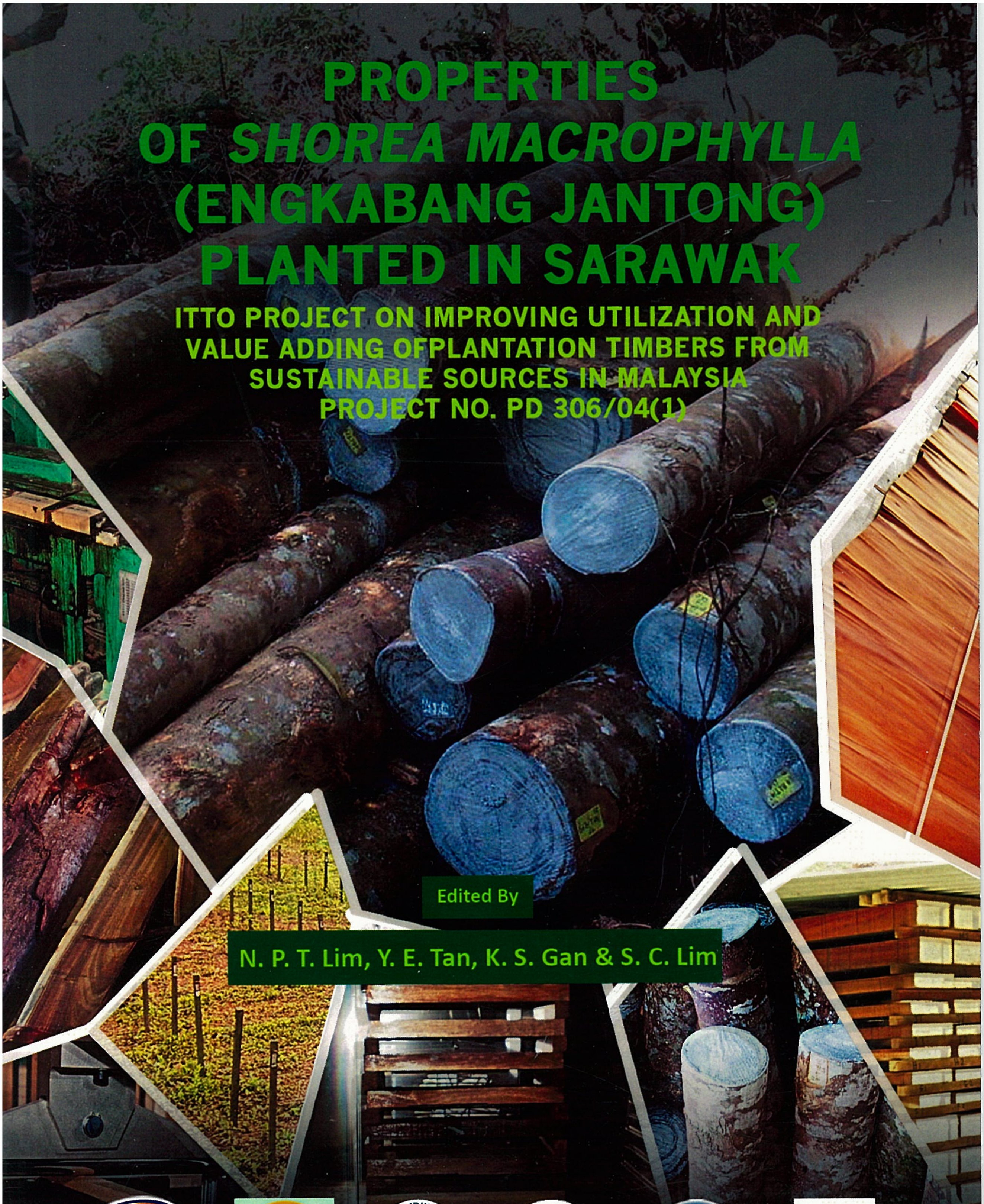

PROPERTIES OF *SHOREA MACROPHYLLA* (ENGKABANG JANTONG) PLANTED IN SARAWAK

ITTO PROJECT ON IMPROVING UTILIZATION AND VALUE ADDING OFPLANTATION TIMBERS FROM SUSTAINABLE SOURCES IN MALAYSIA PROJECT NO. PD 306/04(1)

Edited By

N. P. T. Lim, Y. E. Tan, K. S. Gan & S. C. Lim

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PREFACE

The ITTO project, on IMPROVING UTILIZATION AND VALUE ADDING OF PLANTATION TIMBERS FROM SUSTAINABLE SOURCES IN MALAYSIA PROJECT NO. PD 306/04(1) was implemented for a duration of 36 months, starting on 15 September 2006. This project was jointly funded by International Tropical Timber Organization (ITTO) and the Malaysian Government. It focused on improved utilization and value adding of selected plantation-grown resources in the three regions of Malaysia, namely Peninsular Malaysia, Sarawak and Sabah. The overall development objective was to improve end-uses of Malaysian forest plantation resources through systematic evaluation of their basic physical and other properties. The timber species worked on were *Acacia mangium* from Peninsular Malaysia, engkabang jantong (*Shorea macrophylla*) from Sarawak, and teak (*Tectona grandis*) from Sabah.

The project was a collaborative research project undertaken by the Forest Research Institute Malaysia (FRIM) as the leading agency, the Timber Research & Technical Training Centre (TRTTC), Sarawak, and the Forest Research Centre (FRC), Sabah as collaborative partners. The Forestry and the Forest Products Research Institute (FFPRI), Japan, the international collaborator of the project provided technical guidance and expert training to project members through the dispatch of their experts to Malaysia.

This report on the properties of *Shorea macrophylla* (engkabang jantong) formed part of the output of the project. The results were obtained using the harmonized testing methods proposed during the first phase of the project.

We would like to express our sincere appreciation to ITTO, Government of Japan and the Malaysian Government for funding the project; the Director, Forest Department, Sarawak, and the National Project Director for their support; the Forestry and Forest Products Research Institute (FFPRI), Japan, for providing the training facilities; and finally, to fellow project members for their help and guidance.

N. P. T. Lim
Y. E. Tan
K. S. Gan
S. C. Lim

INTRODUCTION

N. P. T. Lim & T. C. Wong

Sarawak embarked on a number of reforestation and rehabilitation programmes during the 1970s. To date, a myriad of potential species, both indigenous and exotic have been introduced and trial plantation plots covering several thousand hectares have been progressively established in Forest Reserves and other parts of the Permanent Forest Estate (PFE) throughout the State. Based on encouraging findings from some planting trials (Figure 1), the state authorities have set out to promote the establishment of forest plantations for the purpose of reducing reliance on the natural forests for sustaining Sarawak's timber industry. To date, some 2.8 million hectares of land have been demarcated for the targeted establishment of 1 million hectares of planted forests in the state by year 2020.

Figure 1 Engkabang jantong stands

Shorea macrophylla, locally known as engkabang jantong, is considered a medium-fast-growing plantation species from the *Shorea* genus and Dipterocarpaceae family (Figure 1). It is endemic in Sarawak as well as other parts of Borneo and usually found along river banks and flooded alluvial plains where the soil has high water retention ability. *Shorea macrophylla* is a totally protected species in the natural forest as its fruit, known as illipenut, is a commodity of some commercial importance. However, this designation is not applicable to its planted form. *Shorea macrophylla* is a site specific species and grows well (with a growth rate of 2.2 cm mean annual increment in diameter breast height) on clay alluvial soil of riparian forest and lower slopes of clay hills below 600 m above sea level. Its seeds are recalcitrant, taking two to three days to germinate under natural conditions and up to two weeks at 16 °C. The species can be easily propagated by seeds or stem cuttings. There are no known serious pest or disease problems at any stage from seedling to matured tree except for fungal attack on its fruits.

General information on wood properties of naturally grown *Shorea macrophylla* is available. The sapwood is not easily differentiated from the heartwood by colour. The timber is pale cream in colour, sometimes having a pinkish tinge, weathering to light

Figure 2 Engkabang jantong wood-pale cream colour

yellow brown or light straw (Figure 2). The wood grain is interlocked and its texture is moderately coarse to coarse and even. Planed surfaces are lustrous but occasionally with feathery tracery along its tangential or flat-sawn surfaces due to the presence of false growth rings. It has a mean basic density of 329 ± 66 kg m^{-3} but can range from 199 to 622 kg m^{-3} and is classified under Light Hardwood group. Based on its mechanical strength properties, it falls under the Strength Grouping of C. Graveyard tests carried out in at two test sites indicated a natural durability of about 1.5 years. It is also moderately difficult to treat with preservative.

On the other hand, the wood utilization properties of planted engkabang jantong have been relatively unknown. The Timber Research and Technical Training Centre (TRTTC) of Sarawak's Forest Department addressed this problem by introducing the species for study under the auspices of the ITTO project PD 306/04 (I), "Improving Utilization and Value Adding of Plantation Timbers from Sustainable Sources in Malaysia". By application of the harmonized test methodology developed from this project, various physical and utilization properties of 13-y-old and 22-y-old *S. macrophylla* have been thoroughly assessed and established. Based on the findings of the said project, *S. macrophylla* has been found suitable for end-uses such as interior finishing, moulding, paneling, general utility furniture, balustrade, joinery, cabinet-making and general-utility plywood (Figure 3).

Figure 3 Products made using engkabang jantong

It is hoped that this book will serve as a useful guide to forest plantation owners, researchers, timber buyers and end-users who are interested to know more about the properties and utilization of planted *Shorea macrophylla*.

SAMPLING AND COLLECTION

Andrew Nyorik Nibu & Alik Duju

INTRODUCTION

Literature search was extensively carried out to gather information and establish a suitable methodology that can be adopted and universally accepted by the tropical plantation forest community. The existing ISO standard (Anonymous 1982) only covers the sampling of trees for physical and mechanical tests. The FFPRI (Forestry and Forest Products Research Institute) methodology includes the bucking patterns which provide test logs for more tests such as wood anatomy, sawing, machining, drying, durability and gluing. Additional test materials for peeling, slicing and chemical properties are also introduced to the adopted bucking pattern. Based on these considerations, the harmonized test methodology was developed (Tan et al. 2010) and incorporated adopted procedures from both the existing ISO standard and FFPRI methodology (Anonymous 2004).

The reliability and suitability of this methodology for the sampling and collection of *Shorea marcophylla*, a potential reforestation species for plantation establishment in Sarawak, were tested covering:

- Selection of test area
- Selection of sample trees in the test area
- Allocation of logs for different tests

MATERIALS AND METHODS

Selection of sampling plots

The test area selected was Sabal Forest Reserve, Km 100 Kuching-Sri Aman Road, Samarahan Division, and *Shorea marcophylla,* locally known as engkabang jantong, was represented by two age groups, ie 13 years and 22 years old respectively, as shown in Figures 1 and 2. The inventory of all standing trees was carried out in three selected plots from three compartments.

Figure 1 13-y-old *Shorea marcophylla*

Figure 2 22-y-old *Shorea marcophylla*

Selection of sample trees

Inventory

The inventory data of all standing trees collected from the three compartments, namely 8712, 8715 and 8507, are summarized Table 1 below:

Table 1 Summary of inventoried trees

Compartment	8712 (Plot 1)	8715 (Plot 2)	8507 (Plot 3)
Year planted	1994	1994	1985
No. of trees inventoried	170	151	125
DBH (cm)	5.0–32.0	5.6–34.7	18.3–66.0
Comment	Not selected for sampling due to the difficult terrain (directional felling problem, transport and possible compression failure due to felling impact)	Selected for sampling (after eliminating defective trees and those with presence of decay and short bole length)	Selected for sampling. (after eliminating defective trees and those with presence of decay and short bole length)

The field data collected were examined and the average diameters of the *S. macrophylla* were 17.0, 19.8 and 25.7 cm from compartments 8712, 8715 and 8507 respectively. Other factors taken into consideration were visible defects, short bole length and big branches. Based on these data, only Plots 2 and 3 were selected from compartments 8715 and 8507 respectively. The selected trees in each plot were marked with plastic tags, inventory numbers and their diameters. Inventory of the trees is as shown in Figures 3 and 4.

Figure 3 Measuring diameter at breast height

Figure 4 Taking bole length and tagging

Sampling and collection

Sampling and collection were carried out by experienced TRTTC staff to ensure that the test logs felled were in good condition. *Shorea macrophylla* is very prone to compression failure and end-splits due to felling impact. In Plot 3, where the area was flat and slightly swampy, the "kuda-kuda" method (Figure 5) was used to bring the logs out to the landing point. No heavy machinery was used, to minimize impact on the environment at the plantation plots.

Figure 5 "Kuda-kuda" method

Grouping of trees

The inventoried trees were given numbers arranged by diameter size in an alternating descending and ascending order for each group. In each group of 16 trees, they were arranged from the smallest diameter to the biggest diameter (descending order) and immediately followed by the next group starting from the smallest to the biggest diameter (ascending order). This arrangement of grouping ended with the biggest diameter in Group 6 (Tables 2 and 3).

Batch number

Each representative batch was supposed to comprise a wide range of different diameter trees. Both Plots 2 and 3 had even number of trees (16 trees) in each group. In this case, the central row that would be used to determine Batch No. 1 (B1) started from row 8. Subsequently, the rows below Batch No. 1 were allocated with even batch numbers (B2, B4, B6, B8 and B10) and batches above Batch No. 1 with odd numbers (B3, B5, B7 and B9). This was to ensure proper matching of sample tree diameters between batches and is clearly indicated in Tables 2 and 3.

Table 2 Compartment 8715 planted in 1994 (13 y old – Plot 2)

	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5		GROUP 6	
Batch No.	Tree No.	DBH ↓	Tree No.	DBH ↑	Tree No.	DBH ↓	Tree No.	DBH ↑	Tree No.	DBH ↓	Tree No.	DBH ↑
	115	14.0	87	18.7	102	18.7	40	23.4	70	23.4	**	
	45	14.2	142	18.2	103	18.8	27	23.3	64	23.6	**	
	61	14.2	36	18.1	101	19.0	60	23.1	92	24.0	99	34.7
B9	132	14.2	126	18.0	37	19.1	149	23.0	89	24.3	35	33.8
B7	78	14.4	139	17.7	46	19.1	34	22.8	42	24.7	96	33.1
B5	129	14.6	13	17.6	10	19.4	41	22.1	24	25.0	53	30.9
B3	76	15.0	88	17.5	86	19.6	18	22.0	2	25.1	23	30.3
B1	124	15.1	63	17.5	75	19.8	143	21.7	68	25.1	136	30.0
B2	85	15.3	59	17.5	17	19.9	54	21.7	4	25.2	138	29.8
B4	121	15.5	145	17.2	22	19.9	94	21.4	6	25.3	3	29.5
B6	118	15.9	120	17.2	151	19.9	1	21.1	109	25.7	25	29.0
B8	14	16.0	98	17.1	28	20.0	130	20.8	73	26.0	21	28.7
B10	134	16.3	43	17.1	74	20.0	112	20.8	135	26.0	32	28.0
	146	16.5	133	16.9	100	20.0	7	20.8	128	26.3	26	27.8
	8	16.7	119	16.8	11	20.1	16	20.5	33	26.7	56	27.0
	9	16.7	114	16.8	47	20.1	113	20.1	19	26.8	20	26.9

Table 3 Compartment 8507 planted in 1985 (22 y old – Plot 3)

	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5		GROUP 6	
Batch No.	Tree No.	DBH ↓	Tree No.	DBH ↑	Tree No.	DBH ↓	Tree No.	DBH ↑	Tree No.	DBH ↓	Tree No.	DBH ↑
	90	18.3	74	22.7	55	22.8	38	27.5	49	27.5	**	
	10	18.4	47	22.5	18	23.0	93	27.3	53	27.7	125	66.0
	88	18.8	51	22.4	32	23.0	70	27.3	58	27.9	121	41.1
B9	64	18.9	16	22.4	7	23.1	45	27.2	43	28.1	120	40.5
B7	109	19.0	76	22.3	85	23.2	8	27.0	42	28.3	99	37.8
B5	11	19.2	48	22.3	112	23.3	29	26.7	6	28.5	116	37.3
B3	23	19.3	1	22.2	46	23.4	54	26.6	57	28.6	122	37.2
B1	31	19.7	86	21.9	95	23.8	104	26.2	40	29.9	60	36.1
B2	75	20.0	3	21.4	98	23.8	24	26.1	87	30.0	84	35.5
B4	39	20.2	89	21.2	14	24.0	80	25.3	82	31.2	4	35.4
B6	41	20.2	61	21.2	30	24.1	106	25.2	83	31.4	27	35.0
B8	68	20.2	17	21.2	65	24.3	12	25.1	66	31.7	100	34.7
B10	94	20.3	103	21.1	36	24.4	71	24.8	9	32.1	63	33.8
	15	20.5	72	21.0	56	24.4	107	24.7	25	32.5	2	33.6
	44	20.6	20	21.0	91	24.5	21	24.7	96	32.5	26	33.5
	19	20.7	50	20.8	108	24.5	13	24.7	105	32.8	5	32.9

DBH - Diameter at breast height (over bark in cm) at 1.3 m from root collar.
** A few months after the inventory, some sample trees were blown over by strong winds before collection was possible.

ALLOCATION OF LOGS FOR DIFFERENT TESTS

It was anticipated that tests covering most aspects of wood properties and utilization would be conducted, each test requiring different lengths and quantities. Each of the log samples was cut to the required lengths starting from the root collar. The sections from each log for the different tests are listed in Table 4 and illustrated in the bucking pattern shown in Figure 6.

Labelling of log samples

All the log samples were marked with plastic tags, the plot number, group number, batch number and tree number to facilitate traceability. The exposed ends of each log were coated with paint to reduce splits, end-checks and biodeterioration.

Table 4 Distribution of log samples for the different tests

Batch No.		Tests
B1	-	Anatomy/chemistry (*B.M.T. section), mechanical (2.5 m), durability/ preservation (1.5 m)
B2	-	Mechanical testing (2.5 m) & peeling (2.5 m)
B3	-	Slicing (2.5 m) and peeling (2.5 m)
B4	-	Sawing yield, then used for drying (2.0 m) & machining (3.0 m)
B5	-	Sawing yield, then used for drying (2.0 m), sawing & gluing (3.0 m)
B6	-	Sawing yield, then used for drying (2.0 m) & machining (3.0 m)
B7	-	Sawing yield, then used for drying (2.0 m), sawing & gluing (3.0 m)
B8	-	Sawing yield (5.0 m)
B9	-	Sawing yield (5.0 m)
B10	-	Sawing yield (5.0 m)

*B.M.T. sections – Bottom section, Middle section and Top section, each of 5-cm thick discs

It was observed that *S. macrophylla*, being a light-coloured timber is highly susceptible to attack by blue stain fungi and wood borers. All freshly felled logs extracted from the plots were immediately brushed with fungicide and insecticide to prevent biodeterioration. However, logs destined for durability test were not treated, but instead were immediately transported to the TRTTC and stored in a log pond.

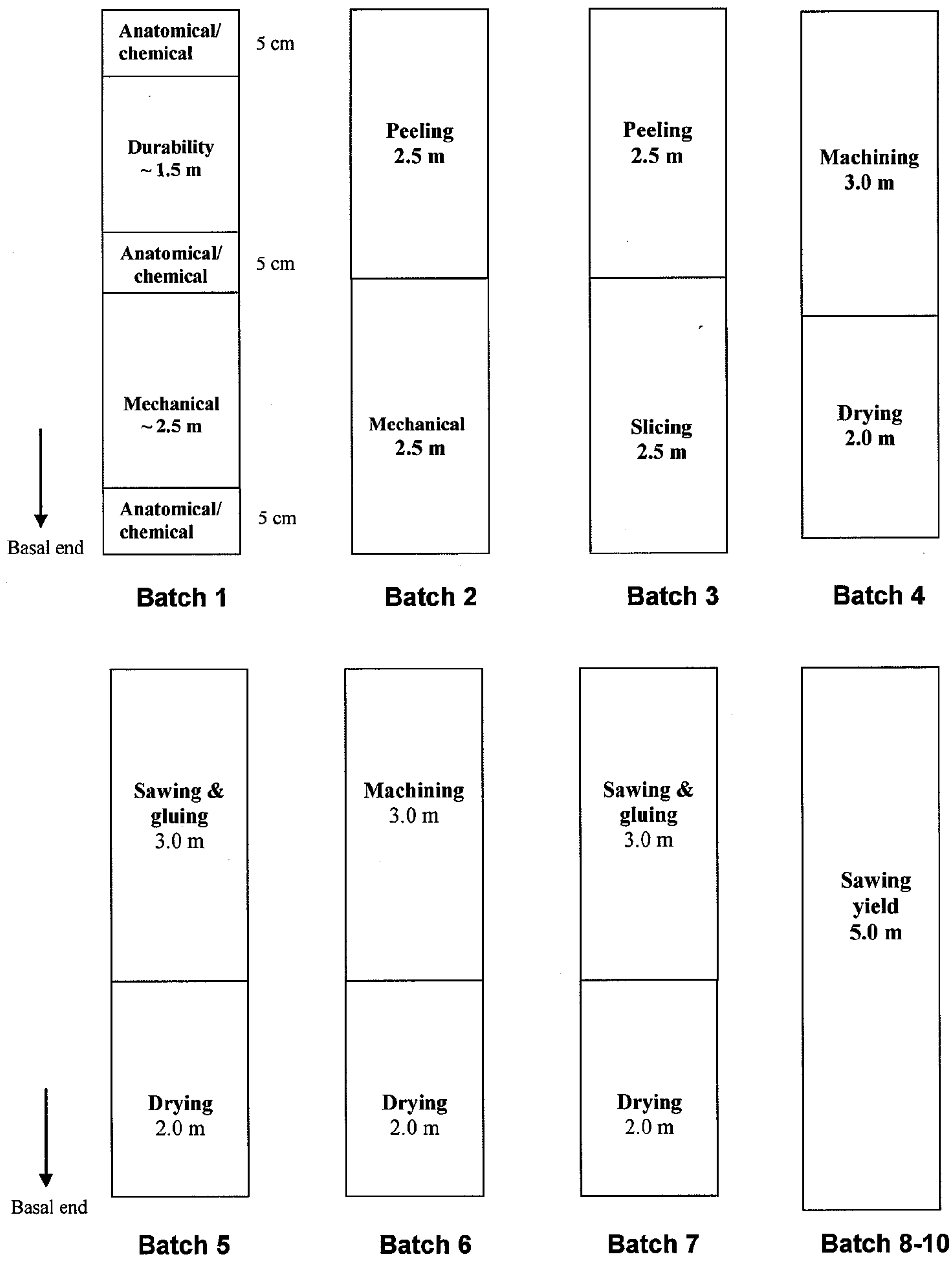


Figure 6 Bucking pattern for sample logs from each batch for different tests

CONCLUSION

The harmonized methodology developed for sampling and collection of tropical plantation timbers was found to be suitable for the sampling and collection of *S. macrophylla.* It is recommended that no heavy machinery be deployed for the extraction of logs from felling sites in order to avoid unnecessary damage to the sample logs, apart from the environmental concern.

REFERENCES

ANONYMOUS. 1982. ISO 4471. *Wood—Sampling Sample Trees and Logs for Determination of Physical and Mechanical Properties of Wood in Homogeneous Stands.*

ANONYMOUS. 2004. *Testing Methods of Various Wood Properties of Fast Growing Tropical Timbers.* Technical Report of the Project Development Committee No. 18. Forestry and Forest Products Research Institute, Tsukuba, Japan.

TAN, Y. E., LIM, N P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

ACKNOWLEDGEMENTS

The authors wish to thank all members of the TRTTC field crew led by Willies Chin in carrying out the sampling and collection of *Shorea macrophylla* trees.

Field activities in pictures

Members of the collection team

Felling the basal section of a sample tree

Recording field data

Getting logs out of a difficult terrain

Loading of logs

Log inspection at the landing site

C2 T23 attacked by wood borers after three weeks


Compartment 8715, Plot 2 after sampling

WOOD ANATOMY AND QUALITY

M. C. Yang & S. L. Voon

INTRODUCTION

Shorea macrophylla (engkabang jantong) was introduced as a plantation species in Sabal Forest Reserve in Kuching, Sarawak, under the reforestation programme in 1985. However, no studies on the wood properties and utilization of this planted engkabang jantong have been carried out.

The present studies were aimed at assessing the testing methods outlined in the manual *Testing Methods for Plantation Grown Tropical Timbers* (Tan et al. 2010).

