strength-to-weight ratio and it is easy and quick to cut and join using basic hand tools. Erection in timber can proceed very fast and thus lead to worth while saving in the otherwise long gestation periods which are characteristic of fixed asset investment.

The aims of this study are;

- To increase the utilization of some timber species from Tanintharyi Region
- To propose initial kiln drying schedules for sixteen hardwood species from Tanintharyi Region

In this research paper, “Quick Drying Tests” will be carried out in order to obtain the proposed kiln schedules of sixteen hardwood species from Tanintharyi Region.

## 2. Literature Review

The Myanmar’s population is increasing and the hardwood demand and consumption on the over ascending trend, it is imperative for effective and increased utilization of forest resources. The global issue for Sustainable Forest Management is the responsibility of the producer countries. In this respect a strong and effective role of the forest is essential for the Sustainable Forest Management. Myanmar has the capacity in forest resources, institutional, and technically trained personnel to develop its forest products industry. However, due to various circumstances it has not develop in technology and efficiency in the use of wood raw material during more than 65 years after their own initiatives. Many countries including developing countries have responded positively to the range of changing conditions in forest products industry involving environmental, economic and market concerns. (Kyaw Lwin, 2000)

By achieving higher recovery rates in wood utilization, it will lead to reduction in the amount of wood harvested from the forest. These were fulfill its ultimate goal, the improved well-being of present and future generations. The primary forest products industry is a dynamic sector which has responded to a range of changing conditions involving environmental, economic and market concerns, and changes in technology as well as the allocation and changing characteristics of its raw material. The industry has made significant advances in the past few years in developing more environmentally friendly processing technologies, achieving higher recovery rates, improving product quality and diversifying the use of raw materials.

Changes in the quality, quantity and source of raw materials are having major impacts on forest products processing and product development. The industry is adjusting to changes in the supply of industrial round wood (different species, smaller size wood, often poorer quality wood) and sources of supply (less from natural forests and more from plantations, woodlots and, in some countries, agroforestry systems). Localized shortages of wood are also a driving force behind greater efficiency of raw material use. Technological advances have been made in plywood and particle board manufacture and various reconstituted products in order to accommodate smaller size wood.

Adoption of major advances in forest product processing and development by the leading industries has contributed to a widening gap between the modern and the less developed industry within countries, and between developed and developing countries. Recent advances in achieving higher recovery rates have in some cases led to a significant reduction in the amount of wood harvested from the forests. Increased consumption of forest products, demand for higher quality products, change in the availability of raw materials, and public pressure, environmental aspects of forest management, production and processing will continue to be major factors affecting technology and product development. (Kyaw Lwin, 2000)

Timber has served through history as an invaluable construction material but the potential for its use has never been greater. One special technical merit of timber as a material for construction is that is most developing countries already exists some basic local infrastructure. The most important factor which predetermines timber as an environmentally friendly material is the fact that it is a renewable building material. A merit of timber construction which is probably more economic than technical is the time-scale within which a timber construction could be exacted when compared with other materials such as concrete or brickwork. If Hardwood Species of timber are to be promoted for use in construction and furniture, then the secondary processing required to transform logs into structural components will all contribute to employment and skill generation, especially technical seasoning. (L Jayanetti 2000)

To increase the utilization of lesser-used species, with the concomitant effect of broadening the use of the forest resource and reducing pressure on exploiting only high grade premium wood species, Freas recommended the undertaking of additional research in two broad areas. One in concerned with improvement in inventory to make a reliable compilation of these species, which occur in sufficient quantity, size and location to have potential for utilization. The other is concerned with a program of research on the technical and technological characteristics needed for the industrial utilization of these species with good potential.

Such as a research program, however, should be carefully planned and rationalized in order to get practical results with the least possible time, effort and money. The impulse to conduct the whole spectrum of anatomical, chemical, physical and mechanical properties of each species should be suppressed. Investigations for this purpose should rather be tailored to potential use or uses of specific species or group of species. The relevant question to be asked is "What optimal use or uses can be made of this lesser-used species" rather than 'what species of wood can be utilized for this or that species purpose". In this regard, insofar as promoting fuller utilized of lesser-used species is concerned, a four-step approach to the solution of the problem maybe considered by those concerned with forestry and forest products research.

## 3. Materials and Methods

### 3.1 Materials

Lumber of size 5 inches x 2 inches x 10 feet for each tested species were collected from Myeik, Tanintharyi and Kyunsu Townships. The total number of lumber collected were fifty. Some of the tested lumber were green whereas some were air dry. Collected lumber were identified at the Wood Anatomy Lab., Forest Research Institute.

Twenty-five specimen of size 20 mm (thickness) by 100mm (width) by 200 mm (length) were prepared for each tested species. Twelve samples which are free from knots, checks and decay are selected for "Quick Drying Tests". Two surfaces of every sample were planned by planning machine. Unlike the ordinary drying tests, coating on end was omitted.

