TESTING METHODS FOR PLANTATION GROWN TROPICAL TIMBERS

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

Editors
Y. E. Tan, N. P. T. Lim, K.S. Gan, T. C. Wong,
S. C. Lim & M. Thilagawathy

Forest Research Institute Malaysia (FRIM)
Timber Research & Technical Training Centre (TRTTC)
International Tropical Timber Organization (ITTO)
Forest Research Centre Sabah (FRC)
Ministry of Natural Resources & Environment, Malaysia (NRE)

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Ministry of Natural Resources and Environment Malaysia

All enquiries should be forwarded to:

Director General
Forest Research Institute Malaysia
52109 Kepong, Selangor Darul Ehsan
Malaysia

Tel: 503-6279 7000
Fax: 603-6273 1314
Homepage: http://www.frim.gov.my

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FOREWORD

The project entitled "Improving utilization and value adding of plantation timbers from sustainable sources in Malaysia" was funded by the International Tropical Timber Organization (ITTO) and jointly executed by the Forest Research Institute Malaysia (FRIM), Timber Research and Technical Training Centre (TRTTC), Sarawak, and Forest Research Centre (FRC), Sabah. I am glad to note that the project has been successfully carried out over a period of three years.

The main objective of the project was to develop a set of harmonized testing methods for the plantation timbers and I am delighted that testing methods for (a) sampling of trees, (b) wood anatomical and quality studies, (c) mechanical properties, (d) sawing and machining, (e) accelerated durability studies, (f) treatability, (g) veneer properties, (h) drying properties, (i) finger and laminate joints, and (j) chemical properties have been developed through the joint effort of scientists from FRIM, TRTTC and FRC.

I am grateful to ITTO for providing the funding for the project. I would also like to extend my sincere thanks to the Forestry and Forest Products Institute (FFPRI), Tsukuba, Japan, for providing guidance, advice and training for the Malaysian scientists during the course of the project.

Finally, I wish to congratulate all the team members of the project for a job well done and I am confident that the harmonized testing methods developed will be adopted by the international communities in the testing of their respective forest plantation species.

Dato' Dr. Abd. Latif Mohmod
Director General
Forest Research Institute Malaysia (FRIM), Kepong, Malaysia

2010

PREFACE

The project (No. PD 306/4(1)), jointly funded by the International Tropical Timber Organization (ITTO) and Malaysian Government, is a collaborative research project undertaken by the Forest Research Institute Malaysia (FRIM) as the leading agency, and the Timber Research and Technical Training Centre (TRTTC), Sarawak, and Forest Research Centre (FRC), Sabah, as collaborative partners. The Forestry and 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. During the project period, the Director General of FRIM together with the respective Directors from the Sarawak and Sabah Forest Departments also rendered technical support and advice.

The project, with a duration period of 36 months, was started on 15 September 2006. It focuses 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 is to improve end-uses of Malaysian forest plantation timbers through systematic evaluation of their basic physical and other properties. The timber species identified are *Acacia mangium* from Peninsular Malaysia, engkabang jantong (*Shorea macrophylla*) from Sarawak, and teak (*Tectona grandis*) from Sabah.

In the evaluation of properties of the plantation timbers, it was found that there was a lack of a set of harmonized testing methods which is essential for the efficient utilization of these timbers. The lack of harmonized testing methods also makes comparison of the testing results from one place with those from another very difficult. Consequently, the use of some of the current plantation timbers, for example *Acacia mangium,* has been confined to low-value applications such as pallet manufacture, formwork and pulping. Such a low return makes any large-scale plantation project less viable.

For the first 12 months of the project period, project members concentrated only on literature review of relevant works carried out elsewhere so that a set of harmonized testing methods could be developed for the testing of tropical forest plantation timbers. The types of testing method compiled and improved include: (a) sampling of trees, (b) wood anatomical and quality studies, (c) mechanical properties, (d) sawing and machining, (e) accelerated durability studies, (f) treatability, (g) veneer properties, (h) drying properties, (i) finger and laminate joints, and (j) chemical properties. It is hoped that these harmonized methods of testing, if adopted, will be used by the international communities in the testing of their respective forest plantation species.

The compilation of this manual is the collaborative effort of all project members from FRIM, TRTTC and FRC who have contributed immensely to make it a reality.

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

Lists of Contributors

Chapter 1	Tan Yu Eng Lim Seng Choon Andrew Nyorik Nibu
Chapter 2	Lim Seng Choon Yang Min Chin James Josue
Chapter 3	Mohamad Omar Mohamad Khaidzir Alik Duju Zamrie Imiyabir
Chapter 4	Wong Ting Chung Chan Chong Siew Ting King Boh Khairul Masseat
Chapter 5	Lai Jiew Kok Salmiah Ujang Kandau Jenang
Chapter 6	Lai Jiew Kok Salmiah Ujang John Sammy
Chapter 7	Nigel Lim Poon Teck Hamdan Hussain Pek Yaw Kee
Chapter 8	Gan Kee Seng Tan Jui Liat Zairul Amin Rabidin
Chapter 9	Ting King Boh Ong Chee Beng
Chapter 10	Koh Mok Poh Siti Hanim Sahari

The Malaysian Working Group wishes to acknowldge the assistance and guidance given by the following scientists from the Forestry and Forest Products Research Institute (FFPRI), Japan, in the preparation of this document: Dr. Takeshi Fujiwara, Dr. Kohji Murata, Mr. Yuji Ikami, Mr. Shuetsu Saito, Dr. Seiji Ohara, Mr. Kiyohiko Fujimoto, Dr. Tsutomu Takano, Dr. Ikuo Momohara, Dr. Hideo Kato, Dr. Yasushi Hiramatsu, Dr. Koichi Yamamoto, Dr. Tomoyuki Hayashi, Dr. Hisashi Abe, Mr. Atsushi Miyatake and Mr. Hideaki Korai.

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The Project Director and team members would like to express their deepest gratitude to the International Tropical Timber Organization (ITTO) for providing the funds for the project. We are also indebted to the President and scientists from the Forestry and Forest Products Research Institute (FFPRI), Tsukuba, Japan, for their support throughout the project period. Our special thanks go to the Malaysian Government through various agencies, particularly the Ministry of Natural Resources and Environment (NRE) and Ministry of Commodities and Plantation Industries, as without their support, the application for funding for the project would have been very difficult. During the project period, invaluable advice, support and encouragement from the Heads of Department of the three collaborating agencies, namely the Director General of the Forest Research Institute Malaysia (FRIM), General Manager, Sarawak Forestry Corporation (SFC), and Director, Forest Department, Sabah, have enabled the project to run very smoothly and on schedule. Credit should also go to the scientists at FRIM, TRTTC and FRC, without whose commitment and dedication the project would not have been successfully carried out. Finally, to other individuals who have contributed directly or indirectly to the project, we would like to record our sincere thanks.

Chapter 1

Sampling of Trees and Allocation of Logs

1.1 Scope and Field of Application

1.1.1 This guideline prescribes methodology for the sampling of logs from a tropical forest plantation associated with a particular set of characteristics such as generation age, stand density, clone, soil type and silvicultural treatment. The method dictates how trees shall be selected from a population of plantation forest from which further sampling of test pieces for determination of basic wood properties will be executed.

1.1.2 *The sampling approach outlined provides good representation for the forest population of interest. Besides suitable for use for the establishment of wood properties of a population with a particular set of characteristics, the sampling approach and bucking pattern proposed here also allow systematic comparison to be made between one population and another.*

1.1.3 The bucking pattern adopted specifies specific height from the basal end from which billets for different tests shall be obtained from a particular sample tree. This has eliminated the effect of height on the test results when comparisons between populations are being made. Furthermore, the batches of logs are also assigned such that all batches are represented by one tree from each diameter group. Together with a unique arrangement of diameter order numbers, they provide a good representation of the population of interest.

1.2 Referenced Document

1.2.1 ISO 4471- 1982 (E). Wood – Sampling Sample Trees and Logs for Determination of Physical and Mechanical Properties of Wood in Homogeneous Stands.

1.3 Definitions

1.3.1 *Characteristics*: Parameters such as age group, stand density, clone, soil type and silvicultural treatment which are associated with a plantation plot.

1.3.2 *Diameter at Breast Height (dbh)*: The diameter of trees at a height of 1.3 m from the root collar.

1.3.3 *Diameter Group*: Grouping of trees from a test area based on dbh.

1.3.4 *Diameter Order Number*: Number assigned to trees based on their dbh after being arranged in ascending diameter sequence.

1.3.5 *Generation Age*: An interval of time measured in classes of age. For rapid growing species, the class of age is five years.

1.3.6 *Root Collar*: The portion where the root passes into the stem.

1.3.7 *Stand of the Same Age*: Plantation whose trees have an age difference not exceeding the duration of one class of age.

1.4 Selection of Test Area

1.4.1 The area selected shall be one with the desired characteristics of interest.

1.4.2 For the full range of tests to be conducted, the test area shall contain at least 120 trees of each generation age of the species to be examined, the diameter at breast height being at least 14 cm.

1.4.3 The description of the test area shall be made in accordance with Form 1.1.

1.4.4 The trees in the test area shall be inventoried separately by species and age generation according to national practice.

While drawing up the inventory, the diameter and height of the trees as well as description of the defects occurring shall be recorded in an inventory report using Form 1.2.

1.5 Selection of Sample Trees in Test Areas

1.5.1 When the average diameter of species of interest is 22 cm or more, the sample trees selected shall be taken from among trees of not less than 18 cm in diameter. In the case where the average diameter is less than 22 cm, sample trees of not less than 14 cm diameter shall be chosen. The inventoried trees shall not contain any visible defects (with the exception of knots) and shall not include any big branches. A 'clear' bole of at least 6 m (small branches allowed) from the root collar is used.

1.5.2 Each sample tree shall be provided with a card as shown in Form 1.3. The characteristics of sample trees shall be determined according to national practice.

1.5.3 During chain-sawing to the required length, if a selected sample tree is found to have some inner defects which prevent it from being sawn out, it will then be rejected. In general, while a sufficient number of defect-free

specimens shall be able to be derived from any sample tree selected, such as those required for the assessment of mechanical properties, it shall also provide a realistic and representative yield output when tests such as sawing and peeling are conducted.

1.5.4 The inventoried trees shall be given an order number after being arranged by diameter in an ascending order in the inventory report (see Form 1.4). These trees shall then be divided into at least six groups, and be given respective Diameter Group number. Each group shall make up of at least 20 trees.

Note: The order number is being arranged in a 'vertically zigzag' manner before batch number is assigned.

1.5.5 For a group having an odd number of trees, the odd-numbered row from the middle band shall be selected as Batch 1 (e.g. Row 11 as in Table 1.1) while an even-numbered row from the middle band shall be taken as Batch 1 for a group with an even number of trees (e.g. Row 10 as in Table 1.2). Subsequent batches will be selected in a 'down-then-up' sequence as illustrated in Table 1.1. This is to ensure proper matching of sample tree diameters between different batches. The process is repeated until ten (10) batches are allocated. The remaining trees in the group will be used as standby.

Note: Since each batch is made up of trees from the same mixture of diameter groups which is reflected by the group number, it facilitates good representation of the population of tree diameter available.

1.5.5 A flow chart illustrating the sampling of trees before bucking pattern is carried out is given in Figure 1.1.

1.5.6 Ten trees per diameter group from the middle band shall be assigned for testing purposes. The remaining trees from the **same group** could be used if excessively defective logs are later found during preparation of specimens for wood property tests. Again, replacements shall only be taken from the remaining logs from the same group with the closest order number to those rejected.

1.6 Allocation of Logs for Different Tests

1.6.1 One log of at least 6 m is cut from the basal end of each sample tree from which about 5 m length is made use of. This is necessary to cater for minor defects during sample preparation. The allocation of test materials from each portion of log to different tests is presented in the bucking pattern proposed (Figure 1.2). The approach is designed such that it eliminates height effect since each test makes use of material from a pre-defined distance from the basal end.

1.6.2 In Figure 1.2, almost in all batches are the logs being shared. An example is Batch 6 whereby the log is cut into billets for machining and drying. Proper marking is necessary to prevent possible mix-ups.

1.6.3 Marking of each log shall include tree, batch and group numbers to facilitate traceability. In addition, a suitable number associated with the test area shall also be provided.

1.6.4 To prevent the ends of the logs from biodeterioration and cracking, proper means of protection shall also be used.

Table 1.1 Division of sample trees into different groups each having an odd number of trees

A*	B	C	D	E	F	
1**	42	43	84	85	126	
2	41	44	83	86	125	
3	40	45	82	87	124	
4	39	46	81	88	123	
5	38	47	80	89	122	
6	37	48	79	90	121	
7	36	49	78	91	120	Batch 9
8	35	50	77	92	119	Batch 7
9	34	51	76	93	118	Batch 5
10	33	52	75	94	117	Batch 3
11	32	53	74	95	116	Batch 1#
13	30	55	72	97	114	Batch 4
14	29	56	71	98	113	Batch 6
15	28	57	70	99	112	Batch 8
16	27	58	69	100	111	Batch 10
17	26	59	68	101	110	
18	25	60	67	102	109	
19	24	61	66	103	108	
20	23	62	65	104	107	
21***	22	63	64	105	106	

* Each alphabet denotes Diameter Group number.

** Every number denotes diameter order of trees in ascending arrangement. Smaller number refers to smaller diameter and vice versa. Note that the order number is arranged in a 'vertically zigzag' manner.

*** This Diameter Group has an odd number of trees in the group, in this case, 21.

Each batch is represented by a tree from each Diameter Group, hence systematically representing the entire range of diameter groups.

Table 1.2 Division of sample trees into different groups each having an even number of trees

A*	B	C	D	E	F	
1**	40	41	80	81	120	
2	39	42	79	82	119	
3	38	43	78	83	118	
4	37	44	77	84	117	
5	36	45	76	85	116	
6	35	46	75	86	115	Batch 9
7	34	47	74	87	114	Batch 7
8	33	48	73	88	113	Batch 5
9	32	49	72	89	112	Batch 3
10	31	50	71	90	111	Batch 1#
12	29	52	69	92	109	Batch 4
13	28	53	68	93	108	Batch 6#
14	27	54	67	94	107	Batch 8
15	26	55	66	95	106	Batch 10
16	25	56	65	96	105	
17	24	57	64	97	104	
18	23	58	63	98	103	
19	22	59	62	99	102	
20***	21	60	61	100	101	

* Each alphabet denotes Diameter Group number.

** Every number denotes diameter order of trees in ascending arrangement. Smaller number refers to smaller diameter and vice versa. Note that the order number is arranged in a 'vertically zigzag' manner.

*** This Diameter Group has an even number of trees in the group, in this case, 20.

Each batch is represented by a tree from each Diameter Group, hence systematically representing the entire range of diameter groups.

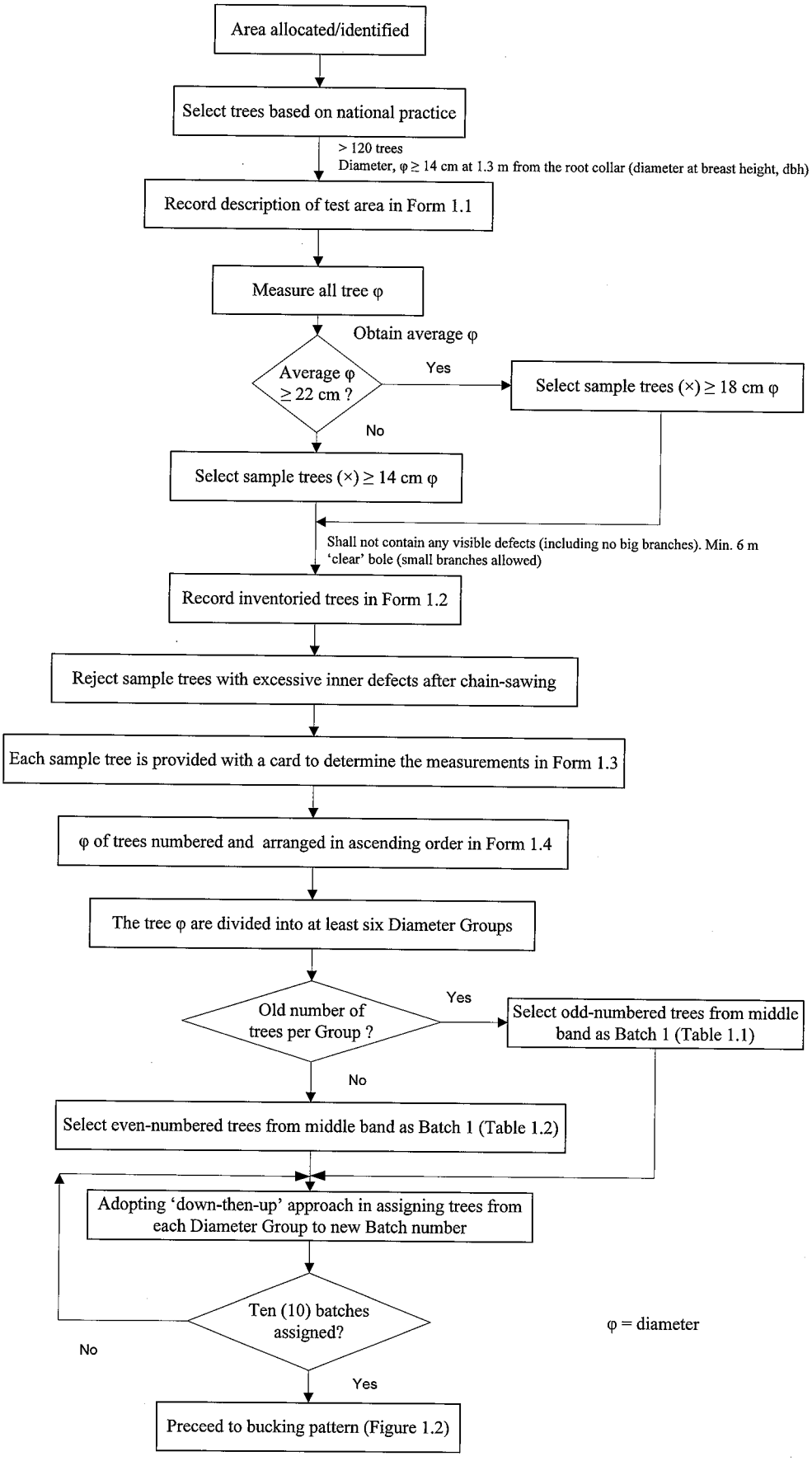

Figure 1.1 Flow chart illustrating sampling for the assignment of batch numbers to sample trees