MATERIALS AND METHODS

Six trees, each of 13-y-old and 22-y-old engkabang jantong planted in Sabal Forest Reserve, Kuching, Sarawak, were collected for the studies (Table 1).

Table 1 Diameters of sample discs taken at the bottom, middle and top of the trees

	13-y-old				22-y-old		
Tree No.	Diameter of sample disc (cm)			Tree No.	Diameter of sample disc (cm)		
	Bottom	Middle	Top		Bottom	Middle	Top
C2G1T124	19.0	17.0	15.0	C3G1T31	20.5	18.8	16.5
C2G2T63	20.5	19.5	18.0	C3G2T86	23.6	22.0	19.5
C2G3T75	21.0	20.5	18.0	C3G3T95	25.9	24.0	22.8
C2G4T143	24.0	21.0	18.0	C3G4T104	27.8	23.1	20.0
C2G5T68	27.0	25.0	23.0	C3G5T40	31.8	29.7	25.6
C2G6T136	32.5	30.0	26.5	C3G6T60	36.7	36.4	32.9

The sampling of trees was based on the procedure as outlined by Tan et al. (2010). The length of log collected for each tree was 5 m from the bottom of the tree. To ensure that test samples and specimens for the studies were consistent, a shallow groove was cut along the length of the log using a chainsaw. Three discs representing the bottom, middle and top ends from each log were collected. Before the discs were cut into samples for the various studies, the diameter, the sapwood and heartwood width were first assessed in order to determine the percentage of sapwood and heartwood.

A 50-mm-wide slab was obtained from each disc along the diameter. Slabs were kept green by storing them in a freezer. From these slabs, sample blocks of dimensions 2 × 2 × 5 cm were taken according to Figure 1, which has the pith at the centre, and Figure 2, where there is eccentricity. For each of the sample block, specimens of 1 cm^3

were prepared for density determination and variation studies. The remaining portion was used for slide preparation for anatomical and fibre morphological studies.

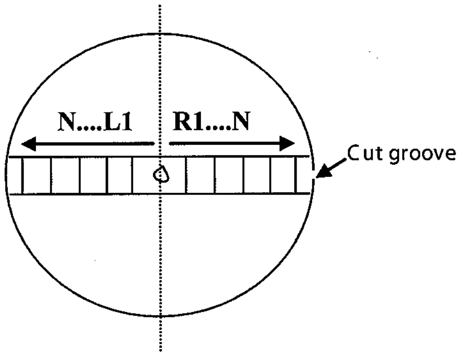


Figure 1 Selection of samples for disc with pith at centre

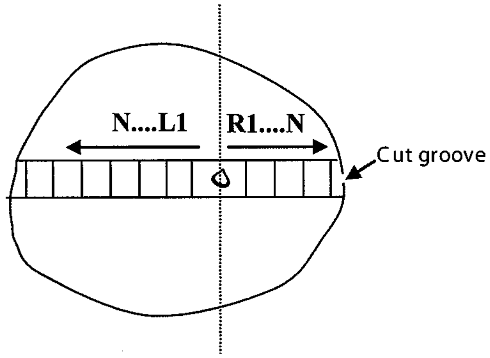


Figure 2 Selection of samples for disc with eccentricity

The moisture content, green and basic densities were determined as outlined in Appendices 8.1 and 8.2 (Tan et al. 2010). The basic density was determined by dividing the oven-dry weight by the green volume of the specimen. The oven-dry weight was obtained by drying the specimen in an oven at 103 ± 2 °C until constant weight was achieved. The volume was obtained by the water displacement method.

For fibre morphological studies, match-stick sized splinters were prepared and macerated in a 10-ml bottle containing a mixture of 30% hydrogen peroxide and 100% glacial acetic acid (1:1 in volume). The bottle was kept in the oven set at 60 °C overnight. The splinters were rinsed several times with distilled water after they became white. The macerated fibres were then placed on the glass slide using tweezers. For each specimen, 25 fibres were randomly selected and measured.

For wood anatomical studies, three specimens each of 1 cm^3 were selected, representing the sapwood, heartwood and wood near the pith. The specimens were first softened by boiling for 2 hr before sectioning. Then, 15-µm-thick sections consisting of transverse, tangential and radial sections were prepared using a sliding microtome. Features of the wood were examined using the guidelines as given in Wheeler et al. (1989).

RESULTS AND DISCUSSION

Sapwood percentage

In engkabang jantong, there is no clear boundary between the sapwood and the heartwood as shown in Figure 3. Hence, the amount of sapwood cannot be determined visually. However, since the sapwood is not resistant to insect and fungal attacks (Brazier 1971), care must therefore be taken to avoid degradation during harvesting and processing, particularly for light-coloured wood like engkabang jantong.

Figure 3 No clear boundary between the sapwood and heartwood

Anatomy of engkabang jantong

Macroscopic features

The sapwood is not differentiated from the heartwood by colour. The wood is pale cream, sometimes having a pinkish tinge, weathering to light yellow-brown or light straw. The grain is interlocked. The texture is moderately coarse to coarse and even. Planed surfaces are fairly lustrous. Tangential or flat-sawn surfaces may have simulated growth ring figures caused by the presence of false growth rings. Attractive speckles and stripe figures are present on radial or quarter-sawn surfaces as shown in Figure 4. Vessel lines are conspicuously present in coarse scratches on longitudinal surfaces.

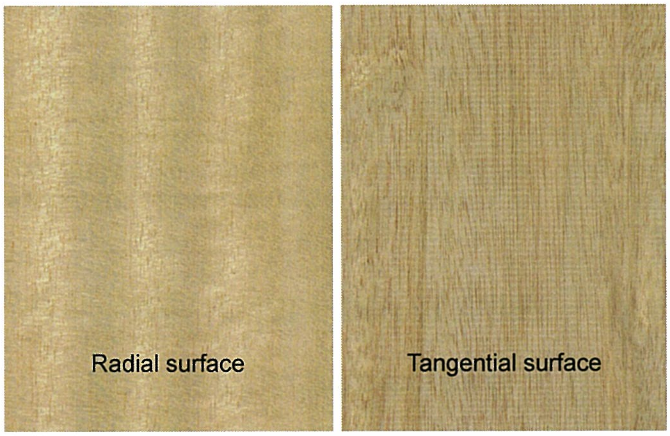


Figure 4 Appearances on the radial and tangential surfaces

Figure 5 shows the macroscopic features as observed on the transverse section. Growth rings are apparent and moderately distinct. Vessels or pores are moderately small to moderately large and not very visible to the naked eye on cross-section;

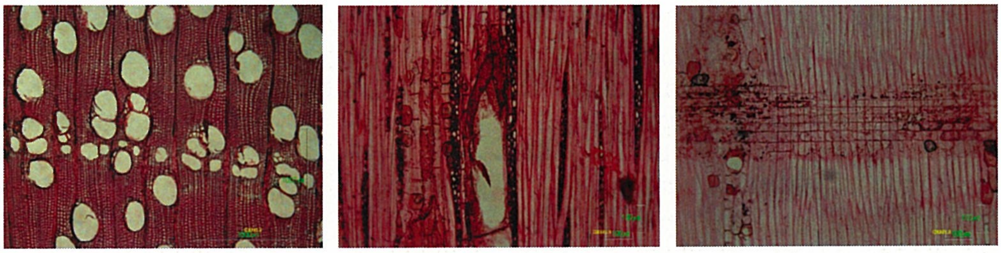
few to moderately numerous; mostly solitary, others in radial or oblique pairs and multiples of up to 4; pore clustering not common; evenly distributed with a tendency to align in short oblique manner; deposits are absent; tyloses are present but not in abundance. Wood parenchyma of both paratracheal and apotracheal types are present. The paratracheal type occurs as incomplete narrow borders to the pores and tends to be aliform or wing-liked and occasionally locally confluent. The apotracheal type occurs as short or irregularly spaced bands embedding the axial resin canals. Diffuse strands which form short lines are also present. Rays are small to medium-sized, not very visible to the naked eye on cross-section and only fairly conspicuous on quarter-sawn surfaces. Intercellular canals present as axial resin canals which are arranged in short and in continuous tangential series. Canals are usually smaller than the pores and filled with whitish deposits. Ripple marks are absent.

Sapwood portion | Heartwood portion | Pith portion

Figure 5 Microscopic features as observed on the transverse section

Microscopic features

Figure 6 shows the microscopic features observed on the transverse, tangential and radial sections. Growth rings are apparent and demarcated by thicker-wall fibres. Vessels or pores are round to oval in shape; with a tangential diameter of 84 to 269 µm; pores are in diffuse arrangement and sometimes in short oblique lines; 2 to 13 pores per mm^2; mostly solitary but also in oblique or radial pairs and multiples of 3 to 4; simple perforation; intervessel pits alternate, 6 to 11 µm, vestured; vessel-ray pits simple, large and round to gash-like; helical thickenings absent. Fibres are non-septate. Fibre length ranges from 821 to 1783 µm. Diameter of fibres ranges from 19 to 36 µm. Fibre-wall thickness ranges from 1.5 to 2.9 µm. Fibre pits are indistinct or minutely bordered. Parenchyma is variable in amount (scarce to moderately abundant, depending on tree), of two types, paratracheal and apotracheal; paratracheal parenchyma restricted to narrow, often incomplete sheaths to the vessels (narrowly vasicentric), sometimes distinctly aliform or locally confluent; apotracheal parenchyma diffuse or diffuse-in-aggregate and appearing as discontinuous, narrow, irregular tangential bands enclosing the resin canals, sometimes as discontinuous lines of 1 to 2 or 3 cells wide. Rays are of two types: uniseriate and multiseriate, 4 to 5 per mm, usually multiseriates, and mostly 2 to 3 cells wide and up to 40 cells high, composed of procumbent central cells and 2 to 4 rows of square to upright marginal cells. Prismatic crystals are present in normal parenchymatic cells and in idioblasts. Resin canals are in tangential rows embedded in the wood parenchyma, filled with resin. Tyloses are present.



Transverse section | Tangential section | Radial section

Figure 6 Microscopic features as observed on the three different sections

Table 2 shows variation of some of the anatomical features of trees of the two age groups.

Table 2 Mean values of some anatomical features of trees in the two age groups

No.	Feature	13-y-old					
		C2G1T124	C2G2T63	C2G3T75	C2G4T143	C2G5T68	C2G6T136
1	Tangential diameter of pore (µm)	154 (94–200)	168 (110–198)	170 (103–211)	160 (85–199)	200 (133–240)	176 (144–207)
2	Number of pores per mm^2	6 (4–13)	5 (3–8)	5 (3–13)	5 (3–9)	4 (2–10)	4 (3–6)
3	Intervessel pit (µm)	7 (6–9)	8 (6–10)	7 (6–10)	8 (6–9)	8 (7–10)	8 (6–11)
4	Ray height (µm)	405 (244–622)	467 (250–874)	381 (210–600)	377 (145–679)	398 (172–705)	348 (184–523)
5	Number of rays per mm	5 (4–5)	4 (3–6)	4 (3–5)	5 (4–6)	4 (4–5)	5 (5–6)

No.	Feature	22-y-old					
		C2G1T31	C2G2T86	C2G3T95	C2G4T104	C2G5T40	C2G6T60
1	Tangential diameter of pore (µm)	194 (144–222)	176 (117–222)	197 (84–268)	209 (127–258)	215 (154–269)	208 (117–256)
2	Number of pores per mm^2	4 (3–7)	5 (2–9)	5 (3–13)	4 (2–8)	4 (2–10)	4 (3–8)
3	Intervessel pit (µm)	8 (6–9)	7 (6–8)	7 (6–9)	8 (6–9)	8 (7–10)	7 (6–9)
4	Ray height (µm)	360 (147–704)	422 (202–717)	363 (179–676)	353 (161–587)	357 (165–597)	374 (148–700)
5	Number of rays per mm	5 (4–5)	5 (4–8)	5 (4–6)	4 (4–5)	5 (4–6)	5 (4–5)

Wood quality of engkabang jantong

Moisture content and density

Table 3 shows the means, standard deviations and ranges of moisture content and density values for trees of the two age groups. Table 4 shows the mean basic densities of trees at different heights for the two age groups. For the 13-y-old age group, the mean moisture content is 87% with a range of 52 to 206%, the mean green density is 580 kg m^{-3} with a range of 346 to 1080 kg m^{-3} and the mean basic density is 311 kg m^{-3} with a range of 199 to 622 kg m^{-3}. As for the 22-y-old age group, the mean moisture content is 101% with a range of 50 to 231%, the mean green density is 690 kg m^{-3} with a range of 409 to 1136 kg m^{-3} and the mean basic density is 344 kg m^{-3} with a range of 237 to 536 kg m^{-3}. The mean density range at 15% moisture content works out to be 228 to 715 kg m^{-3} for the 13-y-old age group and 272 to 616 kg m^{-3} for the 22-y-old age group.

Between the two age groups, the 22-y-old age group tends to have higher mean values. The mean density range at 15% moisture content for the 22-y-old age group is comparable with that reported by Soerianegara and Lemmens (1993) at the range of 270 to 600 kg m^{-3}. The mean basic density obtained for both age groups is also comparable with that of the natural grown engkabang jantong tested in TRTTC, which has a mean basic density of 345 kg m^{-3} (Anonymous, undated).

Table 3 Moisture contents and densities of trees for the two age groups

13-y-old				22-y-old			
Tree No.	Moisture content (%)	Green density (kg m^{-3})	Basic density (kg m^{-3})	Tree No.	Moisture content (%)	Green density (kg m^{-3})	Basic density (kg m^{-3})
C2G1T124	89±32	498±121	262±29	C3G1T31	91±36	686±149	359±55
	(57–186)	(346–846)	(216–323)		(55–225)	(419–1014)	(0.29–0.44)
C2G2T63	77±20	633±186	356±93	C3G2T86	96±48	634±156	326±40
	(54–143)	(389–1080)	(249–622)		(52–219)	(438–1037)	(253–442)
C2G3T75	88±28	526±97	280±34	C3G3T95	125±40	931±129	420±62
	(57–150)	(367–692)	(230–370		(52–228)	(583–1136)	(295–536)
C2G4T143	96±26	535±134	272±52	C3G4T104	79±25	565±104	317±43
	(62–162)	(355–842)	(199–415)		(52–147)	(409–818)	(254–427)
C2G5T68	68±11	563±101	335±56	C3G5T40	128±43	776±120	347±54
	(52–100)	421–732	(256–444)		(67–231)	(599–1071)	(249–482)
C2G6T136	102±42	671±119	336±50	C3G6T60	89±33	572±86	306 ± 45
	(56–206)	(478–936)	(269–455)		(50–200)	(447–852)	(237–415)
MEAN	87±31	580±141	311±66	MEAN	101±42	690±178	344±63
	(52–206)	(346–1080)	(199–622)		(50–231)	(409–1136)	(237–536)

Table 4 Basic densities of trees at different heights (bottom – B, middle – M, top – T) in the two age groups

13-y-old (kg m^{-3})					22-y-old (kg m^{-3})				
Tree No.	B	M	T	MEAN	Tree No.	B	M	T	MEAN
C2G1T124	288	252	242	262	C3G1T31	349	348	382	359
C2G2T63	419	358	283	356	C3G2T86	362	294	313	326
C2G3T75	314	269	251	280	C3G3T95	465	392	395	420
C2G4T143	311	231	266	272	C3G4T104	327	310	315	317
C2G5T68	399	292	303	335	C3G5T40	360	353	321	347
C2G6T136	390	308	301	336	C3G6T60	337	285	293	306

In radial variation, there is no general pattern of distribution for the basic density from pith to sapwood for the 13-y-old trees (Figure 7). However, there is a general increase in density from the pith to the sapwood for the 22-y-old trees (Figure 8).

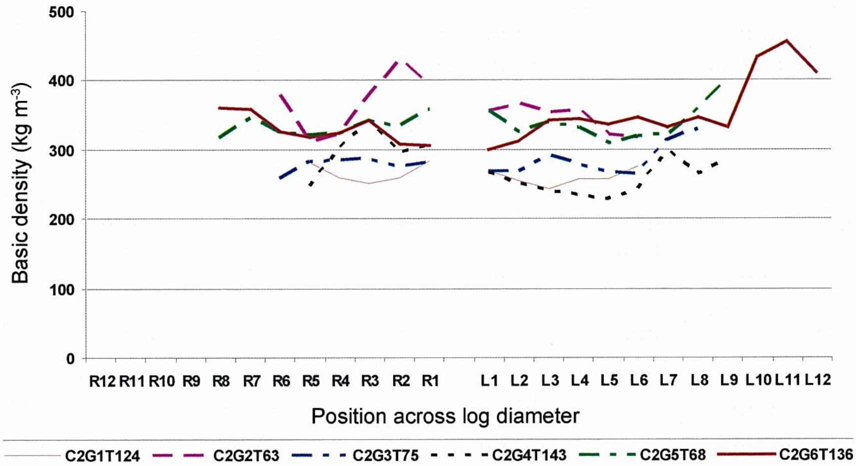


Figure 7 Variations of basic density in radial direction of the 13-y-old trees (R1 and L1 are positions near the pith)

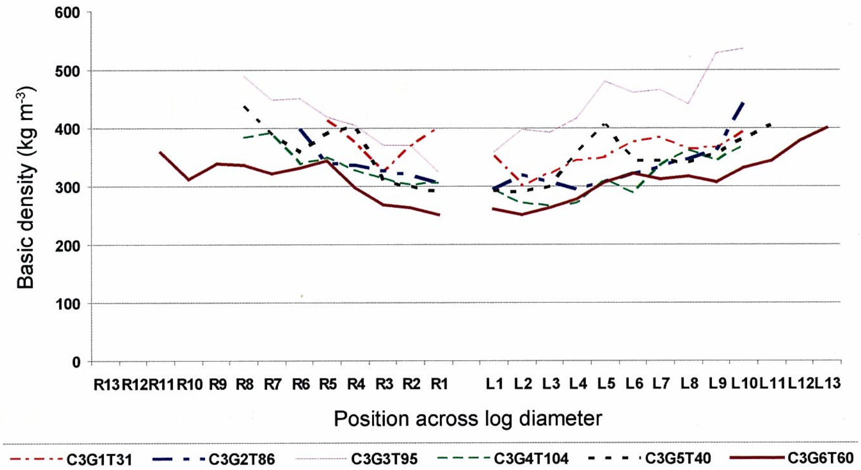


Figure 8 Variations of basic density in radial direction of the 22-y-old trees (R1 and L1 are positions near the pith)

In longitudinal variation, the basic density for trees in the 13-y-old age group is generally higher at the bottom. There is no general pattern from the bottom to the top of the tree. Four trees exhibit a decrease from the bottom to top whereas the other two trees show a decrease at the middle and increase at the top (Figure 9). As for the 22-y-old age group, all except one tree show higher basic density at the bottom part. This exception is due to dead knots present in one of the test specimens at the top part. Four trees show a decrease from the bottom and increase at the top; one tree shows a decrease from the bottom to the top while the other one tree shows an increase from the bottom to the top of the tree (Figure 10).

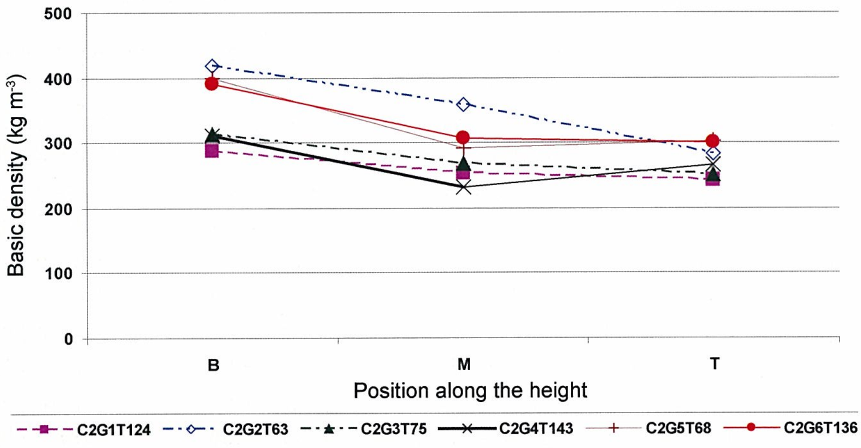


Figure 9 Basic density variations along the height for the 13-y-old trees (B – bottom, M – middle, T – top)

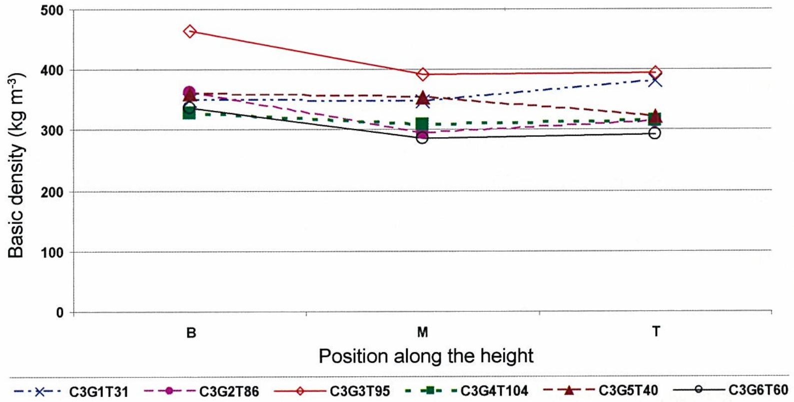


Figure 10 Basic density variations along the height for the 22-y-old trees (B – bottom, M – middle, T – top)

Fibre morphology

Results of the fibre morphology for trees of the two age groups of engkabang jantong are shown in Tables 5 and 6. The mean fibre length for the 13-y-old age group is 1158 µm with a range of 821 to 1728 µm and that of 22-y-old age group is 1334 µm with a range of 927 to 1783 µm. The fibre diameter for the 13-y-old age group is 28.25 µm with a range of 21.40 to 36.80 µm and that of the 22-y-old age group is 28.14 µm with a range of 19.80 to 35.20 µm. The fibre luman for the 13-y-old age group is 24.15 µm with a range of 18.83 to 30.16 µm and that of 22-y-old age group is 22.46 µm with a range of 16.87 to 30.75 µm. The fibre-wall thickness for the 13-y-old age group is 1.97 µm with a range of 1.56 to 2.74 µm and that of 22-y-old age group is 2.31 µm with a range of 1.76 to 2.96 µm.

Table 5 Summary of fibre morphology for the 13-y-old trees

Tree No.	Fibre length (µm)	Fibre diameter (µm)	Fibre luman (µm)	Fibre-wall thickness (µm)
C2G1T124	985±82 (821–1137)	30.40±2.29 (24.00–34.40)	25.92±3.32 (20.41–30.16)	1.77±0.14 (1.56–2.09)
C2G2T63	1205±129 (1011–1527)	29.47±3.80 (21.40–36.80)	24.89±2.34 (21.21–28.01)	2.10±0.22 (1.87–2.72)
C2G3T75	1131±94 (966–1339)	27.53±2.27 (22.60–32.00)	23.44±3.19 (18.94–27.98)	1.83±0.07 (1.75–2.01)
C2G4T143	979±92 (785–1205)	30.14±2.72 (24.80–33.80)	24.67±3.71 (20.31–29.84)	2.13±0.26 (1.90–2.74)
C2G5T68	1375±165 (1069–1728)	27.81±2.83 (23.40–32.60)	23.39 ±3.17 (18.83–27.68)	2.10±0.23 (1.85–2.46)
C2G6T136	1143±109 (925–1340)	25.97±1.99 (21.60–29.80)	22.57±1.76 (20.00–25.09)	1.96±0.08 (1.82–2.12)
MEAN	1158±169 (821–1728)	28.25±3.10 (21.40–36.80)	24.15±3.06 (18.83–30.16)	1.97±0.23 (1.56–2.74)

Table 6 Summary of fibre morphology for the 22-y-old trees

Tree No.	Fibre length (µm)	Fibre diameter (µm)	Fibre luman (µm)	Fibre-wall thickness (µm)
C3G1T31	1361±208 (934–1774)	25.59±2.75 (19.80–31.00)	20.03±2.68 (16.87–25.30)	2.38±0.27 (1.94–2.82)
C3G2T86	1273±143 (1000–1553)	28.48±2.53 (22.40–35.20)	24.43±2.67 (19.18–26.60)	2.13±0.19 (1.76–2.61)
C3G3T95	1290±170 (927–1598)	24.30±1.54 (21.40–28.20)	18.78±1.56 (16.90–21.87)	2.37±0.33 (1.91–2.84)
C3G4T104	1242±176 (945–1606)	30.21±2.77 (24.80–35.20)	23.69±2.82 (20.07–28.54)	2.39±0.25 (2.08–2.96)
C3G5T40	1258±197 (921–1606)	28.02±2.33 (22.40–33.20)	22.09±3.03 (19.51–27.73)	2.39±0.29 (1.93–2.76)
C3G6T60	1404±206 (994–1783)	31.02±2.41 (25.20–35.00)	26.74±3.27 (21.09–30.75)	2.29±0.26 (1.88–2.65)
MEAN	1334±191 (927–1783)	28.14±3.40 (19.80–35.20)	22.46±3.68 (16.8 –30.75)	2.31±0.27 (1.76–2.96)

Between the two age groups there is significant variation in fibre length and fibre-wall thickness. The older trees tend to have longer fibres and thicker walls. The variation of fibre length for the 13-y-old trees is more pronounced than that of the 22-y-old trees.