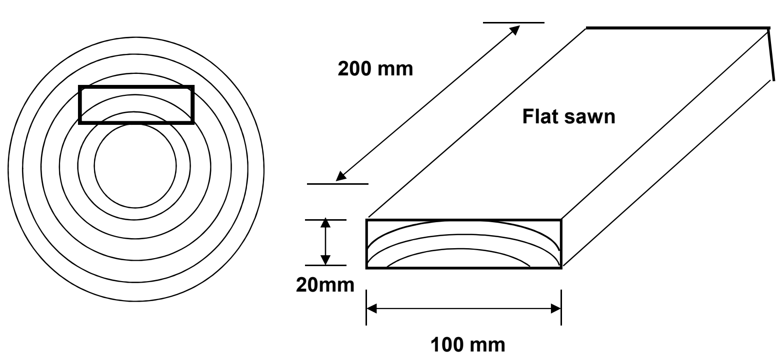



**Figure 1. Size and grain of specimen**

### 3.1.1 Equipment

Natural convection oven (operation temperature 100-105°C, control accuracy ± 2°C );

Balance : Electric balance- measuring MC (Moisture Content) specimens (weighing range 0-3000g, minimum readability 0.1 g)

Measuring Instrument : Vernier caliper (Maximum length 200mm, minimum readability 0.05mm) to measure width of Quick Drying Test samples, thickness gauge/caliper (Maximum length 50mm, minimum readability 0.05mm micrometer to measure deformation of Quick Drying Test samples (Minimum readability 0.01mm)

## 3.2 Methods

**Quick Drying Test Method** provided an easy means for the determination of kiln drying control or temperature settings. Emphasis is placed on the method of determination of such control parameters as the initial dry bulb temperature (DBT) initial wet bulb depression (WBD) (or difference between dry bulb temperature and wet bulb temperature, WBT) and final dry bulb temperature after classifying the deformation hazards as initial checks, honeycombing and collapse. For this purpose, test specimens of regular dimensions are prepared and dried quickly in the oven (natural convection type) to observe end and surface checks. After drying, the center of each specimen is cut in order to detect any honeycombing and measure the cross-sectional spool-like deformation for setting the temperature and relative humidity in the kiln.

## 3.3 Test Procedures

(1) Each sample was weighed to get the initial weight. The samples were oven dried at a Temperature of 103 ± 2°C.

(2) Changes in weight and the development of end checks and surface checks of each and every samples were observed and recorded at every one hour during the dryinf process.

(3) At the end of drying test (i.e after getting the oven-dry weight), each sample was cut at the center in order to observe the degree of honeycombing (internal checks) and the cross-sectional deformation.

(4) Three different kinds of defects initial checks-D1, Deformation D2 and Honeycombing-D3, were then examined carefully and graded according to the detail procedures given in Figure 2,3,4, 5 and Table(1).

(5) Based on the grades of these three defects, initial Dry Bulb Temperature (DBT), Initial Wet Bulb Depression (WBD) and Final Dry Bulb Temperature were estimated for each species by using Table (2). The relationship between the time needed to reduce the constant moisture content and the actual kiln drying period is as shown in figure 6 .

The relationship between the actual kiln-drying time and the initial DBT and WBT difference (or WBD) determined in Table 2 is also presented in figure 6.

(6) A pair of patternized kiln schedule codes of Dry Bulb Temperature (DBT) and Wet Bulb Depression (WBD) for each species was then determined based on the intersection of two straight lines drawn using a combination of the initial check-D1, deformation-D2, honeycombing-D3 and initial moisture content-Ua. These steps were done by using Figure 7 and 8.

(7) As a final step, to develop a complete kiln schedule (propose), a pair of determined DBT and WBD were placed side by side, using moisture content as an indicator Table (3) and (4).