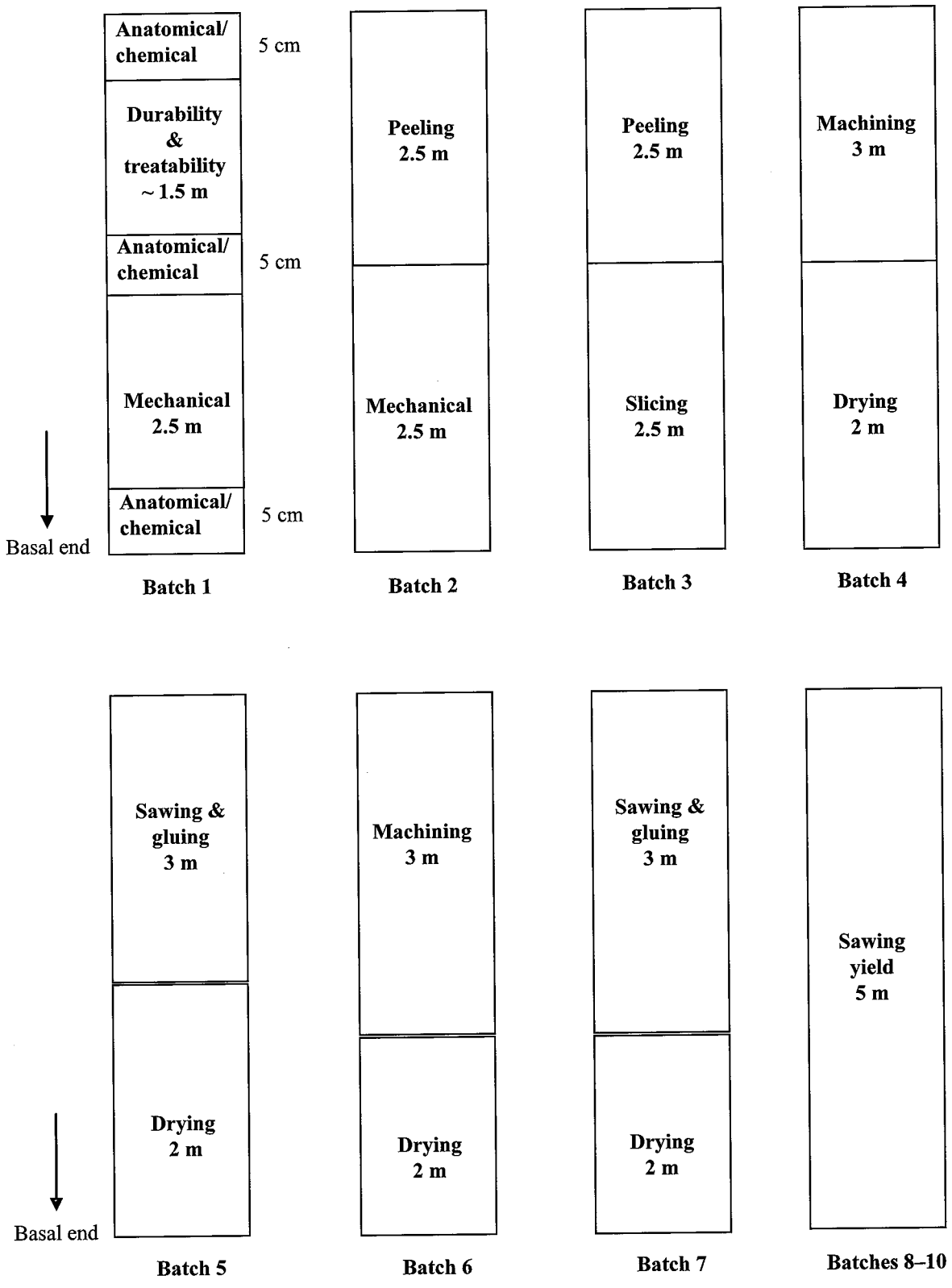

Figure 1.2 Bucking pattern for sample logs from each batch for different tests

Forms

Form 1.1 Description of test area and trees

1 Organization .....

2 Location .....

3 Species .....

4 Year planted and age .....

		Of the whole stand	**Of the species to be examined**
1	Type of forest	.....	Species .....
2	Composition of stand	.....	.....
3	Average age	.....	.....
4	Average diameter at a height of 1.3 m from the root collar	..... cm	..... cm
5	Average height	..... m	..... m
6	No. of trees/ha	.....	.....
7	Spacing	.....	.....
8	Soil	.....	.....
9	Specific features of the stand and the method of selecting the test area	.....	.....

Date : .....

Signature : .....

Form 1.2 Inventory report on trees to be examined

1 Organization .....

2 Location .....

3 Species .....

4 Year planted and age .....

Tree No.	Height at first branch (m)	Tree height (m)	Diameter at breast height (dbh, cm)	Description of defects occurring	Notes

Date : .....

Signature : .....
(Name:)

Form 1.3 Card of sample tree No.....

1 Organization .....
2 Location .....
3 Species / genetic source .....
4 Age .....
5 Diameter of trunk with bark at height of 1.3 m taken at right angles ..... cm
6 Height ..... m
7 Distance to the first branch .... m
8 Overall trunk volume ..... m^3
9 Top diameter of trunk :
with bark ..... cm
without bark ..... cm
10 Measurements of log sawn from each sample tree used to establish basic wood properties:

Log measurements	
Basal end diameter, cm	
Top end diameter, cm	
Cutting height from basal end, m	

11 Other special remarks (silvicultural system, site information, planting information, details of tending, record of damage, stand condition, date and height of pruning, etc.)

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Date : .....

Signature : .....
(Name:)

Form 1.4 Inventory report on selection of sample trees in test area

1 Organization .....

2 Location .....

3 Species .....

Diameter order No.	Diameter (cm)	Tree No.	Group No.	Sample tree code	Notes

Date : .....

Signature : .....
(Name:)

Chapter 2

Wood Anatomical and Quality Studies

2.1 Scope

This guideline specifies the methods and sampling and preparation of samples used in the studies of wood anatomical characteristics and wood quality.

2.2 Referenced Documents

2.2.1 B.S. 373:1957. Methods of Testing Small Clear Specimens of Timber. British Standards Institution, London.

2.2.2 Wheeler, E.A., Baas, P. & Gasson, P.E. (Eds.) 1989. IAWA List of Microscopic Features for Hardwood Identification. I.A.W.A. Bulletin n.s. 10(3):219–332.

2.3 Definitions

The terms used for the anatomical studies follow the list provided by the International Association of Wood Anatomists (IAWA). For density and moisture content, B.S 373: 1957 is used.

2.4 Equipment

2.4.1 *Anatomical Studies*

2.4.1.1 *Preparation of microslides*: Sliding microtome, microtome knife, hot plate or burner, handsaw, razor blade.

2.4.1.2 *Microscopic studies and observations*: Light compound microscope, measuring scale, calibration slide.

2.4.2 *Wood Quality Studies*

2.4.2.1 *Density determination*: Saw, weighing machine, oven (adjustable to 103±2 °C).

2.4.2.2 *Marceration*: Razor blade, test tube/bottle, hot plate or burner.

2.4.2.3 *Fibre morphology studies*: Light compound microscope and accessories, projection microscope or any other suitable measuring devices.

2.5 Preparation of Test Materials

2.5.1 *Sampling of Trees*: A total of six trees per age group shall be selected based on the method described in Chapter 1. Three sample discs per tree shall be obtained from Batch 1 at the bottom, middle and top ends of the sample log (see 2.5.2., Figure 2.1)

2.5.2 *Sampling of Logs*

Anatomical / chemical	5 cm @ 5.0 m
Void	1 m
Durability	~1.5 m
Anatomical / chemical	5 cm @ 2.5 m
Mechanical	2.5 m
Anatomical / chemical	5 cm @ 0.5 m

Figure 2.1 Discs from the bottom (0.5 m height), middle (2.5 m height) and top (5.0 m height) parts of the 5-m log shall be taken for evaluation

Before the discs are cut, a shallow groove along the length of the log shall be cut using a chain-saw to ensure that the positions of the samples are consistent throughout the length of the log (Figure 2.2).

Figure 2.2 Cutting a groove throughout the length of the log using a chain-saw

2.5.3 *Sample Preparation*

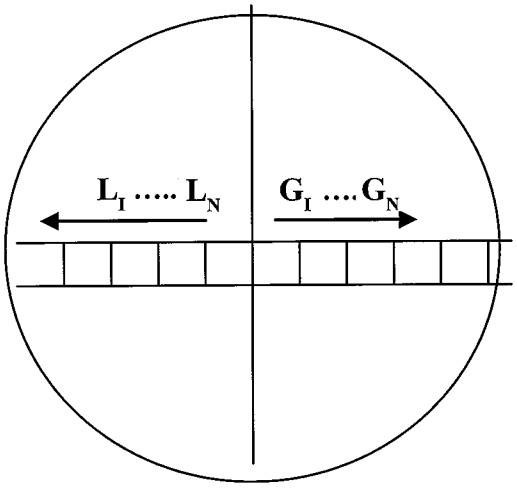


Figure 2.3 Selection of specimens from log with pith at the centre

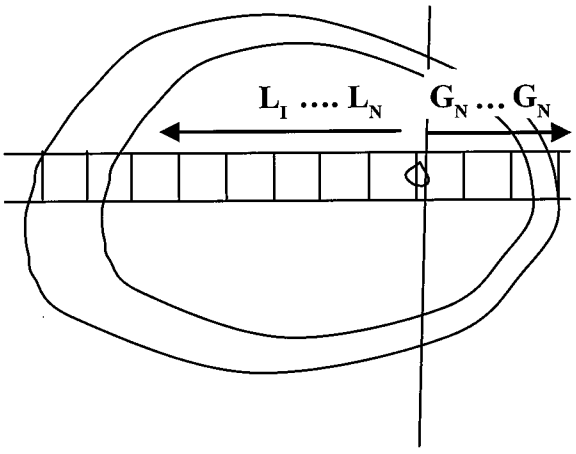


Figure 2.4 Selection of specimens from log with eccentricity

All samples obtained shall be used for (a) fibre morphology and (b) density variation studies. They are taken as shown in Figures 2.3 and 2.4, depending on the shape of the disc.
To ensure consistency in the sampling, the 'groove' part of the discs shall be 'G' and the opposite part shall be 'L' (Figures 2.3, 2.4 and 2.5).

Figure 2.5 Samples for fibre morphology and density variation/moisture content studies

For anatomical studies, three samples per disc shall be taken (near pith, between pith and bark, and near bark) as shown below (Figure 2.6).

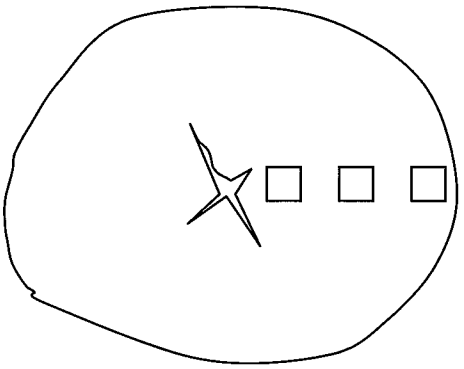


Figure 2.6 Sampling for the anatomical study

For sapwood and heartwood determination, measurements based on the geometric centre shall be taken (Figure 2.7) and Form 2.3.shall be used for recording.

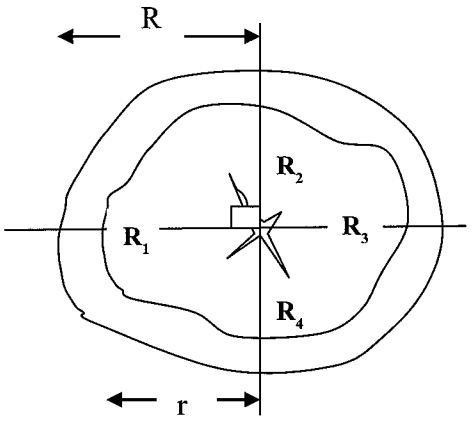


Figure 2.7 Sampling for the sapwood and heartwood studies (R = radius of disc; r = heartwood radius)

2.6 Test Procedures

2.6.1 *Wood Anatomical Studies*

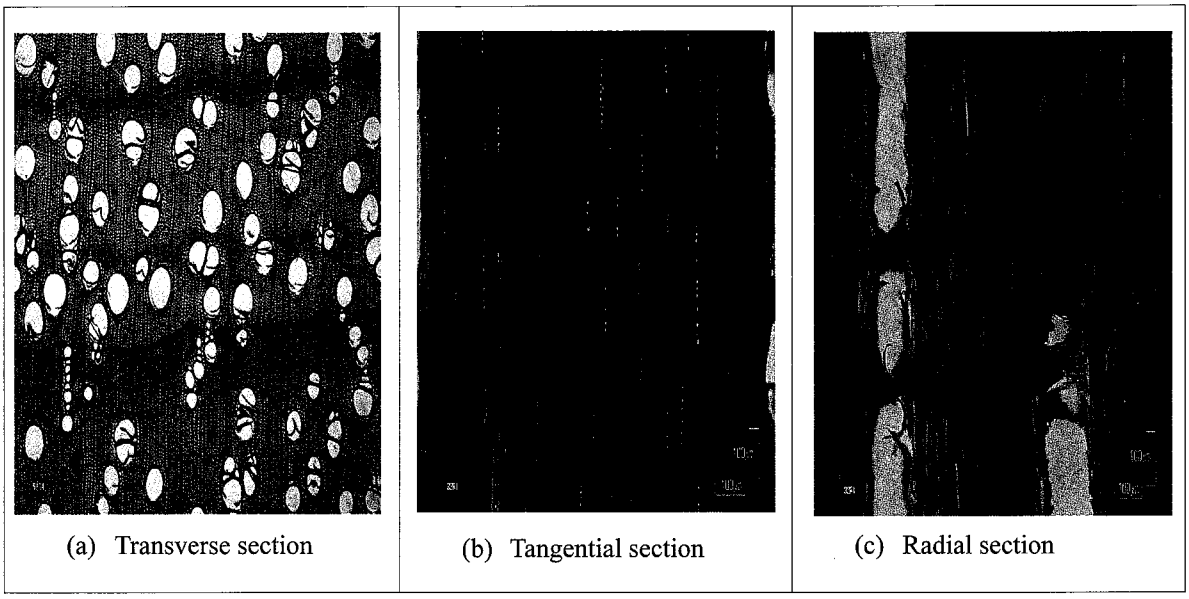
The anatomical studies of wood shall include the examination of its macroscopic and microscopic features.

2.6.1.1 *Macroscopic examination*

The evaluation of the macroscopic features shall be carried out only on air-dried samples. The checklist provided in Form 2.1 shall be used to ensure that important information is not left out. Some examples to describe the macroscopic features of wood are shown in Appendix 2.1. A typical description of the macroscopic features of wood is given in Appendix 2. 2.

2.6.1.2 *Microscopic examination*

The study of the microscopic features requires the preparation of microscopic slides that contain transverse, tangential and radial sections (eg. Figures 2.8 (a), (b) and (c)).



(a) Transverse section (b) Tangential section (c) Radial section

Figure 2.8 Examples of (a) transverse, (b) tangential and (c) radial sections

2.6.1.2.1 Sampling and preparation of samples

For anatomical studies, three specimens (5–10 mm block) per disc shall be taken, i.e. near pith, between pith and bark, and near bark as shown in Figure 2.6. These specimens shall be kept in a liquid mixture of ethanol and glycerin while waiting to be sectioned. Boiling would be required if the blocks are hard (difficult to section).

2.6.1.2.2 Preparation of sections

Sections of 10–20 μm in thickness for transverse, tangential and radial sections shall be obtained using sledge/ sliding microtome.

2.6.1.2.3 Staining procedure

- Stain sections with 1% safranin for 30 min (time to be adjusted accordingly to avoid over-staining).
- Dehydrate sections using increasing concentrations of ethanol (30, 50, 70, 90, 99 %).
- Preserve the sections from drying up using clove oil.
- Place the sections in 100% xylene.
- Place the sections, with the transverse section near to the label, followed by the tangential and radial sections on a glass slide. Add some drops of Canada balsam (or any other suitable mounting agent), cover the sections with cover slip and blot away excessive balsam (or other mounting agent).
- Keep the slide in an oven at 60 °C until the balsam/mounting agent is hardened.

2.6.1.2.4 Features to observe

Features to observe shall follow the checklist as shown in Form 2.2. A typical description of the microscopic features of wood is shown in Appendix 2.2.

2.6.2 *Wood Quality Studies*

Plantation timbers harvested from trees at a much younger age are likely to be quite different and less stable compared with the same species obtained from the natural forest. Thus, data on the density and fibre variation are

important as they may be used to interpret the quality of the timbers obtained. In order to ensure that adequate information is collected, a collection form is devised as shown in Form 2.3.

2.6.2.1 *Density variation study & moisture content determination*

2.6.2.1.1 Sampling

Strips 50 mm wide shall be obtained along the longest and the shortest radii. Specimens shall be obtained at 5–10-mm intervals along growth layers. Sampling and marking of the disc are according to Figures 2.3 or 2.4 depending on the type of disc obtained.

2.6.2.1.2 Density & moisture content determination

Density and moisture content determinations are based on the methods as described in Appandices 8.2 and 8.1 respectively. Form 2.4 is used to record the data.

2.6.2.2 *Fibre morphology study*

2.6.2.2.1 Sampling

Specimens for the density determination (see 2.6.2.1.1) shall also be used for the fibre dimension study.

2.6.2.2.2 Method of maceration

Matchstick-sized wood splinters shall be obtained from the outermost surface (bark-side surface) of the specimen and immersed in a 10-ml bottle containing a mixture solution of 30% hydrogen peroxide and 100% acetic acid (1:1 to 2:1 in volume). The bottle is kept in the oven at 60 °C overnight. After confirming the colour change of the sticks to white, the sticks are then rinsed several times with distilled water/warm water. A small portion of the macerated fibres is removed using tweezers and placed on the glass slide with gum choral. To separate into individual fibres, stir the fibres on the slide and cover them with cover glass.

However, other standard methods which yield similar results may also be used.

2.6.2.2.3 Measurements

Macerated fibres shall be observed with an optical microscope equipped with micrometer eyepieces and condenser lens with a dark field or small optical aperture. Measurements can also be made using projection microscope or any other suitable measuring devices.

A total of 25 fibres shall be randomly selected for measurement. Form 2.5 shall be used for recording. However, commercial software which is capable of storing the data can also be used.