In radial variation, both age groups show an increase of fibre length from pith to bark (Figures 11 & 12).

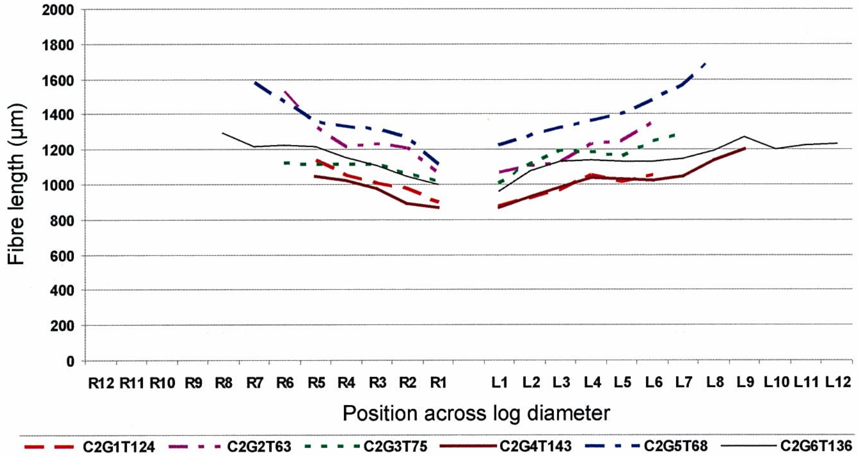


Figure 11 Variations of fibre length in radial direction of the 13-y-old trees (R1 and L1 are positions near the pith)

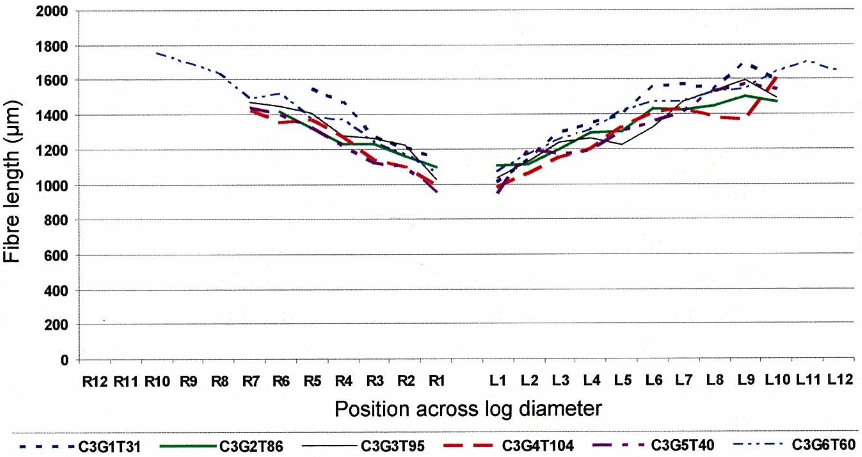


Figure 12 Variations of fibre length in radial direction of the 22-y-old trees (R1 and L1 are positions near the pith)

In longitudinal variation, the 13-y-old trees show a decrease in fibre length from the bottom to the middle and almost a constant value towards the top of the tree. There is also quite a significant difference in fibre length between trees at the same portion of the tree (Figure 13). As for the 22-y-old trees there is not much variation between the different portions of the trees as well as between the trees (Figure 14).

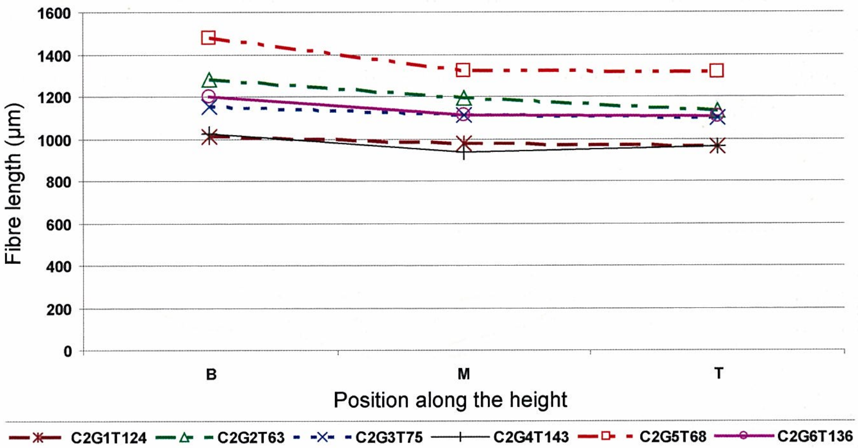


Figure 13 Fibre length variations along the height for the 13-y-old trees (B – bottom, M – middle, T – top)

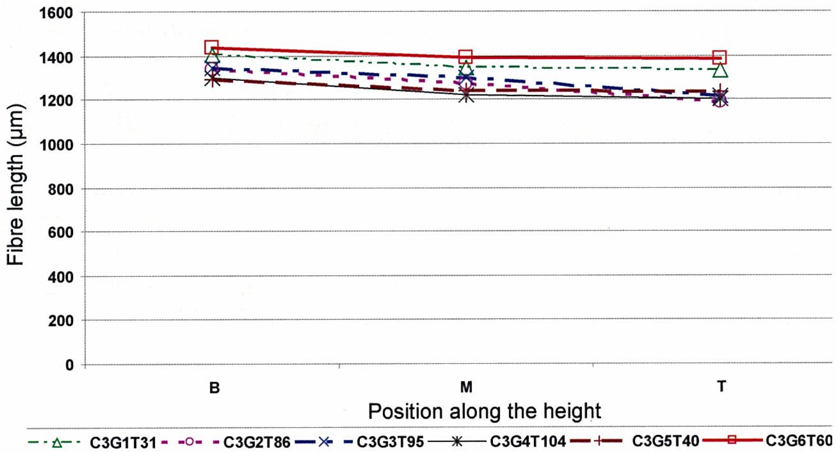


Figure 14 Fibre length variations along the height for the 22-y-old trees (B – bottom, M – middle, T – top)

CONCLUSION

In carrying out the tests, there was no problem encountered in adopting the harmonized testing methods for wood anatomy and quality studies on engkabang jantong.

From the studies, it can be concluded that engkabang jantong is comparable with light red meranti and falls under the Light Hardwood group of timber. For basic density, although the 22-y-old age group shows a higher average value (344 ± 63 kg m^{-3}) as compared with that of the 13-y-old age group (311 ± 66 kg m^{-3}), the variation is insignificant. As for fibre length, the 22-y-old age group has longer fibres than the 13-y-old age group. The variation among the trees in the 13-y-old age group is more significant than in the 22-y-old age group. Trees of both age groups show shorter fibre lengths near the pith as compared with the outer portion.

ACKNOWLEDGEMENTS

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REFERENCES

Anonymous. (undated). Strength Properties of Some Sarawak Timbers. Timber Research and Technical Training Centre, Sarawak (Unpublished report).

BRAZIER, J. D. 1971. Sapwood – what is it and can it be used? Reprint from Forestry Supplement of *Timber Trade Journal.* Department of Environment, England. 2 pp.

SOERIANEGARA, I & LEMMENS, R. H. M. J. (Eds.) 1993. *Timber Trees: Major Commercial Timbers.* Plant Resources of South-East Asia No. 5(1). Pudoc Scientific Publishers, Wageningen, The Netherlands. 610 pp.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. (Eds) 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC and FRC.

WHEELER, E. A., BAAS, P. & GASSON, P. E. 1989. IAWA list of microscopic features for hardwood identification. *IAWA Bulletin* n.s.10(3): 219–332.

PHYSICAL AND STRENGTH PROPERTIES

Alik Duju & Andrew Nyorik Nibu

INTRODUCTION

The technical information with regard to the physical and strength properties of *Shorea macrophylla* is not known yet. Hence, the objectives of this study are to determine the physical and strength properties of the planted and naturally grown species.

MATERIALS AND METHODS

Trees of two age-groups, viz 13 and 22 y old, were collected from Sabal Forest Reserve, Kuching-Sri Aman Road. The naturally grown trees with diameter at breast height overbark (dbhob) ranging from 510 to 660 mm were obtained from Bintulu Lumber Development Sdn Bhd, Miri, and Ulu Skrang, Sri Aman. The ages of these trees were not known and based on their diameters, they were considered to be of merchantable sizes. The criteria for selection of the trees for sampling were healthy and good forms. After the trees were felled, the logs were ripped into flitches. In the green condition, the flitches were then machined into boards and subsequently planed to produce sticks of 20 mm by 20 mm cross-section. The sticks were then visually graded and only the defect-free samples were cut into specified lengths in accordance with the required standard. The other flitches had to undergo drying until they reached the equilibrium moisture content and subsequently processing was carried out.

The harmonized testing method that was adopted from the British Standard BS 373 was used to determine the strength properties (Tan et al. 2010). A universal testing machine with a maximum loading capacity of 50 kN was used to evaluate the strength properties, viz modulus of rupture (MOR), modulus of elasticity (MOE), compression parallel to grain, shear parallel to grain, hardness, cleavage and tension. Impact bending strength was determined using Charpy impact bending machine. The test specimens were tested both at green and air-dry conditions. The temperature of the testing room was maintained at 20±3 °C. Moisture content and density of the species were determined using the oven-dry and water displacement methods respectively.

RESULTS AND DISCUSSION

Moisture content and density

The testing conditions, number of test specimens, physical and strength properties of the two age groups and naturally grown *S. marcophylla* are summarized in Table 1. The average moisture contents were 58% for the 13-y-old group, 40% for the 22-y-old group, and 68% for the naturally grown trees at green condition whilst at air-dry condition the mean values for both age groups were 16% and for the naturally grown trees 15%. The mean air-dry density values were 0.36 , 0.39 and 0.41 g cm^{-3} for the younger, older and naturally grown trees respectively. This shows that there was not much difference in their air-dry densities as far as these three groups are concerned. However, the older trees were heavier than the younger ones.

Table 1 Physical and strength properties of *Shorea marcophylla*

Age group	Cond.	MC	Density	Static bending		Comp// to grain	Shear // to grain		Hardness		Cleavage		Tension// to grain	Impact bending
				MOR	MOE		T	R	T	R	T	R		
		(%)	(g cm^{-3})	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(kN)	(kN)	(N/mm)	(N/mm)	(MPa)	(Joule)
13 y	G	**58**	**0.47**	**43**	**5940**	**22**	**6.4**	**6.0**	**1.3**	**1.2**	**8.2**	**6.5**	**71**	**12.1**
		19.2	0.11	10.5	1346	4.4	1.4	1.3	0.5	0.4	2.4	1.6	12.7	6.1
	A	**16**	**0.36**	**47**	**6420**	**27**	**8.0**	**7.3**	**1.4**	**1.3**	**6.3**	**4.5**	**89**	**10.7**
		1.0	0.06	9.6	1339	4.6	1.7	1.3	0.4	0.4	1.8	1.4	9.5	5.5
22 y	G	**40**	**0.44**	**44**	**6180**	**23**	**6.7**	**6.2**	**1.4**	**1.4**	**6.9**	**6.8**	**73**	**13.5**
		15.0	0.08	7.2	911	3.1	0.9	0.9	0.5	0.5	1.6	2.1	12.3	3.2
	A	**16**	**0.39**	**51**	**7160**	**30**	**8.6**	**7.5**	**1.6**	**1.5**	**6.4**	**4.9**	**90**	**12.8**
		1.5	0.05	8.4	1019	4.1	1.2	1.2	0.6	0.5	1.7	1.5	14.8	2.9
NG	G	**68**	**0.59**	**54**	**7800**	**26**	**6.6**	**6.0**	**1.9**	**1.8**	**8.4**	**6.5**	-	**15.7**
			0.08	6.3	991	2.5	0.6	0.6	0.3	0.3	1.4	0.8		2.8
	A	**15**	**0.41**	**66**	**8580**	**35**	**7.8**	**7.6**	**2.0**	**1.9**	**7.8**	**5.7**	-	**14.9**
			0.04	5.6	750	3.7	1.1	0.8	0.3	0.8	1.4	0.7		3.2

Note: The bold figures are the mean values and below are the standard deviations.

Cond.	:	Test condition	MOE	:	Modulus of elasticity
G	:	Green	//	:	Parallel
A	:	Air-dry	T	:	Tangential plane
MC	:	Moisture content	R	:	Radial plane
MOR	:	Modulus of rupture	NG		Naturally grown

Static bending

The mean values for ultimate bending strength (MOR) for the 13-y-old trees at green and air-dry conditions were 43 and 47 MPa, for the 22-y-old trees 44 and 52 MPa, and for the naturally grown trees 54 and 66 MPa respectively. There were not much differences in their MOR values; however, there was a tendency for the strength values to increase with the age of the trees. In modulus of elasticity (MOE) values, the younger trees exhibited 5940 and 6420 MPa whereas the older trees 6180 and 7160 MPa and the naturally grown trees were higher at 7800 and 8580 MPa under the two test conditions respectively. A marked increase in MOR and MOE values ranging from 8 to 22% on specimens tested from the green to the air-dry conditions was found as shown in Figures 1 and 2.

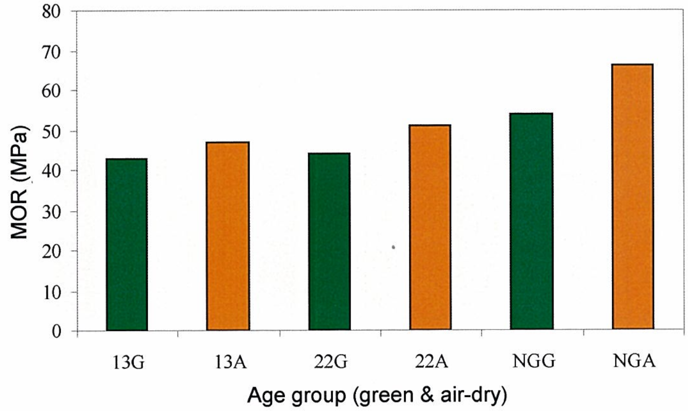

Figure 1 Modulus of rupture at green (G) and air-dry (A) conditions

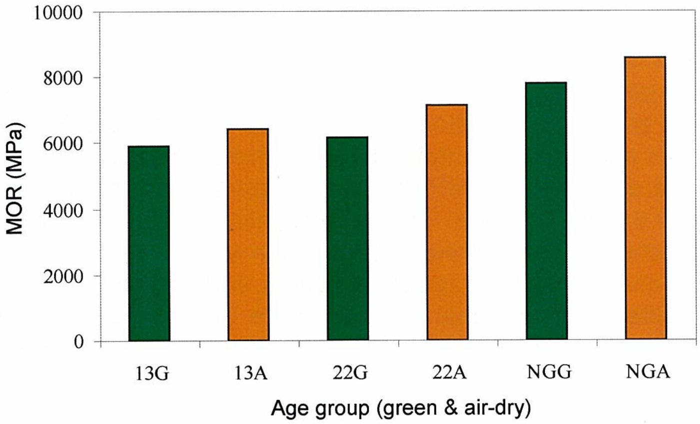

Figure 2 Modulus of elasticity at green (G) and air-dry (A) conditions

Compression parallel to grain

In compressive strength parallel dry to grain, the mean values for the 13-y-old group were 22 and 27 MPa tested at green and air-dry conditions respectively. For the 22-y-old group, their values were 23 MPa at green and 30 MPa at air-dry conditions. For the naturally grown trees, the strength values were 26 and 35 MPa under the two different test conditions. The results indicate that there was a marked increase in their strength values ranging from 23 to 34% between the two test conditions as shown in Figure 3.

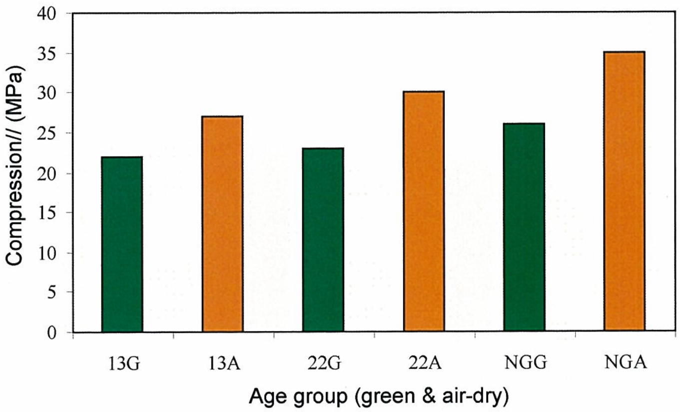

Figure 3 Compressive strength at green (G) and air-dry (A) conditions

Shear parallel to grain

For the 13-y-old trees, the mean values for shear strength parallel to grain were 6.4 MPa for the tangential plane and 6.0 MPa for the radial plane tested at green condition whilst at air-dry condition their strength values were 8.0 and 7.3 MPa for the tangential and radial orientations respectively. For the 22-y-old trees, their mean values were 6.7 and 6.2 MPa for the tangential and radial planes at green condition and 8.6 and 7.5 MPa for the tangential and radial planes at air-dry condition respectively. The corresponding mean values for the naturally grown trees were 6.6 and 6.0 MPa at green condition and 7.8 and 7.6 MPa at air-dry condition. No differences in shear strength were found as far as the age of the trees was concerned. The tangential plane exhibited higher strength values than the radial plane which ranged from 3 to 13%. Air-dry specimens indicated slightly higher values than those at the green condition as shown in Figure 4.

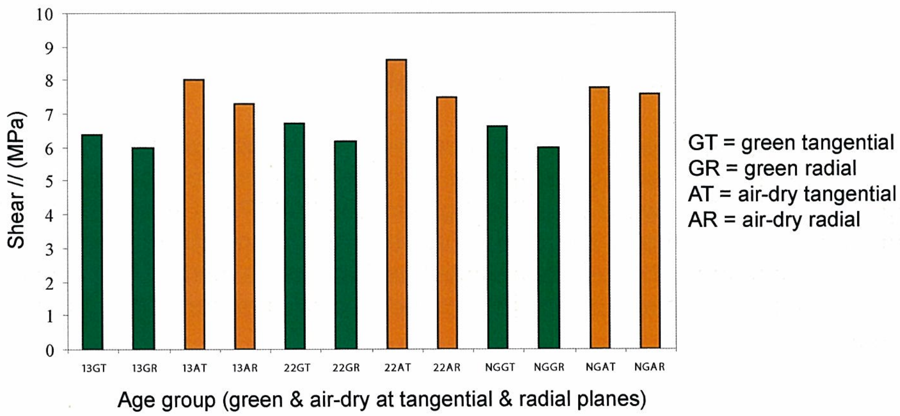

Figure 4 Shear strength at green and air-dry conditions

Hardness

The mean hardness values for the younger trees were 1.3 kN for the tangential plane and 1.2 kN for the radial plane at green condition whilst for the air-dry condition the values were 1.4 and 1.3 kN for the tangential and radial orientations respectively. For the older trees, their mean values were 1.4 kN both for the tangential and radial planes at green condition and 1.6 and 1.5 kN for the tangential and radial orientations at air-dry condition respectively. For the naturally grown trees, their mean values were 1.9 and 1.8 kN for the tangential and radial planes at green condition and 2.0 and 1.9 kN for the tangential and radial planes at air-dry condition respectively. At the radial and tangential planes the naturally grown trees performed slightly better than the 22-y-old and 13-y-old trees. The tangential exhibited higher hardness values than the radial surfaces as shown in Figure 5. Specimens at air-dry condition seemed to perform slightly better in hardness than those at green condition at both directions.

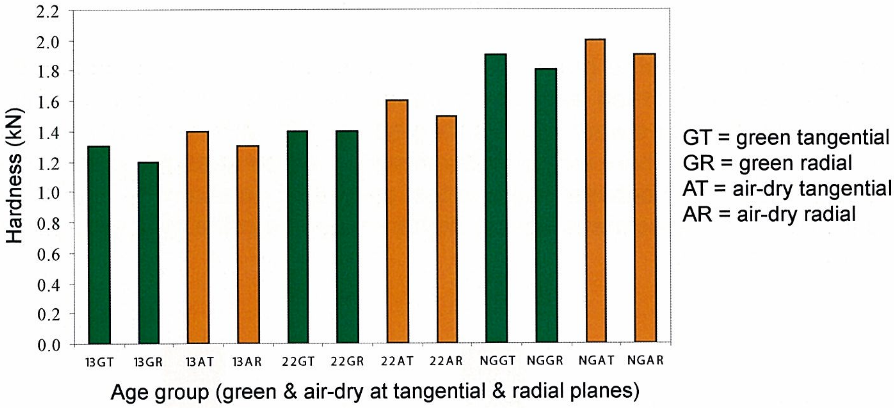

Figure 5 Hardness strength at green and air-dry conditions

Cleavage

The average values for cleavage strength for the 13-y-old trees were 8.2 N mm^{-1} for the tangential and 6.5 N mm^{-1} for the radial surfaces at green condition whilst at air-dry condition the values were 6.3 and 4.5 N mm^{-1} for the tangential and radial planes respectively. The mean values for the 22-y-old trees were 6.9 and 6.8 N mm^{-1} for the tangential and radial planes at the green condition and 6.4 and 4.9 N mm^{-1} for the tangential and radial planes at air-dry condition. For the naturally grown trees, their strength values were 8.4 and 6.5 N mm^{-1} at the green condition and 7.8 and 5.7 N mm^{-1} at the air-dry condition at both orientations. The cleavage strength both at the radial and tangential surfaces did not indicate any differences between the three groups. Their strength at green condition seemed to be better than at air-dry condition. The tangential surface exhibited higher strength values than the radial surface as shown in Figure 6.

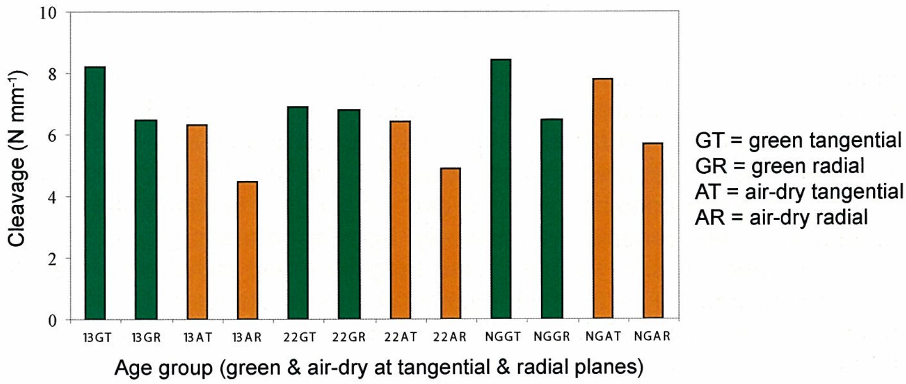

Figure 6 Cleavage strength at green and air-dry conditions

Tensile strength

In tensile strength parallel to grain, the mean values for the 13-y-old trees were 71 and 89 MPa tested at green and air-dry conditions respectively. For the 22-y-old trees, their strength values were 73 MPa for green and 90 MPa for air-dry conditions. The results indicate that there was a slight difference in their strength values between the two age groups and between the two test conditions as shown in Figure 7, with the older and air-dry specimens having higher values than the younger and green specimens respectively.