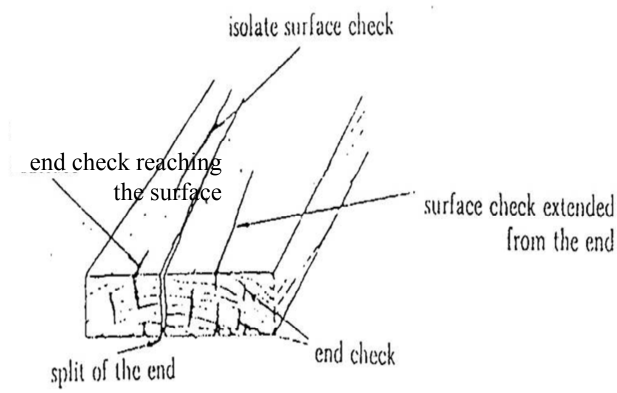



**Figure 2. Various checks appearing on the early stage of drying**

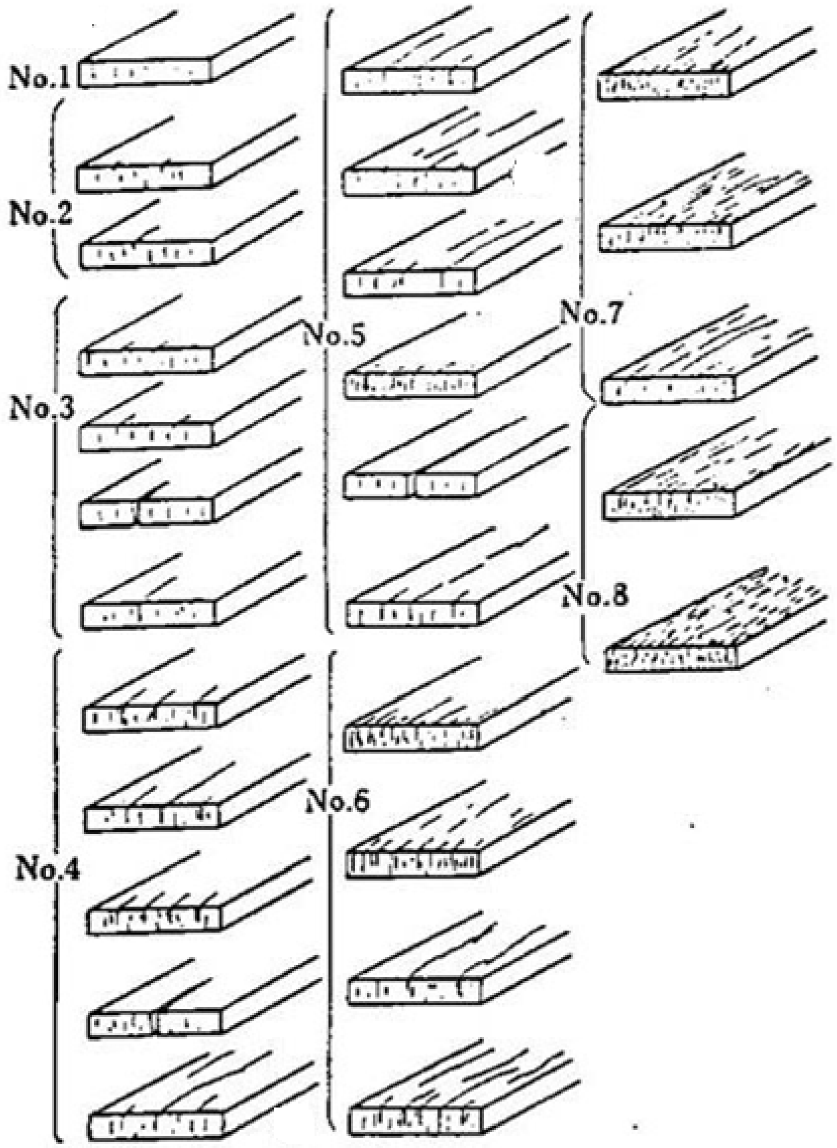



Figure 3. Comparison sheet for degrees of end and surface checks

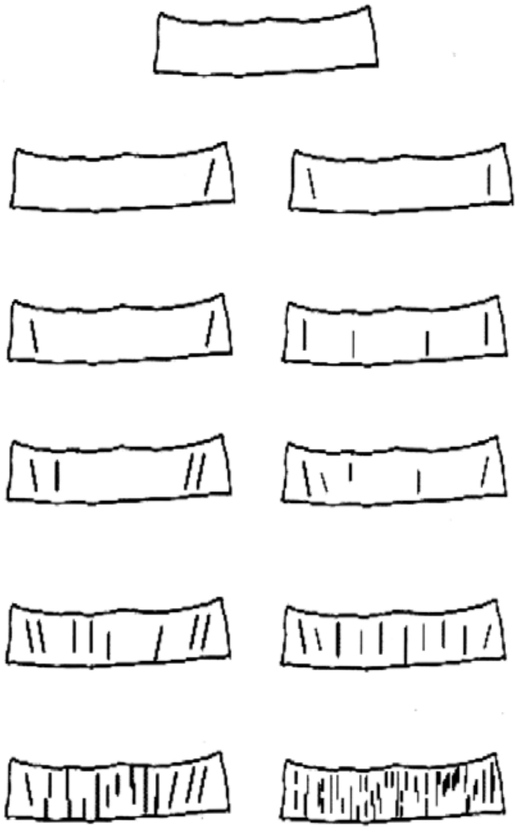
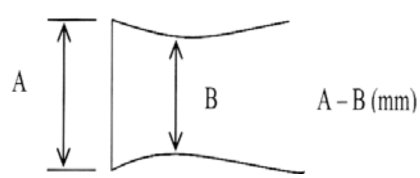



**Figure 4. Degree of internal check (Honeycombing) (Treazawa, 1965)**




A = original thickness before drying

B = reducing thickness after drying

**Figure 5. Spool-like deformation**

**Table 1. Degrees of deformation based on A-B**

| 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 |

**Table 2. Drying Condition based on degree of each defects (Treazawa, 1965)**

| Variety of defects | Drying condition | Degree of defects | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Check on early stage | Initial temp. (°C) | 70 | 65 | 60 | 55 | 53 | 50 | 47 | 45 |
| | W.B. Depr. (Initial) (°C) | 6.5 | 5.5 | 4.3 | 3.6 | 3.0 | 2.3 | 2.0 | 1.8 |
| | Final Temp (°C) | 95 | 90 | 85 | 83 | 82 | 81 | 80 | 79 |
| Deformation | Initial temp. (°C) | 70 | 66 | 58 | 54 | 50 | 49 | 48 | 47 |
| | W.B. Depr. (Initial) (°C) | 6.5 | 6.0 | 4.7 | 4.0 | 3.6 | 3.3 | 2.8 | 2.5 |
| | Final Temp (°C) | 95 | 88 | 83 | 80 | 77 | 75 | 73 | 70 |
| Honeycombing | Initial temp. (°C) | 70 | 55 | 50 | 49 | 48 | 45 | - | - |
| | W.B. Depr. (Initial) (°C) | 6.5 | 4.5 | 3.8 | 3.3 | 3.0 | 2.5 | - | - |
| | Final Temp (°C) | 95 | 83 | 77 | 73 | 71 | 70 | - | - |

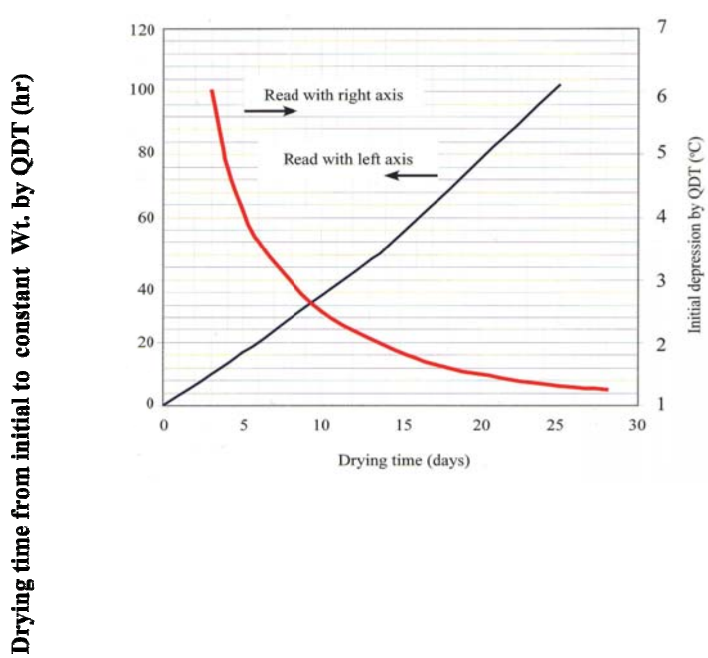


**Figure 6. Estimation of drying time for 0.8 inch (20mm) timber from green to constant Moisture Content by conventional steam kiln**