The classifications of fibre-wall thickness shall be as follows:

- *Fibres very thin-walled*: fibre lumen three or more times wider than the double-wall thickness
- *Fibres thin to thick-walled*: fibre lumen less than three times the double-wall thickness, and distinctly open
- *Fibres very thick-walled*: fibre lumen almost completely closed

2.7 General References

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Forms

Form 2.1 Macroscopic features of wood

Species:
Sample No.:

	Description	+/-	?	Remark
	GROWTH RINGS			
1	Boundaries indistinct or absent			
2	Boundaries distinct or present			
a	Marked by denser fibres			
b	Narrow bands of parenchyma tissues			
	Others (describe)			
	POROSITY			
3	Ring-porous			
4	Semi-ring-porous			
5	Diffuse-porous			
	VESSEL ARRANGEMENT			
6	Tangential bands			
7	Diagonal and/or radial pattern			
8	Dendritic pattern			
	VESSEL GROUPINGS			
9	Exclusively solitary (90%) or more)			
10	Radial multiples of four or more common			
11	Clusters common			
	SOLITARY VESSEL OUTLINE			
12	Angular outline			
13	Round			
14	Oval			
	SIZE OF VESSELS			
15	Large			
16	Medium			
17	Small			
18	Other comments			
	TYLOSES			
19	Absent			
20	Present			
21	Sparse			
22	Other comments			

	DEPOSITS			
23	Absent			
24	Present (state colour of deposits)			
	RAYS			
25	Very fine			
26	Fine			
27	Broad			
28	Rays of two sizes			
29	Others			
	PARENCHYMA			
30	Abundant			
31	Moderate			
32	Bands present			
33	Others			
	RIPPLE MARKS			
34	Present			
35	Absent			
	SAPWOOD			
36	Colour			
37	Tinge			
38	Distinct from heartwood			
39	Width of sapwood			
	HEARTWOOD			
40	Colour			
41	Tinge			
42	Colour on exposure			
	GRAIN			
43	Straight			
44	Interlocked			
45	Wavy			
46	Others			
	TEXTURE			
47	Fine and even			
48	Coarse and even			
49	Others			
	LUSTRE			
50	Lustrous			
51	Dull			
52	Others			

	ODOUR			
53	Absent			
54	Present (specify)			
55	FIGURE			
56	Striped			
57	Streaked			
58	Growth rings			
59	Others			
	INTERCELLULAR CANALS			
60	Axial canals in long tangential lines			
61	Axial canals in short tangential lines			
62	Axial canals diffuse			
63	Radial canals			
64	Intercellular canals of traumatic origin			
	CAMBIAL VARIANTS			
65	Included phloem, concentric			
66	Included phloem, diffuse			
67	Other cambial variants			
	LATEX TRACES			
68	Absent			
69	Present (state size)			
70	Overall general & additional comments			

Form 2.2 Microscopic features of wood

Species:
Sample No.:

	Description	+/-	?	Remark
	GROWTH RINGS			
1	Boundaries distinct			
2	Boundaries indistinct or absent			
	POROSITY			
3	Ring-porous			
4	Semi-ring-porous			
5	Diffuse-porous			
	VESSEL ARRANGEMENT			
6	Tangential bands			
7	Diagonal and/or radial pattern			
8	Dendritic pattern			
	VESSEL GROUPINGS			
9	Exclusively solitary (90%) or more)			
10	Radial multiples of four or more common			
11	Clusters common			
	SOLITARY VESSEL OUTLINE			
12	Angular outline			
	PERFORATION PLATES			
13	Simple			
14	Scalariform			
15	With up to 10 bars			
16	With 10–20 bars			
17	With 20–40 bars			
18	With 40 or more bars			
19	Reticulate, foraminate &/or other types			
	INTERVESSEL PITS: ARRANGEMENT AND SIZE			
20	Scalariform			
21	Opposite			
22	Alternate			
23	Shape of alternate pits polygonal			
	Intervessel pit size (alternate and opposite)			
24	Minute—4 μm or less			
25	Small—4–7 μm			
26	Medium—7–10 μm			
27	Large—10 μm or more			
28	Range of intervessel pit size (μm)			

	VESTURED PITS			
29	Vestured pits			
	VESSEL RAY PITTING			
30	w/distinct border: similar to intervessel pits in size and shape throughout the ray cell			
31	w/reduced borders to simple: pits rounded or angular			
32	w/reduced borders to simple: pits horizontal to vertical			
33	Two distinct sizes or types in the same ray cell			
34	Unilaterally compound and coarse (over 10 µm)			
35	Restricted to marginal rows			
	HELICAL THICKENINGS IN VESSEL ELEMENTS			
36	Present			
37	Throughout body of vessel element			
38	Only in vessel element tails			
39	Only in narrower vessel elements			
	TANGENTIAL DIAMETER OF VESSEL LUMINA			
40	50 µm or less			
41	50–100 µm			
42	100–200 µm			
43	200 µm or more			
44	Mean, +/- Std. Dev., Range (µm)			
45	two distinct diam. classes (not ring-porous)			
	VESSELS PER SQUARE MILLIMETRE			
46	5 or less			
47	5–20			
48	20–40			
49	40–100			
50	100 or more			
51	Mean, +/- Std. Dev., Range			
	MEAN VESSEL ELEMENT LENGTH			
52	350 µm or less			
53	350–800 µm			
54	800 µm or more			
55	Mean, +/- Std. Dev., Range (µm)			
	TYLOSES AND DEPOSITS IN VESSELS			
56	Tyloses common			
57	Tyloses sclerotic			
58	Gums and deposits in heartwood vessels			
	WOOD VESSEL-LESS			
59	Wood vessel-less			

	IMPERFORATE TRACHEARY ELEMENTS			
60	Vascular/vasicentric tracheids present			
	GROUND TISSUE FIBRES			
61	Fibres with simple to minutely bordered pits			
62	Fibres with distinctly bordered pits			
63	Fibre pits common in rad. & tan. walls			
	HELICAL THICKENINGS			
64	Helical thicken. in ground tissue fibres			
	SEPTATE FIBRES AND PARENCHYMA-LIKE FIBRE BANDS			
65	Septate fibres present			
66	Non-septate fibres present			
67	Parenchyma-like fibre bands alternating with ordinary fibres			
	FIBRE-WALL THICKNESS			
68	Very thin-walled			
69	Thin- to thick-walled			
70	Very thick-walled			
	MEAN FIBRE LENGTH			
71	900 μm or less			
72	900–1600 μm			
73	1600 μm or more			
74	Mean, +/- Std. Dev., Range (μm)			
	AXIAL PARENCHYMA			
75	Absent or extremely rare			
	APOTRACHEAL AXIAL PARENCHYMA			
76	Diffuse			
77	Diffuse-in-aggregates			
	PARATRACHEAL AXIAL PARENCHYMA			
78	Scanty paratracheal			
79	Vasicentric			
80	Aliform			
81	Lozenge-aliform			
82	Winged-aliform			
83	Confluent			
84	Unilateral paratracheal			
	BANDED PARENCHYMA			
85	Banded, > three cells wide			
86	Narrow bands/lines, three cells wide			
87	Reticulate			
88	Scalariform			
89	Marginal or marg. bands			

	AXIAL PARENCHYMA CELL TYPE/STRAND LENGTH			
90	Fusiform parenchyma cells			
91	Two cells per strand			
92	Four (3–4) cells per strand			
93	Eight (5–8) cells per strand			
94	Over eight cells per strand			
95	Unlignified parenchyma			
	RAY WIDTH			
96	Exclusively uniseriate			
97	One to three cells wide			
98	Larger rays commonly 4- to 10-seriate			
99	Larger rays commonly > 10-seriate			
100	Rays with multiseriate portion(s) as wide as uniseriate portions			
	AGGREGATE RAYS			
101	Aggregate rays			
	RAY HEIGHT			
102	Ray height > 1 mm			
	RAYS OF TWO DISTINCT SIZES			
103	Rays of two distinct sizes			
	RAYS: CELLULAR COMPOSITION			
104	All ray cells procumbent			
105	All ray cells square and/or upright			
	Body ray cells procumbent (features 106–108)			
106	With one row upright &/or marg. cells			
107	With mostly 2-4 rows of upright &/or square cells			
108	With over four rows of upright &/or square cells			
109	Procumbent, square and upright cells mixed throughout the ray			
	SHEATH CELLS			
110	Sheath cells			
111	Tile cells			
	PERFORATED RAY CELLS			
112	Perforated ray cells			
	DISJUNCTIVE RAY PARENCHYMA CELL WALLS			
113	Disjunctive ray parenchyma cell walls			
	RAYS PER MM			
114	< 4/mm			
115	4–12/mm			
116	12 or more /mm			

	WOOD RAYLESS			
117	Wood rayless			
	STOREYED STRUCTURE			
118	All rays			
119	Low rays storeyed, high rays non-storeyed			
120	Axial parenchyma and/or vessel elements storeyed			
121	Fibres			
122	Rays and/or axial elements irreg. storeyed			
123	Number of ray tiers per axial mm			
	OIL MUCILAGE CELLS			
124	Associated with ray parenchyma			
125	Associated with axial parenchyma			
126	Present among fibres			
	INTERCELLULAR CANALS			
127	Axial canals in long tangential lines			
128	Axial canals in short tangential lines			
129	Axial canals diffuse			
130	Radial canals			
131	Intercellular canals of traumatic origin			
	TUBES/TUBULES			
132	Laticiferous or tanniniferous tubes			
	CAMBIAL VARIANTS			
133	Included phloem, concentric			
134	Included phloem, diffuse			
135	Other cambial variants			
	PRISMATIC CRYSTALS			
136	Prismatic crystals present			
137	In upright and/or square ray cells			
138	In procumbent ray cells			
139	In radial alignment in procum. ray cells			
140	In chambered upright and/or square ray cells			
141	In non-chambered axial parenchyma cells			
142	In chambered axial parenchyma			
143	In fibres			
	DRUSES			
144	Druses present			
145	In ray parenchyma cells			
146	In axial parenchyma cells			
147	In fibres			
148	In chambered cells			

	OTHER CRYSTAL TYPES			
149	Raphides			
150	Acicular crystals			
151	Styloids and/or elongate crystals			
152	Crystals of other shapes (mostly small)			
153	Crystal sand			
	OTHER DIAGNOSTIC CRYSTAL FEATURES			
154	>1 crystal of about the same size per cell or chamber			
155	Two distinct sizes of crystals per cell or chamber			
156	Crystals in enlarged cells			
157	Crystals in tyloses			
158	Cystoliths			
	SILICA			
159	Silica bodies present			
160	In ray cells			
161	In axial parenchyma cells			
162	In fibres			
163	Vitreous silica			

Form 2.3 Wood quality study

SPECIES	
TREE NO.	
YEAR PLANTED	
AGE	
LOCATION	
DATE	
HEIGHT (m)	
CLEAR BOLE (m)	
DIAMETER (DBH) (cm)	
SPACING	
TREATMENTS	
SEED SOURCE	

Measurements of sapwood and heartwood

Disc No.	Disc ht. (m)	Disc diameter (cm)				Width of SW (cm)					r =R-S	% SW= $(R^2-r^2)/R^2 \times 100$
		1	2	A	R	1	2	3	4	S		

A = average; S = average sapwood (SW) width; R = radius of disc; r = radius of heartwood

Form 2.4 Determinations of moisture content and density

Species:
Sample No.:
Date:

No.	Sample	Moisture content			Vol. (V_1) (cm^3)	Density			
		W_1 (g)	W_o (g)	MC (%)		$D_1 = W_1/V_1$	$D_1 \times 1000$ ($kg\ m^{-3}$)	$D_o = W_o/V_1$	$D_o \times 1000$ ($kg\ m^{-3}$)

Calculation of moisture content (%) (MC) = W_1-$W_o/W_o \times 100$, where W_1= initial weight, W_o = oven-dry weight
D_1 = density at test, D_o = density based on oven-dry weight or basic density

Form 2.5 Determination of fibre dimensions

Species:
Sample No.:
Date:

No	Length (μm)		Diameter (μm) (A)		Lumen (μm) (B)		Fibre-wall thickness (μm) (A-B/2)
	Reading	Actual	Reading	Actual	Reading	Actual	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
Mean							
SD							
Range							
C.V (%)							
Fibre-wall classification (see 2.6.2.2.3) = B/(A-B) =							

Appendix 2.1

MACROSCOPIC FEATURES

The following are the important features to observe and many ways to describe them. For every feature, one or more important timbers are included as a guide and reference for the researcher.

GROWTH RINGS

- distinct/present (*Afzelia, Altingia, Intsia*)
- presence marked by:
  - zones of denser wood (*Calophyllum*)
  - narrow bands of parenchyma tissue (*Calophyllum*)
  - zones of fibres without parenchyma and vessels (*Cynometra*)
  - vessels less numerous (*Intsia*)
  - width of ring (*Anthocephalus*, 2–13 mm)
- moderately distinct but not conspicuous, visible to the naked eye (*Anthocephalus*)
- indistinct/absent (*Alstonia, Anisoptera, Campnosperma, Cotylelobium, Dipterocarpus*)
- usually indistinct but sometime evident due to (1) darker layers of denser wood (*Endospermum*)
- barely distinct / inconspicuous (*Agathis, Calophyllum*)

SAPWOOD

General description

- distinctly demarcated from the heartwood / well-defined from the heartwood (*Afzelia, Dialium, Hopea, Hopea*–giam type, *Koompassia, Madhuca, Swietenia, Tectona grandis*)
- indistinctly demarcated from the heartwood/ not distinct from the heartwood/ not well-defined (*Alstonia, Endospermum, Dyera, Gmelina, Paraserianthes*)
- distinctly or indistinctly demarcated (*Heritiera, Palaquium*)
- with gradual transition to dark-coloured heartwood (*Cynometra*)

Colour

- grey-white (*Afzelia*)
- whitish/ creamy white (*Agathis, Gmelina*)
- straw-coloured or pale yellow-brown (*Araucaria*)
- yellow-brown/buff, with a pink tinge (*Calophyllum, Pometia*)
- grey becoming darker grey on exposure (*Campnosperma*)
- yellow-brown / yellowish brown / light yellowish brown / light brown (*Cotylelobium, Eusideroxylon, Koompassia, Manilkara*)
- yellowish (*Cratoxylum*- geronggang)
- creamy white to yellowish (*Dialium*)
- pale with grey tinge (*Dipterocarpus*)
- yellow-brown or pinkish (*Dryobalanops*)
- pale, white to creamy yellow, sometimes with a slight greenish hue, turning to light yellow-brown or straw-coloured (*Endospermum, Neobalanocarpus*)
- whitish, pinkish or cream (*Eucalyptus*)
- pale brown-yellow to reddish (*Heritiera*)
- yellowish white/ whitish to pale yellowish (*Hopea, Hopea*–giam type, *Intsia, Scaphium, Swietenia*) to pale yellowish brown (*Tectona grandis*)
- yellow-brown to purple grey-brown (*Madhuca*)
- pale red (*Palaquium*)
- light grayish brown or beige with a pink tinge (*Sindora*)

Width of sapwood

Sapwood very wide (*Alstonia, Koompassia, Cynometra*, up to 90 mm wide; *Dryobalanops*, 50 to 100 mm wide; *Eucalyptus*, 25 to 60 mm wide: varying with growth rate)

Tinge

- greenish (*Gmelina*)
- yellowish (*Gmelina*)
- pink (*Sindora*)

HEARTWOOD

General description

- distinctly demarcated from the sapwood/clearly demarcated from the sapwood/ well-defined from the sapwood (*Afzelia, Cotylelobium, Dryobalanops, Hopea, Koompassia, Swietenia, Tectona grandis*)
- indistinct from the sapwood/ indistinctly demarcated from the sapwood/ not well-defined from the sapwood/ not distinct from the sapwood (*Alstonia, Endospermum, Dyera, Gmelina, Gonystylus, Paraserianthes*)
- distinctly or indistinctly demarcated from the lighter sapwood (*Heritiera, Palaquium)*

Colour

- pale yellow-brown (*Agathis*)
- straw-coloured or buff (*Agathis*)
- dirty red-brown (*Afzelia*)
- yellowish, cream-white or straw-coloured to pale yellow-brown (*Alstonia*), with light red tinge (*Peronema*)
- pink to dull reddish brown (*Altingia*)
- light to dark yellow, usually with a characteristic rose tinge or with streaks (*Anisoptera*)
- faint yellow cast (*Anthocephallus*)
- red-brown, pink-brown or orange-brown (*Calophyllum*)/salmon-coloured or yellowish when fresh, darkening to deep red or brown with age (*Swietenia*)
- grey-pink (*Campnosperma*)
- red-brown, on exposure darker brown (*Cotylelobium, Neobalanocarpus*)
- light brick-red to dark pink when fresh (*Cratoxylum*–geronggang)
- light brown to medium brown (*Dialium, Intsia*)
- deep red-brown (*Dalbergia*)
- brown or reddish brown/dark red, darkening on exposure to almost black with age (*Dialium, Koompassia, Pometia)*
- varying from grayish brown, pink-brown to red-brown, sometimes with a purple tinge, darkening on exposure (*Dipterocarpus*)
- pink-brown or red-brown, darkening on exposure to dark red-brown (*Dryobalanops*)
- varying from light to dark reddish brown (*Eucalyptus*) except *E. citriodora* where it is light brown to grey-brown and sometimes waxy to the touch
- dark yellowish brown or reddish brown with a greenish tinge (*Eusideroxylon*)
- light brown to yellowish brown (*Pouteria*), sometimes with a pinkish tinge (*Gmelina*)
- white to light yellowish white (*Gonystylus*), pale pink or light reddish brown (*Paraserianthes*)
- brown to various shades of red-brown (*Manilkara*), sometimes with dark streaks (*Heritiera*)
- yellowish brown with a greenish tinge (*Hopea, Hopea*—giam type); pinkish tinge (*H. sangal*); reddish brown with dark streaks, darkening to brown with a greenish tinge (*H. nervosa*)
- light brown, red-brown to purple or chocolate red-brown; with lighter streaks (*Madhuca*);with dark streaks (*Palaquium*)
- yellow or yellowish red to orange-brown (*Pinus*—in older trees)
- pink-brown to shades of golden brown or red-brown, weathering to darker shade (*Sindora*)
- golden brown, dark golden brown, sometimes aging to dark brown or dark greyish brown (*Tectona grandis*)

On exposure / aging

- darkening (*Cotylelobium, Dialium, Dipterocarpus*)
- turning dark brown or chocolate brown on exposure (*Eusideroxylon*)

Tinge

- pinkish/ light red (*Araucaria, Gmelina, Hopea sangal, Peronema*)
- purple (*Cratoxylum*—derum)
- pale with grey tinge (*Dipterocarpus*)
- greenish (*Eusideroxylon, Hopea*)

Feeling when touched

- waxy (*Eucalyptus citriodora*)

SAPWOOD & HEARTWOOD NOT DIFFERENTIATED

- heartwood not present (*Alstonia, Dyera*)

GRAIN

- straight (*Afzelia, Anthocephallus, Dalbergia, Intsia*)
- straight to shallowly interlocked (*Cotylelobium, Gonystylus, Heritiera*) or deeply interlocked, occasionally spiral (*Cynometra*)
- straight to interlocked (*Alstonia, Dipterocarpus, Eucalyptus, Eusideroxylon, Gmelina, Lophopetalum*)
- straight, irregular (or curly-run in irregular curves) to interlocked (*Altingia*)
- straight, interlocked or sometime spiral (*Anisoptera*)
- straight (sometimes), interlocked or wavy (*Dialium, Dryobalanops*)
- straight to shallowly interlocked, slightly wavy or spiral (*Endospermum*)
- wavy (means running in fairly regular waves or ripples)
- shallowly or deeply interlocked (*Campnosperma, Koompassia*), sometimes wavy (*Hopea*)
- interlocked, spiral or wavy (*Calophyllum*)
- diagonal/cross-grain