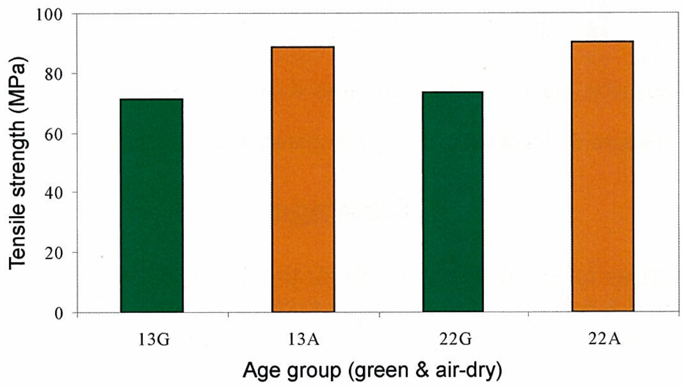

Figure 7 Tensile strength at green (G) and air-dry (A) conditions

Impact bending

In impact bending or work done to break the specimens, the mean values for the 13-y-old trees were 12.1 and 10.7 J tested at green and air-dry conditions respectively. For the 22-y-old trees, their impact bending strength values were 13.5 J for green and 12.8 J for air-dry conditions. The mean values for the naturally grown trees were 15.7 and 14.9 J at green and air-dry conditions respectively.

There was a slight decrease in their strength values at air-dry compared with the green conditions as shown in Figure 8. The older trees seemed to perform slightly better than the younger trees as far as the three groups are concerned.

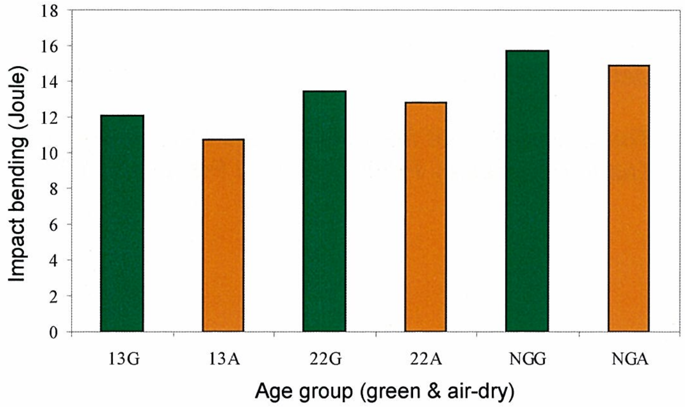

Figure 8 Impact bending at green (G) and air-dry (A) conditions

CONCLUSION

There was not much difference in their air-dry density and strength properties between the two age groups and the naturally grown trees. Most of the strength properties of the naturally grown trees of *S. marcophylla* performed slightly better than trees of the two age groups. The modulus of rupture, modulus of elasticity, compressive strength, shear, hardness and tension at air-dry condition exhibited slightly higher strength values than at green condition. However, cleavage and impact bending gave the opposite results. Properties at the tangential direction seemed to perform better than at the radial direction.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Kendawang, J. J. 1994. *Current Status of Forest Plantation Development in Sarawak.* Forest Department, Sarawak.

Newman, M. F., Burgess, P. F. & Whitemore, T. C. 1996. *Borneo Island Light Hardwoods—Manual of Dipterocarps for Foresters.* Royal Botanic Garden, Edinburgh and CIFOR, Edinburgh, U. K.

NG, F. S. P. & TANG, H. L. 1974. Comparative growth rates of Malaysian trees. *Malaysian Forester* 37: 2–23.

SOERINEGARA, I. & LEMMENS, R. H. M. T.1993 (Eds). *Timber Trees: Major Commercial Timbers*. Plant Resources of South East Asia No. 5(1). Pudoc Scientific Publisher, Wageningen.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers*. FRIM, TRTTC & FRC.

WONG, S. 1988. *The Chocolate Fat from the Borneo Illipe Trees*. Consultant to P.T Cahaya Kalbar (Indonesia). Printed by Vivar Printing Sdn Bhd Malaysia.

SAWING AND MACHINING PROPERTIES

T. C. Wong, C. S. Chan & X. Y. Teng

INTRODUCTION

There is a dearth of documented methodology for the evaluation of sawing properties of timber species, planted or naturally grown. Most of the existing documented sawmill conversion systems are based on practices or methodologies adopted in North America, Europe, Japan and Australasia. Conversion systems used in the tropical countries are not well documented and the literature review has revolved around the few available references authored by Japanese researchers, particularly those from the Forestry and Forest Products Research Institute. Documents found to be useful include Procedure of Sawing Yield Test (FFPRI) (Anonymous 2007), Technical Report of the Product Development Committee No. 13 (FFPRI) (Anonymous 2004) and ASTM D 1666-87 (Reapproved 1999)(Anonymous 1999).

Over the years, sawing efficiency has become more a function of processing or machine innovation than of timber properties. In the light of growing national interest and desire to develop forest plantations amongst the tropical countries, it is deemed timely and pertinent that proper methodologies should be drawn up to evaluate potential plantation species before planting decisions are made. The evaluation of sawmilling and machining properties is an essential and decisive part of the required evaluation.

The objective of this study was to determine the suitability and reliability of 'harmonized' test methodologies for evaluating the sawing and machining properties of tropical plantation species, *Shorea macrophylla*, 13 and 22 years of age.

MATERIALS AND METHODS

Materials

- Sawing yield test: Minimum of 30 logs collected at random as per "Sampling of Sample Trees and Allocation of Logs for Determination of Basic Properties of Wood from Tropical Forest Plantation" in the project manual (Tan et al. 2010).
- Sawing properties test: five slabs each for a total of nine test conditions as per details in the project manual.
- Wood machining test: 50 specimens for each of six sub-tests stipulated in the project manual.

Test procedures

- Sawing yield test
- Sawing properties test
- Wood machining test (actually consisting of six separate tests)

RESULTS AND DISCUSSION

Sawing yield test

(i) *Volumetric yield*

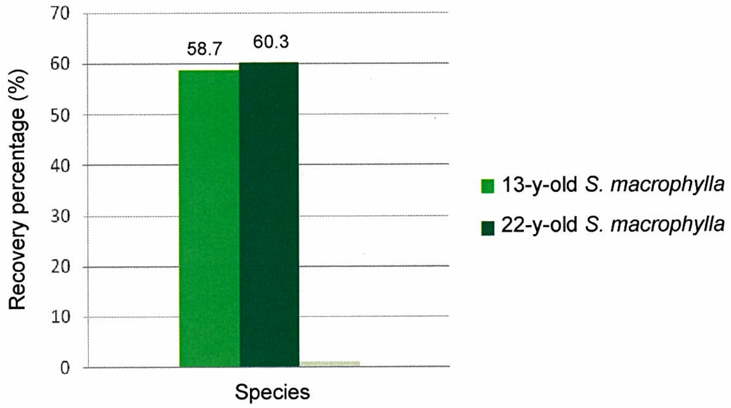

Figure 1 Mean recovery of *Shorea macrophylla*

- The mean recovery (volumetric yield) was quite similar for the two age groups of *S. macrophylla* (58.7–60.3%) as shown in Figure 1.
- Occurrence of severe end-splitting of slabs after sawing was observed. This was attributed to release of internal stresses brought about by fast growth rates.
- *Shorea macrophylla* produced higher yields than established plantation species like rubberwood (*Hevea brasiliensis*) that had been reported to have average recovery of 32% (Gan et al. 1987). However, the sawing pattern and targeted sizes used for those studies were different.
- The growth rate (species) would appear to have greater effect on the recovery than the age of trees.

(ii) *Value yield*

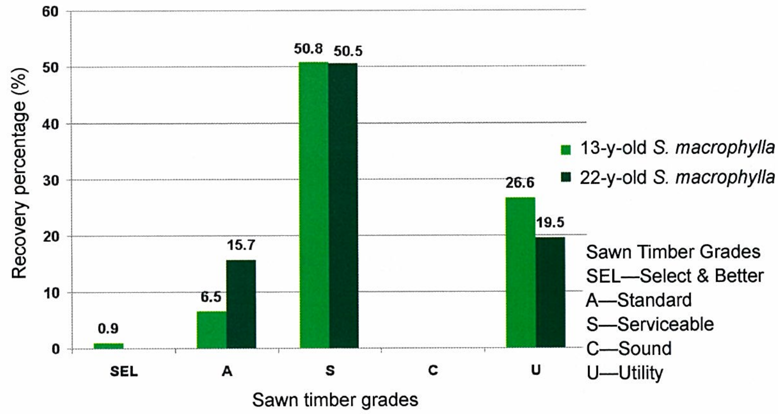

Figure 2 *Shorea macrophylla* timber recovery in relation to MGR grades

- The timber recovery was conducted using Malaysian Grading Rules (MGR).
- The bulk (>80%) of the yield for both age groups of *S. macrophylla* has been graded at 'Serviceable' or worse (Figure 2), indicating that the value yield is relatively low for this fast-grown species.
- More of the better quality planks were obtained from the older and larger trees, consistent with findings from most sawmilling studies.

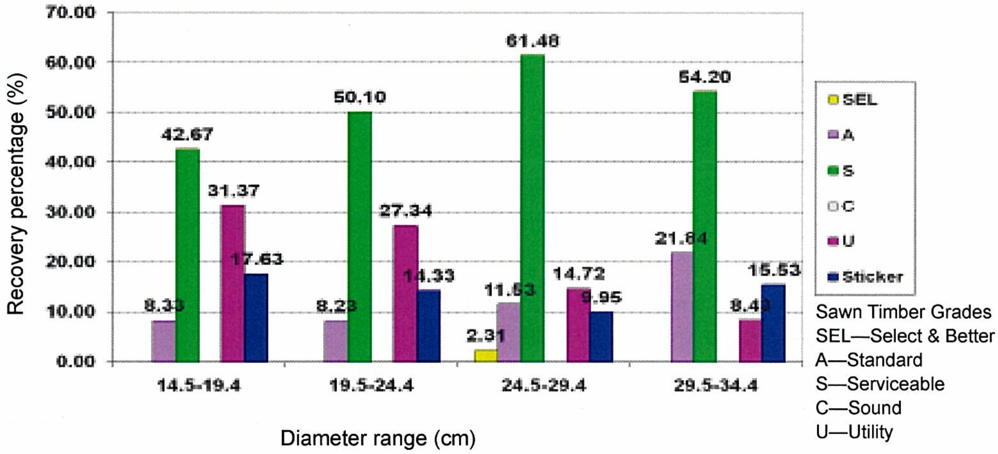

Figure 3 Timber grades of *Shorea macrophylla* in relation to log diameter

- Figure 3 shows that the bulk of sawn timbers obtained are of the lower grades irrespective of diameter range. However, the proportions of 'Utility' grade timber are somewhat higher from the two smallest diameter ranges.
- These results are generally consistent with value yield findings on small-diameter logs by other researchers.

Sawing properties test

(i) *Power consumption*

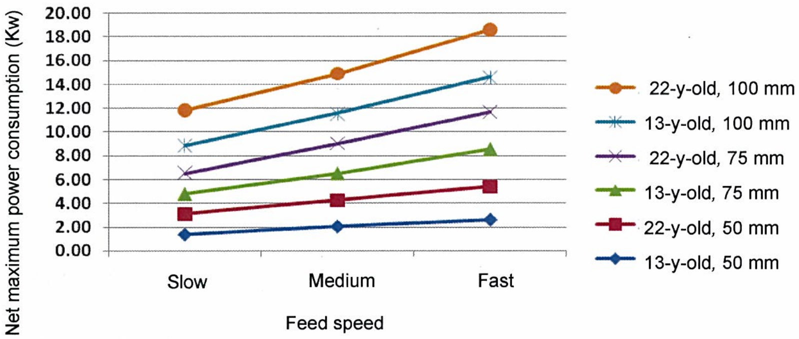

Figure 4 Net maximum power consumption in relation to feed speed of *Shorea macrophylla*

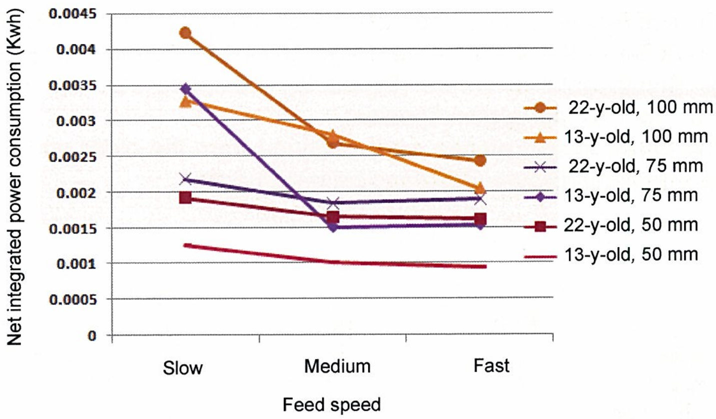

Figure 5 Net integrated power consumption in relation to feed speed of *Shorea macrophylla*

The power consumption results of *S. macrophylla* indicate that:

- With increase in feed speed, there is generally:
  - increase in net maximum power consumption (Figure 4).
  - decrease in net integrated power consumption (Figure 5).
- With increase in specimen height, there is increase in both net maximum and integrated power consumptions (Figures 4 and 5).
- Generally, power consumption is higher for the older age group than the younger age group due to the density factor.
- There is no significant difference in power consumption when cutting the outer, middle and inner parts of the log. (Note: the cutting pattern for this study was the round-and-round method.)

(ii) *Surface roughness*

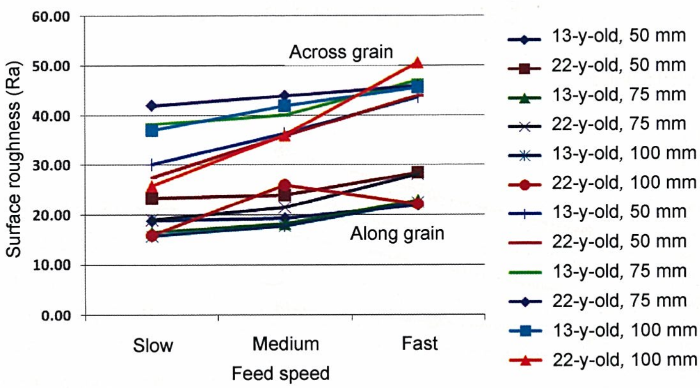

Figure 6 Surface roughness of *Shorea macrophylla* in relation to feed speed

- The surface roughness of *S. macrophylla* increases with feed speed (Figure 6).
- Specimen height does not appear to have effect on surface roughness.
- Grain direction 'across-the-grain' machining increases the surface roughness of *S. macrophylla.*

- The location (outer, middle and core) of the specimen within the log has no significant effect on surface roughness.

(iii) *Sawing accuracy*

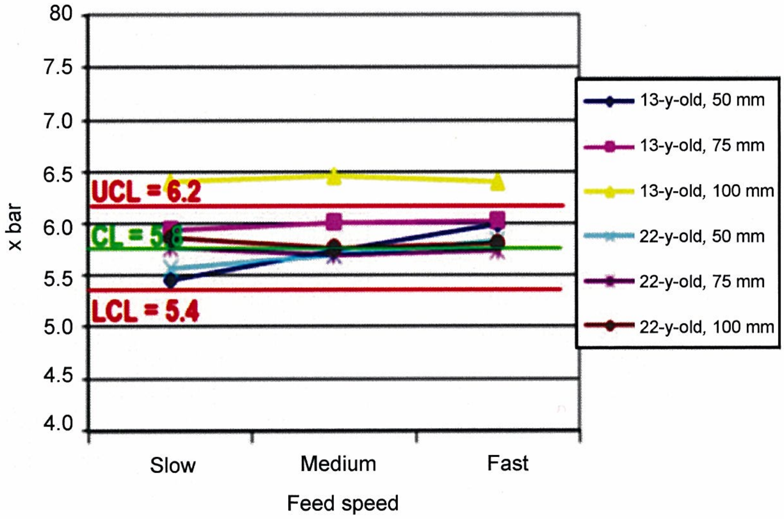

Figure 7 Sawing accuracy of *Shorea macrophylla*

- Sawing accuracy is attributed more to the quality and condition of setworks than to physical attributes of the timber. This inference is borne out by the results of this part of the test (Figure 7).

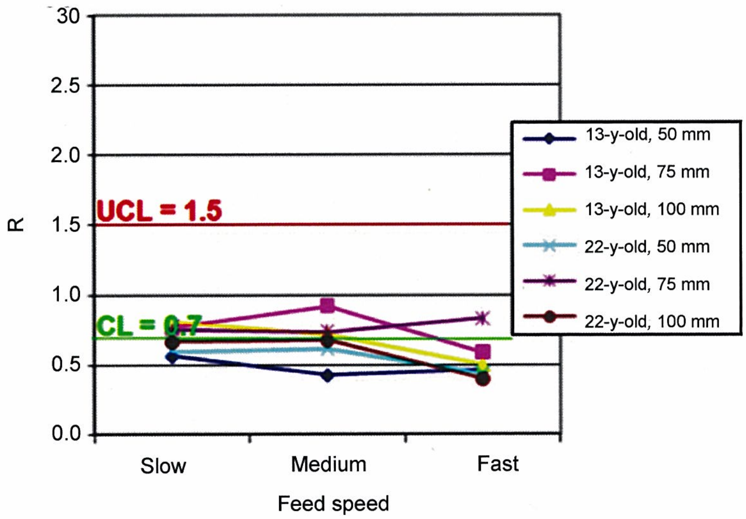

Figure 8 Sawing deviation of *Shorea macrophylla*

- Sawing deviation for *S. macrophylla* is within the control limit range (Figure 8).

Wood machining test

(i) *Planing test*

- The best sharpness angle for planing is 35 degree in terms of power consumption as well as visual grading of surface quality.
- The planed surface quality generally improves with decreasing feed per knife. The best surface quality is obtained at 0.38 mm of feed per knife.
- *Shorea macrophylla* is assessed as easy to plane. However, planing defects such as fuzzy grain (Figure 9), chip mark and torn grain (Figure 10) are quite commonly observed.

Figure 9 Fuzzy grain from planing test

Figure 10 Torn grain from planing test

(ii) *Sanding test*

- *Shorea macrophylla* is assessed as 'easy' to sand as surface quality from sanding test was consistently graded as 'good to excellent'.
- One sanding defect, namely 'fuzzing' (Figure 11), was observed in some specimens tested.

Figure 11 "Fuzzing" defect of sanding test

(iii) *Boring test*

- The boring property of *S. macrophylla* is graded as 'fair to good'.
- Boring defects such as tear-outs (Figure 12), crushing (Figure 13) and fuzziness were observed in a small number of specimens.

Figure 12 Tear-outs from boring test

Figure 13 Crushing from boring test

(iv) *Mortising test*

- The mortising property of *S. macrophylla* is graded as 'fair to poor'.
- Mortising defects such as crushing (Figure 14) and tearing (Figure 15) were observed in many specimens, particularly at the corners of the mortise.

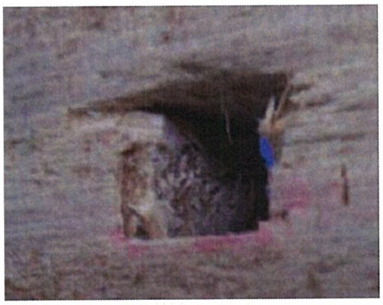

Figure 14 Crushing from mortising test

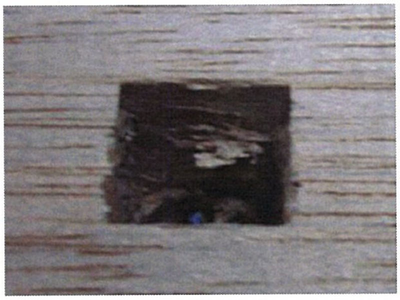

Figure 15 Tearing from mortising test

(v) *Shaping test*

- *Shorea macrophylla* has 'excellent' shaping properties.
- Fuzzy grain (Figure 16) as shaping defect was observed (for side grain cut) in a small number of specimens.
- Rough-end grain (Figure 17) and chipped grain as shaping defects were also observed (for end grain cut) in some specimens.

Figure 16 Fuzzy grain as shaping defect

Figure 17 Rough-end grain as shaping defect

(vi) *Turning test*

- The turning property of *S. macrophylla* is graded as 'fair to good'.
- There was no significant difference in turned surface quality between air-dried and conditioned (12% M.C.) specimens for both species tested.
- Turning defects of fuzzy grain (Figure 18) and torn grain (Figure 19) were observed in many specimens.

Figure 18 Turning defect of fuzzy grain

Figure 19 Turning defect of torn grain

(vii) *General*

- The results show that the older age group and flat-sawn board have better machining properties than younger age group and quarter-sawn board respectively.

Modifications to harmonized testing methodologies

Certain measurements and determinations provided for in the three tests may be either omitted or alternatively carried out due to non-availability of equipment or other compelling circumstances. Such options and alternatives, where available, are indicated and explained in the respective test procedures.

- In the absence of a log carriage, the sawyer may improvise with a push-wagon or any contraption that would allow for a log / cant to be securely mounted and pushed through the band-saw.
- In the absence of clamp-on power meter, electronic computing or data storage devices, the researcher may record and compute the power consumption by manual means based on the formula $P = IV$, where P is power consumption, I is current and V is voltage. Alternatively, the researcher may use an XY plotter, pen recorder or any other recording device that can capture power, voltage and/or ampere readings over the cutting time.
- Due to the difficulty of maintaining constant feed speed with a saw carriage not equipped with proper speed control, the sawyer may just try to keep within the stipulated carriage speed range and compile the results corresponding to the three speed groups from the elapsed sawing time recorded.
- In the absence of a surface roughness meter, the researcher may estimate the relative roughness of the sawn surface by visual means with the help of reference photographs depicting three pre-determined roughness conditions.
- Three of the six wood machining tests are stipulated as optional in the project manual and are to be carried out subject to availability of requisite equipment.

CONCLUSION

Based on the above findings, the following conclusions are:

- The methodology adopted to conduct the three tests is found to be generally suitable for *S. macrophylla*. The whole range of desired properties could be determined.
- *Shorea macrophylla* is evaluated to be a good plantation species in terms of sawing recovery and certain machining properties. However, the grades of lumber produced are mostly of 'serviceable' and 'utility' or lower grades. It is also inferred that the 13-y-old *S. macrophylla* is sufficiently old for the purpose of lumber production.

ACKNOWLEDGEMENTS

Kohji Murata, Yuji Ikami and Kiyohiko Fujimoto of the FFPRI, Japan, contributed to the harmonization of methodology and conduct of testing.

REFERENCES

ANONYMOUS. 1999. ASTM D 1666-87 (Reapproved 1999). *Standard Methods for Conducting Machining Tests of Wood and Wood-Base Materials.*

ANONYMOUS. 2004. *Testing Methods of Various Wood Properties of Fast Growing Tropical Timbers.* Technical Report of the Product Development Committee No. 13. Forestry and Forest Products Research Institute, Japan.

ANONYMOUS. 2007. *Procedure of Sawing Yield Test, Sawmilling and Machining Laboratory.* Forestry and Forest Products Research Institute, Japan.

GAN, L. T., HO, C. Y. & CHEW, O. K. 1987. Rubberwood: Sawn timber production and recovery studies. Pp 97–122 in Dalject Singh, K., Choo, K. T. & Hong, L. T. (Eds) *Proceedings of the Second Rubberwood Seminar,* 19–20 November 1985, Kuala Lumpur.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

ACCELERATED LABORATORY TEST ON NATURAL DECAY RESISTANCE

J. K. Lai, J. Sammy & Kandau Jenang

INTRODUCTION

The traditional method of timber durability evaluation through outdoor ground stake test is always a very tedious task and sometimes variation of results on the same species can be very great due to the unpredictable changes in the micro-environment. Thus, the method may not be suitable when fast and reproducible results are needed.

An effective, quick and reliable method of evaluating decay resistance of wood species is carried out through accelerated laboratory decay tests using weight loss as an indicator of decay resistance. This method has the advantage of producing results in a short period of time compared with the long-term in-ground graveyard test method. It has also the additional advantage of reproducing the test results anywhere when the conditions are favourably controlled. While established methods such as ASTM 2017, EN 113 and JIS K1571 have been used by many researchers around the world, it is still debatable as to which method is best and reliable where optimization of the wood decay process is concerned. Nicholas and Crawford (2003) mentioned the necessity to develop a better understanding of the many variables that influence microbial decay rates including improved methods for detecting and quantifying the extent of wood decay and couple these developments with improved designs of test specimens and methods.