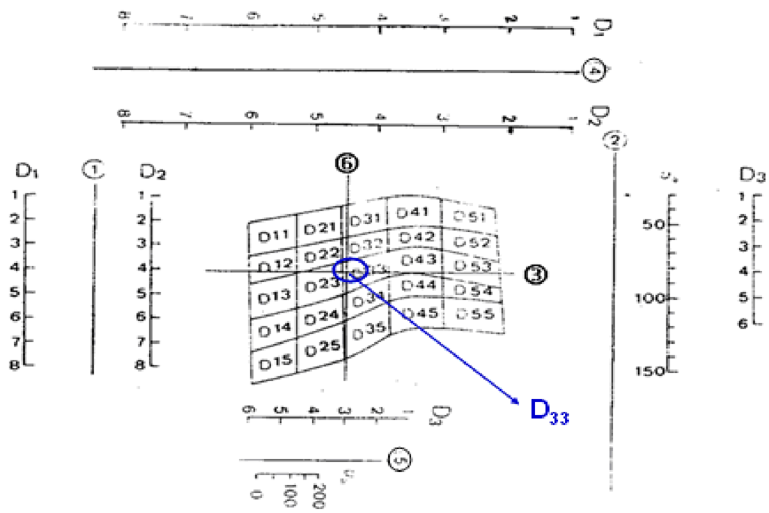



Fig 7 . Chart for estimation of the code number of patternized Dry Bulb temperature schedule (Treazawa , 1965)

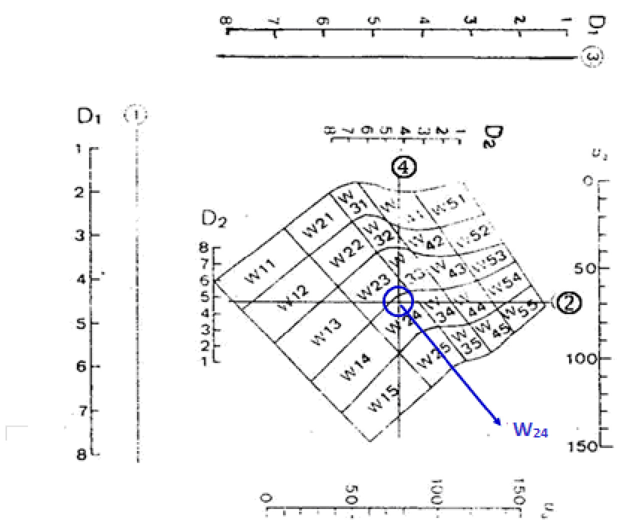



Fig 8. Chart for estimation of the code number of patternized wet-bulb depression schedule (Treazawa , 1965)

### Table 3 Patternized dry bulb temperature schedule

| Moisture Content (%) | D 11 | D 12 | D 13 | D 14 | D 15 | D 21 | D 22 | D 23 | D 24 | D 25 | D 31 | D 32 | D 33 | D 34 | D 35 | D 41 | D 42 | D 43 | D 44 | D 45 | D 51 | D 52 | D 53 | D 54 | D 55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dry bulb temperature for each schedule type (℃) | | | | | | | | | | | | | | | | | | | | | | | | |
| 60 | | | | | 45 | | | | | 50 | | | | | 55 | | | | | 60 | | | | | 70 |
| | | | | 45 | | | | | 50 | | | | | 55 | | | | | 60 | | | | | 70 | |
| 50 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | 50 | | | | | 55 | | | | | 60 | | | | | 65 | | | | | 75 |
| | | | 45 | | | | | 50 | | | | | 55 | | | | | 60 | | | | | 70 | | |
| 40 | | 45 | | 50 | | | 50 | | 55 | | | 55 | | 60 | | | 60 | | 65 | | | 70 | | 75 | |
| | | | | | | | | | | | | | | | | | | | | | 70 | | | | |
| | 45 | | 50 | | 55 | 50 | | 55 | | 60 | 55 | | 60 | | 65 | 60 | | 65 | | 70 | | | 75 | | |
| | | 50 | | | | | 55 | | | | | 60 | | 65 | | | 65 | | 70 | | | 75 | | | 80 |
| 30 | | | | 55 | | | | | 60 | | | | | | | | | | | | 75 | | | 80 | |
| | 50 | 55 | 55 | | 60 | 55 | 60 | 60 | | | 60 | 65 | 65 | | 70 | 65 | 70 | 70 | | 75 | | | 80 | | |
| | | | | | | | | | | 65 | | | | 70 | | | | | 75 | | | 80 | | | |
| | 55 | 60 | 60 | 60 | | 60 | 65 | 65 | 65 | | 65 | 70 | 70 | | | 70 | 75 | 75 | | | 80 | | | | |
| 20 | | | | | 65 | | | | | | | | | | 75 | | | | | 80 | | | 85 | 85 | 85 |
| | 60 | 65 | 65 | 65 | | 65 | 70 | 70 | 70 | 70 | 70 | 75 | 75 | 75 | | 75 | 80 | 80 | 80 | | 85 | 85 | | | |
| | 70 | 70 | 70 | 70 | 70 | 75 | 75 | 75 | 75 | 75 | 80 | 80 | 80 | 80 | 80 | 85 | 85 | 85 | 85 | 85 | 90 | 90 | 90 | 90 | 90 |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | |

### Table 4 Patternized wet bulb depression schedule

| Moisture Content (%) | W 11 | W 12 | W 13 | W 14 | W 15 | W 21 | W 22 | W 23 | W 24 | W 25 | W 31 | W 32 | W 33 | W 34 | W 35 | W 41 | W 42 | W 43 | W 44 | W 45 | W 51 | W 52 | W 53 | W 54 | W 55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wet bulb temperature for each schedule type (℃) | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 80 | | | | | | | | | | | | | | | | | | | | 5 | | | | | |
| | | | | | | | | | | | | | | | 4 | | | | | | | | | 7 | 8 |
| 70 | | | | | | | | | | | | | | | | | | | 5 | 6 | | | | | |
| | | | | | | | | | | 3 | | | | 4 | 5 | | | | | | | | 7 | 9 | 10 |
| 60 | | | | | 2 | | | | | | | | | | | | | 5 | 7 | 8 | | 7 | | | |
| | | | | | | | | | 3 | 4 | | | 4 | 5 | 7 | | 5 | | | | 7 | | 9 | 12 | 13 |
| 50 | | | | | 3 | | | | | | | | | | | | | 7 | 9 | 11 | | 10 | | | |
| | | | | 2 | | | | 3 | | | | 4 | 5 | | | 5 | 7 | | | | 9 | | | | |
| 45 | | | | | | | | | 4.5 | 6 | | | | 8 | 10 | | | | | | | | 13 | 15 | 16 |
| | | | 2 | 3 | | | 3 | 4 | | | 4 | 5 | 7 | | | 7 | 9 | 10 | | | 12 | | | | |
| 40 | | | | | 5 | | | | | | | | | | | | | | 13 | 14 | | 15 | | | |
| | | 2 | 3 | 4 | | 3 | 4 | 6 | 7 | | 6 | 7 | 9 | | | 10 | 12 | 13 | | | 16 | | | | |
| 35 | | | | | | | | | | 9 | | | | 12 | 13 | | | | | | | | 19 | 20 | 20 |
| | 2 | 3 | 5 | 6 | 8 | 5 | 6 | 8 | 9 | | 9 | 10 | 12 | | | 14 | 15 | 16 | 18 | | 20 | 20 | | | |
| 30 | | | | | | | | | | | | | | | | | | | | 19 | | | | | |
| | 3 | 5 | 7 | 8 | | 8 | 10 | 11 | 12 | 14 | 13 | 15 | 16 | 18 | 18 | 20 | 20 | 20 | | | 25 | 25 | 25 | 25 | |
| | 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | 12 | | | | | | | | | | | | | | 24 | | | | | | 25 |
| | 5 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 9 | 10 | 11 | | 13 | 15 | 16 | 16 | | 20 | 21 | 21 | | | 25 | 25 | 25 | | | 30 | 30 | 30 | 30 | |
| | 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | 20 | | | | 25 | 23 | | | | | 25 | | | | | |
| | 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 15 | 16 | 16 | 18 | 21 | 22 | 22 | 21 | | 30 | 30 | 30 | | | 30 | 30 | 30 | 30 | | | | | | 30 |
| 15 | 14 | | | | | | | | | | | | | | | | | | | | | | | | |
| | 20 | 25 | 25 | 25 | 25 | 30 | 30 | 30 | 30 | 30 | | | | 30 | 30 | | | | | 30 | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | |

## 4. Result and Discussion

(1) Three kinds of drying defects which are developed during the "Quick Drying Tests" of the tested species are given in Table (6), according to the test procedure column No. 3,4,5.

(2) According to these results, it can be seen that initial checks (surface check and end check) which occurred in the early stage were found in all of the tested species except in Thingan, U-Ban, Sagawa, Kaungmu, Thitmin, Kadauk, Tharapi and Pinle-on. Severe checks were observed in Timbers, such as Auk Chin Sa Ni and Leikthe.

(3) Severe deformation which occurred in the middle of drying was found to develop only in Kanyin-Ni. However, deformation occurred in Thingan, U-Ban, Sagawa, Kaungmu, Thitmin, Kadauk, Tharapi , Pinle-on, Kadu, Kant Zaw, Taungpayone, Tittto, Auk Chin Sa Ni , Leikthe and Kashit were found to be negligible.

(4) Honeycombing (internal checks) occurred in Kashit and Kanyin-Ni which used to occur during the end of drying. However, it was negligible.

Estimated Initial Dry Bulb Temperature (DBT), Initial Wet Bulb Depression (WBD) and Final Dry Bulb Temperature (DBT) of each species are also given in columns (6,7,8) of Table (6).

Based on the combination of three drying defects and initial moisture content of each species, patternized kiln schedule codes for each tested species were obtained and are given in columns (9) of Table (6).

Finally, the proposed kiln schedules of each of the tested species are given in Table (8) to (23). Based on these schedules, drying time to get 10 percent final moisture content are also estimated for each species and are shown in column (10) of Table (6).

According to the drying defects developed during the "Quick Drying Test", sixteen hardwood species in this paper are classified into six Grade, namely non-refractory timbers (i.e. easy to dry) as Grade I, moderately-refractory timbers as Grade II and III, refractory timbers (i.e. difficult to dry) as Grade IV, very refractory timber as Grade V and extremely refractory timber as Grade VI and are given in Table ( 7 ).