TEXTURE

- very fine and even (*Agathis, Campnosperma*)
- fine and even (*Altingia, Cotylelobium*)
- fine to moderately fine and even (*Anthocephalus, Dalbergia, Lophopetalum*)
- fine to moderately coarse (medium) and even (*Dialium*)
- moderately fine and even (*Gonystylus, Hopea*)
- moderately fine to moderately coarse (medium) (*Alstonia*)
- moderately coarse (medium) (*Afzelia, Eusideroxylon, Intsia*)
- moderately coarse (medium) but even (*Anisoptera*)
- moderately coarse (medium) to coarse and even (*Dipterocarpus, Dryobalanops, Heritiera*)
- moderately coarse (medium) to coarse and uneven (*Calophyllum*)
- coarse and even (*Endospermum*)
- course and uneven (*Eucalyptus*)
- course to very coarse and even (*Koompassia*)

LUSTRE (usually refers to planed surface)

- lustrous (*Agathis*)
- more or less lustrous (*Heritiera, Intsia*)
- medium lustre (*Dryobalanops*)
- very lustrous (*Calophyllum*)
- dull/ without lustre (*Calophyllum*—end surface, *Campnosperma*)
- dull but with some lustre/ slight lustre (*Altingia, Cynometra, Endospermum, Eucalyptus*)

SIZE OF VESSELS

- large (*Anthocephalus*)
- intermediate (medium) to moderately large (*Dipterocarpus*)
- intermediate (medium) to large (*Endospermum*)
- moderately large (*Anisoptera*)
- intermediate (medium) to small (*Alstonia, Cynometra*)
- small (*Campnosperma*)
- distinct to the naked eye (*Alstonia, Anisoptera, Anthocephalus, Calophyllum, Cotylelobium, Dalbergia, Dipterocarpus, Dryobalanops, Endospermum, Heritiera, Intsia*)
- indistinct to the naked eye (*Alstonia, Dialium*)
- vessel lines conspicuous on longitudinal surfaces (*Anisoptera, Anthocephalus, Cotylelobium, Dipterocarpus, Eucalyptus*)

Note: For describing the size of vessels, the following parameters should be noted (IAWA 1989):

Tangential diameter of vessel (microns)	Classification
≤ 50 µm	very small
50–100 µm	small
100–200 µm	medium
≥ 200 µm	large

TYLOSES

- absent (*Campnosperma*)
- present
- present in varying amounts (*Dipterocarpus, Dryobalanops*)
- sparse (*Endospermum*)
- sparse to abundant (*Anisoptera*)
- abundant (*Eusideroxylon*)

DEPOSITS

- absent (*Campnosperma*)
- present (*Cynometra*—white, pinkish, chalk-like; *Heritiera*—reddish, yellow or white; *Intsia*—red-brown, yellow)

RAYS

- very fine (*Agathis, Calophyllum*)
- very fine or fine (*Campnosperma*)
- fine (*Cynometra, Endospermum*)
- broad
- visible to the naked eye (*Dipterocarpus, Dryobalanops*)
- not visible to the naked eye (*Agathis, Calophyllum*)
- prominent on the radial surface
- not prominent on the radial surface/inconspicuous (*Agathis, Endospermum*)
- rays of two sizes—finer rays not visible to the naked eye (*Anisoptera, Cotylelobium, Dipterocarpus*)

PARENCHYMA

- abundant (*Endospermum*—in bands)
- moderately abundant (*Dryobalanops*)
- bands present (*Alstonia, Cynometra*)
- distinct in narrow, widely-spaced, dark-coloured lines

RIPPLE MARKS

- present/distinct (*Dalbergia, Dialium, Dryobalanops sumatrensis* and others, *Heritiera*)
- absent/indistinct (*Agathis, Anisoptera, Anthocephalus, Campnosperma, Cotylelobium, Cynometra, Dryobalanops rappa, Intsia*)

ODOUR

- absent/without any characteristic odour (*Anthocephallus*)
- present with odours:
  - caramel-like (*Agathis*)
  - mild resinous (freshly-sawn *Anisoptera* from PNG)
  - resinous (*Dipterocarpus*)
  - camphor-like (when fresh) (*Dryobalanops,* especially *D. sumatrensis*)

FIGURE

- stripes (on radial surface/quarter-sawn)/ribbon (*Anisoptera*—sometime present, *Calophyllum*, *Dialium*, *Eucalyptus*)
- streaks (dark-coloured) (*Cynometra, Heritiera*—sometimes, *Intsia, Palaquium*—sometimes, *Sindora*)
- streaks (purple-coloured) (*Dalbergia*)
- streaks (light-coloured) (*Madhuca*)
- growth rings/zig-zag (tangential surface) (*Calophyllum, Cynometra*)
- fiddleback (caused by wavy grain–pattern runs horizontally) (*Dryobalanops, Eucalyptus*)

LATEX CANALS (*Alstonia, Dyera*)

INCLUDED PHLOEM (*Koompassia malaccensis, K. excelsa*)

AXIAL INTERCELLULAR CANALS (sometimes in combinations of the following)

- in long tangential series (especially in *Anisoptera costata, Cotylelobium*—rarely, *Dryobalanops, Hopea, Shorea, Neobalanocarpus, Sindora*)
- in short tangential lines (*Dipterocarpus*)
- diffuse (most *Anisoptera, Cotylelobium*—sometimes in pairs)
- as large as vessels (*Anisoptera laevis*)
- less than half the vessel diameter (*Anisoptera scaphula, Dryobalanops*)
- half the size of larger vessels (*Cotylelobium*)
- larger than vessels (*Cotylelobium*)
- resin absent (*Cotylelobium*—sometimes, *Dipterocarpus*—sometimes)
- resin present (*Cotylelobium*—chalky white, *Dipterocarpus*—chalky white or black, *Dryobalanops*—chalky white)

HORIZONTAL CANALS

- absent (needs no mention)
- present (*Campnosperma*—large, clearly visible to the naked eye or with a hand-lens)

Appendix 2.2

Description of the Macroscopic and Microscopic Features – An Example Taken from PROSEA (1995) on *Shorea* Roxb. Ex Gaertner. (Red Meranti)

Macroscopic characters

Heartwood light red (varying to almost white), light pinkish brown or dark red and weathering to dark red-brown (dark red meranti), usually distinctly demarcated from the lighter sapwood (often with a grey tinge). Grain usually interlocked and wavy. Texture rather coarse but even; planed radial surface often with a prominent stripe figure (especially dark red meranti), quarter-sawn surface sometimes with attractive speckles (light red meranti), planed surface fairly lustrous. Growth rings usually indistinct or absent (sometimes moderately distinct in light red meranti); vessels mostly solitary, less often in oblique or radial pairs or radial multiples (up to four vessels in a series); tyloses generally present but not abundant; vessels visible to the naked eye; parenchyma sparse to moderately abundant, distinct or indistinct with a lens; rays usually distinct to the naked eye on cross-section, conspicuous (light red meranti) or fairly conspicuous (dark red meranti) on the radial surface. Ripple marks usually absent or indefinite, but occasionally distinct. Resin canals generally smaller than vessels, barely distinct to the naked eye, in long concentric lines, filled with white or yellow-white resin.

Microscopic characters

Growth rings usually absent or indistinct. Vessels diffuse, 3–10 mm^{-2}, mostly solitary but also in oblique or radial multiples of 2–4, sometimes with a tendency to form diagonal lines, round to oval, with a tangential diameter of 160–330 μm; perforations simple; intervessel pits alternate, vestured, with an average diameter of 8 μm; vessel-ray pits simple, large and round to gash-like; helical thickenings absent. Fibres 900–1600 μm long, 16–25 μm in diameter, usually non-septate; walls 3–6 μm thick; pits indistinct or minutely bordered; lumen sometimes filled with colourless, solid substances. Parenchyma variable in amount (scarce to abundant, depending on the species), 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 or appearing as discontinuous, narrow, irregular tangential bands enclosing resin canals, sometimes as discontinuous lines of one to a few cells wide; parenchyma strands irregularly storeyed in some specimens. Rays 4–5 (-12) mm^{-1}, usually multiseriates, mostly 3–4 cells wide (average width 60 μm), up to 40 cells high, composed of procumbent central cells and 2–4 rows of upright or square marginal cells (Kribs type heterogenous II) or with a single row of square marginal cells (Kribs type heterogenous III). Prismatic crystals scarce to moderately frequent in normal parenchymatic cells and/or in enlarged idioblasts, sometimes crystals absent. Resin canals in tangential rows and in elongated groups embedded in parenchyma, their number varying greatly between the species, average diameter 40–80 μm, but sometimes up to 200 μm, filled with white resin; radial canals occasionally present in *Shorea leprosula*.

Chapter 3

Mechanical Properties

3.1 Scope

This chapter entails the determination of the mechanical properties, i.e. strength and elasticity, of small clear specimens produced from plantation species.

3.1.1 Due to the small diameter of plantation logs, the method of testing for small clear specimens as stipulated in BS 373:1957 (confirmed, 2008) is found to be practical. The relevant strength properties to be evaluated are:

i) static bending
ii) compression parallel to grain
iii) compression perpendicular to grain
iv) shear parallel to grain
v) tension parallel to grain (optional)
vi) hardness
vii) impact bending (optional)
viii) cleavage (optional)

3.1.2 Since the preparation of samples for tension and cleavage tests is cumbersome and needs a well-trained worker to produce the shapes, it is proposed that these tests be optional. The impact bending test is also proposed to be optional since not every testing laboratory would possess the Charpy impact tester. All of the other tests are necessary to be conducted by any laboratory that wishes to evaluate the strength and elasticity performance of plantation species.

3.2 Referenced Document

3.2.1 BS 373: 1957 (confirmed, 2008). Method of Testing Small Clear Specimens of Timbers. British Standards Institution.

3.3 Equipment

3.3.1 *Preparation of Specimens*

3.3.1.1 Band-saw, circular saw, planer and thicknesser.

3.3.2 *Evaluation of Mechanical Properties*

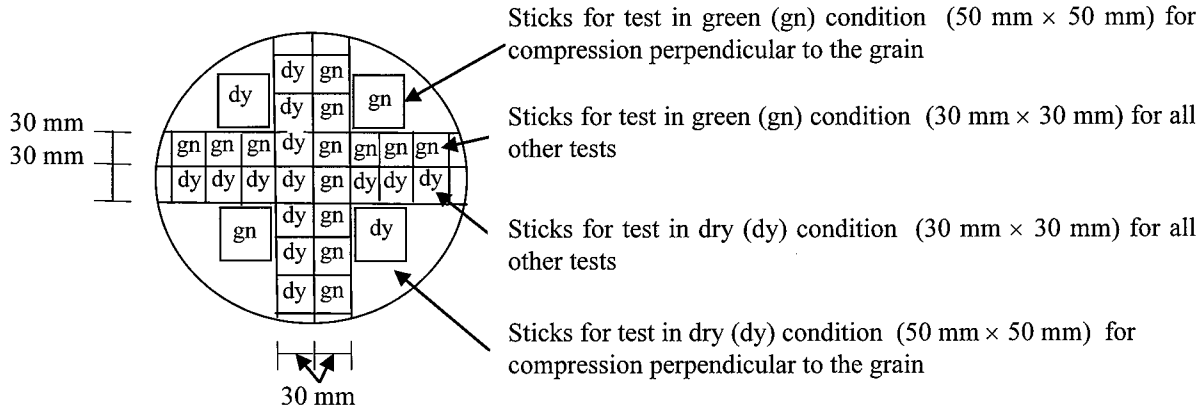
3.3.2.1 Universal testing machine with the appropriate jigs and fixtures. The machine should be annually calibrated to a traceable standard. If the impact testing is chosen, impact bending machine should be made available with the fixtures suitable for testing of timber.

3.3.3 *Measuring Devices*

3.3.3.1 Ruler, vernier caliper and dial gauge.

3.4 Preparation of Specimens

3.4.1 The sample log shall be 2.5 m in length. The specimens shall be cut as shown in Figure 3.1.



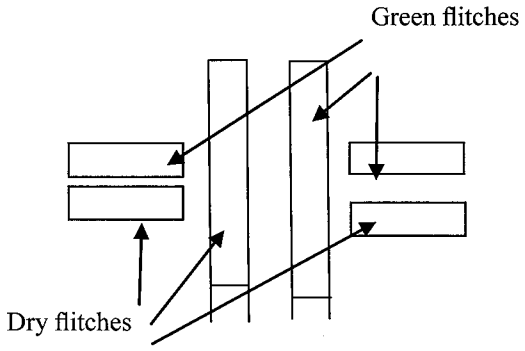


Figure 3.1 Log-to-flitch and flitch-to-stick cutting configurations

3.4.2 The small diameter end of the log shall be marked accordingly to yield test sticks as shown in Figure 3.2. The log is reaped using band-saw into six flitches.

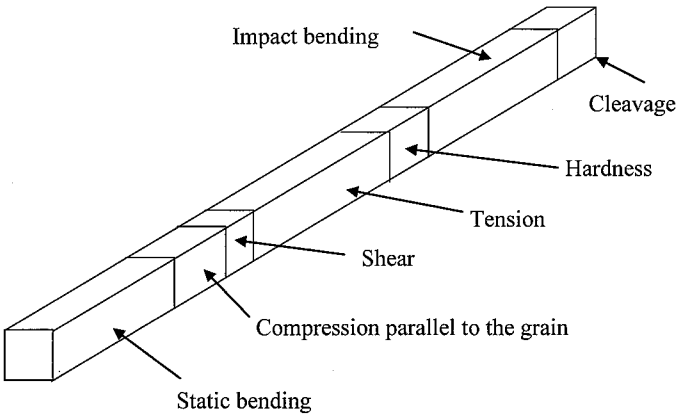


Figure 3.2 Stick-to-test specimen configuration

3.4.3 To minimize moisture loss, the newly-felled logs shall be painted at both cut ends. The logs shall be ripped into flitches meant for the air-dry and green tests (see Figure 3.1). The flitches shall then be cut into sticks having cross-sectional dimensions of 30 mm by 30 mm. Sticks of 60 mm by 60 mm shall also be prepared from the other parts of the log besides the flitches if the testing of compression perpendicular to the grain needs to be done. The test of specimens under green condition shall be done as soon as possible to avoid moisture evaporation from the specimens. The sticks for the green condition shall be immediately cut to test specimen sizes. If the green sticks are not able to be cut into test specimen sizes, they shall be stored in large freezer or walk-in freezer. If the freezer facility is not available the sticks shall be wrapped in plastic bags or placed under gunny sacks or equivalent materials which are wetted daily. The strength test shall follow soon after the test specimens are already cut.

3.4.4 For test of specimens under dry condition, the flitches shall be air-dried to an MC of less than 19%. The method of drying is left to the affordability of the testing laboratory. While kiln drying is faster as compared to air drying, it will cost more.

3.4.5 For both the dry and green conditions, the sticks shall be cut to 20-mm test specimen sizes as stipulated in BS 373. The scheme as shown in Figure 3.2 is proposed, but the sequence of the type test on the stick is not fixed as in the diagram. For compression perpendicular to the grain, the final dimensions of the stick shall be 50 mm by 50 mm.

3.4.6 Each of the specimens shall be coded with the following scheme:

Year & Month / Batch / Tree No. / Stick No. / Test No. / Condition (green or dry)

3.4.7 The laboratory shall be air-conditioned to achieve a constant temperature of 20 ± 3 °C.

3.4.8 Dimensions of test pieces shall be determined to an accuracy of not less than ± 0.3%.

3.5 Test Procedures

3.5.1 *Static-Bending Test*

3.5.1.1 The static-bending test shall be carried out by the *three-point bending method.*

3.5.1.2 The dimensions of the test piece shall be 20 mm × 20 mm × 300 mm. The distance between the points of support of the test piece shall be 280 mm, and the load shall be applied as shown in Figure 3.3. A constant loading speed of 6.0 mm min^{-1} shall be applied throughout the test.

3.5.1.3 The contour of the loading head which is in contact with the beam shall have a radius of 30 mm. The test pieces shall be supported at the ends such that they will be quite free to follow the bending action and will not be restrained by friction which would resist the bending and tend to introduce longitudinal stresses.

3.5.1.4 The deflection of the beam at mid-length shall be measured with reference to the outer points of loading.

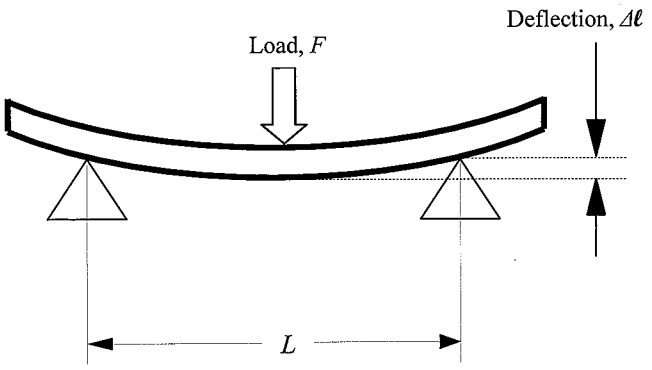


Figure 3.3 Static-bending test by three-point bending method

3.5.1.5 Modulus of rupture (MOR) and modulus of elasticity (MOE) in megapascal (1MPa = 1 N mm^{-2}) are to be calculated using the following formulae respectively:-

$$MOR = \frac{3}{2}\frac{FL}{WT^2} \quad \text{..... Eqn. 3.1}$$

where, F : maximum load, in N
L : span, in mm
W : width, in mm
T : depth, in mm

$$\text{MOE} = \frac{L^3}{4WT^3}\frac{\Delta F}{\Delta \ell} \quad \text{..... Eqn. 3.2}$$

where, L : span, in mm

$\frac{\Delta F}{\Delta \ell}$: slope of graph, in N mm^{-1}

W : width, in mm

T : depth, in mm

3.5.2 *Compression Tests*

The resistance to compression shall be determined both (a) parallel to the longitudinal grain, and (b) perpendicular to the longitudinal grain.

3.5.2.1 *Compression parallel to grain*

3.5.2.1.1 The form and dimensions of the test pieces shall be 20 mm × 20 mm × 60 mm. The load shall be applied parallel to the grain. To ensure accuracy of results, the ends of the rectangular test piece shall be smooth and normal to the axis of force (Figure 3.4). The top compression platen shall be kept parallel to the bottom platen throughout the test. A constant loading speed of 0.6 mm min^{-1} shall be applied during the test.

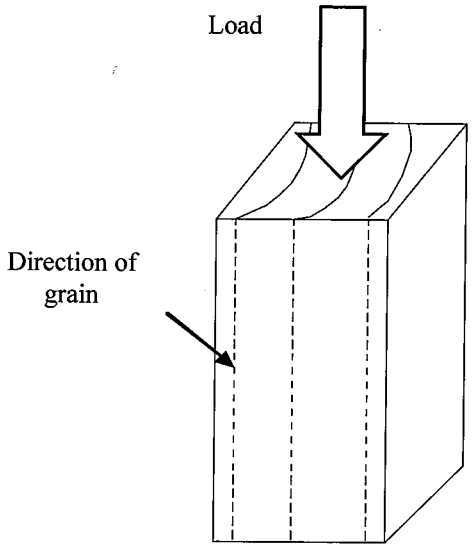


Figure 3.4 Compression-parallel-to-grain test

3.5.2.1.2 Compressive stress at maximum load in megapascal is calculated by using the formula as follows:

$$\text{Compressive stress at maximum load} = \frac{F}{A} \quad \text{..... Eqn. 3.3}$$

where, F : maximum load, N

A : cross-sectional area, mm^2

3.5.2.2 *Compression perpendicular to grain*

3.5.2.2.1 The specimen size shall be 50 mm × 50 mm × 50 mm as shown in Figure 3.5. The test shall be made by loading the specimen between parallel compression platens, and it shall be made in both the radial and tangential directions. A constant loading speed of 0.6 mm min^{-1} shall be applied during the test. The load compression curve shall be plotted to the point when the compression of the test piece reaches 2.54 mm. The maximum load maximum load and its associated strain shall both be recorded.