More often than not in laboratory tests, the adopted procedures are similar in spite of the different types of substrate or medium used. The substrate or medium used in the case of ASTM 2017 is soil while EN 113 and JIS K1571 use agar and sand respectively. Regardless, these methods have been successfully used in many accelerated decay tests by scientists. One of the objectives of the ITTO project, "Improving Utilization and Value Adding of Plantation Timbers from Sustainable Sources in Malaysia" is to develop a harmonized test methodology for conducting accelerated laboratory test on natural decay resisitance. A modified method incorporating relevant parts of ASTM 2017, EN 113 and JIS K1571 was used to assess the suitability and effectiveness of the test procedures for evaluating the durability of tropical plantation timbers against brown-rot and white-rot fungi (Tan et al. 2010)

The adopted test procedure at a glance has some of the minor variations from the major testing methods as shown in the following table:

Table 1 Accelerated laboratory test of natural decay resistance of woods—comparison of test methods

	ASTM 2017-05	EN 113-1996	JIS K1571	Adopted
Replicates	At least 6	30–45	9 for each fungus	20
Size of samples (mm)	25 × 25 × 9	50 × 25 × 15	20(R) × 20(T) × 10(L)	25 × 25 × 9
Medium of test	Soil + feeder strip	Agar	Glucose+malt extract agar + + peptone (4+1+0.3%) + sea sand	Malt extract agar + agar (2+2%)
Exposure time (wks)	8–16 weeks determined by the weight loss of reference samples reaching >50%	16	12	8–16 determined by the weight loss of reference samples reaching >50%
Growth chamber conditioning	25–27 ± 1 °C & RH 65 – 75 ± 2%	22 ± 2 °C & RH 70 ± 5%	26 ± 2 °C & RH≥70%	25 ± 2 °C & RH 70 ± 5%
Timber samples conditioning prior and after test	Air-drying followed by conditioning at 20–30 ± 1 °C & RH 25–75 ± 2% preferably set the same as growth room	20 ± 2 °C & RH 65 ± 5% to constant mass with three additional samples oven-dried to calculate the theoretical dry mass of test samples	60 ± 2 °C in oven for 48 hrs, both test and reference samples subjected to the same conditions	60 ± 2 °C in oven for 48 hrs, both test and reference samples subjected to the same conditions

The objective of the study was to find a suitable and harmonized test method for evaluation of natural decay resistance of tropical plantation timber.

MATERIALS AND METHODS

Materials

Wood species

The selected timber species for this experiment, the 13-y-old and 22-y-old *Shorea macrophylla,* locally known as engkabang jantong, was collected from the reforestation site at Sabal Forest Reserve in Sarawak, Malaysia. Pulai, *Alstonia* spp, a non-durable species also collected from the nearby area, was used as reference material. Heartwood samples, free from fungal attack and defects such as knots, were obtained and later processed to 25 × 25 × 9 mm test blocks with the 9 mm in the grain direction.

Test fungi

Two white-rot fungi, *Trametes versicolor* (L. ex. Fr.) Pilat. and *Lentinus sajor-caju* (a dominant and aggressive species in Malaysia), and a brown-rot fungus, *Gloeophylum trabeum* (Pers. ex. Fr.), were used for the test.

Table 2 Replicates for test (No. of test blocks)

Wood species	Fungus		
	Gloeophyllum trabeum	*Trametes versicolor*	*Lentinus sajor caju*
Shorea macrophylla (13 y)	24	24	24
Shorea macrophylla (22 y)	24	24	24
Alstonia spp (reference blocks)	16	16	16
Total	64	64	64

Culture medium

Malt agar substrate (2% malt extracts and 2% agar by weight) was used for culturing and subculturing the test fungi in Petri dishes. Following EN 113, this medium was also used as culture bottle substrate instead of soil (ASTM 2017), making it an agar-block test method.

Methods

Sterilization

The steam sterilization method using autoclave was used for both culture medium and wood blocks. Malt agar medium was sterilized at 121 °C for 15 min while wood blocks were sterilized at 100 °C for 20 min. Other options of sterilization that include gas sterilization with propylene oxide and ionizing radiation which avoid driving out volatiles in wood blocks are also acceptable.

Exposure of wood blocks

When the medium surfaces were fully colonized by successfully grown pure cultures of the fungus type, both reference and test blocks were exposed at a ratio of 1 block per bottle with cross-section face in contact with the mycelium mat. For exposure to the brown-rot fungus *Gloeophylum trabeum* (Pers. ex. Fr.), however, wood blocks were made to sit on sterile fine gauze plastic mesh lying on top of the grown mycelium mat. Exposed blocks were then incubated in a dark growth room at controlled temperature of 25±2 °C and relative humidity of 70±5%.

Evaluation and interpretation of results

All blocks were conditioned before and after exposure in an oven at 60 ± 1 °C and their weights determined until constant. Following ASTM 2017, weight loss was calculated based on the difference of oven-dry weights of test blocks before and after exposure. Measurements of the relative decay susceptibility or, inversely, of decay resistance of the wood blocks were based on the following:

Table 3 Decay susceptibility classification

Average weight loss (%)	Average residual weight (%)	Resistance class to specified fungus
0 to 10	90 to 100	Highly resistant
11 to 24	76 to 89	Resistant
25 to 44	56 to 75	Moderately resistant
45 to above	55 or less	Slightly resistant or non-resistant

RESULTS AND DISCUSSION

Results

Table 4 summarizes the test results of the three trials carried out on *S. macrophylla*. The first two trials were based on the adopted test procedure while the third trial was carried out by Ikuo Momohara at the Forestry and Forest Products Research Institute (FFPRI), Japan, based on JIS K1571, which has a slight variation from the adopted test method.

Table 4 Comparison of weight losses (%) among the three separate trials

Trial	Fungus	Termination (wks)*	Mean weight loss (%) (standard deviation) 13 y	22 y
Preliminary evaluation of test procedure	*Lentinus sajor-caju (LT)*	11	45.2	
	Trametes versicolor (TV)	10	57.8	
	Gloephyllum trabeum (GT)	16	1.5	
Actual trial	*Lentinus sajor-caju (LT)*	11	50.2 (10.98)	39.9 (10.45)
	Trametes versicolor (TV)	8	48.9 (10.57)	36.2 (11.74)
	Gloephyllum trabeum (GT)	16	1.7 (0.27)	1.5 (0.52)
Trial test conducted by FFPRI using JIS K1571	*Trametes versicolor (TV)*	12	28.3	24.6
	Fomitopsis palustris	12	4.0	1.4

DISCUSSION

The weight losses of the reference samples used as a yardstick to terminate the test for white-rot fungi *Trametes versicolor* and *Lentinus S. caju* were both found to be in the 8th and 11th weeks respectively, and generally met the requirement by most major standards of between 8 and 16 weeks. This suggests that the test conditions of the procedure adopted are severe and suitable.

However, 50% rate of decay weight loss of reference blocks caused by the brown-rot fungus *Gloephyllum trabeum* was not achievable even at the end of the 16th week. This could be due to several possible reasons that require further investigation. Among the reasons could be that hardwoods are less susceptible (sometimes referred to as resistant) to brown-rot fungi as compared with softwoods. Another cause could be due to the fungal strain which after much subculturing had lost its virulence.

The weight losses obtained in *S. macrophylla* from the first two trials agree very well both in terms of magnitude and trend indicating that the adopted test procedure is suitable rendering the reproducibility of test results.

With reference to Table 4, the results obtained from the adopted test method are more severe than those obtained from the JIS K1571 method conducted by the FFPRI, showing that the adopted test method may be more suitable to be used to determine the natural decay resistance of tropical plantation timbers.

The age of the tree does have a very clear effect on the durability of the wood against the decay fungi. In this evaluation, *S. macrophylla* can be classified based on the adopted test procedure as follows:

Table 5 Resistance classification of *Shorea macrophylla* to white- and brown-rot fungi

Fungus	*Shorea macrophylla*	
	13 y	22 y
Lentinus sajor-caju (LT) (white rot)	Non-resistant	Moderately resistant
Trametes versicolor (TV) (white rot)	Non-resistant	Moderately resistant
Gloephyllum trabeum (GT) (brown rot)	Highly resistant	Highly resistant

If the same classification is to be applied to the results obtained from the JIS K1571 method, the only difference is that the 13-y-old *S. macrophylla* is classified as moderately durable against *T. versicolor*, while it is classified as non-resistant by the adopted test method.

This result agrees very well with the natural durability result for naturally grown *S. macrophylla* reported as 0.5 y (non-durable) in the in-ground contact graveyard test conducted in Sibu Sarawak, Malaysia (Lai & Sammy 2005).

COMMENTS

The results of this study indicate that younger trees are generally more susceptible to decay fungi with the hardwood more susceptible to white-rot fungi than brown-rot fungi. Comparatively, the results obtained from the harmonized test procedure agree very well with the test conducted at the FFPRI by Ikuo Momohara following the JIS K1571 method. As a whole, the harmonized test procedure has shown to be suitable and severe enough to produce the required results within 8 to 16 weeks of test.

CONCLUSION

The study demonstrates that the harmonized agar block test method can be used successfully for conducting the accelerated decay test in the laboratory for plantation species such as *Shorea macrophylla.* While internationally accepted test fungi such as *Trametes versicolor* (L. ex. Fr.) Pilat and *Gloeophylum trabeum* (Pers. ex. Fr.) have been successfully used, the local strain white-rot fungus *Lentinus sajor-caju* is equally aggressive and provides an option for future testing of natural durability of wood against white rot. On the other hand, the reference material used, viz pulai, *Alstonia* spp, showed resistance to *G. trabeum.* However, no conclusion can be drawn at this stage as to whether the cause was due to its natural resistance as a hardwood or that the fungal strain was less aggressive due to reduced virulence after much subculturing of the species. Further tests need to be carried out to confirm the cause. Despite this, the study has shown that this harmonized method is fairly easy to conduct with little problem of contamination and the results reproducible in any laboratory.

ACKNOWLEDGEMENT

We would like to express our gratitude to Ikuo Momohara of the FFPRI, Japan, for his kind advice and guidance on the setting up of our mycology laboratory, test methodology and solutions to problems. Also we deeply appreciate his effort in conducting the test on *S. macrophylla* and providing the test results for comparison.

BIBLIOGRAPHY

ANONYMOUS. ASTM D1413. *Test Method for Wood Preservatives by Laboratory Soil-Block Cultures.*

ANONYMOUS. ASTM D 2017-05. *Standard Test Method of Accelerated Laboratory Test of Natural Decay Resistance of Woods.*

ANONYMOUS. 1994. EN 350-1 : 1994E. *Durability of Wood and Wood-based Products—Natural Durability of Solid Wood*—Part 1: *Guide to the Principles of Testing and Classification of the Natural Durability of Wood.*

ANONYMOUS. 1996. EN 113 : 1996E. *Wood Preservatives—Test Method for Determining the Protective Effectiveness Against Wood Destroying Basidiomycetes—Determination of the Toxic Values.*

Anonymous. JIS K 1571. *Test Methods for Dermining the Effectiveness of Wood Preservatives and the Performance Requirements.*

LAI, J. K. & SAMMY, J. 2005. Natural durability of Sarawak timbers under outdoor ground contact conditions. Paper presented at Conference on Forestry & Forest Products Research 2005.

NICHOLAS, D. D. & CRAWFORD, C. 2003. *Concepts in the Development of New Accelerated Test Methods for Wood Decay.* © 2003 American Chemical Society.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

TREATABILITY AGAINST FUNGAL AND TERMITE ATTACKS

J. K. Lai, J. Sammy & Kandau Jenang

INTRODUCTION

When the natural durability of a timber species is low to allow the timber to be used for certain hazardous conditions, the durability of such timber could possibly be enhanced through wood preservative treatment. The success of the preservative treatment to enhance timber durability depends upon whether sufficient amount of preservative can be imparted into the timber and how well the preservative distributes itself inside the timber. Such characteristic of the timber is referred to as the treatability of the timber. One of the limiting factors to treatability is of course the inherent characteristics of the timber. Unless such characteristics are determined and known, selecting and developing an effective treatment method for the timber to be used in the required hazard conditions would not be possible.

With the development of many effective wood preservatives against most of the timber biodegrading agents (fungi and insects), coupled with timber treatment technology advancements, theoretically it is possible to choose the right wood preservative and the right treatment method to impart sufficient amount of preservative into the timber to make it possible for use in any hazardous conditions.

The term treatability, more often than not, is correlated with permeability and appears in many major standards. Although there is no established standard method to determine treatability of timber, the vacuum/pressure method is most commonly used as opposed to the non-pressure method of treatment since it is more effective in optimizing penetration of preservative. Tests can be carried out in a small retort equipped with a vacuum and pressure pump. A full-cell process involving an initial vacuum followed by pressure and a final vacuum can then be run to optimize penetration. Treatability can be assessed by measuring preservative uptake and penetration of preservative in the heartwood. The heartwood is used because generally all sapwood of timber is easily treatable. Wang and Degroot (1994) described factors contributing to the lowered heartwood treatability that include higher extractive content, the increased irreversible aspirated pits, and, in addition, in hardwoods, the formation of tyloses.

In principle, treatability of a wood species is normally affected by 1) the anatomical characteristics of the wood species, 2) the characteristics of the treating fluids and 3) the method and parameters of the treating processes (Wang & Degroot 1994). With the treatability of the wood species determined, only then can it be classified into different groups with reference to ease of treatment. By doing so, the end-use applications of treated timber can then be made. The classification of timber treatability, however, has been found to vary or not clearly specified in some standards.

Previous research conducted on mature and naturally grown *Shorea macrophllya* classified the timber on average as treatable, at 197 litres m^{-3} (Ling et al. 2003). It is desirable, however, to investigate similar properties of the planted timber stand and evaluate if there is any difference. One important factor is the difference in age of the trees. Hence in this study, the heartwood of the planted *S. macrophllya* of two age groups was specifically investigated following the harmonized and modified methods of practice (Tan et al. 2010).

The objective of this evaluation was to develop method(s) for treatability determination.

MATERIALS AND METHODS

Materials

Shorea macrophylla of 13 and 22 y of age were collected from Sabal Forest Reserve in Sarawak and used in this study. CCA Tanalith C 10% solution wood preservative was used for treatment.

Sample preparation

Timber samples were extracted following the harmonized procedures and later processed into 20 × 20 × 45.7-cm test specimens (Figure 1). Only clear heartwood specimens free from knots and other noticeable defects were selected. Test specimens were air-dried to moisture content of less than 20%. The test specimen dimensions were prepared according to ASTM D1758-96 (Standard Test Method of Evaluating Wood Preservatives by Field Tests with Stakes) with slight modification. In the vacuum-desiccator method, specimen dimensions were 2 × 2 × 10 cm. All test specimens were end-sealed with Duco automotive paint to prevent end/longitudinal penetration by the wood preservative. A total of 20 specimens comprising a minimum of three trees per replicate were selected for each treatment group.

Preservative formulation and preparation

A 10% copper-chrome-arsenic wood preservative solution was prepared by diluting 1 part CCA to 10 parts water.

Preservative	Solution strength	Active ingredients
Tanalith C (CCA Type C)	10%	Copper sulphate 35% Potassium dichromate 45% Arsenic pentoxide 20%

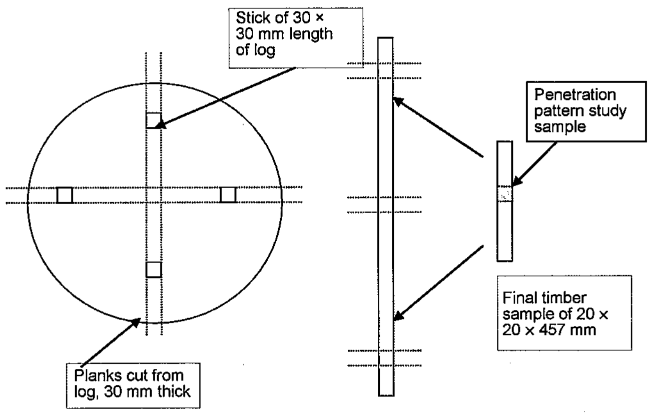

Figure 1 Test sample preparation from logs

Methods

Treatment process and evaluation

Vacuum-pressure method

The full-cell (Bethell) process was used in the evaluation of the treatability of the timber from both age groups. The schedule used comprised an initial vacuum of -85 kPa for 60 min, followed by 1400 kPa pressure for 120 min and a final vacuum of -85 kPa for 30 min. This was equivalent to treatment to refusal, a term used to describe the timber's inability to absorb anymore preservative even if the time of treatment is prolonged. The test was carried out in a small capacity 0.394 m^3 pressure impregnation plant.

Vacuum-desiccator method

The vacuum-desiccator method involves a vacuum phase at -85 kPa for 60 min with the test specimens submerged in the preservative as shown in Figure 2.

The preservative absorption and subsequently the penetration pattern of the preservative thus treated were similar to the method used for the full-cell pressure process and the method of calculation and classification are detailed in the harmonized test procedures. The retention is obtained by the difference between the final weight of the specimen after treatment and the initial weight of the specimen before treatment divided by its volume.

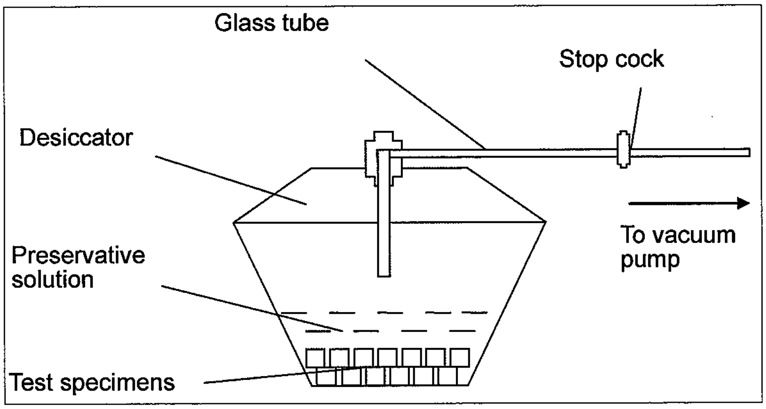

Figure 2 Wood permeability test—vacuum-desiccator set-up

Evaluation of results

Treatability is then determined as follows:

$$\text{Treatablity, in litres m}^{-3} = \frac{(W_2 - W_1)}{G * V} \times 1000$$

where,

W_1 = weight before treatment
W_2 = weight after treatment
G = specific gravity of wood preservative (measured with a hydrometer)
V = volume of specimen

The species was classified following: MS544: PART 10:2003 (Code of Practice for Structural Use of Timber: Part 10: Preservative Treatment of Structural Timber) classification.

Table 1 Treatability classification

Permeability class	Absorption of preservative in litres m^{-3} of timber
Very easy	Over 320
Easy	240 – 320
Average	160 – 240
Moderately difficult	80 – 160
Difficult	Less than 80

Although the preservative adsorption expressed in litres m^{-3} is a good indicator of how easy the wood can be treated, it is also equally important to assess how well the preservative distributes itself within the wood cells. A qualitative method following the Australian / New Zealand Standard, AS/NZS 1605:2000 (Methods for Sampling and Analyzing Timber Preservatives and Preservative-treated timber) was used to determine the spread of CCA in the wood. A small section measuring 50 mm from the treated specimen was first cut at the centre leaving a clean cross-section face. The cross-section was then sprayed with chrome azurol–S copper indicator. A clear royal blue colour indicates penetration while a reddish brown colour indicates no penetration. Depth of penetration is referred to as the least perpendicular distance from the edges measured in millimeter. The penetration pattern is described as fully penetrated, in continuous band, scattered, patchy or confined to pores, etc.

RESULTS AND DISCUSSION

The method employing the use of the full-cell process to determine the treatability of *S. macrophylla* is rather straightforward. The results were analysed by calculating the preservative uptake in litres m^{-3} and determining the penetration pattern through the colorimetric test. Treatabilty was then classified in accordance with Table 1.

Table 2 summarizes the results of the two age groups of *S. macrophylla*. From the treatability classification shown in Table 1, specimens of both age groups are classified as very easy to treat with a high average loading of 380 and 349 litres m^{-3} respectively. During examination of the cross-section penetration pattern, it was suspected that the unpenetrated patches were attributed to the presence of mature heartwood while the more immature wood exhibited an almost 100% penetration. This phenomenon was confirmed when examined under the microscope, where the unpenetrated parts of the timber specimens showed the presence of pores blocked by tyloses. This is in agreement with Wang and Degroot (1994) who mentioned that tylose formation in the heartwood is one of the factors contributing to the lowered heartwood treatability. The same trend also had been confirmed by Ling et al. (2003), who reported that treatability of naturally grown matured *S. macrophylla* as treatable, on average at 197 litres m^{-3}. Generally, both age groups of *S. macrophylla* showed high loading and satisfactory penetration pattern. *Shorea macrophylla*, if so treated, could be utilized for hazard class up to H5 (see Appendix).

Table 2 Summary of penetration and retention for *Shorea macrophylla* (pressure-impregnation process)

Preservative	Age group (y)	Loading, litres m^{-3}		Penetration pattern	
		Mean	Standard deviation	Depth	Pattern description
CCA-Tanalith C 10%	13	380	144.6	Fully penetrated	Fully penetrated
CCA-Tanalith C 10%	22	349	155.6	Fully penetrated	>95% of specimens penetrated

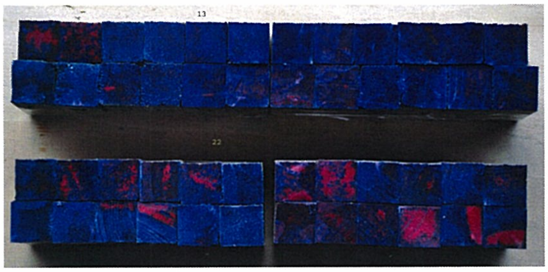	**Full-cell method** *Shorea macrophylla* (13 y) Fully penetrated *Shorea macrophylla* (22 y) >95% of specimens penetrated
	**Vacuum-desiccator method** *Shorea macrophylla* (13 y) Marginal penetration *Shorea macrophylla* (22 y) Marginal penetration

Figure 3 Cross-section penetration patterns of treated *Shorea macrophylla*

When a treatment plant is not available, another option to conduct treatability study of wood species is by the use of an alternative simple method with only a vacuum desiccator. The method described earlier can give a good estimate of the permeability of timber. For comparison purpose, this method was also used to determine the treatabilty of both age groups of *S. macrophylla*. The results are shown in Table 3.

The average loading uptakes of the 13- and 22-y-old *S. macrophylla* using this vacuum-desiccator method were 91 and 75 litres m^{-3} respectively, very much lower than by the pressure method. This is estimated to be about a quarter (1/4) of what is achievable by the full-cell method for both age groups at 24% and 22% respectively. Despite these drawbacks, the method can provide a measure of permeability using only vacuum process but would not provide a conclusive result as the full-cell pressure method. Cross-section penetration determination showed only marginal penetration around the sides as seen in Figure 3. With further research, however, it is anticipated that the vacuum-desiccator method can be used to predict treatability by working out the ratio of uptake of the wood species between the methods used.

Table 3 Summary of penetration and retention for wood species (vacuum-desiccator process)

Preservative	Age group (y)	Loading, litres m^{-3}		Loading as a ratio to pressure treatment (%)
		Mean	Standard deviation	
CCA-Tanalith C 10%	13	91 (380}	25	24
CCA-Tanalith C 10%	22	75 (349)	40	22

CONCLUSION

It is concluded that the full-cell pressure method can be easily used to determine wood treatability characteristics. Both age groups of *S. macrophylla* are classified as easily treatable following the MS 544 standard method of classification. Treatability is, however, not significantly different as far as classification is concerned between both age groups. However, if compared to the earlier report by Ling et al. (2003), the treatability of planted stands for *S. macrophylla* is better than its matured and naturally grown counterpart. The vacuum-desiccator method provides an indication of treatability but needs further investigation to relate the results to the full-cell pressure method. The results obtained here may be used as a measure in the development of effective treatment methods against both fungal and termite attacks for this particular species.

BIBLIOGRAPHY

ANONYMOUS. 2000a. AS 1604.1: 2000. *Specification for Preservative Treatment Part 1: Sawn and Round Timber.*

ANONYMOUS. 2000b. AS/NZS 1605: 2000. *Methods for Sampling and Analyzing Timber Preservatives and Preservatives-treated Timber.*

ANONYMOUS. 2000c. ASTM D1758-96: 2000. *Standard Method of Evaluating Wood Preservatives by Field Tests with Stakes.* 2002 Annual Book of ASTM Standards.