## 5. Conclusions

According to "Quick Drying Tests" there are six grades of recommended proposed kiln schedule based on wrinkling, honeycombing, collapse, end check and surface check. According to the kiln schedule results, Thingan, Kadauk, Pinle-on, Sagawa, U-Ban and Tharapi species are in Grade I (Non- Refractory) because of the least probability in wrinkling and checks. Kaunghmu, Kashit or Shit-kha or Thit-kha, Kant Zaw, Thit Min, Thitto and Taungpayone species are in Grade II

(Moderately Refractory). Auk Chin Sa Ni, Kadu and Leikthe species are in Grade III (Moderately Refractory) and Kanyin-Ni species is in Grade IV ( Refractory) respectively.

**Table 5. List of the Tested Hardwood Species**

| No | Local Name (Myanmar Name) | Botanical Names | Family | General Description |
|---|---|---|---|---|
| 1. | Auk Chin Sa Ni | *Amoora wallichii* King | Meliaceae | Roseate |
| 2. | Sagawa | *Michelia champaca* Linn. | Magnoliaceae | Greenish Yellow |
| 3. | Kaunghmu | *Anisoptera scaphula*(Roxb.)Pierre | Dipterocarpaceae | Pale yellowish-white |
| 4. | Kashit | *Pentace burmanica* Kz. | Tiliaceae | Reddish Brown |
| 5. | Kant Zaw | *Payena paralleloneura* Kurz. | Sapotaceae | Dark Chocolate Brown |
| 6. | U-Ban | *Shorea farinosa* Fischer | Dipterocarpaceae | Olive White |
| 7. | Tharapi | *Calophyllum amoenum Wall*. | Hypericaceae | Whitish Brown Streak |
| 8. | Thit Min | *Podocarpus wallichianus* Presl. | Podocarpaceae | Brownish-grey |
| 9. | Thingan | *Hopea odorata* Roxb. | Dipterocarpaceae | Pale Yellowish Green |
| 10. | Kanyin-Ni | *Dipterocarpus turbinatus Gaertn.f* | Dipterocarpaceae | Reddish-brown |
| 11. | Kadauk | *Aporusa wallichii* Hook.f. | Euphorbiaceae | Pinkish-white |
| 12. | Kadu | *Blumea virens* Dc. | Asteraceae | Greyish-brown |
| 13. | Thitto | *Sandiricum koetjiape* (Burm.f.) Merr. | Meliaceae | Light Pinkish-red |
| 14. | Pinle-on | *Xylocarpus gangeticus* (Prain) C.E. Park. | Meliaceae | Pinkish Red |
| 15. | Leikthe | *Diospyros spp.* | *Ebenaceae* | Pinkish dark black streaks |
| 16. | Taungpayon | | | Yellowish White |

**Table 6. Experimental results by Tanintharyi species**

| Species | Initial MC% | Variety & Degree of drying defect | | | Drying Condition | | | Pattenrize dSchedule Code No. | Estimate Drying Time (Days) |
|---|---|---|---|---|---|---|---|---|---|
| | | Initial Check | Deform-ation | Honey - combing | Initial DBT (°C) | Initial WBD (°C) | Final DBT (°C) | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Thingan(*Hopea odorata* Roxb.) | 37.40 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{51}W_{52}$ | 4-6 |
| U-Ban (*Shorea farinosa* Fischer) | 44.7 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{51}W_{52}$ | 4-6 |
| Sagawa (*Michelia champaca* Linn.) | 53.33 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{52}W_{43}$ | 4-6 |
| Kaunghmu (*Anisoptera scaphula*(Roxb.)Pierre | 100.8 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{45}W_{45}$ | 4-6 |
| Thit Min (*Podocarpus wallichianus* Presl.) | 74.41 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{43}W_{44}$ | 4-6 |
| Kadauk (*Aporusa wallichii* Hook.f.) | 53.01 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{52}W_{43}$ | 4-6 |
| Tharapi (*Calophyllum amoenum Wall.*) | 62.24 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{51}W_{43}$ | 4-6 |
| Pinle-on (*Xylocarpus gangeticus* (Prain) C.E. Park.) | 44.46 | 1 | 1 | 1 | 70 | 6.5 | 95 | $D_{51}W_{52}$ | 4-6 |
| Kadu | 145.38 | 2 | 1 | 1 | 65 | 5.5 | 90 | $D_{35}W_{35}$ | 4-7 |
| Kant Zaw (*Payena paralleloneura* Kurz.) | 54.30 | 3 | 1 | 1 | 60 | 4.3 | 85 | $D_{42}W_{33}$ | 5-7 |
| Taungpayone | 61.48 | 4 | 1 | 1 | 55 | 3.6 | 83 | $D_{43}W_{24}$ | 6-8 |
| Thitto (*Sandiricum koetjiape* (Burm.f.) Merr.) | 47.1 | 4 | 1 | 1 | 55 | 3.6 | 83 | $D_{42}W_{23}$ | 6-8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Auk Chin Sa Ni (*Amoora wallichii* King) | 28.59 | 6 | 1 | 1 | 50 | 2.3 | 81 | $D_{31}W_{22}$ | 9-13 |
| Leikthe (*Diospyros spp.*) | 29.78 | 6 | 1 | 1 | 50 | 2.3 | 81 | $D_{31}W_{13}$ | 9-13 |
| Kashit or Shit –kha or Thit-kha (*Pentace burmanica* Kz.) | 54.25 | 4 | 1 | 2 | 55 | 3.6 | 83 | $D_{42}W_{23}$ | 6-8 |
| Kanyin-Ni (*Dipterocarpus turbinatus Gaertn.f* ) | 59.1 | 2 | 7 | 2 | 48 | 2.8 | 73 | $D_{23}W_{43}$ | 9-13 |