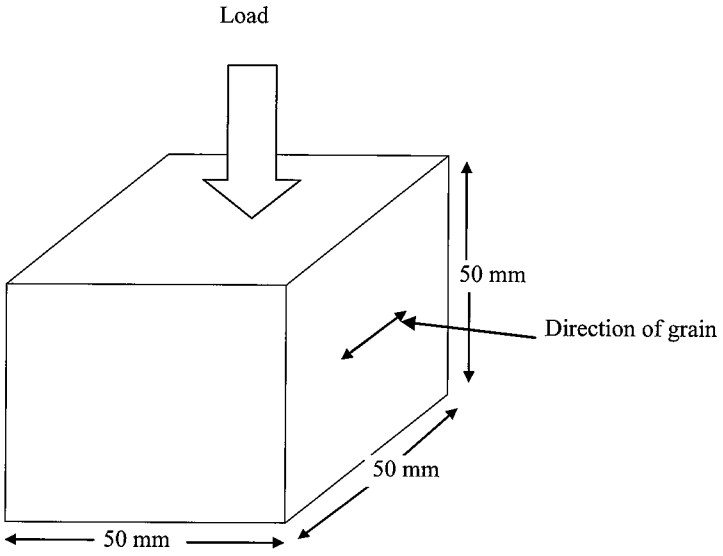


Figure 3.5 Compression-perpendicular-to-grain test

3.5.3 *Shear-Paralle-to-Grain Test*

3.5.3.1 The test is performed by introducing a shear failure along a plane parallel to the tangential direction of the grain and also with the plane of shear failure parallel to the radial direction (Figure 3.6). A constant loading speed of 0.6 mm min^{-1} is to be applied during the test. The test piece shall be a cube of 20 mm side.

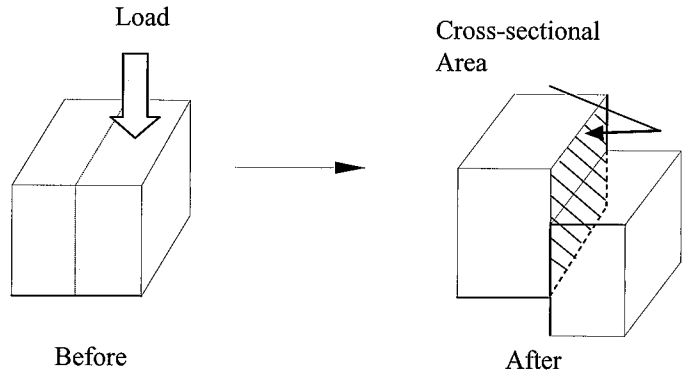


Figure 3.6 Shear-parallel-to-grain test

Shear stress at maximum load in megapascal is calculated by using the formula as follows:

$$\text{Shear stress at maximum load} = \frac{F}{A} \quad \text{..... Eqn. 3.4}$$

where, F : maximum load, N

A : cross-sectional area, mm^2

3.5.4 *Tension-Parallel-to-Grain Test*

3.5.4.1 The form and dimensions of the test piece for determining the tension parallel to grain strength are illustrated in Figure 3.7. The actual dimensions at the minimum cross-section shall be measured. The tension force parallel to grain should be applied such that the failure in tension happens at the minimum cross-section. The test piece is held on both ends by toothed and self-aligning grips. The load shall be applied to the test piece at a constant head speed such that the specimen will break in 1.5 to 2 min from the start of loading.

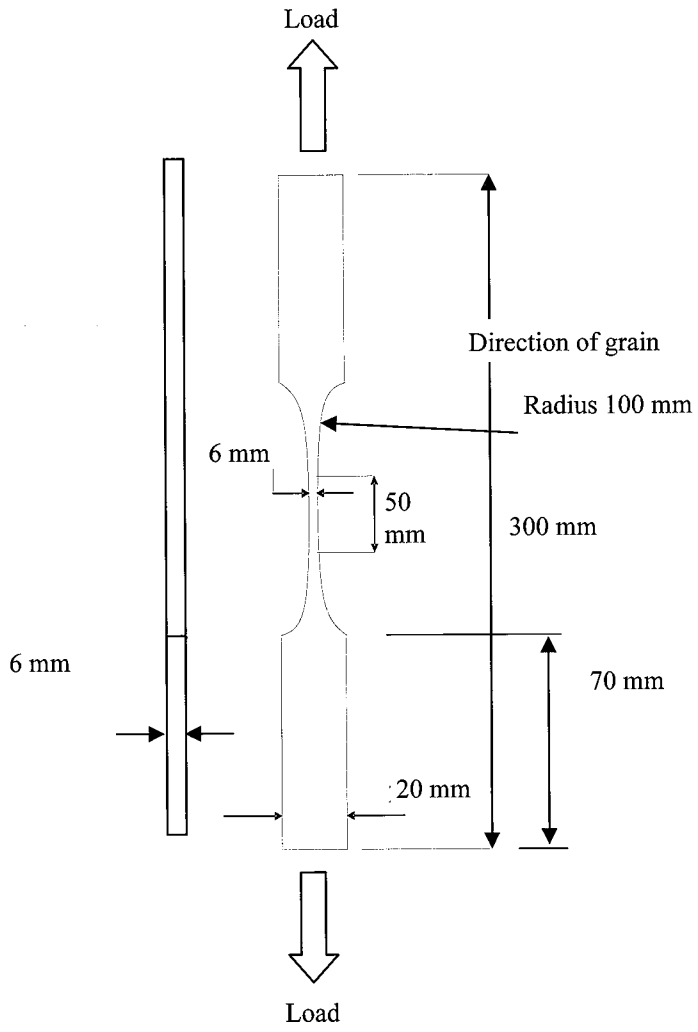


Figure 3.7 Tension-parallel-to-grain test

Tensile stress at maximum load in megapascal is calculated by using the formula as follows:

$$\text{Tensile stress at maximum load} = \frac{F}{A} \quad \text{Eqn. 3.5}$$

where, F : maximum load, N
A : cross-sectional area, mm^2

3.5.5 *Hardness Test*

3.5.5.1 The test is carried out such that a loading head with a hemispherical end of a steel bar, 11.28 mm in diameter, is forced onto the test specimen (Figure 3.8). A constant loading speed of 3 to 6 mm min^{-1} shall be used during the test. The load is to be applied on the radial and tangential surfaces of the test specimen to a depth of 5.64 mm. The radial and tangential surfaces chosen for the test shall be those which most closely approach the true radial and tangential directions of the grain. The load corresponding to the penetration depth of 5.64 mm is then noted for each specimen.

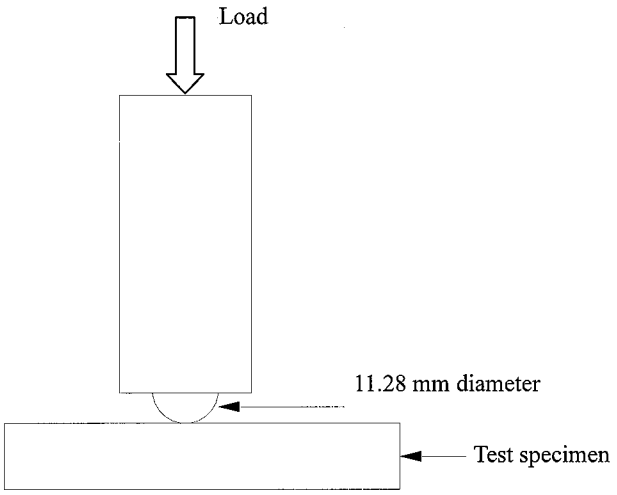


Figure 3.8 Hardness test

3.5.6 *Impact Bending*

3.5.6.1 Specimen with dimensions of 20 mm × 20 mm and 300 mm length is placed on two supports 240 mm apart as shown in Figure 3.9. The striking edge of a hammer and the supports are rounded with a radius of 15 mm. The hammer strikes against the test specimen in the centre and breaks it. The weight of the hammer is 10 kg and the height of fall is 1 m. This test is to determine the impact force and work done (energy) to break the specimen (Figure 3.10).

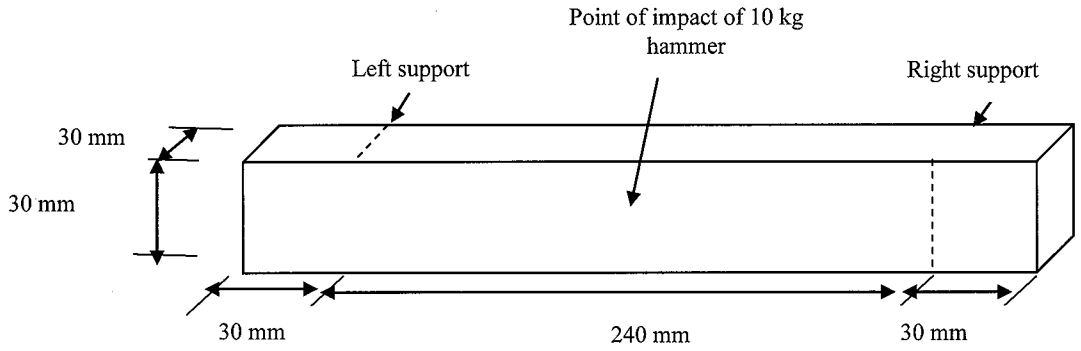


Figure 3.9 Impact-bending test specimen

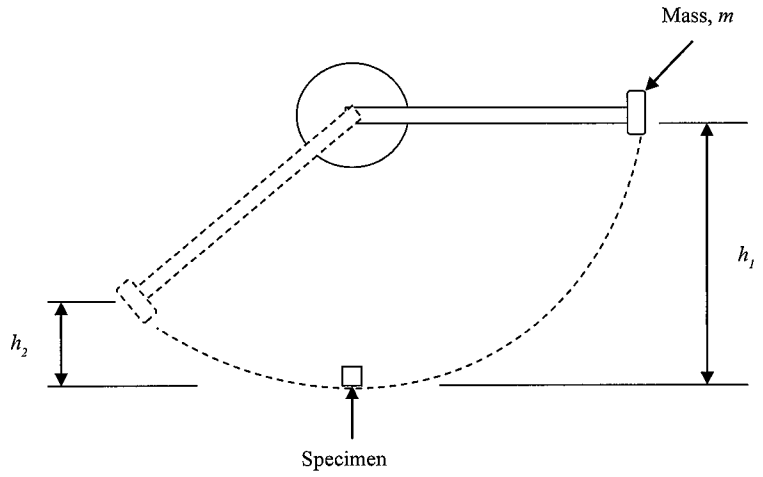


Figure 3.10 Impact-bending test configuration

Work done in impact bending, $W = mg\,(h_1 - h_2)$ ..... Eqn. 3.6

Energy absorbed in impact bending, $E = \frac{W}{bd}$ ..... Eqn. 3.7

where, W : work in impact bending (J)
m : mass of hammer (kg)
g : gravitational acceleration (m sec^{-2})
h_1 : height of hammer before fall (m)
h_2 : height of hammer after fall (m)
E : energy absorbed in impact bending(J mm^{-2})
b : width of the specimen (mm)
d : height of the specimen (mm)

3.5.7 *Cleavage*

3.5.7.1 The specimen for cleavage test with dimensions of 20 mm × 20 mm × 45 mm length, called "Monnin" type, is shown in Figure 3.11. The load shall be applied for both tests at a constant crosshead speed of 2.5 mm min^{-1}. Tests are made on some specimens cut so as to give a failure along radial and tangential surfaces. The maximum load causing failure in either the radial or tangential direction is a measure of the resistance of the timber to splitting.

Load per mm of width to resist splitting = $\frac{P}{b}$ ..... Eqn. 3.8

where,

P : maximum load in kN

b : breath in mm

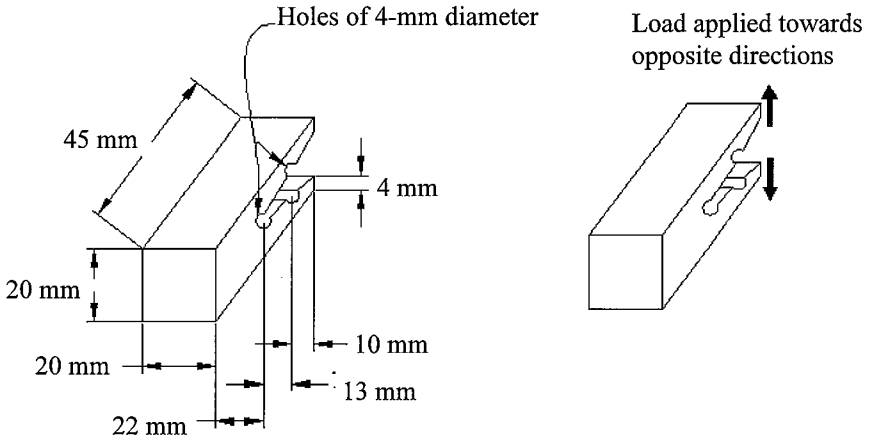


Figure 3.11 Cleavage test

3.6 Results

The test parameters and results of the mechanical tests shall be recorded as in Forms 3.1 to 3.8.

Forms

Form 3.1 Static-bending test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Depth (mm)	Width (mm)	Span (mm)	Maximum deflection (mm)	Maximum load (N)	MOR ($N\ mm^{-2}$)	MOE ($N\ mm^{-2}$)	Remarks

Prepared by: ..... Checked by: .....

Form 3.2 Compression-parallel-to-grain test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Width (mm)	Height (mm)	Maximum load (kN)	Compressive stress ($N\ mm^{-2}$)	Remarks

Prepared by: ..... Checked by: .....

Form 3.3 Compression-perpendicular-to-grain test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Width (mm)	Height (mm)	Load @ 2.54 mm (1.1 inch) deformation (kN)	Compressive stress @ 2.54 mm (0.1 inch) deformation (N mm^{-2})	Load @ elastic limit (kN)	Compressive stress @ elastic limit (N mm^{-2})

Prepared by: ..... Checked by: .....

Form 3.4 Shear-parallel-to-grain test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Width (mm)	Height (mm)	Maximum load (kN)	Shear stress (N mm^{-2})

Prepared by: ..... Checked by: .....

Form 3.5 Tension-parallel-to-grain test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Width (mm)	Minimum area of cross-section of test length (mm^2)	Length (mm)	Maximum load (kN)	Tensile stress at maximum load ($N\ mm^{-2}$)	Remarks

Prepared by: ..... Checked by: .....

Form 3.6 Hardness/Janka indentation test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Width (mm)	Length (mm)	Load @ 5.64 mm (0.22 inch) indentation (kN)

Prepared by: ..... Checked by: .....

Form 3.7 Impact-bending test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Weight of hammer: ..... (kgf)

Span between support: ..... (mm)

Specimen No.	Length (mm)	Thickness (mm)	Width (mm)	Height of hammer before falling (m)	Height of hammer after falling (m)	Work done (energy) to break specimen (N.m or Joules)

Prepared by: ..... Checked by: .....

Form 3.8 Cleavage test

Samples received from: ..... Testing date: .....

Temperature at test (°C): ..... RH at test (%): ..... Speed:.....

Specimen No.	Thickness (mm)	Length (mm)	Width (mm)	Maximum load (kN)	Load per width to resist splitting ($kN\ mm^{-1}$)

Prepared by: ..... Checked by: .....

Chapter 4

Sawing and Machining

4.1 Scope

4.1.1 This segment of the manual contains procedures for conducting three tests in the field of sawing and machining, namely sawing yield, sawing properties and wood machining tests.

4.1.2 The procedures are based on methodologies that have been modified to various degrees to address requirements and circumstances typical of the testing of tropical plantation timbers.

4.1.3 *Options and Alternatives*

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.

4.2 Referenced Documents

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

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

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

4.3 Definitions

4.3.1 *Sawing Yield*: The outputs of the sawing process expressed in volumetric or value terms.

4.3.2 *Sawing Properties*: Characteristics of the sawing process or of the output(s) of the process or 'machinability' of wood by sawing.

4.3.3 *Wood Machining*: Characteristics of wood as the facility with which it can be machined and fabricated.

4.3.4 *Slab*: Portion of log for further sawing to produce boards and other types of products.

4.3.5 *Slat*: Small board used as specimen for density and moisture content determinations.

4.4 Equipment

4.4.1 *Sawing Equipment*: Saw station comprising band mill, band-saw and log carriage.

4.4.2 *Measurement Equipment*: Clamp-on power tester (e.g. HIOKI Hitester), tachometer, diameter tape, measuring tape, micrometer, stopwatch, digital caliper, stylus-type surface roughness meter, electronic balance and oven.

4.4.3 *Computing Equipment*: Notebook computer, analog/digital converter, data acquisition card.

4.4.4 *Labelling Equipment*: Permanent marker pen, tagging tape.

4.4.5 *Machining Equipment*: Moulding machine (planer), wide-belt sanding machine, boring machine, mortiser, spindle-moulder (shaper) and turning machine.

4.5 Preparation of Specimens

4.5.1 *Sawing Yield Test*: Saw logs debarked, cleaned and bucked to 3.0 m length. If kept in storage exceeding two weeks after felling, the logs should be kept in log pond or kept wet in log yard. Log conversion should be carried out within one month of harvesting.

4.5.2 *Sawing Properties Test*: 2.0 m length and 50.0 mm, 75.0 mm and 100.0 mm thick slabs sawn from green logs. If kept in storage, slabs should be kept in water or wrapped in plastic sheets to prevent drying.

4.5.3 *Wood Machining Test*: Work pieces prepared in compliance with stipulations of ASTM D 1666-87 (Reapproved, 1999).

4.6 Test Procedures

4.6.1 *Sawing Yield Test*

4.6.1.1 *Pre-sawing measurements*

4.6.1.1.1 Mark the log ID number clearly using a permanent marker pen / tagging tape on the butt end and the log face of the top end (Figure 4.1). Record log measurements and particulars using Form 4.1 in Section 4.7.