ANONYMOUS. 2003. MS544: PART 10: 2003. *Code of Practice for Structural Use of Timber: Part 10: Preservative Treatment of Structural Timber.*

LING, W. C., LAI, J. K. & SAMMY, J. *2003. A Guide to Natural Durability and Treatment Properties of Sarawak Timbers.* Forest Department Sarawak, TRTTC Technical Report No: TR/21. 14 pp.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

WANG, J. Z. & DEGROOT, R. 1994. *Treatability and Durability of Heartwood.* National Conference on Wood Transportation Structures. General Technical Report FPL-GTR-94 Timber.

Appendix Hazard-class selection guide

Hazard class	Exposure	Specific service conditions	Biological hazard	Typical uses	Minimum net dry salt retention (kg m^{-3})	Minimum depth of penetration (mm)
H1	Inside, above ground	Completely protected from weather and well ventilated, and protected from termites	Insects other than termites (eg lyctid)	Framing, flooring, furniture, interior joinery	-	-
H2	Inside, above ground	Protected from wetting and leaching	Borers and termites	Framing, flooring, and similar, used in dry situations	5.6	12
H3	Outside, above ground	Subject to periodic moderate wetting and leaching	Moderate decay, borers and termites	Weather board, fascia, pergolas (above ground), window joinery, framing and decking	8	12
H4	Outside, in ground	Subject to severe wetting and leaching	Severe decay, borers and termites	Fence posts, greenhouses, pergolas (in ground) and landscaping timbers	12	12
H5	Outside, in-ground contact with or in fresh water	Subject to extreme wetting and leaching and/ or where the critical use requires a higher degree of protection	Very severe decay, borers and termites	Retaining walls, piling, house stumps, building poles, cooling tower	16	25
H6	Marine waters	Subject to prolonged immersion in sea water	Marine wood borers and decay	Boat hulls, marine piles, jetty cross-bracing, landing steps and similar uses	32	25

* Table extracted from MS544: Part 10:2003

BASIC VENEER PROPERTIES

N. P. T. Lim, Y. K. Pek & Januarie Kulis

INTRODUCTION

Veneering is a popular way of utilizing the whole log that can produce veneers with a recovery rate of about 95%. Wood veneer is a thin sheet of wood varying from 0.3 to 6.0 mm thick having its grain parallel to the surface of log. The veneer sheet is most commonly cut from a selected log either by rotary peeling and flat slicing. Depending on the manner in which a log is cut, the veneers produced can exhibit distinctive wood grains and characteristics.

Extensive literature search reveals that there are not many established standards or procedures for determining the quality and attributes of peeled and sliced veneers. However, most machinery manufacturers have their own manual guides with operational instructions and settings to obtain the desired veneer thickness, thickness uniformity and smoothness. The harmonized test methodology on peeling and slicing in the manual by Tan et al. (2010) was developed with expert assistance from the Forestry and Forest Products Research Institute (FFPRI), Tsukuba, Japan, as well as from consultations with industries that have been peeling and slicing tropical hardwood species for several years. The test methodology did not cover the aspect on lathe and slicer settings for knife angle and nosebar compression and only included the experimental procedures for obtaining rotary peeled and flat-sliced veneers of two ranges of desired thickness, sampling and drying of test specimens, yield, thickness uniformity, surface roughness and depth of peeler checks.

The aim of this study was to test the suitability of the harmonized methodology for determination of some basic veneer properties of *Shorea macrophylla,* a potential tropical plantation species.

MATERIALS AND METHODS

Assessment of veneering properties using the harmonized testing method was conducted on 13-y-old and 22-y-old *S. macrophylla* taken from Sabal Forest Reserve, Km 100 Kuching/Sri Aman Road. Green logs of about 2.6 m long were sampled and stored in water to prevent splits. Twenty-four logs were peeled at Destiny Veneer Sdn Bhd, Bintulu, using a rotary spindle-less lathe to obtain veneer thicknesses of 1.5 and 2.5 mm. The peeled veneers were clipped at 1.3 m and labelled. Most of the logs were peeled to a residual core of about 4 cm. From each log, veneer samples were taken from three regions, namely outer, mid- and inner sections, where shrinkage, yield, depth of peeler checks and surface roughness were determined. Similarly, 24 logs were sliced at Moh Sing Hiong & Sons Sdn Bhd, Kuching, to produce veneer thicknesses of 0.6 and 2.5 mm. Five random samples were taken from each log and assessed for yield and surface roughness.

Figure 1 Peeling on an industrial rotary spindle-less veneer lathe

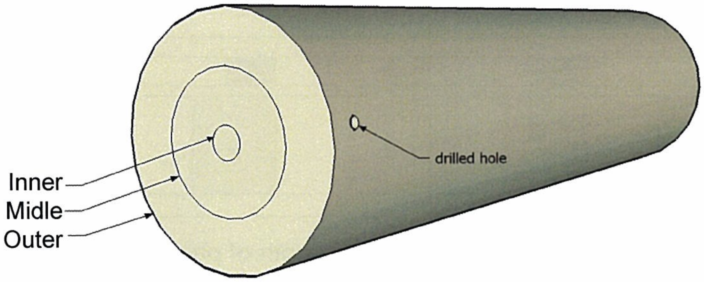

Figure 2 Locations of the three circumferential positions for taking representative veneer samples

Representative veneer samples were taken as shown in Figure 2. As the peeled veneers were clipped to constant dimensions with numbering from 1 to *N* (outer to inner), the identities of the veneer sample representing the outer, middle and inner sections of the log were as follows:

Outer = 1

Middle = $\frac{N}{4}\left(\frac{3R+r}{R+r}\right)$, rounded to the nearest whole number

Inner = *N*

where *N* = total number of pieces of veneer of constant dimension

R = radius of rounded log before peeling (cm)

r = radius of the core left after peeling (cm)

Shrinkage tests were done on the freshly peeled veneer samples as shown in Figure 3. Points a, b and c were used to determine the thickness shrinkage. Points A and B, which were about 20 cm apart, were used to obtain the lengthwise shrinkage.

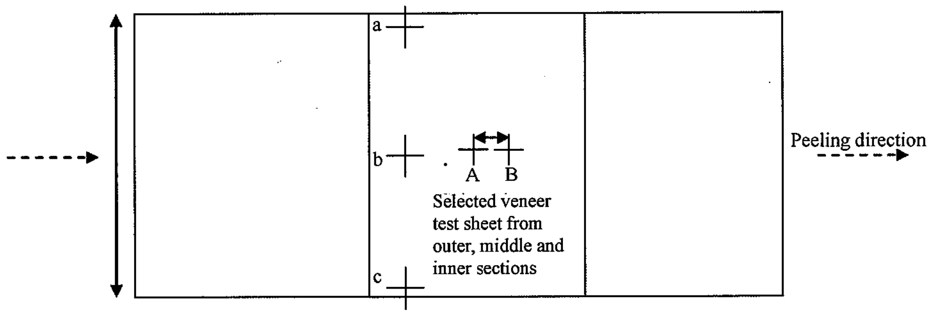

Figure 3 Shrinkage tests on freshly peeled veneer samples

Samples for the determinations of peeler check and surface roughness were taken as indicated in Figure 4.

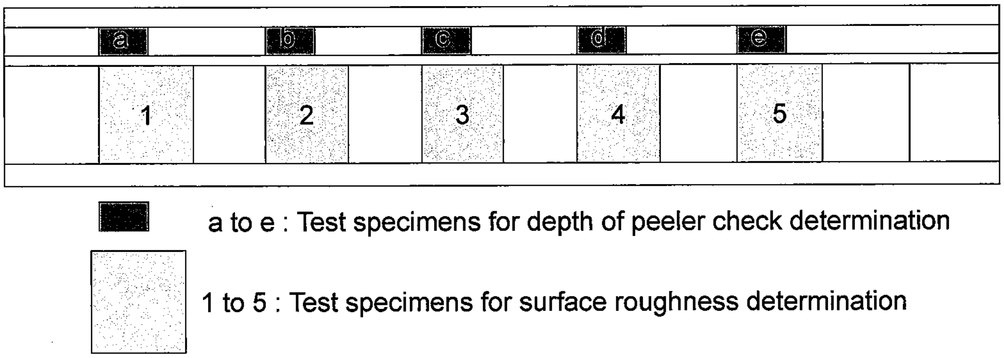

Figure 4 Sampling of samples for depth of peeler check and surface roughness determinations

Logs for slicing were trimmed to a block with two parallel sides and soaked in hot water at temperature of about 60–80 °C. Blocks for obtaining 0.5–1.5-mm veneers are usually soaked for 1–2 days whereas those of 2.5–3.0-mm veneers are soaked for 4–5 days. Each sliced veneer was labelled according to the block number. Figure 5 shows slicing in progress on an industrial veneer slicer.

Picture 5 Optimizing sliced veneer recovery by slicing from a 3rd set of parallel sides

Three test sheets from each log were sampled for the determination of surface roughness. Five samples of 100 mm × 100 mm were taken from each test sheet as shown in Figure 6.

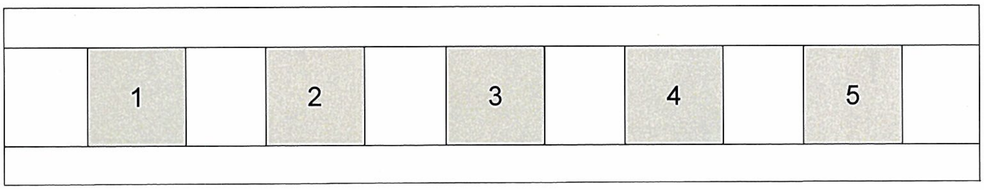

Figure 6 Sampling of samples for surface roughness determination

The test data collected were R_a (mean arithmetic deviation of profile), R_z (mean peak to valley height) and R_{max} (maximum roughness). Definitions for these three tests are illustrated in Figures 7, 8, and 9.

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|Y_i|$$

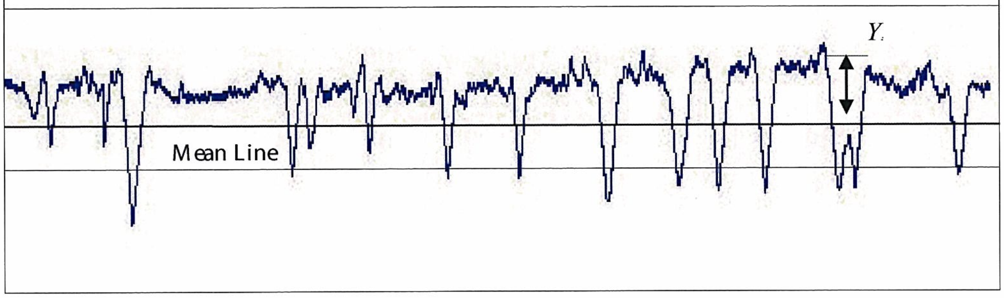

Figure 7 Definition of R_a

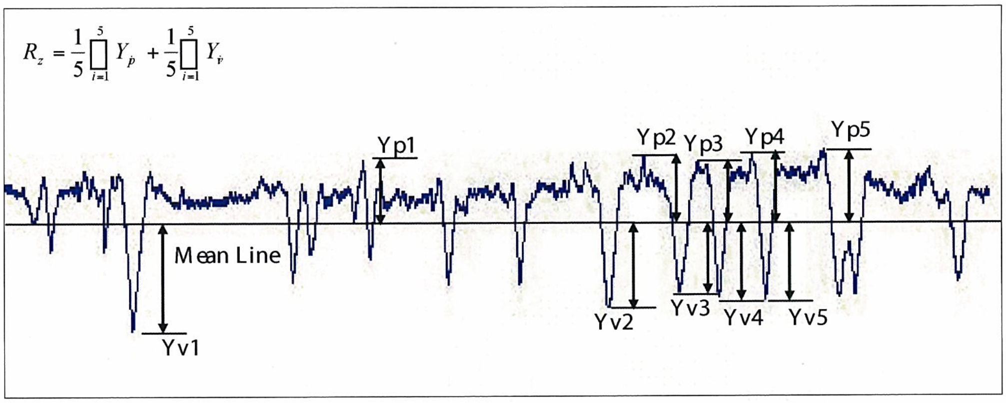

Figure 8 Definition of R_z

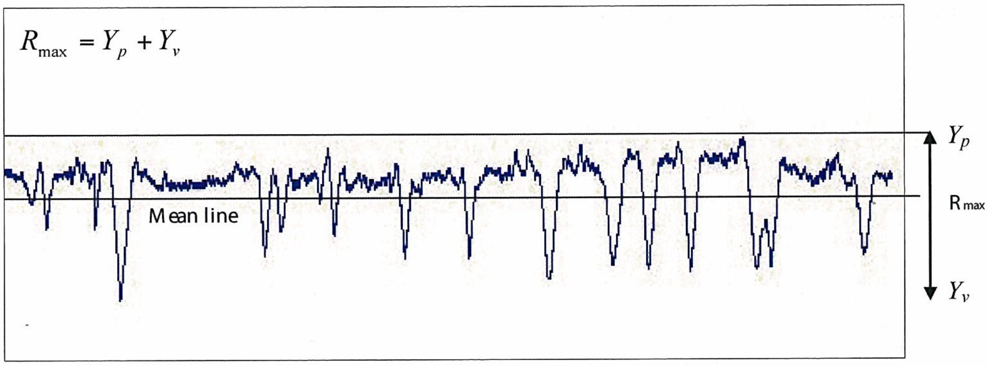

Figure 9 Definition of R_{max}

RESULTS AND DISCUSSION

The results for peeled veneer are shown in Table 1.

Table 1 Results for peeled veneer

Age of tree (y)	Veneer thickness (mm)	Shrinkage (%)		Yield (%)	Depth of peeler checks (%)	Surface roughness (μm)		
		Lengthwise	Thickness			R_a	R_{max}	R_z
13	1.5	3.5	6.1	63	36	31	184	120
	2.5	5.8	5.7	64	46	30	179	116
22	1.5	5.4	6.7	65	38	28	170	110
	2.5	6.9	5.5	65	47	29	176	112

Shrinkage values increased more in the lengthwise direction for the thicker veneer of both age groups. The peeled veneer yield was fairly independent of age of tree and veneer thickness. The depth of peeler checks is a measure of veneer surface tightness. As the thickness of veneer increased, the percentage depth of peeler check also increased. Surface roughness results also exhibited independence from age of tree and veneer thickness.

The results for sliced veneer are shown in Table 2.

Table 2 Results for sliced veneer

Age of tree (y)	Veneer thickness (mm)	Yield (%)	Surface roughness (µm)		
			R_a	R_{max}	R_z
13	0.6	22	14	108	65
	2.5	47	18	152	96
22	0.6	26	13	106	63
	2.5	32	17	135	86

Sliced veneer yield of the 13-y-old trees for 0.6-mm thickness was substantially lower as compared with that for 2.5-mm thickness. However, the same did not apply for the older trees. The surface roughness values of thicker veneer for both age groups were generally much higher for R_{max} and R_z whereas the R_a values did not vary considerably between the two ages.

CONCLUSION

Based on the above assessment, the following deductions can be inferred:

(i) The harmonized methodology developed is suitable for the evaluation of basic veneer properties of *S. macrophylla.*

(ii) The difference in the age of the trees does not produce any significant variation in veneering properties.

(iii) The yield for peeled veneer is about 50% more than for sliced veneer.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Tsutomu Nakano of the FFPRI, Tsukuba, Japan, for his contribution in the preparation of the harmonized methodology. Our special thanks go to Moh Sing Hiong & Sons Sdn Bhd, Kuching, and Destiny Veneer Sdn Bhd, Bintulu, for their invaluable inputs and assistance in the preparation of test materials.

BIBLIOGRAPHY

ANONYMOUS. 1996a. AS/NZS 2098.6: 1996. *Method 6: Depth of Peeler Checks in Veneer and Plywood.*

ANONYMOUS.1996b. ISO 4288: 1996. *Rules and Procedures for Assessment of Surface Texture.*

ANONYMOUS. 2002. ISO 1302: 2002. *Indication of Surface Texture in Technical Product Documentation.*

ANONYMOUS.1996c. JIS B0651: 1996. *Geometrical Product Specifications—Surface Texture: Profile Method-Nominal Characteristics of Contact (Stylus) Instruments.*

ANONYMOUS. 2001. JIS B0601: 2001. *Geometrical Product Specifications—Surface Texture: Profile Method Terms, Definations and Surface Texture Parameters.*

WONG, W. C., HO, K. S. & WONG, C. N. 1988. *Acacia mangium* from Sabah for plywood and decorative panel manufacture: initial trials. *Journal of Tropical Forest Science* 1 (1): 42–50.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

SOME DRYING CHARACTERISTICS

J. L. Tan

INTRODUCTION

Wood in service needs to be dried until its moisture content is in equilibrium with the surrounding air. The removal of moisture from wood requires skill and application of the right technique. Drying is the process required to improve the quality of timber for other further processed products and prior to all downstream processing industries. Seasoned timber tends to achieve dimensional stability and is much less prone to defects in service, such as warping and split.

The threat caused by the decline in log supply from the natural forest has led to urgent exploration into the use of fast-growing plantation species. And with this arose the need for an effective harmonized drying methodology for the new potentially important species introduced. *Shorea macrophylla*, known as engkabang jantong locally, was chosen to test the suitability and applicability of the derived harmonized drying methodology (Tan et al. 2010) with reference to the introduced Japanese method.

Evaluation of the potential values of *S. macrophylla* in terms of solid wood material for some selected tests is discussed below.

MATERIALS AND METHODS

Shorea macrophylla was collected from Sabal Forest Reserve, Km 100, Kuching/ Sri Aman Road, Samarahan Division, Sarawak. The logs were collected from two compartments of age groups of 13 and 22 y with a diameter range of 115–330 mm. Random selection of log diameter ≥ 200 mm was carried out to give a complete distribution of sample requirement. The materials for drying tests were taken from the first log of each tree as stated in the standing instruction in the manual (Tan et al. 2010). All logs were cross-cut to the desired lengths and cut into flitches to obtain the required samples for the tests.

The drying characteristics were studied and evaluated according to the harmonized methodology and procedure introduced by the Forestry and Forest Products Research Institute (FFPRI) of Japan with some modifications made. The revised harmonized methodology and procedure are established and prescribed in the manual. The tests conducted were:

(i) Quick-drying test (QDT)
(ii) Schedule test (DST)
(iii) Air-drying test (AD)
(iv) Drying-rate test (DRT)

RESULTS AND DISCUSSION

Quick-drying test

The quick-drying test results for *S. macrophylla* reveal this species as highly porous and drying relatively well under very harsh condition without any severe drying degrades. The only possible drying defect may arise from external checks that varied from 'perfect' to 'moderate'. Tables 1 and 2 give a summary of the QDT results for the two age groups combined and individually respectively. The deformation of this species was small. Timber cut from this species was thus expected to be stable. As the timber is light and porous, drying duration was short with an estimated time of drying of 6–8 days in a conventional dryer.

Table 1 Summary of quick-drying test results

Sample no.	Initial MC (%)	Grading of defects			Estimated drying schedule (°C)			Estimated drying time from green to 10% MC in ordinary kiln (days) for 1" thick board			Oven-dry shrinkage (%)	
		Initial check	Defor-mation	Honey-combing	Initial DBT	Initial WBD	Final DBT	By time in oven*	By WBD**	Avg.	Tang.	Rad.
G5B4T6-1-2a	74.7	2	1	1	65	5.5	90	6	4	5	6.3	3.6
G6B4T3-1-2c	62.5	4	1	1	55	3.6	83	5	8	6.5	5.8	1.8
G3B4T14-1-2a	82.6	4	1	1	55	3.6	83	8	8	8	4.4	2.2
G4B4T80-1-1b	70.5	3	1	1	60	4.3	85	6	5	5.5	4.7	2.8
G5B4T82-1-2b	54.6	1	1	1	70	6.5	95	6	3	4.5	4.9	2.3
G6B4T4-1-2c	71.5	3	1	1	60	4.3	85	7	5	6	5.2	3.1
G5B5T24-1-1b	70.2	3	1	1	60	4.3	85	4	5	4.5	4.4	1.9
G6B5T5-1-1c	69.8	2	1	1	65	5.5	90	5	4	4.5	4.7	2.0
G6B6T25-1-2a	56.6	1	1	1	66	6.0	88	5	3	4	5.6	2.0
G6B2T84-1-1a	61.0	1	1	1	70	6.5	95	6	3	4.5	5.1	3.7
G6B5T116-1-1b	71.9	2	2	1	65	5.5	90	7	4	5.5	4.5	2.0
G6B6T27-1-2c	63.1	1	1	1	70	6.5	95	7	3	5	5.6	2.4
Result:		4	2	1				-	-			
Mean MC: 67.1%												
MC range: 54.6–82.6%												
2/3 Max.: 55%												
Suggested drying schedule (temperature & depression for kiln charge)					55	3.6	83					

* Time from green to 1% MC
** Initial WBD

Table 2 Summary of QDT results according to age group

Age group (y)	Grading of defects			Estimated drying schedule (°C)			Estimated drying time for 1" board in kiln			OD shrinkage (%)	
	Initial checks	Defor-mation	Honey combing	Initial DBT	Initial WBD	Final DBT	By time in oven	By WBD	Average	Tang.	Rad.
13	4	1	1	55	3.6	83	5	8	6.5	6.3	3.6
22	4	2	1	55	3.6	83	8	8	8	5.1	3.7

Schedule test

Primary drying schedules were deduced from two methods introduced by the FFPRI, Japan. Tables 3 and 4 show the derived primary drying schedules formulated from the QDT using both methods A and B respectively. Only the milder one would be selected to start the schedule test. In this case, the schedule generated using method B was selected to run the 1st trial in the schedule test. The schedule test was carried out using a ½-ton experimental dryer as shown in Figure 1. A dummy stack was constructed prior to the schedule test, with 15 slot-in pockets as in Figure 2 to accommodate the samples under test for each run. One thickness of 27 mm was tested under the schedule test. The drying degrades with the application of each derived drying schedule were assessed. At the end of the run, all specimens were cross-cut to determine their individual moisture content and moisture distribution.

A total of three runs, starting with the selected primary drying schedule, were carried out. The primary and modified drying schedules with assessed degrades are shown in Tables 5, 6 and 7. No defects were observed even though the modified schedule was very harsh.

Table 3 Primary drying schedule, method A

Drying schedule					
MC (%)	DBT (°C)	WBD (°C)	WBT (°C)	RH (%)	EMC (%)
Green	55	3	52	85	15.8
50	55	4	51	80	14
40	55	6	49	72	11.7
35	55	10	45	57	8.6
30	60	18	42	34	5.4
25	65	30	35	14	2.7
20	70	30	40	17	2.9
15	80	30	50	22	3.1

Table 4 Primary drying schedule, method B

		Drying schedule			
MC (%)	DBT (°C)	WBD (°C)	WBT (°C)	RH (%)	EMC (%)
Green	55	3.6	51.4	84	14.6
55	55	4.2	50.8	78	13.3
50	55	6	49	72	11.7
40	55	10	45	57	8.6
30	60	15	45	45	6.4
25	68	20	48	34	5.0
20	78	26	52	29	3.9
15	83	30	53	23	3.0

Figure 1 The experimental dryer used to conduct the schedule test

Figure 2 The experimental dryer with dummy stack of 15 slot-in pockets for inserting samples under test in the schedule test

Table 5 Primary drying schedule

Drying schedule 1: DST 1 (run 1)—Primary drying schedule derived from the QDT						
MC (%)	DBT (°C)	WBD (°C)	WBT (°C)	RH (%)	EMC (%)	Drying defects
Green	55	3.6	51.4	84	14.6	Sound
55	55	4.2	50.8	78	13.3	Nil
50	55	6	49	72	11.7	Nil
40	55	10	45	57	8.6	Nil
30	60	15	45	45	6.4	Nil
25	68	20	48	34	5.0	Nil
20	78	26	52	29	3.9	Missed
15	83	30	53	23	3.0	Nil

Table 6 Modified primary drying schedule

Drying schedule 2: DST 2 (run 2)						
MC (%)	DBT (°C)	WBD (°C)	WBT (°C)	RH (%)	EMC (%)	Drying defects
Green	55	3.6	50.0	76	12.6	Nil
50	55	4.2	49.0	71.5	11.3	Missed
40	55	6.0	47.0	63	9.7	Nil
35	55	10.0	40.0	40	6.6	Nil
30	60	15.0	37.5	27.5	4.4	Nil
25	68	20.0	40.5	20	3.0	Nil
20	78	26.0	40.5	13	1.9	Nil
15	83	30.0	38.5	<10	1.0	No defects (actual conditions could only achieve DBT/WBT 83 °C / 41 °C that gave a corresponding RH/ EMC of 10% / 1.4%)

Table 7 Modified DST 2 drying schedule

Drying schedule 3: DST 3 (run 3)						
MC (%)	DBT (°C)	WBD (°C)	WBT (°C)	RH (%)	EMC (%)	Drying defects
Green	60	4.8	55.2	77	12.6	Sound
50	60	6.0	54	73	11.3	Nil
40	60	8.2	51.8	64	9.7	Nil
35	60	14.5	45.5	44	6.6	Nil
30	65	21.5	43.5	28	4.4	Nil
25	73	29.5	43.5	20	3.0	Nil
20	83	37.5	45.5	15	1.9	Nil
15	88	46.3	41.7	< 10	1.0	Discarded

Comparing the stress formation during drying in runs 2 and 3, the latter showed a higher trend of severe stresses that amounted to 20.0% of that of 6.7% in run 2. Table 8 shows the details of drying stresses in the three runs of the experiment.