**Table ( 7) Grading of sixteen Hardwood Species According to their Drying Behavior**

| Grade - I | Grade - II | Grade - III | Grade - IV |
|---|---|---|---|
| Non-Refractory Timbers | Moderately-Refractory Timbers | Moderately-Refractory Timbers | Refractory Timbers |
| 1. Thingan | 1. Kaunghmu | 1. Auk Chin Sa Ni | 1. Kanyin-Ni |
| 2. Kadauk | 2. Kashit or Shit-kha or Thit-kha | 2. Kadu | |
| 3. Pinle-on | 3. Kant Zaw | 3. Leikthe | |
| 4. Sagawa | 4. Thit Min | | |
| 5. U-Ban | 5. Thitto | | |
| 6. Tharapi | 6. Taungpayone | | |

**6. Recommendation**

Some hardwood species in Tanintharyi Region are in good quality and also attractive because of their bright colors. Moreover, Thingan and U-Ban species has been using mainly in construction of fishing boats and masts. Leikthe species is very attractive due to its bright color. Sagawa, Pinle-on, Tharapi, Kaunghmu and Kashit or Shit-Kha or Thit-kha species has been utilizing in making altar, bed, table, show case, dressing table, dream bed and other furniture. Auk Chin Sa Ni species is being used in making tables and settee.

Therefore, to reduce the depletion of value added hardwood species in Tanintharyi Region, establishing hardwood plantations should be done more widely.

**Proposed Kiln Schedules for Sixteen Hardwood Species from Tanintharyi Region**

**Table (8) Auk Chin Sa**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 40 | 55 | 3 |
| 40~35 | 55 | 4 |
| 35~30 | 55 | 6 |
| 30~25 | 60 | 10 |
| 25~20 | 65 | 15 |
| 20~15 | 70 | 22 |
| 15~10 | 80 | 30 |
| <10 | 80 | 30 |
| | | |
| | | |
| | | |

**Table (9) Sagawa**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 5 |
| 55~50 | 70 | 7 |
| 50~45 | 70 | 7 |
| 45~40 | 70 | 10 |
| 40~35 | 70 | 13 |
| 35~30 | 75 | 16 |
| 30~25 | 80 | 20 |
| 25~20 | 80 | 25 |
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |

**Table (10) Taunng Payon**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 50 | 60 | 3 |
| 50~45 | 60 | 4.5 |
| 45~40 | 60 | 4.5 |
| 40~35 | 65 | 7 |
| 35~30 | 65 | 9 |
| 30~25 | 70 | 12 |

**Table (11) Kant Zaw**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 50 | 60 | 4 |
| 50~45 | 60 | 5 |
| 45~40 | 60 | 7 |
| 40~35 | 60 | 9 |
| 35~30 | 65 | 12 |
| 30~25 | 70 | 16 |

| | | |
|---|---|---|
| 25~20 | 75 | 16 |
| 20~15 | 80 | 21 |
| 15~10 | 85 | 30 |
| <10 | 85 | 30 |

**Table (12) Kashit or Shit-kha or Thit-kha**

| | | |
|---|---|---|
| 25~20 | 75 | 21 |
| 20~15 | 80 | 30 |
| 15~10 | 85 | 30 |
| <10 | 85 | 30 |

**Table (13) Pinle-on**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 45 | 60 | 3 |
| 45~40 | 60 | 4 |
| 40~35 | 60 | 6 |
| 35~30 | 65 | 8 |
| 30~25 | 70 | 11 |
| 25~20 | 75 | 16 |
| 20~15 | 80 | 22 |
| 15~10 | 85 | 30 |
| <10 | 85 | 30 |
| | | |
| | | |

**Table (14) Kadu**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 7 |
| 55~50 | 70 | 10 |
| 50~45 | 70 | 10 |
| 45~40 | 70 | 15 |
| 40~35 | 70 | 16 |
| 35~30 | 70 | 20 |
| 30~25 | 75 | 25 |
| 25~20 | 80 | 30 |
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |

**Table (15) Leikthe**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 70 | 55 | 4 |

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 40 | 55 | 2 |

| | | |
|---|---|---|
| 70~65 | 55 | 5 |
| 65~60 | 55 | 5 |
| 60~55 | 55 | 7 |
| 55~50 | 60 | 7 |
| 50~45 | 60 | 10 |
| 45~40 | 60 | 10 |
| 40~35 | 65 | 13 |
| 35~30 | 65 | 13 |
| 30~25 | 70 | 18 |
| 25~20 | 75 | 23 |
| 20~15 | 75 | 23 |
| 15~10 | 80 | 30 |
| <10 | 80 | 30 |

| | | |
|---|---|---|
| 40~35 | 55 | 3 |
| 35~30 | 55 | 5 |
| 30~25 | 60 | 7 |
| 25~20 | 65 | 10 |
| 20~15 | 70 | 16 |
| 15~10 | 80 | 25 |
| <10 | 80 | 25 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Table (16) U-Ban**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 7 |
| 55~50 | 70 | 10 |
| 50~45 | 70 | 10 |
| 45~40 | 70 | 15 |
| 40~35 | 70 | 16 |
| 35~30 | 70 | 20 |
| 30~25 | 75 | 25 |

**Table (17) Kaungmu**

| Moisture Content(%) | Dry Bulb Temperature (°C | Wet Bulb Depression (°C) |
|---|---|---|
| Above 75 | 60 | 5 |
| 75~70 | 60 | 6 |
| 70~65 | 60 | 6 |
| 65~60 | 60 | 8 |
| 60~55 | 60 | 8 |
| 55~50 | 65 | 11 |
| 50~45 | 65 | 11 |

| | | |
|---|---|---|
| 25~20 | 80 | 30 |
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |
| | | |
| | | |
| | | |
| | | |

| | | |
|---|---|---|
| 45~40 | 65 | 16 |
| 40~35 | 70 | 16 |
| 35~30 | 70 | 19 |
| 30~25 | 75 | 19 |
| 25~20 | 80 | 25 |
| 20~15 | 80 | 25 |
| 15~10 | 85 | 30 |
| <10 | 85 | 30 |