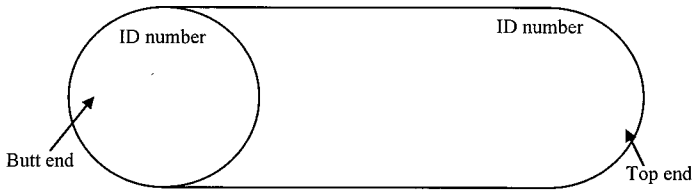
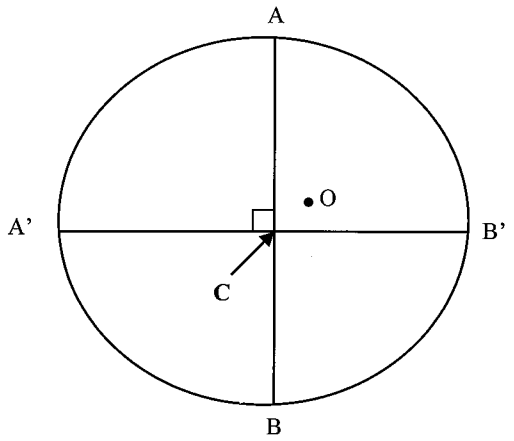


Figure 4.1 Marking of log ID number

ID number shall be used to identify the logs by indicating from which tree they were cut.

4.6.1.1.2 Measure the short and long diameters of both ends of the log using a ruler (Figure 4.2).



O: pith
C: geometric centre (visually ascertained)
AB: short diameter (mm)
A'B': long diameter (mm)

Figure 4.2 Measurements of short and long diameters

Short diameter and long diameter shall be measured in units of 1 mm on the both top and butt ends using a ruler. The shorter diameter through the geometric centre of the end should be regarded as the short diameter. The diameter perpendicular to the short diameter through the geometric centre of the end should be regarded as the long diameter.

4.6.1.1.3 Measure the log length (shortest distance between log ends) using a measuring tape (Figure 4.3).

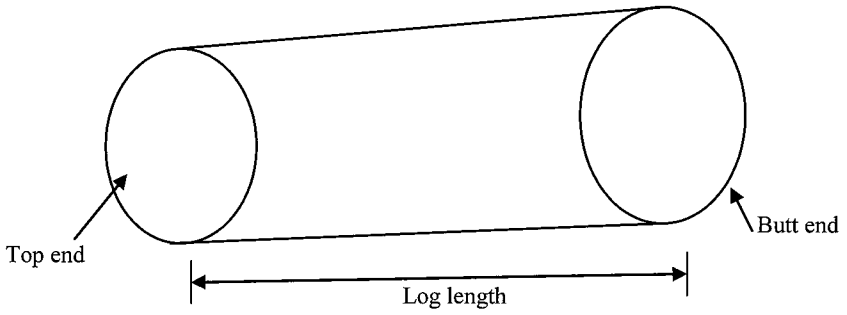
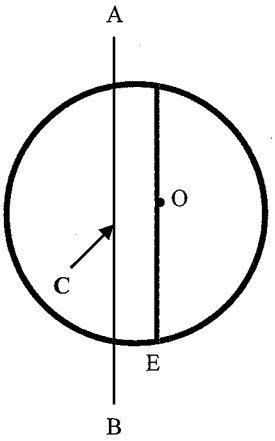


Figure 4.3 Measurement of log length

Length of a log shall be measured in units of 1 mm using a measuring tape. The shortest distance between the two ends is regarded as the log length.

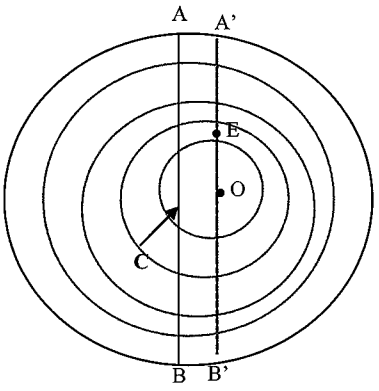
4.6.1.1.4 Measure the radius of the heartwood (if discernible) at the top end (Figure 4.4).



O: pith
C: geometric centre
AB: short diameter (mm)
OD: radius of heart wood (mm)
(OD < OE)

Figure 4.4 Measurement of radius of the heartwod

4.6.1.1.5 Count the number of growth rings at the top end (if discernible) (Figure 4.5).

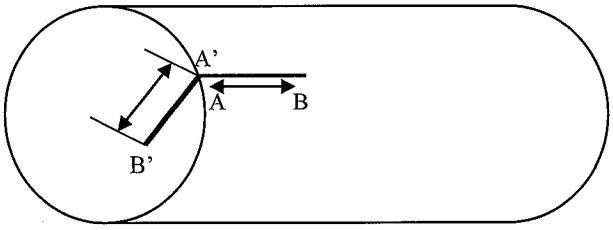


Top end

O: pith
C: geometric centre
AB: short diameter (mm)
OA': short radius (mm) (OA' < OB')
OE: 100 mm
A'B' parallel to AB

Figure 4.5 Counting of number of growth rings

4.6.1.1.6 Measure the length of end check(s) at both ends (Figure 4.6).



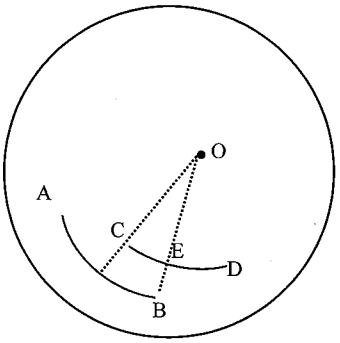
AB: length of end check (mm) (longest end check if more than one)

Figure 4.6 Measurement of length of end check

$$\text{End check rate (\%)} = \frac{\text{AB for top end} + \text{AB for butt end}}{\text{log length}} \times 100\% \quad \text{..... Eqn. 4.1}$$

For both the top and butt ends, the length (AB) of the end check shall be measured in units of 1 mm using a ruler. A'B' is used only to plan for opening cut.

4.6.1.1.7 Measure the length of ring shakes at both ends (Figure 4.7).



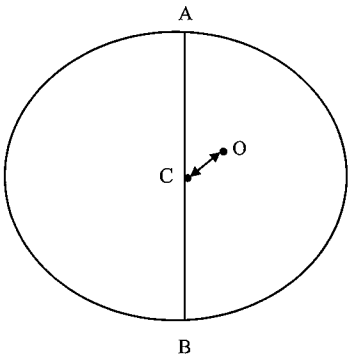
O: pith
AB: ring shake (mm)
CD: ring shake (mm)
Length of ring shakes (mm):
AB + CD – CE

Figure 4.7 Measurement of length of ring shakes

$$\text{Ring shake rate (\%)} = \frac{\text{length of ring shakes}}{\text{circumference of end}} \times 100\% \quad \text{..... Eqn. 4.2}$$

On both the top and butt ends, the length of the ring shake (AB + CD – CE) shall be measured in units of 1 mm using a measuring tape.

4.6.1.1.8 Measure the eccentricity at both ends (Figure 4.8).



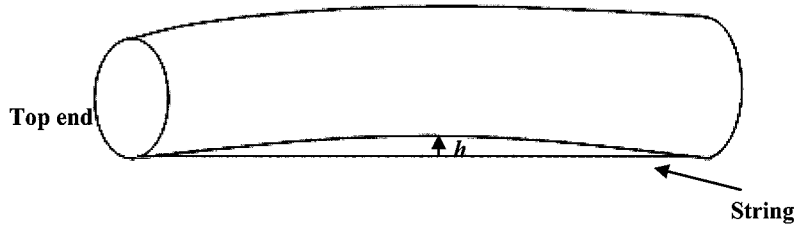
O: pith
C: geometric centre
AB: short diameter (mm)
CO: eccentricity (mm)

Figure 4.8 Measurement of the eccentricity

$$\text{Eccentric rate (\%)} = \frac{\text{eccentricity}}{\text{short diameter}} \times 100\% \quad \text{..... Eqn. 4.3}$$

On both the top and butt ends, the distance between the pith and the geometric centre shall be measured in units of 1 mm using a ruler.

4.6.1.1.9 Measure the log warp (Figure 4.9).



$$\text{Warp rate} = \frac{h}{\text{short diameter of top end}} \times 100\% \quad \text{..... Eqn. 4.4}$$

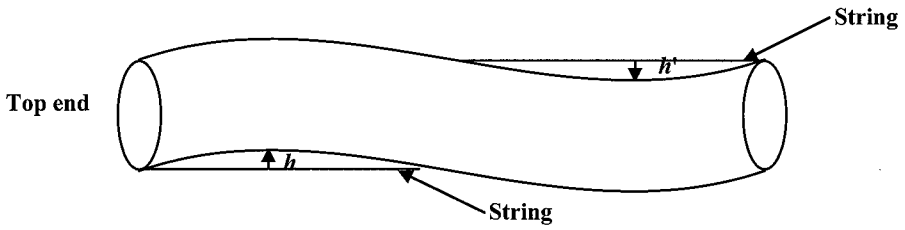


Figure 4.9 Measurement of log warp

$$\text{Warp rate} = \frac{1.5 \times (h + h')}{\text{short diameter of top end}} \times 100\% \quad \text{..... Eqn. 4.5}$$

The string shall be extended between both ends along a concave warp and the maximum chord height shall be measured in units of 1 mm using ruler.

4.6.1.1.10 Measure the diameters of knots and location of each knot (Figure 4.10) and record the data using Form 4.2 in Section 4.7.

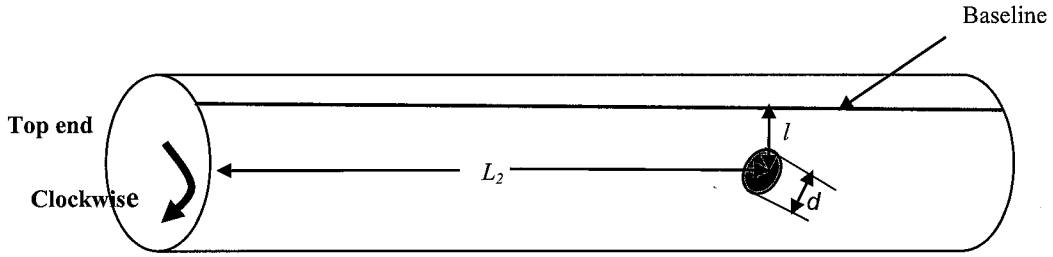


Figure 4.10 Measurements of diameters of knots and location of each knot

Baseline shall be drawn along a concave warp.

d : long diameter of knot measured in units of 1 mm using a ruler

L_2: distance between centre of the knot and the top end measured in units of 1 mm using a measuring tape

l: distance between centre of knot and the baseline measured clockwise viewing from the top end measured in units of 1 mm using a measuring tape

4.6.1.2 *Sawing log into sawn lumber (boards)*

4.6.1.2.1 Alternative equipment

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.

4.6.1.2.2 Measure and record all saw specifications using Form 4.3 in Section 4.7.

4.6.1.2.2.1 The replicas of band-saw used shall be made at two locations using inkpad and sheets (Figure 4.11).

4.6.1.2.2.2 The pitch, tooth angles shall be measured on the replica using a protractor and a ruler.

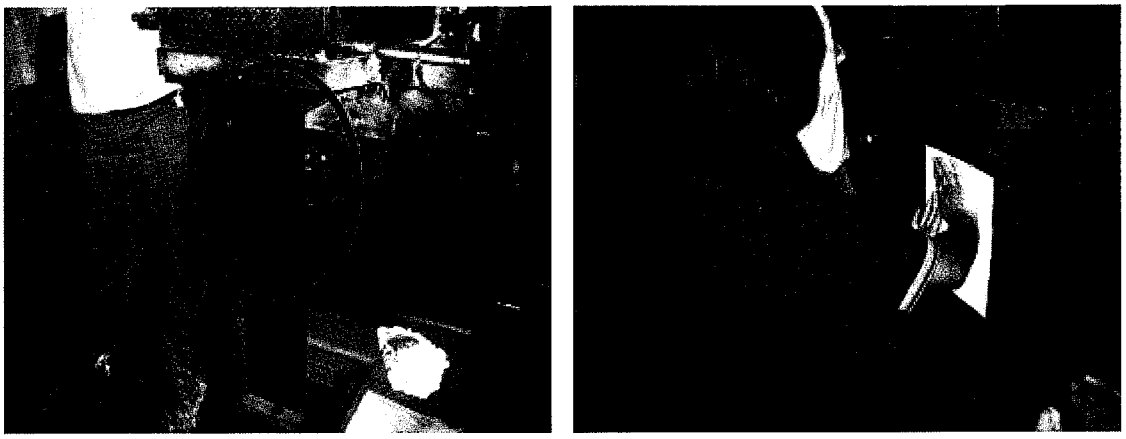


Figure 4.11 Making replica of saw blade

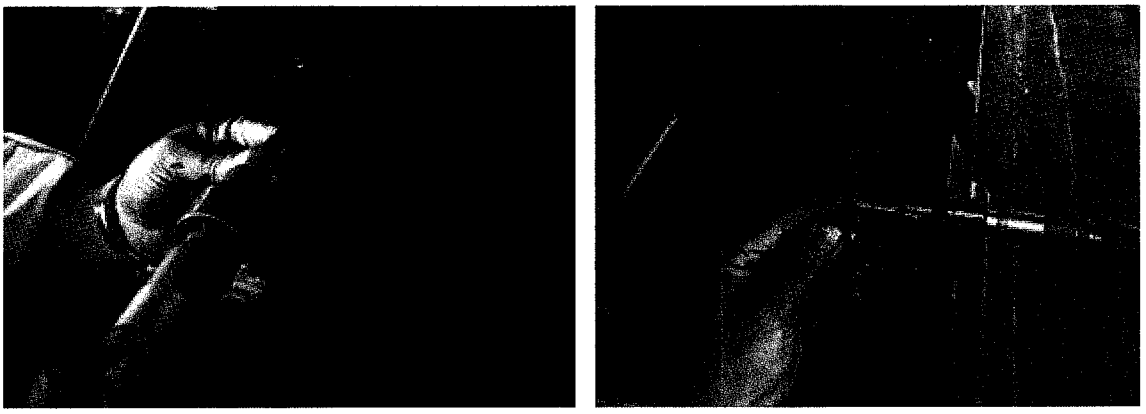


Figure 4.12 Kerf measurement

4.6.1.2.2.3 The number of teeth shall be counted.

4.6.1.2.2.4 The width of saw kerfs of every 10 teeth and thickness of saw blade of the band-saw shall be measured in units of 0.01 mm using a micrometer (Figure 4.12).

4.6.1.2.3 Decide on the opening face of a log considering the log face and log quality.

4.6.1.2.4 Proceed with sawing using the 'modified cant sawing' pattern with targeted sizes (50 mm × 150 mm, 50 mm × 100 mm, 25 mm × 100 mm) of the sawn lumber (boards) (Figure 4.13).

4.6.1.2.5 Record also the quantity and dimensions of stickers (25 mm × 25 mm, 50 mm × 50 mm) and scantling, if any.

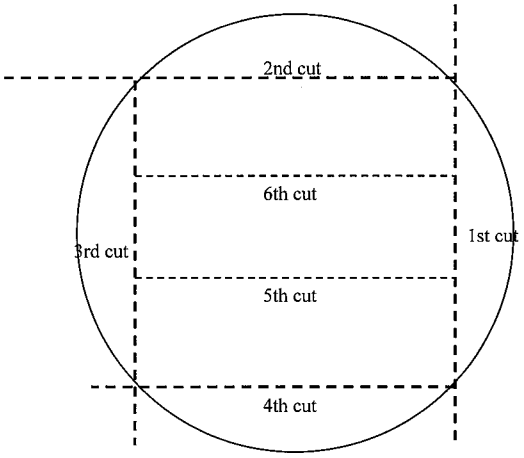


Figure 4.13 'Modified cant sawing' pattern

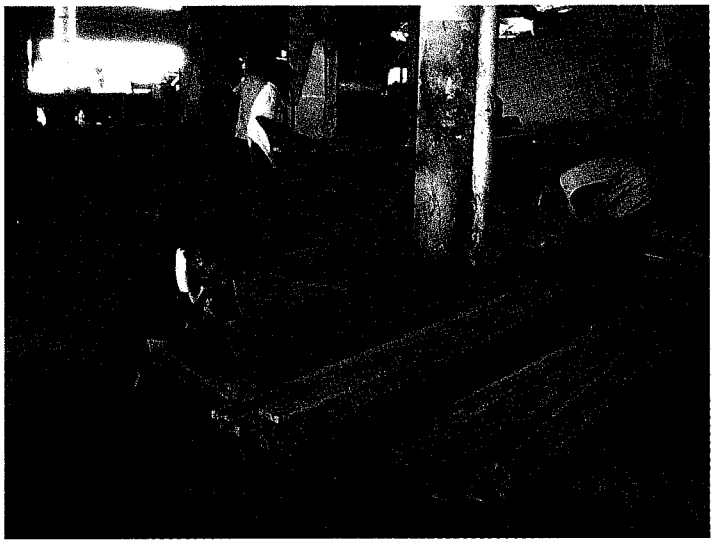


Figure 4.14 Labelling of boards

4.6.1.2.6 Label every piece of sawn board, sticker and scantling from the sawing or re-sawing (Figure 4.14).

4.6.1.3 *Post-sawing recording and assessments*

4.6.1.3.1 Take samples to determine the moisture content of each board at three locations (Figure 4.15). Measure and record data using Forms 4.4 and 4.5 in Section 4.7.

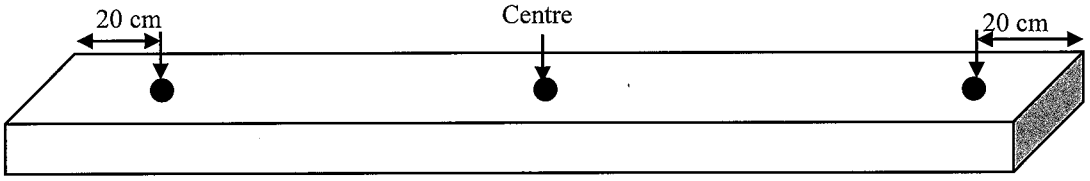


Figure 4.15 Sampling for moisture content determination

4.6.1.3.2 Measure and record the bow and spring/crook of each board (Figures 4.16 and 4.17).

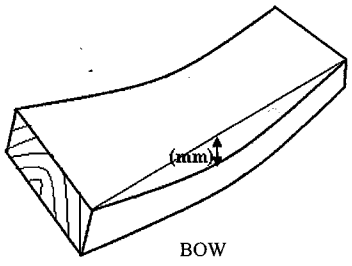


Figure 4.16 Measurement of bow

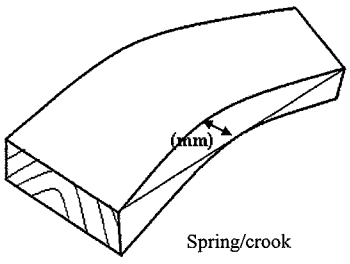


Figure 4.17 Measurement of spring/crook

4.6.1.3.3 Grade each board based on the Malaysian Grading Rules (MGR).

4.6.1.3.4 Record the nominal dimensions and grade of each board.

4.6.1.3.5 Calculate the log volume by the Brereton rule,

$$V_B \frac{\pi D_a^2 \ell}{40{,}000} \quad \text{.....Eqn. 4.6}$$

where,

V_B: log volume in the Brereton rule (m^3)
D_1: short diameter of top end (cm)
D_2: long diameter of top end (cm)
D_3: short diameter of butt end (cm)
D_4: long diameter of butt end (cm)
D_a: $(D_1 + D_2 + D_3 + D_4)/4$
l: log length (m)

4.6.1.3.6 Calculate the sawing yield in volume yield,

$$Y_{vol} = \frac{\Sigma V_i}{V_B} \times 100\% \text{ ..... Eqn. 4.7}$$

where,

Y_{vol} (%): volume yield
V_i (m^3): volume of each lumber
V_B (m^3): volume of a log

4.6.2 *Sawing Properties Test*

4.6.2.1 *Work-piece preparation*

4.6.2.1.1 Prepare five work pieces (slabs) of 50.0 mm, 75.0 mm and 100.0 mm thickness each and 2 m length using the round-and-round cutting pattern, while "α", the thickness allowance, is 5.0 mm (Figure 4.18).