Table 8 Occurrences of drying stresses in the schedule test

Degree of drying stresses	Percentage of stresses		
	Run 1	Run 2	Run 3
Slight	10/14 (71.4%)	9/15 (60.0%)	8/15 (53.3%)
Moderate	0/14 (0%)	5/15 (33.3%)	4/15 (26.7%)
Severe	4/14 (28.6%)	1/15 (6.7%)	3/15 (20.0%)

From the experimental results, either the 2nd or 3rd schedule can be utilized for commercial drying of the species except that the period of conditioning for stress relief treatment at the end of drying will be longer. It might be a safeguard against defects and for economical reason to pick the 2nd drying schedule. However, if the kiln-dried product is not for immediate use, equalizing and conditioning can be exempted, as the material will achieve stability naturally.

Air-drying

The tests for air-drying involved two thicknesses, ie 27 and 54 mm. The specimens were both stacked under shed on top of a constructed metal platform of height 76 mm segregated by 25-mm stickers at each layer to a stack height of nine layers of specimens. The environmental air conditions (DBT & RH) were monitored and recorded by a thermo-hygrometer with a weekly recording chart (Figure 3). The experimental procedure followed the guideline as stipulated in Chapter 8 of the manual (Tan et al. 2010).

Shorea macrophylla is a low density wood that can be dried perfectly well in air-drying. The duration required to achieve air-dry condition for the 27- and 54-mm thick boards varied from 6 to 10 weeks and from 11 to 23 weeks respectively. Again, the occurrence of drying degrade was very low. Evaluation of the results for the 27-mm and 54-mm boards is shown in Table 9.

Table 9 Evaluation of air-drying results

(i) Thickness 27 mm

Age group (y)	Est. drying time (days) (30% MC–A/D)	Drying degrade	
		Checks	Max. distortions
13	34.6 (21 ~ 45)	Nil	Bow (7%) Twist (14%) Cup (7%)
22	33.0 (17 ~ 40)	Nil	Bow (5.6%) Twist (11%)

(ii) Thickness 54 mm

Age group (y)	Est. drying time (days) (30% MC–A/D)	Drying degrade	
		Checks	Max. distortions
13	66.1 (53 ~ 88)	End-checks (7%)	Bow (7%)
22	71.5 (53 ~ 93)	End-checks/ end-split (11%)	Twist (17.6%)

From the experimental results, the species dried perfectly well for the 27-mm thick boards without any drying defect and with little distortion (25% only distorted within the range of 1.0 ~ 7.0 mm). For the 54-mm thick boards minor end-checks (3 out of 30) were observed with some distortion, mainly twist and bow. The estimated drying time from a moisture content of 30% to EMC at air-dry condition for the 27-mm boards was in the range of 17 ~ 45 days with a mean value of 33 days. For the 54-mm boards, the range of time to achieve air-dry stage from MC 30% was 53 ~ 93 days with a mean of 69 days.

The density values of *S. macrophylla* were 310 and 323 kg m^{-3} for age groups of 13 and 22 y respectively. The shrinkage was relatively low. The shrinkage values, however, can be taken as guidelines only (Figures 4 and 5).

Figure 3 Both the 27- and 54-mm thick *Shorea macrophylla* test boards sitting on 30" high metal platform for the air-dry test with air conditions recorded by a thermo-hygrometer

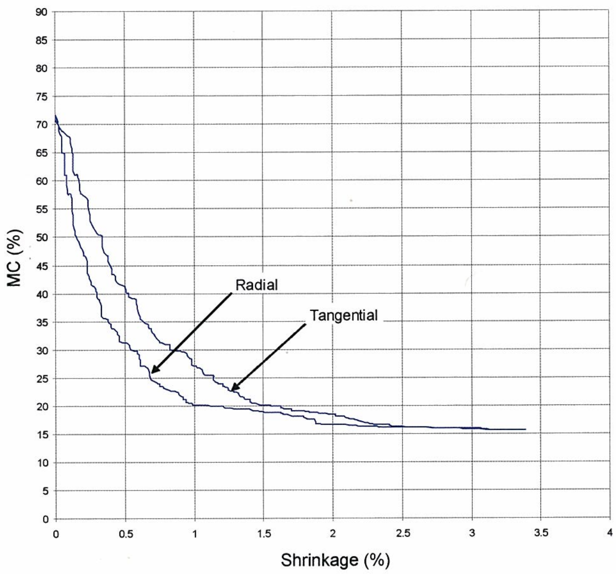

Figure 4 Graph showing the combined quarter- and flat-sawn tangential and radial shrinkages for the 27-mm thick board

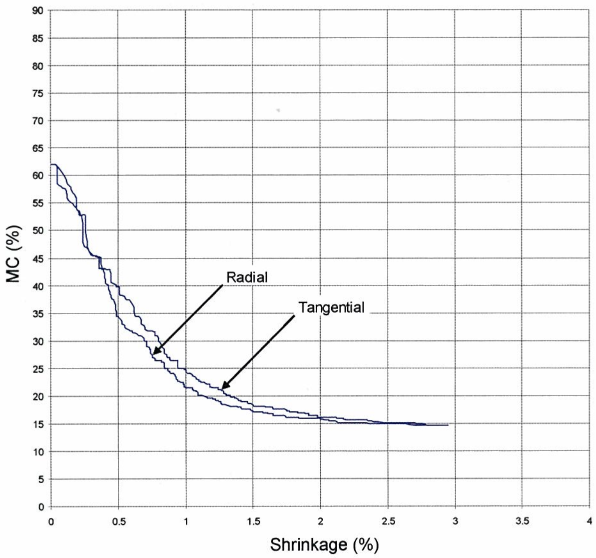

Figure 5 Graph showing the combined quarter- and flat-sawn tangential and radial shrinkages for the 54-mm thick board

Drying-rate test

The test was conducted in a forced air circulation convectional oven with internal dimensions of 1030 × 660 × 1200 mm (L × D × H). The chamber is equipped with double fans at the top and bottom on the back wall of the chamber. To make sure that air can be directed to specimens under test, the chamber is divided into top and bottom compartments by segregating with the aid of a perforated tray (Figure 6). Specimens were first planed to a common thickness of 27 mm so that all surfaces were smooth. They were segregated by 25-mm thick stickers laid perpendicular to the back wall of the chamber to ensure air movement through the test specimens. The only controlled condition was the DBT set at 60 °C. Figure 6 shows the actual specimens tested in a forced-air convectional oven. From the experimental results the coefficient k for 13- and 22-y Shorea macrophylla were 0.32 and 0.23 respectively (Table 10).

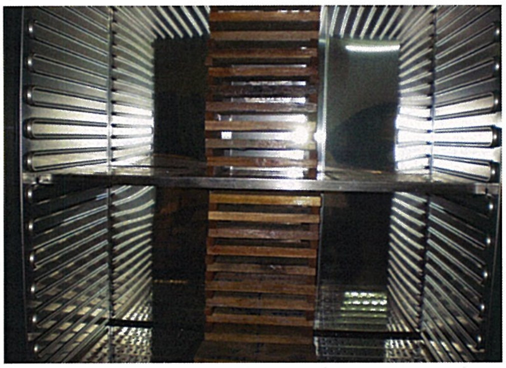

Figure 6 Drying-rate test samples in a forced-air convectional oven

Table 10 Summary of test results

No.	Sample No.	Sawing[t] pattern	Time of MC dropped from 15 to 10% (hr) $(t_{15}-t_{10})$	Cal. final MC (%)	Total moisture lost from green to final (%)	Shrinkage (%) Width	Shrinkage (%) Thick-ness	Cal. density (kg m^{-3})
Age group: 13 y								
1	G5B4T6-4-2a	Q/S	20	3.82	61.6	1.91	6.34	296
2	G5B4T6-5-2	F/S	10	3.29	76.4	3.76	3.08	296
3	G6B4T3-3-2	Q/S	15	3.86	92.5	1.62	7.38	342
4	G6B4T3-5-2	F/S	10	3.21	104.0	5.67	2.53	351
5	G3B4T14-4-1	F/S	19	3.19	91.7	6.01	2.23	536
6	G5B5T24-2-2a	F/S	10	3.15	131.9	3.76	2.01	289
7	G5B5T24-4-2b	Q/S	21	4.82	122.8	2.45	5.03	289
8	G6B5T5-3-1b	Q/S	30	6.01	113.1	1.82	4.00	288
9	G6B5T5-5-1a	F/S	12	3.35	112.2	3.67	1.79	339
10	G6B6T25-3-2b(2)	Q/S	15	3.60	79.7	1.92	4.95	312
11	G6B6T25-4-2a(2)	F/S	11	3.32	96.1	4.47	3.33	302
	Average $(t_{15}-t_{10})$		15.4 (10~30)			Av. density:		310
Age group: 22 y								
12	G3B4T14-3-1b(2)	Q/S	32	7.28	108.6	3.00	1.33	483
13	G4B4T80-2-2b	F/S	18	3.83	86.7	4.23	2.91	343
14	G5B4T82-1-1b	Q/S	20	4.07	70.2	1.87	5.56	261
15	G5B4T82-2-2a	F/S	19	3.66	79.8	4.20	2.23	265
16	G6B4T4-2-1b	F/S	22	4.36	98.9	4.91	2.31	391
17	G6B4T4-5-1a	Q/S	26	5.35	88.0	2.38	4.50	363
18	G6B2T84-4-2b	Q/S	28	4.95	83.7	1.75	5.03	334
19	G6B2T84-6-2a	F/S	15	3.52	72.8	6.07	2.47	358
20	G6B5T116-7-1	F/S	7*	3.04	82.5	5.72	2.72	347
21	G6B6T27-1-1a	F/S	16	3.60	71.7	4.65	2.59	326
22	G6B6T27-5-1a	Q/S	19	3.90	80.1	2.56	5.62	324
	Average $(t_{15}-t_{10})$		21.3 (15~32)			Av. density:		323

* Figure ignored

[t]Q/S = quater-sawn
F/S = flat-sawn

From the experimental results the coefficient k is determined using the given formula:
$du/dt = k\,(u - u_e)$
where du/dt = change in moisture content drying rate at final drying period (% hr^{-1})
$u - u_e$ = change in moisture content (%)
$k = (15 - 10)\ \% \,/\, (t_{15}-t_{10})$
Thus, coefficient k for age group 13 y is,
= 5/15.4 hr^{-1}
= 0.32 hr^{-1} and,
Coefficient k for age group 22 y is,
= 5/21.3 hr^{-1}
=0.23 hr^{-1}

A resorting of radial and tangential measurements between width and thickness of both flat- and quarter-sawn specimens to come out with a final combined shrinkage curve was conducted and plotted into a graph as shown in Figure 7.

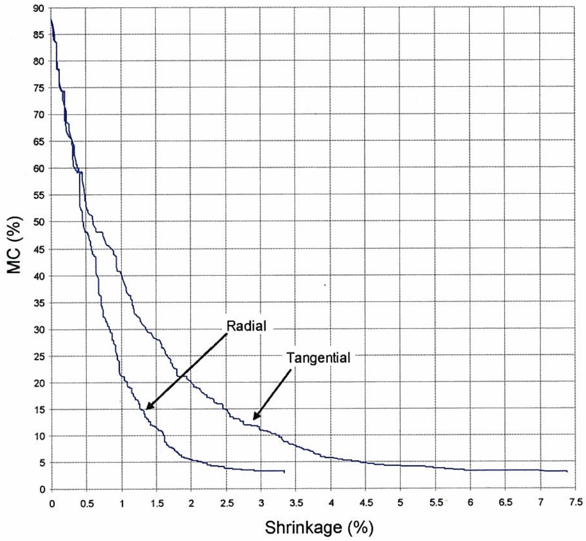

Figure 7 Drying-rate test shrinkage curve

CONCLUSION

The results of this study indicate that all the four tests can be conducted using the harmonized methodology and test procedures. The species can easily be handled by the timber industry in Sarawak using their existing facilities.

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BIBLIOGRAPHY

Basri, E., Hayashi, K., Shibuya, M. & Nishiyama, H. 2001. Optimum drying schedule for some fast grown species from Indonesia. 7th International IUFRO Wood Drying Conference 2001.

Dayang Hartini, Tan, J. L., Foo, E., P. L., Kho, P. C. S. & Ismail Sulaiman. 1997. Drying of boards cut from baby-small keruing. International Tropical Wood Conference, June 17–20, 1997, Kuala Lumpur, Malaysia.

Hisada, T., Sato, S. & Sumi, H. 1986. *Patternizing of Kiln Drying Schedule of Tropical Woods*. Bulletin of the Forestry & Forest Products Research Institute, Japan, No. 340.

ISMAIL SULAIMAN. 1996. New developments in kiln schedules for some Sarawak timbers. TRTTC/STA Forest Products Seminar 1996.

MCMILIEN, J. M. & WENGERT, E. M. 1978. *Drying Eastern Hardwood Lumber.* Forest Products Laboratory, Forest Service, U. S. Department of Agriculture. Agriculture Handbook No. 528.

SUMI, H., ISMAIL, B. S., FOO, E. P. L. & TAN, J. L. 1995. *Kiln Drying Properties and Kiln Drying Schedules of Nine Species of Sarawak Timbers.* TRTTC Technical Report No. TR/14, Timber Research & Technical Training Centre.

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

TERAZAWA, S. 1965. *Method of Easy Determination of Kiln Drying Schedule of Wood.* Wood Industry, Japan, Vol. 20, No. 5.

DETERMINATION OF FINGER-JOINTING AND BONDING PROPERTIES

K. B. Ting

INTRODUCTION

Finger-jointing and lamination can be defined as techniques to join shorter or smaller pieces of timbers together using an appropriate adhesive to produce a required length and width. These techniques are very useful to improve the grade or value of the timber; if there are some grading defects in a piece of timber, that piece can be cross-cut, removing the defects and then finger-jointed together to become a piece of higher grade. This can maximize the recoveries due to growth stress, smaller log size and the higher frequency of knots of plantation timber.

Nowadays, most of the timber mill operators are processing smaller-diameter and low-grade logs because of the massive agricultural conversion schemes and logs harvested from the planted forests. These have contributed to lower recovery rates and generated a substantial amount of low-quality sawn timber and wood residues. Some timber companies have taken concerted efforts to effectively utilize these low-grade timbers and wood residues. Finger-jointing and lamination are important techniques which can turn a large percentage of timbers of short length and residues that traditionally are either incinerated or discarded into valuable products. While facing the higher log prices and recent economy downturn, the mill operators have placed emphasis on the importance of higher recovery rates in order to reap maximum profits from their raw materials.

The suitability of the testing methodologies for assessment of finger-jointing and bonding properties for non-structural purposes of *Shorea macrophylla* from two age groups was evaluated.

MATERIALS AND METHODS

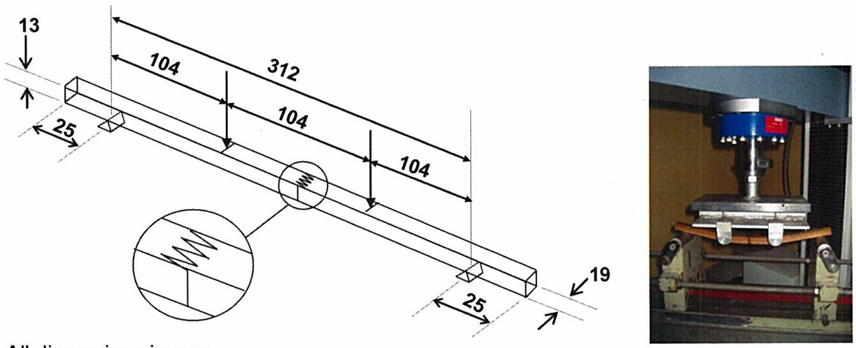
A total of 2820 specimens each of 13-y-old and 22-y-old *S. macrophylla* were prepared. The specimens were kiln dried to 12% moisture content and the density values of the of 13-y-old and 22-y-old timber were 308 and 347 kg m^{-3} respectively. The specimens were divided into four groups and used to conduct four types of tests, namely bending, tension, block-shear and delamination tests. The finger-jointed specimens were made by passing the specimens through the finger shaper, which cut the ends into the required finger pattern. The length of the finger cutter used was 12 mm. These specimens were used for the bending and tension tests. Laminated specimens used for conducting the block-shear and delamination tests were prepared using pressing jigs. All test specimens were bonded with three types of adhesives, namely polyvinyl acetate (PVAc), emulsion polymer isocyanate (EPI) and phenol-resorcinol formaldehyde (PRF), and the sizes of test specimen for the respective tests are shown as follows:

	Test size (thickness × width × length)			
	Bending	Tension	Block shear	Delamination
Size (mm)	13 × 19 × 312	6 × 19 × 254	thickness × 25 × 25	thickness × 75 × 100
No. of specimens	30	30	30	30

All the testing procedures were carried out in accordance with the methodologies as stipulated in the manual *Testing Methods for Plantation Grown Tropical Timbers* (Tan et al. 2010).

Bending test

The test specimens for the bending test were treated to four service conditions, namely dry, water soak, boil and vacuum-pressure. The 4-point bending test was conducted on the finger-jointed specimen with the loading speed of 12 mm min^{-1} applied perpendicular to the face of the specimen and the bending span was 312 mm as shown in Figure 1. The bending strength or modulus of rupture (MOR) for each specimen was calculated after the test.



All dimensions in mm

Figure 1 Diagram of 4-point bending test

Tension test

The test specimens for the tension test were treated to six service conditions, namely dry, water soak, boil, vacuum-pressure, elevated temperature (104 °C) and temperature-humidity (65 °C, 16% EMC). A universal testing machine with the loading speed of 13 mm min^{-1} was used to conduct the tension test as shown in Figure 2. The specimen was gripped firmly by a jig over a length of 63 mm at both ends. The tensile strength or MOR of each specimen was calculated and mode of failure was visually inspected after the test.

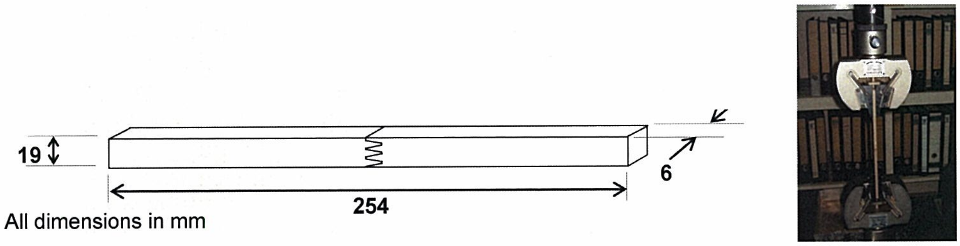


Figure 2 Diagram of tension test

Block-shear test

The test specimens for the block-shear test were treated to five service conditions, namely dry, water soak, boil, vacuum-pressure and elevated temperature (104 °C). The block-shear test was conducted on the stair-step shaped specimen as shown in Figure 3. The load was applied to the glue-line until failure occurred. The shear strength or MOR of the glue-line was calculated and the wood failure percentage was also evaluated.

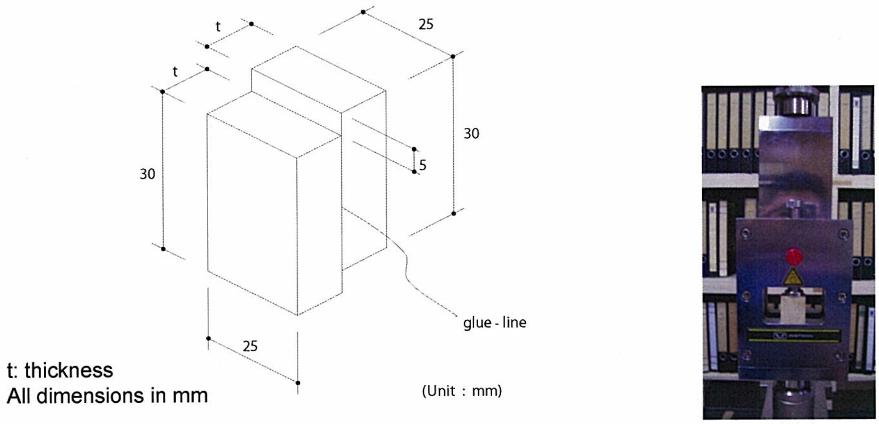


Figure 3 Diagram of block-shear test

Delamination test

The delamination test was carried out to evaluate the bonding performance of the glue-line of the laminated specimen. Thirty specimens each, as shown in Figure 4, were used to undergo four tests, namely water immersion 6 and 24 hr, boil water soak and vacuum-pressure test. After the respective tests, the total length of glue-line delamination of each specimen was measured and the delamination ratio in percentage was calculated.

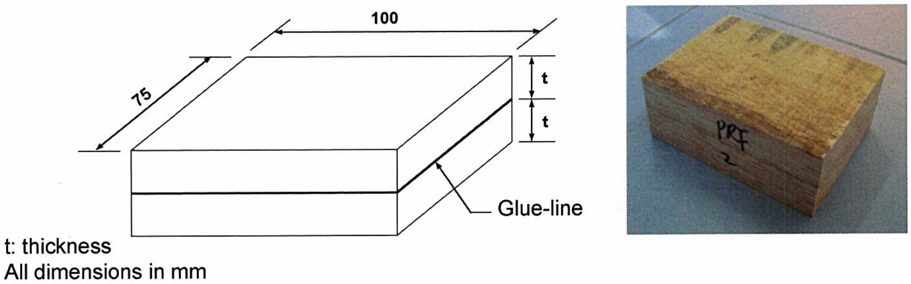


Figure 4 Diagram of delamination test sample

RESULTS AND DISCUSSION

Bending test

The bending strength results of *S. macrophylla* of both age groups are shown in Figure 5. All specimens bonded with the three types of adhesives treated to the four conditions satisfied the minimum requirements of strength values as stipulated in the manual. The results also show that there is not much significant difference in terms of bending strength between the two age groups.

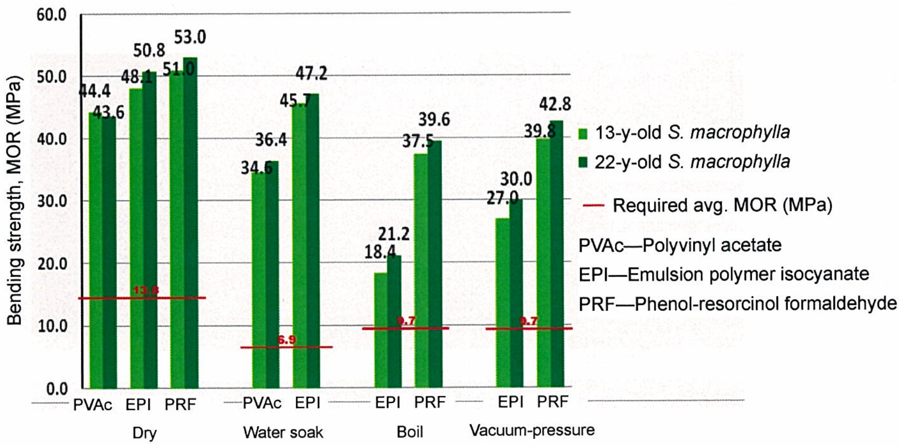


Figure 5 Bending strength of *Shorea macrophylla* using different adhesives and treatment conditions

Tension test

Figure 6 shows the tension test results of both 13-y-old and 22-y-old *S. macrophylla* treated to the six conditions. The tensile strength of all specimens bonded with the three types of adhesive met the minimum requirements of tensile strength values as stipulated in the manual. Generally, there is not much significant difference in terms of tensile strength between both age groups.