**Table (18) Tharapi**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 5 |
| 55~50 | 70 | 7 |
| 50~45 | 70 | 7 |
| 45~40 | 70 | 10 |
| 40~35 | 70 | 13 |
| 35~30 | 70 | 16 |
| 30~25 | 75 | 20 |
| 25~20 | 80 | 25 |
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |
| | | |

**Table (19) Thit Min**

| Moisture Content(%) | Dry Bulb Temperature (°C | Wet Bulb Depression (°C) |
|---|---|---|
| Above 60 | 60 | 5 |
| 60~55 | 60 | 7 |
| 55~50 | 60 | 9 |
| 50~45 | 60 | 9 |
| 45~40 | 60 | 13 |
| 40~35 | 65 | 13 |
| 35~30 | 65 | 18 |
| 30~25 | 70 | 24 |
| 25~20 | 75 | 24 |
| 20~15 | 80 | 30 |
| 15~10 | 85 | 30 |
| <10 | 85 | 30 |

**Table (20) Thingan**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 7 |
| 55~50 | 70 | 10 |
| 50~45 | 70 | 10 |
| 45~40 | 70 | 15 |
| 40~35 | 70 | 16 |
| 35~30 | 70 | 20 |
| 30~25 | 75 | 25 |
| 25~20 | 80 | 30 |
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |

**Table (21) Kanyi-ni**

| Moisture Content(%) | Dry Bulb Temperature (°C | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 50 | 5 |
| 55~50 | 50 | 7 |
| 50~45 | 50 | 7 |
| 45~40 | 50 | 10 |
| 40~35 | 55 | 13 |
| 35~30 | 55 | 16 |
| 30~25 | 60 | 20 |
| 25~20 | 65 | 25 |
| 20~15 | 70 | 30 |
| 15~10 | 75 | 30 |
| <10 | 75 | 30 |

**Table (22) Kadauk**

| Moisture Content(%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Above 55 | 70 | 5 |
| 55~50 | 70 | 7 |
| 50~45 | 70 | 7 |
| 45~40 | 70 | 10 |
| 40~35 | 70 | 13 |
| 35~30 | 75 | 16 |
| 30~25 | 80 | 20 |
| 25~20 | 80 | 25 |

**Table (23) Thitto**

| Moisture Content(%) | Dry Bulb Temperature (°C | Wet Bulb Depression (°C) |
|---|---|---|
| Above 45 | 60 | 3 |
| 45~40 | 60 | 4 |
| 40~35 | 60 | 6 |
| 35~30 | 65 | 8 |
| 30~25 | 70 | 11 |
| 25~20 | 75 | 16 |
| 20~15 | 80 | 22 |
| 15~10 | 85 | 30 |

| | | |
|---|---|---|
| 20~15 | 85 | 30 |
| 15~10 | 90 | 30 |
| <10 | 90 | 30 |

| | | |
|---|---|---|
| <10 | 85 | 30 |
| | | |
| | | |

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Appendix

**Recommended Kiln Schedule**

Schedule A

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 70 | 6 |
| 75 | 70 | 5 |
| 65 | 70 | 8 |
| 55 | 70 | 11 |
| 45 | 75 | 14 |
| 35 | 80 | 19 |
| 25 | 85 | 25 |
| 15 | 90 | 30 |

Schedule B

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 60 | 4 |
| 60 | 60 | 5 |
| 50 | 65 | 8 |
| 40 | 70 | 12 |
| 30 | 75 | 18 |
| 20 | 80 | 25 |
| 15 | 85 | 30 |
| | | |

Schedule C

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 55 | 3 |
| 60 | 55 | 4 |
| 50 | 60 | 6 |
| 40 | 65 | 9 |
| 30 | 70 | 14 |
| 20 | 75 | 20 |
| 15 | 80 | 30 |
| | | |

Schedule D

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 50 | 3 |
| 45 | 50 | 4 |
| 40 | 50 | 6 |
| 35 | 55 | 8 |
| 30 | 60 | 11 |
| 25 | 65 | 16 |
| 20 | 70 | 22 |
| 15 | 75 | 30 |

Schedule E

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 50 | 2 |
| 45 | 50 | 3 |
| 40 | 50 | 4 |
| 35 | 55 | 6 |
| 30 | 60 | 8 |
| 25 | 65 | 11 |
| 20 | 70 | 16 |
| 15 | 75 | 25 |

Schedule F

| Moisture Content (%) | Dry Bulb Temperature (°C) | Wet Bulb Depression (°C) |
|---|---|---|
| Green | 45 | 3 |
| 60 | 45 | 4 |
| 50 | 45 | 6 |
| 40 | 50 | 8 |
| 35 | 55 | 11 |
| 30 | 60 | 16 |
| 25 | 65 | 22 |
| 20 | 70 | 30 |

**Photos of Some Commercial Hardwood Species from Tanintharyi Region**

Thingan Trees

Thingan Timber

Construction of Fishing Boats with Thingan and U-Ban

Sample Preparation

Quick Drying Test

Tested of Some Commercial Species

Furniture of Leikthe

Furniture of Auk-Chin-Sa-Ni

Furniture of Pinle-on

Furniture of Kashit (or) Shit-kha (or) Thit-kha

Furniture of Sagawa