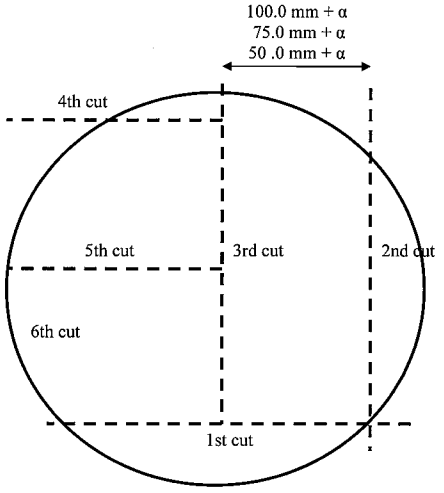


Figure 4.18 Round-and-round cutting pattern

All slabs shall be planed to thicknesses of 50.0 mm, 75.0 mm and 100.0 mm.

4.6.2.1.2 Measure and record band-mill and band-saw specifications using Form 4.3 in Section 4.7.

4.6.2.1.2.1 The replicas of band-saw used shall be made at two locations using inkpad and sheets.

4.6.2.1.2.2 The pitch, tooth angles shall be measured on the replica using a protractor and a ruler.

4.6.2.1.2.3 The number of teeth shall be counted.

4.6.2.1.2.4 The width of saw kerfs of every 10 teeth and thickness of saw blade of the band-saw shall be measured in units of 0.01 mm using a micrometer.

4.6.2.1.3 Sawing condition:
Feed per tooth, f_t where.

$$f_t = \frac{f \times p}{c} \quad \text{..... Eqn. 4.8}$$

f: feed speed (m min^{-1})
p: tooth pitch (mm)
c: saw speed (m min^{-1})
f_t: 0.25 — 0.67 mm

4.6.2.1.4 Three speed groups shall be targeted during sawing, which are 20, 30, 40 m min^{-1}, in order to acquire the f_t range from 0.25 to 0.67 mm.

For example:

$$20 \text{ m min}^{-1} = \frac{2 \text{ m}}{t \times 60 \text{ (sec)}}, \; t = \text{sawing time in sec}$$

4.6.2.2 *Power consumption measurement*

4.6.2.2.1 Option/alternative

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 $P = IV$, whereby 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.

4.6.2.2.2 Set up clamp-on power meter at the electricity distribution board with data directly inputted to a computer notebook (Figure 4.19).

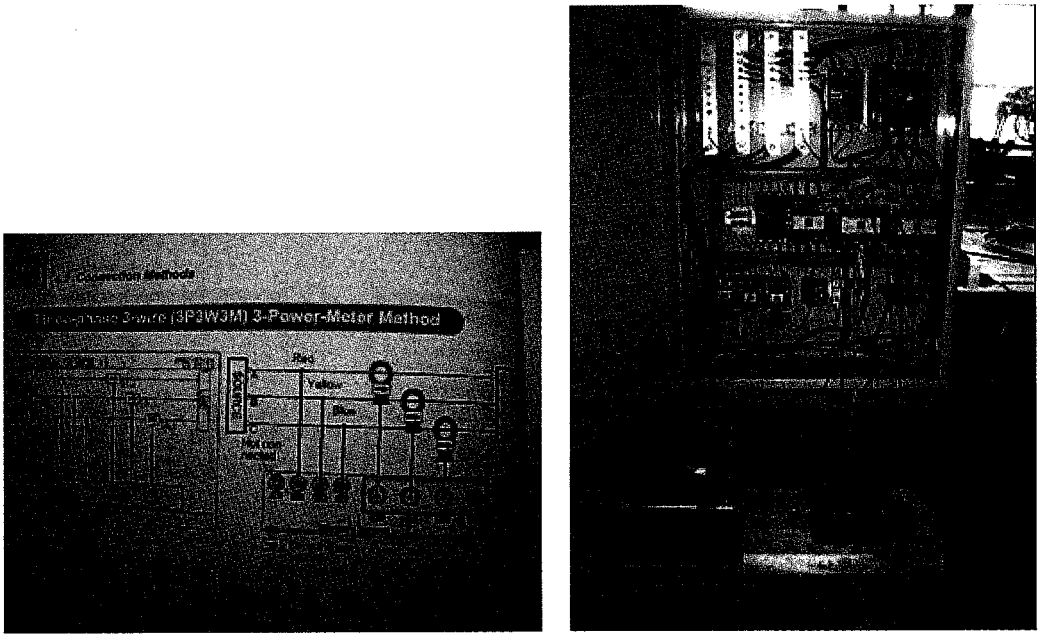


Figure 4.19 Use of power tester for 3-phase power consumption measurement

4.6.2.2.3 Measure and record the power consumption while cutting 5.0 mm thick boards from the flitches.

4.6.2.2.4 Measure sawing time and record in 0.1 sec using Form 4.6 in Section 4.7 and calculate feed speed from the sawing time elapsed.

4.6.2.2.5 Five replicates for each sawing condition are illustrated in Figure 4.20.

4.6.2.2.6 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.

4.6.2.2.7 Calculating the power consumption and record using Form 4.10 in Section 4.7.

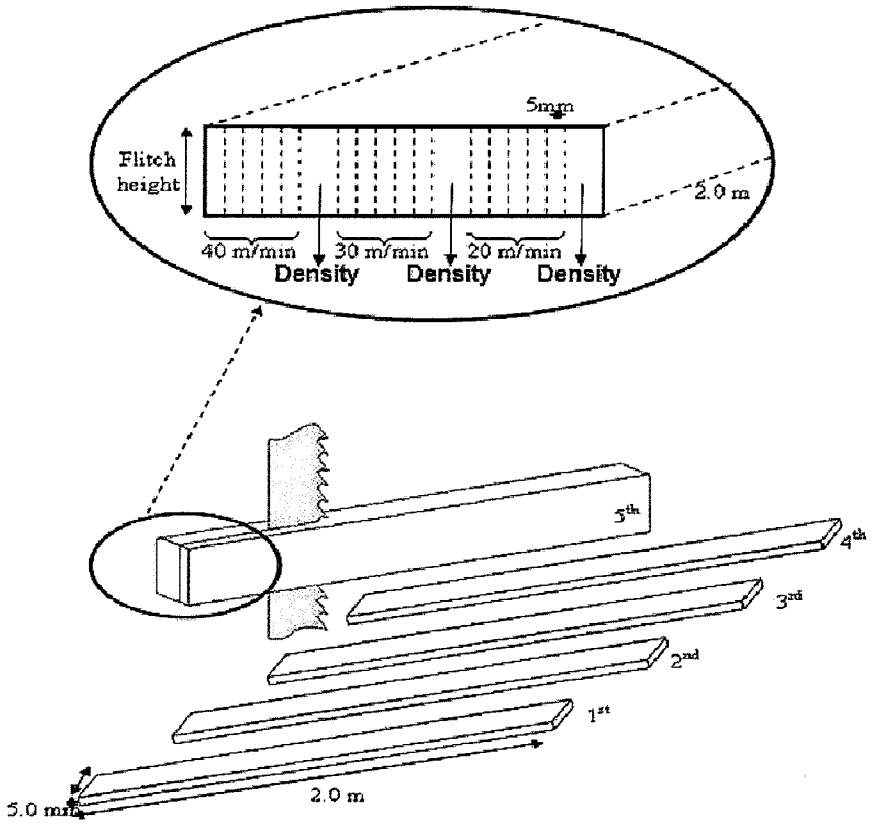


Figure 4.20 Preparation of samples for sawing-properties test

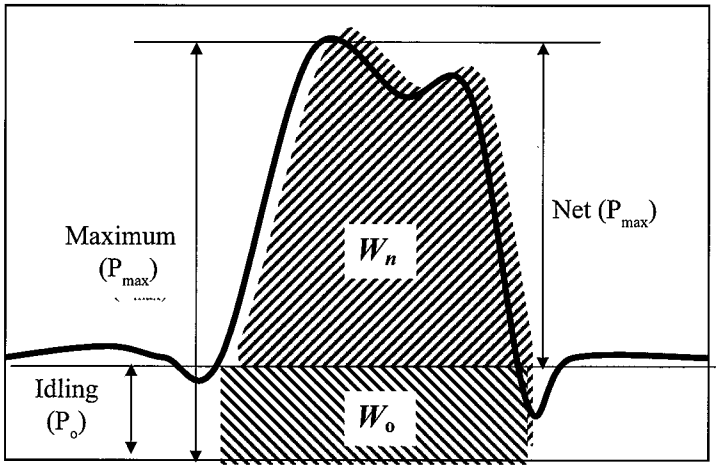


Figure 4.21 Calculating the power consumption

The difference between the maximum power consumption during sawing and the average power consumption during idling is regarded as net maximum power consumption during sawing (Figure 4.21).

$P_{nmax} = P_{max} - P_o$ ..... Eqn. 4.9

where,
P_{nmax} = net maximum power consumption during sawing
P_{max} = maximum power consumption during sawing
P_o = average power consumption during idling

It is desired to calculate the net integrated power consumption during sawing too:

$W_n = W - W_o$ ..... Eqn. 4.10

where,
W_n = net integrated power consumption during sawing
W = integrated power consumption during sawing
W_o = integrated power consumption concerning idling during sawing

$$W = \sum_{i}^{n} (P_{(i)} \times \frac{t}{3600}) \, kwh$$ ..... Eqn. 4.11

$W_o = P_o \, x \, t \, x \, n$ ..... Eqn. 4.12

t: interval time of 0.1 sec
n: elapsed sawing interval captured by power meter

4.6.2.3 *Sawing accuracy assessment*

4.6.2.3.1 Thoroughly clean the 5-mm board from the power consumption test.

4.6.2.3.2 Measure the thickness of the board with a digital caliper at three locations on the same side of the board (Figures 4.22 and 4.23) and record the data using Form 4.7 in Section 4.7.

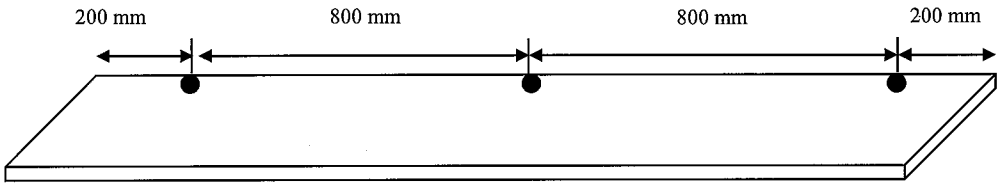


Figure 4.22 Three locations on the same side of the board

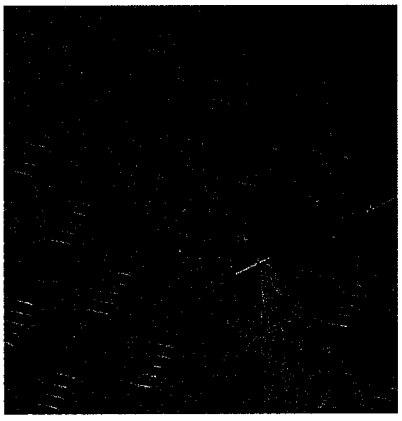


Figure 4.23 Measuring the thickness of the sawn board

4.6.2.3.3 Record all measurements and compute the unevenness, if any, in the board.

4.6.2.3.4 Conduct quality control analysis using the control chart method.

4.6.2.4 *Measuring moisture content*

4.6.2.4.1 Cut three slats of 50 mm in length from three points of the 1st and 5th sawn boards cut and mark the ID number. Keep the slats in a plastic bag in order to prevent drying until weighing (Figures 4.24 and 4.25).

4.6.2.4.2 The moisture content of the slats is determined using the oven-dry method (refer to Appendix 8.1).

4.6.2.4.3 Record the data using Form 4.8 in Section 4.7.

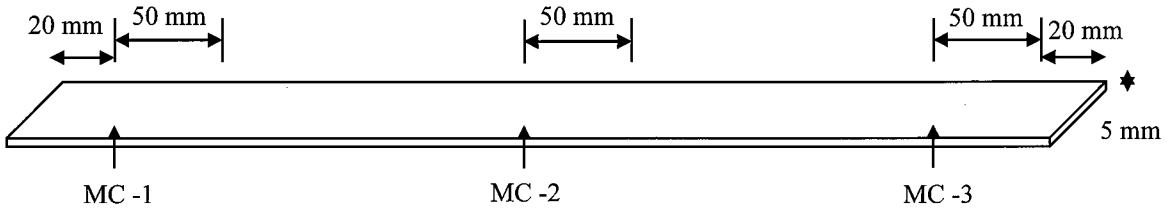


Figure 4.24 Sampling for measuring moisture content

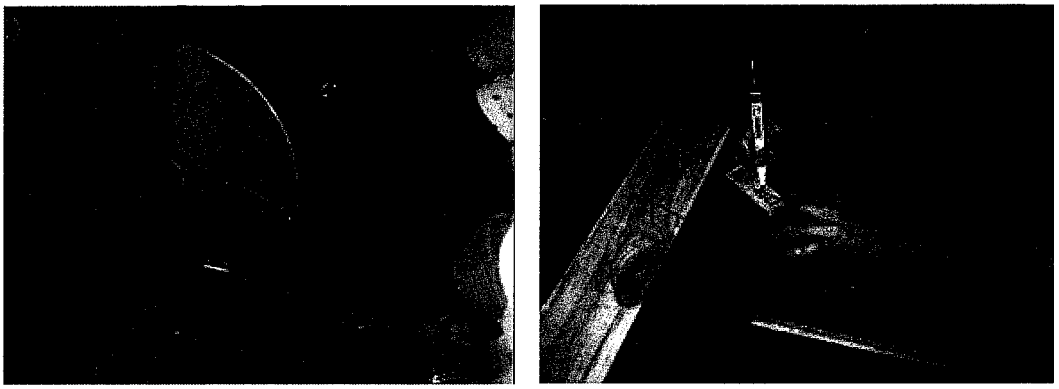


Figure 4.25 Slat preparation for moisture content measurement

4.6.2.5 *Measuring density of slab*

4.6.2.5.1 Prepare dressed (planed) specimens, 10 mm in thickness, 30 mm in width and 50 mm in length, from the slabs sawn and mark the ID number with permanent marker pen (Figures 4.26 and 4.27).

4.6.2.5.2 Keep the specimens in a plastic bag to prevent drying.

4.6.2.5.3 Determine the density using the density determination method in Appendix 8.2.

4.6.2.5.4 Record the data using Form 4.9 in Section 4.7.

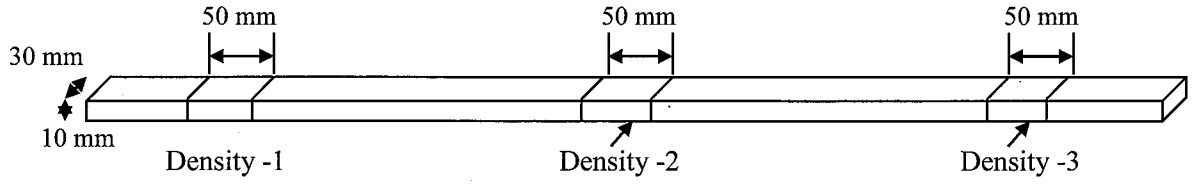


Figure 4.26 Sampling for density measurement

Figure 4.27 Planed specimen cut for density measurement

4.6.2.6 *Surface roughness assessment*

4.6.2.6.1 Option / alternative

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.

4.6.2.6.2 Cut a slat 250 mm in length from the centre of the 2nd, 3rd and 4th sawn boards cut and mark the ID number (Figure 4.28).

4.6.2.6.3 Measure the surface roughness along the grain and across the grain of each slat at three sites on the slat with a stylus-type surface roughness meter. Record the roughness profile using Form 4.11 in Section 4.7. Measuring direction (moving direction of the stylus) should be the same as feeding direction of slab.

4.6.2.6.4 The surface roughness meter should have the following settings: stylus radius—5 μm; measuring distance—25 mm; measuring speed—0.5 mm sec^{-1}; cut-off value—2.5 mm G.

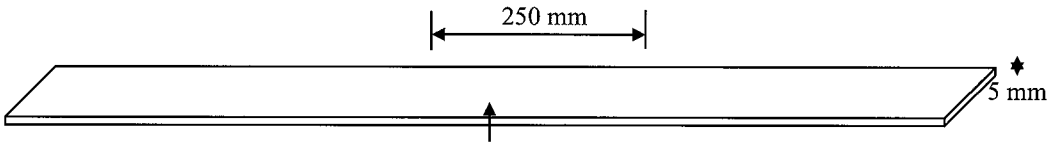


Figure 4.28 Surface roughness assessment

4.6.2.6.5 The roughness values desired are as shown in Form 4.11, namely:

R_a = mean arithmetic deviation of profile

R_{max} = maximum roughness

R_z = mean peak-to-valley height

4.6.3 *Wood Machining Tests*

The machining operations studied are those encountered in commercial secondary wood processing (value-added) plants, including planing, sanding, boring, shaping, mortising and turning. The machining tests are conducted according to American Society for Testing and Materials (ASTM) D 1666-87 (Reapproved, 1999), with minor additional parameters.

The objective of this work is to define the machining quality of tropical plantation species. Machining tests are made to determine the working quality and characteristics of wood and wood-based materials under a variety of machining operations such as are encountered in commercial manufacturing practice. These tests evaluate the potential suitability of tested wood species for certain uses.

4.6.3.1 *Lumber preparation*

Arrangement of flat-sawn and quarter-sawn specimens in a log is as shown in Figure 4.29. The number of specimens needed for the test is 50 for each species tested, which are 25 flat sawn and 25 quarter sawn, preferably from different trees. Dimensions of the sawing lumber are as shown in Figure 4.30, the thickness of lumber is 19 mm. The ID number shall be labelled on every prepared sawn lumber from which log it is sourced and record the information using Form 4.12 in Section 4.7. Moisture content of the lumber shall be at air-dry condition.