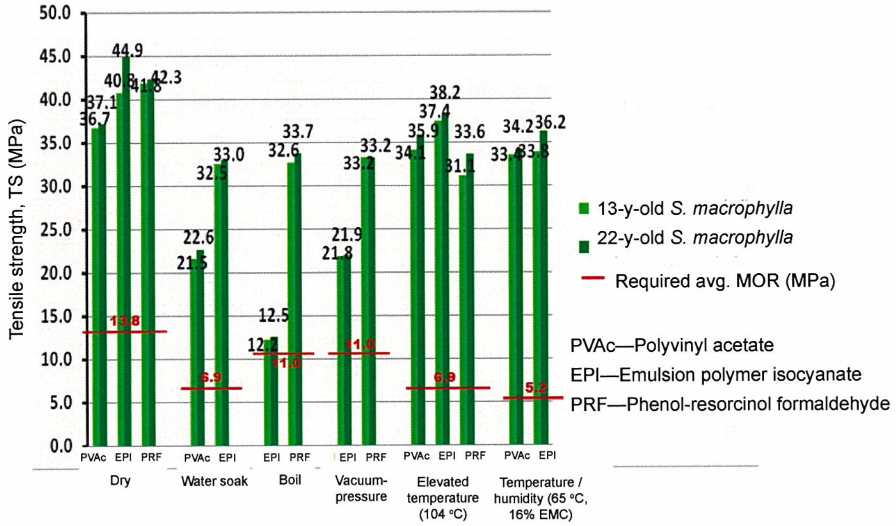


Figure 6 Tensile strength of *Shorea macrophylla* using different adhesives and treatment conditions

Figure 7 shows the average wood failure (WF) of the 13-y-old and 22-y-old specimens in tension test under various test conditions. All specimens met the required WF (%) as stipulated in the manual, except for specimens bonded with EPI in boil condition. There are no minimum requirements for test conditions of elevated temperature (104 °C) and temperature/humidity (65 °C, 16% EMC) as stated in the manual.

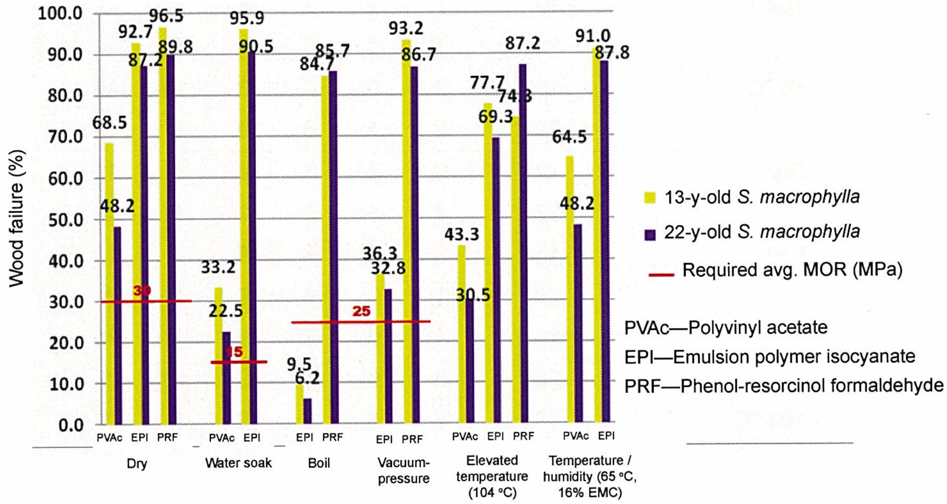


Figure 7 Wood failure percentages of *Shorea macrophylla* specimens in tension test

The failure mode results of the two age groups in tension test using different adhesives and test conditions are shown in Table 1 and illustrated in Figure 8.

Table 1 Failure modes of *Shorea macrophylla* specimens in tension test

Adhesive	Test condition	Age group (y)	No. of counts*						Total counts
			Failure mode						
			1	2	3	4	5	6	
PVAc	Dry	13	9	1	4	2	5	9	30
		22	16	2	1	4	3	4	30
	Water soak	13	19	5	3	2	1	0	30
		22	23	0	3	3	1	0	30
	104 °C	13	18	1	4	0	3	4	30
		22	20	0	5	1	0	4	30
	65 °C	13	12	0	1	1	6	10	30
		22	16	0	2	1	3	8	30
EPI	Dry	13	0	0	6	1	12	11	30
		22	1	1	8	5	6	9	30
	Water soak	13	1	0	1	1	8	17	28**
		22	3	0	0	1	6	20	30
	Boil	13	28	0	0	2	0	0	30
		22	29	0	1	0	0	0	30
	Vacuum-pressure	13	20	0	1	1	5	3	30
		22	19	2	4	1	3	1	30
	104 °C	13	7	2	3	4	11	3	30
		22	7	0	8	1	9	4	29***
	65 °C	13	2	0	0	0	14	14	30
		22	2	1	6	0	9	12	30
PRF	Dry	13	0	2	3	2	12	11	30
		22	1	1	8	7	5	8	30
	Boil	13	3	3	3	5	5	11	30
		22	1	2	6	7	6	8	30
	Vacuum-pressure	13	1	0	2	3	8	16	30
		22	3	0	5	3	10	9	30
	104 °C	13	7	6	5	2	9	1	30
		22	2	4	4	6	11	3	30

*No. of counts based on 30 specimens tested. **Two specimens showed no visible sign of wood failure.
***One specimen showed no visible sign of wood failure.

The failure mode results of *S. macrophylla* show that:

(a) PVAc specimens failed mostly in mode 1;

(b) EPI specimens treated in dry, water soak, elevated temperature (104 °C) and temperature humidity (65 °C, EMC 16%) conditions failed mostly in modes 5 and 6 whereas samples treated in boil and vacuum-pressure conditions failed mostly in mode 1; and

(c) PRF specimens failed mostly in modes 5 and 6.

Mode 1 Mode 5 Mode 6

Figure 8 Failure modes

Block-shear test

The shear strength results of the two age groups using different adhesives treated under five conditions are shown in Figure 9. The shear strength of *S. macrophylla* specimens bonded with the three types of adhesive met the minimum requirements of shear strength values as stipulated in the manual. The results also show that there is not much significant difference in terms of shear strength between the 13-y-old and 22-y-old *S. macrophylla*.

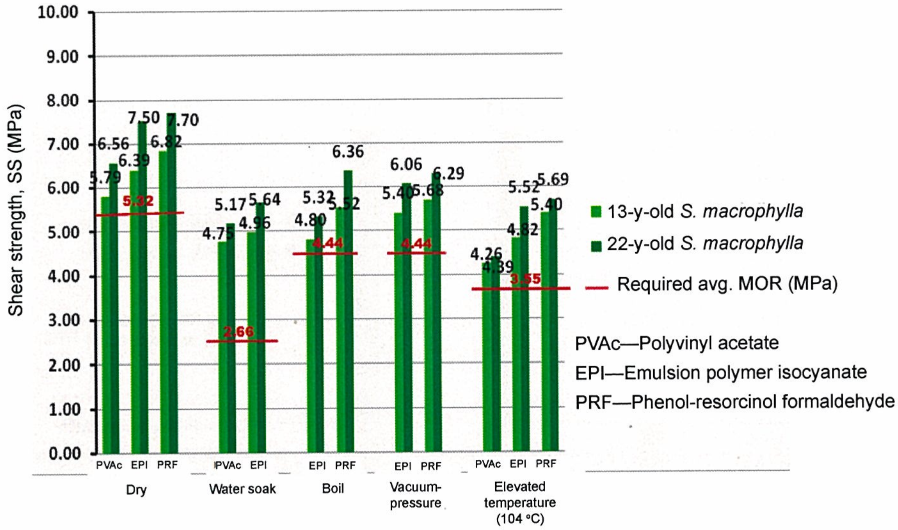


Figure 9 Shear strength of *Shorea macrophylla* using different adhesives and treatment conditions

The average wood failure (WF) percentages of the specimens with the three types of adhesive treated with five conditions are shown in Figure 10. The average wood failure of *S. macrophylla* of the two age groups met the required WF as stipulated in the manual.

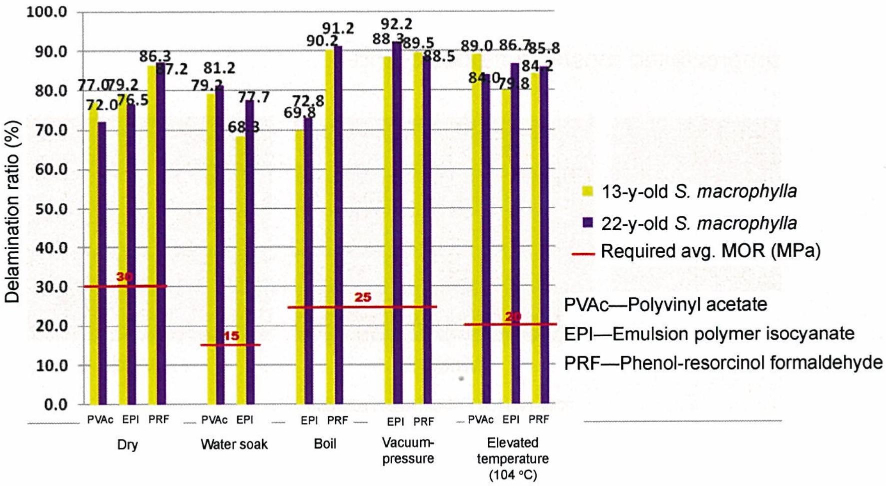


Figure 10 Wood failure percentages of *Shorea macrophylla* in block-shear test

Delamination test

The delamination test results for both age groups treated to the four conditions are shown in Figure 11. The results show that *S. macrophylla* specimens bonded with PVAc adhesive failed the required delamination ratio of less than 10% under the test conditions of water immersion for 24 hr, boil and vacuum-pressure while the specimens bonded with other adhesives satisfied the requirement.

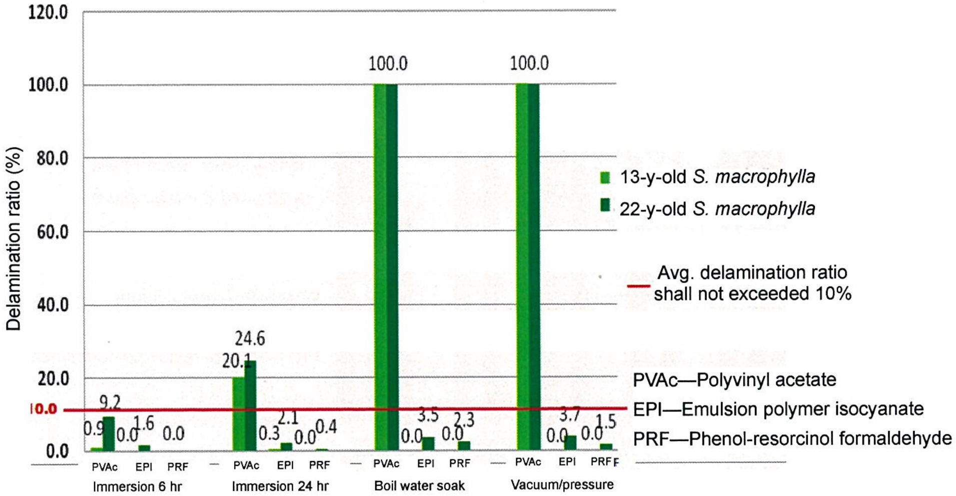


Figure 11 Delamination ratios (%) of *Shorea macrophylla* using different adhesives and treatment conditions

Selection of harmonized testing methodologies

Selection of testing methods depends on the requirement of product application. For example, if the end-use is meant for indoor usage with little or no water interruption and the surrounding humidity is low, it is not required for the user to test the product with boil test, etc.

CONCLUSION

The methodology adopted is suitable for use to evaluate the finger-jointing and bonding properties of *S. macrophylla*. Samples bonded with PVAc adhesive are not necessary to undergo boil water soak and vacuum-pressure tests as the results indicated that they have 100% delamination. In other words, products bonded with PVAc adhesive are not recommended for use in wet condition.

ACKNOWLEDGEMENT

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BIBLIOGRAPHY

ANONYMOUS. 1999. ASTM D5751-99 (1999). *Standard Specification for Adhesives Used for Laminate Joints in Nonstructural Lumber Products.*

ANONYMOUS. 2003. ASTM D5572-95 (2003). *Standard Specification for Adhesives Used for Finger Joints in Nonstructural Lumber Products.*

ANONYMOUS. 2003. MAFF, Notification No. 234. *Japanese Agricultural Standard for Glued Laminated Timber.*

ANONYMOUS. 2006. ISO 17087:2006(E). *Specifications for Adhesives Used for Finger Joints in Non-structural Lumber Products.*

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

CHEMICAL PROPERTIES OF TIMBER AND BARK

S. Siti Hanim

INTRODUCTION

Wood is composed essentially of lignin, cellulose, carbohydrates and extractives. Each of these components contributes to wood fibre properties, which eventually have an effect on product properties.

Wood contains approximately 20 to 30% lignin. Lignin is a complex polymer, the chief non-carbohydrate constituent of wood that binds cellulose fibres and hardens and strengthens the cell walls of plants. For pulp and paper manufacturers, removal of the lignin is the primary objective of the pulping and bleaching processes. Determination of the lignin content in wood can provide them with information for the evaluation and application of these processes.

Holocellulose is the fibrous material in wood comprising all the hemicelluloses and cellulose that can be obtained when the extractives and the lignin are removed from the wood. The non-cellulosic carbohydrates in wood are called hemicelluloses and for hardwood, its hemicelluloses consist mainly of pentosans. Pentosans contained in pulp indicate the retention or loss of hemicellulose in general during the pulping and bleaching processes. Since hemicelluloses contribute to the strength of paper pulps, high pentosan content is desirable.

Extractives are non-volatile materials in wood which are soluble in polar and non-polar solvents. They are not generally considered part of the wood polymer structure. These materials should be removed before any chemical analysis of the wood. Ethanol-benzene extractable content of wood is a measure of the total extractives which comprise waxes, fats, some resins and portions of wood gums. Hot water removes part of the extraneous materials such as tannins, gums, sugars, starches and colouring matter while dichloromethane or hexane extracts substances such as oils and waxes.

The major components in bark are polyphenolic components, referred to as tannins which are widely distributed in the bark and the sugars that coexist with them. Non-tannins, especially sugars, affect the effective utilization of the tannins. These compounds are particularly abundant in various species of acacia, hemlock, *Tsuga* spp, oak and related genera, ie *Quercus, Castanea* and *Lithocarpus*, and certain mangrove species (Anonymous 1995). Tannins are considered to be among the most important products from tree bark. Tannin has been used to tan animal skins and produce leather. In addition to the production of leather, it is used in food processing, fruit ripening and as an ingredient of many beverages.

In the last two decades, there has been considerable interest worldwide in the development of tannin wood adhesives as substitutes for wood adhesives derived from non-renewable resources, and in particular phenol and resorcinol which are derived from the petrochemical industry.

The objectives of this study were:

- To assess the chemical properties of *Shorea macrophylla* timber
- To assess the tannin and sugar contents of *S. macrophylla* bark

MATERIALS AND METHODS

Materials

Shorea macrophylla of ages 13 y and 22 y was collected from Sabal Forest Reserve in Sarawak, Malaysia. A total of six trees per age group were used in this study.

Sample preparation

Specimens were collected from one-inch thick disc samples as shown in Figure 1.2 [Chapter 1 in *Testing Methods for Plantation Grown Tropical Timbers* (Tan et al. 2010)] The specimens were then reduced to size using a Wiley mill to pass through ASTM mesh-40 screen.

Methods

For details of the methods used, refer to Chapter 10 of the manual *Testing Methods for Plantation Grown Tropical Timbers.*

Chemical analysis on wood

(i) Determination of moisture content
The moisture content determination was conducted using the oven-dry method.

(ii) Determination of water solubles
For the determination of hot water solubility, the wood meal was extracted with water under reflux in a boiling water bath for 3 hr.

(iii) Determination of oils and waxes
For the determination of oils and waxes, ie hexane solubility, the wood was extracted with hexane under reflux in a heating mantle for 6 hr after which the solvent was evaporated to dryness using a rotary evaporator.

(iv) Determination of total extractives
The wood meal was extracted with 2:1 benzene-ethanol (95%) under reflux in a heating mantle for 6 hr after which the solvent was evaporated to dryness using a rotary evaporator.

(v) Determination of acid insoluble lignin
The carbohydrates in wood were hydrolyzed and solubilized by sulphuric acid. Then the acid-insoluble lignin was filtered off, dried and weighed (Figure 1).

(vi) Determination of holocellulose
Holocellulose from extractive-free wood meal was extracted using 10% acetic acid and sodium chlorite.

(vii) Determination of pentosans
Figure 2 shows the set-up of apparatus for the determination of pentosans. Pentosans (in wood) were transformed in boiling 3.85N hydrochloric acid to furfural, which was collected in the distillate and determined colorimetrically with orcinol-ferric chloride reagent.

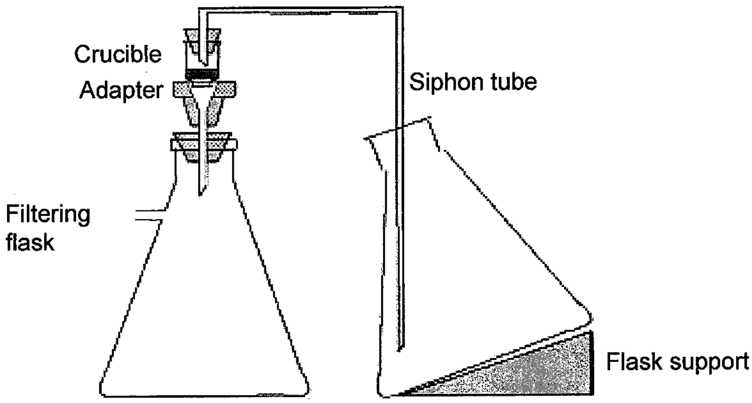

Figure 1 Lignin filtration apparatus

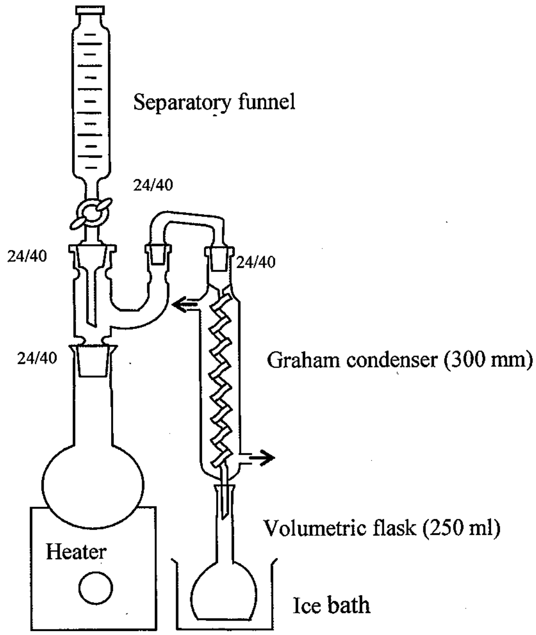

Figure 2 Set-up for pentosan determination

Analyses of tannins and sugars in bark

Bark was stripped from the stem discs, air-dried and ground in a Wiley mill into particles to pass ASTM mesh-40 screen. The bark meal was then extracted with hot water. The extracted liquor was used for the determination of tannins and sugars.

(i) Determination of tannins

Tannins in bark from the extracted liquor were determined using the Folin-Ciocalteu Method. The working curve was drawn using catechin as a standard sample.

(ii) Determination of sugars

Total sugars were determined according to the phenol-sulphuric acid method. The working curve was drawn using D-glucose as a standard sample.

RESULTS AND DISCUSSION

Chemical properties of *Shorea macrophylla* wood

Table 1 Average chemical properties of *Shorea macrophylla* wood

Timber age (y)	Moisture content (%)	Hot water solubility (%)	Ethanol - toluene solubility (%)	Hexane solubility (%)	Pentosans (%)	Lignin (%)	Hollocellulose (%)
13	10.25	6.28	2.59	0.67	11.14	24.16	61.47
33	10.12	5.13	2.20	0.73	10.77	30.36	61.76

Table 1 shows the average chemical properties of *S. macrophylla* of two age groups (with a total of six trees per age group). The moisture content (MC) ranged from 8.98 to 11.18%, with an average of 10.25% for the 13-y-old trees and 10.13% for the 22-y-old trees.

From the table, it can be observed that there was no significant difference in the percentage of total extractable content (ethanol-toluene solubility), hexane solubility, and pentosan and hollocellulose contents between the two age groups of trees.

However, it can be seen that the percentage of hot water solubility was higher for the 13-y-old trees while the lignin content for the older age group seemed to be slightly higher.

Tannin and sugar contents of *Shorea macrophylla* bark

Table 2 Tannins and sugars in *Shorea macrophylla* bark

Timber age (y)	Tannin content %	Sugar content %
13	1.15	1.07
22	1.26	2.16

From Table 2 above, it can be observed that there was no significant difference in the tannin content between the 13-y-old and 22-y-old *S. macrophylla* bark, while the percentage of sugars of the 22-y-old bark was found to be higher than that of the 13-y-old bark.

In comparison with the tannin contents from the barks of other timber species that have been commercially used, such as *Pinus radiata* (contains approximately 10-11 percent tannins) and *Tsuga canadensis* (tannin content of about 10-12 percent), the tannin content of *S. macrophylla* bark was quite low and therefore, has no potential for commercialization.

CONCLUSION

The content of total extractables (ethanol-toluene solubility) and the hexane solubility, pentosan and hollocellulose contents in timber did not vary very much between the two age groups of *Shorea macrophylla*. However, the older age group of *S. macrophylla* timber had higher lignin content while the 13-y-old trees had slightly higher hot water solubility content. The tannin content of *S. macrophylla* bark was quite low and has no potential for commercialization.

BIBLIOGRAPHY

ANONYMOUS. 1984. TAPPI Test Method T 223 – CM 84. *Pentosans in Wood and Pulp.*

ANONYMOUS. 1988a. TAPPI Test Method T 204 – OM 88. *Solvent Extractives of Wood and Pulp.*

ANONYMOUS. 1988b. TAPPI Test Method T 222 – OM 88. *Acid Insoluble Lignin in Wood and Pulp.*

ANONYMOUS. 1993. TAPPI Test Method T 207 – OM 93. *Water Solubility of Wood and Pulp.*

ANONYMOUS. 1995. Non-wood forest products from conifers. Chapter 5 in *Non-Wood Forest Products 12*, Food and Agriculture Organization of the United Nations (FAO).

ANONYMOUS. 2000. Measurement of total phenolics and tannins using Folin-Ciocalteu method. *Quantification of Tannins in Tree and Schrub Foliage. A Laboratory Manual for the FAO/IAEA Coordinated Research Project on "Use of Nuclear and Related Techniques to Develop Simple Tannin Assays for Predicting and Improving the Safety and Efficiency of Feeding Ruminants on Taniniferrous Tree Foliage".* IAEA, Vienna Chap 3. (Handar, P. S. Makkar *et al.*, Eds)

ANONYMOUS. 2004. *Determination of Sugars—Testing Methods of Various Wood Properties of Fast Growing Tropical Timbers.* Technical Report of the Project Development Committee No. 18. Forestry and Forest Products Research Institute, Tsukuba, Japan.

Malaysian Standard MS 837: 2006. *Solid Timber—Determination of Moisture Content.*

TAN, Y. E., LIM, N. P. T., GAN, K. S., WONG, T. C., LIM, S. C. & THILAGAWATHY, M. 2010. *Testing Methods for Plantation Grown Tropical Timbers.* FRIM, TRTTC & FRC.

WISE, MURPHY & D'ADDICO. 1946. Holocellulose in wood. *Paper Trade Journal: 122 # 2,* p. 35.

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