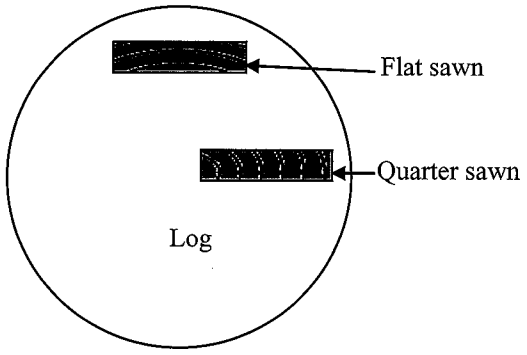


Figure 4.29 Sampling arrangement of log

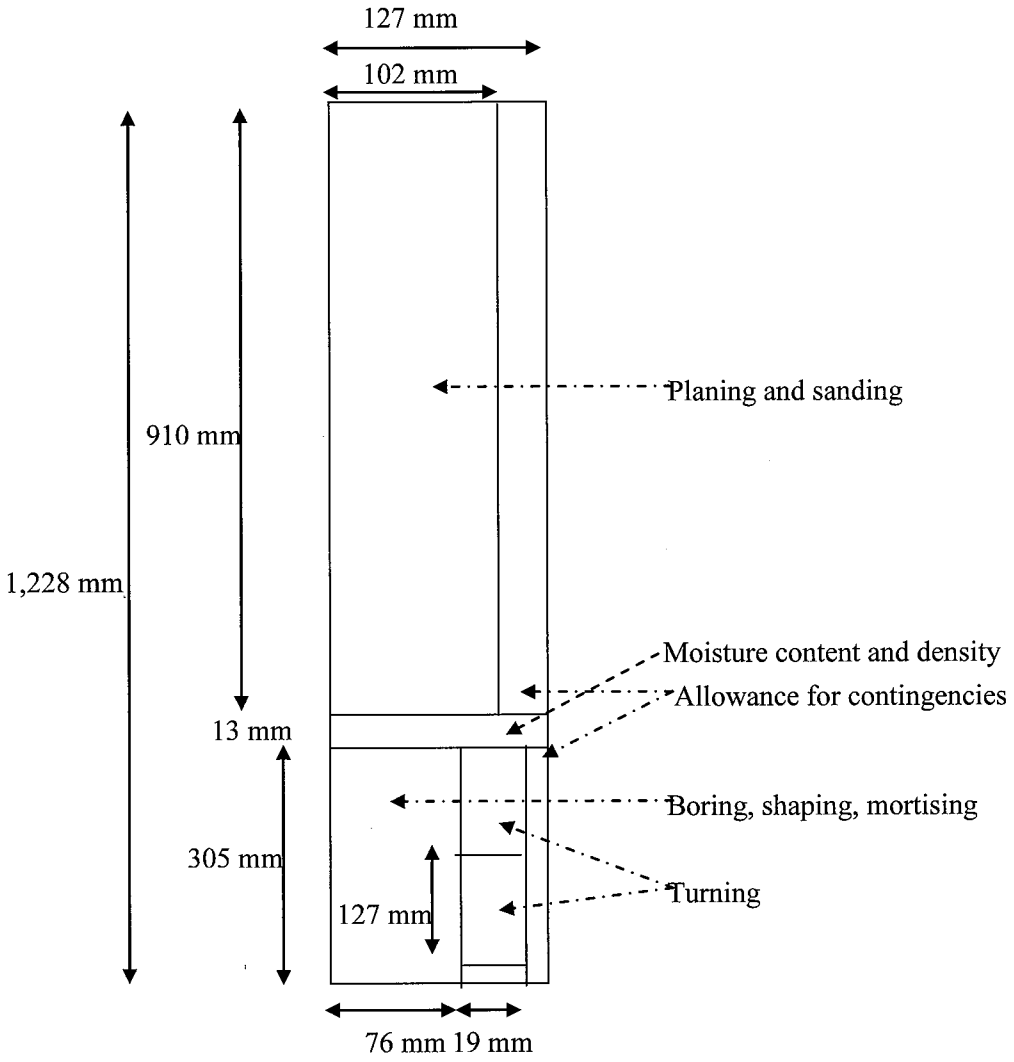


Figure 4.30 Diagram for sawing lumber samples into smaller samples for individual tests

4.6.3.1.1 Measurements of moisture content and density

The specimen dimensions for moisture content and density measurements are 13 mm by 19 mm by 127 mm. The moisture content and density of specimens shall be determined based on standard procedures stipulated in Appendices 8.1 and 8.2 of this manual respectively. Record the data using Form 4.14 in Section 4.7.

4.6.3.2 *Planing test*

Dimensions of the sawn lumber as shown in Figure 4.31 shall be prepared. In this study, the planing test is carried out using moulder. In the absence of moulder, a planer or planer-matcher may be used. The measurements of power consumption using clamp-on power meter and evaluation of surface roughness using stylus-type surface roughness measuring instrument are implemented as additional requirements.

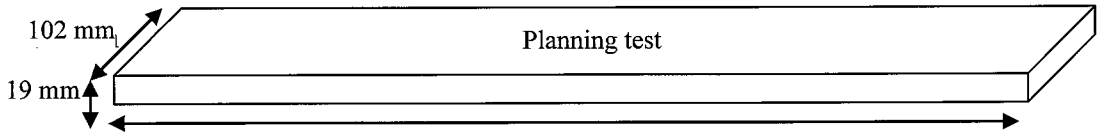


Figure 4.31 Board for planing test

4.6.3.2.1 The following cutting conditions are employed in the planning test.

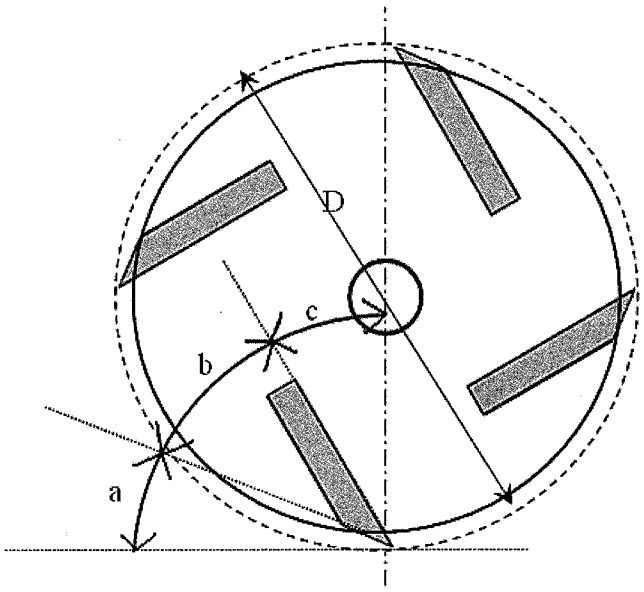


Figure 4.32 Various angles of cutter block

a: clearance angle, b: sharpness (knife) angle, c: rake angle, D: cutting circle diameter

- Knife material: high speed steel (HSS)
- Knife condition: straight, new one
- Rotation speed of cutter block: 5,700 rpm
- Cutter block with 4 knives (Figure 4.32)
- Sharpness angle: 30°, 35°, 40° and 45°
- Feed per knife: 0.38, 0.45, 0.60 and 0.75 mm
  $f = F_s/Nn$
  f: feed per knife (m), F_s: feed speed of specimen (m min^{-1}),
  N: rotation speed of cutter block (rpm), n: number of knives
- Feed speed: 8.66, 10.26, 13.68, 17.10 m min^{-1}
- Depth of cut: 1 mm
- Cutting direction: Up milling
- Cutting circle diameter: 124.5 mm

4.6.3.2.2 Pre-test procedures

4.6.3.2.2.1 For flat-sawn sample, the planing test surface is determined by considering the direction of growth rings, whereby the outer ring surface is used for the test (Figure 4.33).

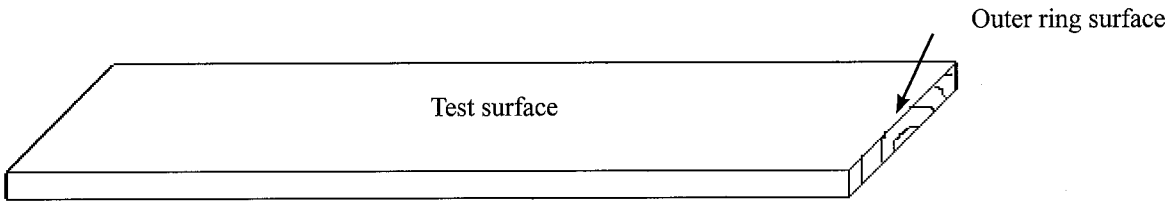


Figure 4.33 Flat-sawn sample

4.6.3.2.2.2 For quarter-sawn sample, the planing test surface could be either one of the board surfaces (Figure 4.34).

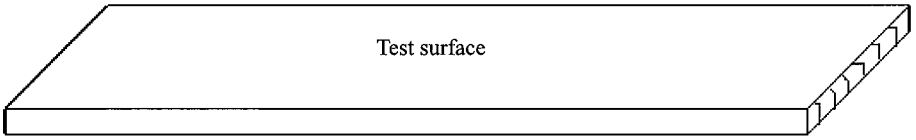


Figure 4.34 Quarter-sawn sample

4.6.3.2.2.3 Prior to the planing test, the bottom surface of the boards must be planed first. The grain orientation of the tested lumbers needs to be determined. The specimens are fed into the machine by constant grain orientation. Mark the end of each specimen as it emerges from the machine to indicate the direction of feed and the tested surface that has just been machined. Feed individual specimens in the same direction at each cut.

4.6.3.2.3 Effect of feed per knife

The depth of cut is set precisely at 1 mm. The cutter block with 40° sharpness angle is set. The experiment is carried out under various conditions of feed per knife to follow the sequence of 0.38 mm, 0.45 mm, 0.60 mm and 0.75 mm (Table 4.1). Adjust the feed speed. Planing test is carried out on all specimens (50 specimens). Knife re-sharpening shall be carried out after each planing test condition. After the planing test, the planing surface quality is measured by visual grading.

Table 4.1 Planing test conditions— effect of feed per knife

Sharpness angle (°)	Feed per knife (mm)
40	0.38
	0.45
	0.60
	0.75

4.6.3.2.4 Effect of sharpness angle

The depth of cut is set precisely at 1 mm. Feed per knife is set to 0.75 mm. The experiment is carried out under various conditions of sharpness angle to follow the sequence of 30°, 35°, 40° and 45° (Table 4.2). Planing test is carried out on all specimens (50 specimens). Knife re-sharpening shall be carried out after each planing test condition. After the planing test, the planing surface quality is measured by visual grading.

Table 4.2 Planing test conditions— effect of sharpness angle

Sharpness angle (°)	Feed per knife (mm)
30	0.75
35	
40	
45	

4.6.3.2.5 Measurement of power consumption (optional)

Power consumption of the main motor of moulder is measured using a clamp-on power meter during idling and planing. Codes of a clamp-on power meter are connected to a panelboard. The difference between the maximum power consumption during planing and the average power consumption during idling should be regarded as the net maximum power consumption. Net integrated power consumption during planing shall be calculated. Record the data using Form 4.16 in Section 4.7.

4.6.3.2.6 Visual grading

The planing quality is graded visually on the basis of five groups. Record the data using Form 4.13.1 in Section 4.7 as follows:

Grade 1: excellent
Grade 2: good
Grade 3: fair
Grade 4: poor
Grade 5: very poor

Grades 1 and 2 provide fully acceptable quality. By contrast, from Grades 3 up to 5, the machined timber could be rejected, according to final uses. The planing defects are described by the standard according to various defect types as follows:

- the raised grain is a roughened condition of the surface of timber in which the hard late wood is raised above the soft early wood but is not turned loose of it;
- the fuzzy grain is due to small particles or groups of fibres which did not sever clearly in machining but which stood up above the general level of the surface;
- the torn grain is the part of the wood torn out in dressing;
- the chip marks are the shallow dents in the surface caused by chips that have clung to the knives instead of passing off in the exhaust as intended.

4.6.3.2.7 Measurement of surface roughness (optional)

Planed surface roughness is measured with a stylus-type surface roughness measuring instrument. The tracer moves parallel to the cutting direction at the feed rate of 2 mm sec^{-1}. Measurement is carried out at three points on the cutting surface per five specimens for each sawn type (Figure 4.35). Arithmetical mean deviation of the assessed profile R_a is obtained in μm. At the same time, the roughness profile is also recorded using Form 4.15 in Section 4.7. The diameter of the stylus, evaluation length and cut-off value are 5 μm, 12.5 mm and 2.5 mm respectively.

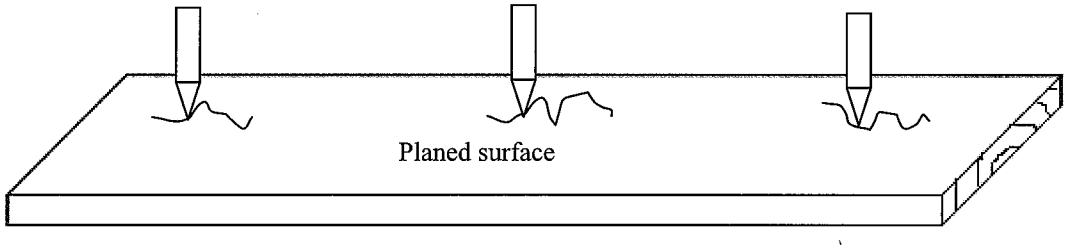


Figure 4.35 Measurement of surface roughness

4.6.3.3 *Sanding test (optional)*

4.6.3.3.1 The test specimens shall be from material left after the planing test.

4.6.3.3.2 The machine shall preferably be a two-headed, wide-belt sander. If such a machine is not available then the machine shall be fully described. Conduct the sanding operation using a contact roll or drum. Do not use a stroke sanding machine.

4.6.3.3.3 The first head shall carry a 80-grit, aluminium-oxide cloth or paper-back belt with a rotation speed of 2,000 rpm. The second head shall carry a 120-grit, aluminium-oxide cloth or paper-back belt with a rotation speed of 1,800 rpm.

4.6.3.3.4 Feed speed shall be on the order of 20 ft min^{-1} (6.1 m min^{-1}).

4.6.3.3.5 Examine the specimens and grade them for scratching and fuzzing. Record the data using Form 4.13.2 in Section 4.7. The basis of comparison shall be the percentage of specimens that are free from these defects.

4.6.3.4 *Boring test*

4.6.3.4.1 The borer shall preferably be a single-spindle electric machine equipped with power feed. If necessary, a smaller machine equipped with hand or foot feed may be used.

4.6.3.4.2 The bit shall be a 1-inch (25-mm) size of the single-twist, solid-centre brad-point type. Sharpen it lightly at intervals of not more than 1 hour of work.

4.6.3.4.3 The borer shall be run at a spindle speed of 2,000 rpm.

4.6.3.4.4 The rate of boring shall be low enough to enable the drill to cut rather than tear through the specimen.

4.6.3.4.5 Bore two holes through each specimen.

4.6.3.4.6 The boring properties of different woods shall be based on examination of the holes for crushing, tear-outs, fuzziness and general smoothness of cut. Grade each hole on a scale of five as in the preceding test. Record the data using Form 4.13.3 in Section 4.7. Base the comparison on the percentages of Grades No.1 and 2 holes present.

4.6.3.5 *Shaping test (optional)*

4.63.5.1 The machine shall be a commercial size, hand-fed spindle shaper with either one or two spindles.

4.6.3.5.2 The knives shall be ground and maintained in good cutting condition.

4.6.3.5.3 The specimen shall be from material left after the boring test. The specimen shall be band-sawn to the pattern as shown in Figure 4.36.

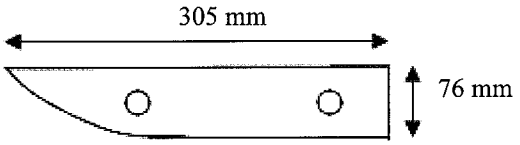


Figure 4.36 Test specimen for shaping test

4.6.3.5.4 Make a preliminary roughing cut with the shaper making use of the jig taking care to cut with the grain as far as possible.

4.6.3.5.5 Make a finishing cut 1.6 mm deep.

4.6.3.5.6 The spindle speed shall be with a rotation speed of 4,650 rpm.

4.6.3.5.7 Grade the test material piece by piece for raised, fuzzy and chipped grains and rough-end grain and record the results on prepared forms. Keep a separate record for side-grain and end-grain cuts using Forms 4.13.4.1 and 4.13.4.2 in Section 4.7.

4.6.3.5.8 Base the comparisons of shaping properties on the percentages of Grades No.1 and 2 specimens present.

4.6.3.6 *Mortising test (optional)*

4.6.3.6.1 The mortising machine shall be of the hollow chisel type equipped with power feed and spindle speed of 2,870 rpm. As a second choice, hand or foot feed may be used.

4.6.3.6.2 The chisel shall be the ½-inch (13-mm) size.

4.6.3.6.3 Re-sharpen both the bit and the chisel at intervals of not more than 1 hour of work.

4.6.3.6.4 Use the same specimens as for the boring and shaping tests (Figure 4.37).

4.6.3.6.5 Operate the machine at a spindle speed of 2,870 rpm.

4.6.3.6.6 Make two mortises in each specimen extending through into a hardwood backing.

4.6.3.6.7 Cut the mortises with two sides parallel to the grain and two sides perpendicular to it. They need not be placed in any specific part of the specimen.

4.6.3.6.8 Grade all mortises on a scale of five as in the previous tests. Record the data using Form 4.13.5 in Section 4.7. Base the comparison on the percentages of Grade No.3 and better mortises. The defects to be considered in grading the mortises are crushing, tearing and general smoothness of cut.

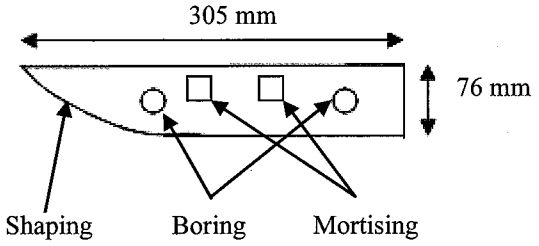


Figure 4.37 Specimen for boring, shaping and mortising tests

4.6.3.7 *Turning test*

4.6.3.7.1 The lathe shall be a well-made machine of the hand-lathe type with a swing over the bed of not less than 12 inches (305 mm) and with several rotation speeds of less than 3,200 rpm.

4.6.3.7.2 It shall be equipped with a compound rest, such as is used in metal turning.

4.6.3.7.3 A one-piece freshly sharpened knife shall be prepared, together with a suitable tool holder, to hold this knife in place on the compound rest. The knife may be hardened to reduce the amount of sharpening that will be necessary.

4.6.3.7.4 Lathe centres are desirable if a large number of turnings is to be made. They are made with square recesses 9.5 mm deep which taper from 21 mm on the entrance end to 16 mm at the bottom. These automatically centre the squares and hold them firmly against the thrust of the knife.

4.6.3.7.5 Mark the ID number on each turning specimen near one end, where the mark will not be machined off.

4.6.3.7.6 Adjust the position of the knife to make turnings 9.5 mm thick at the thinnest point, using trial pieces to ensure correct size. Test at several rotation speeds.

4.6.3.7.7 One of the two turning specimens from each board shall be at air-dry condition and the other at equilibrium moisture content of 12 %.

4.6.3.7.8 Grade the test specimen piece by piece making a record of all defects found on a scale of one to five as in the previous machining operations using Forms 4.13.6.1 and 4.13.6.2 in Section 4.7. Average the results for both moisture contents and make comparisons based on the percentages of the two best grades. The common defects of turning are fuzzy grain, roughness and torn grain.

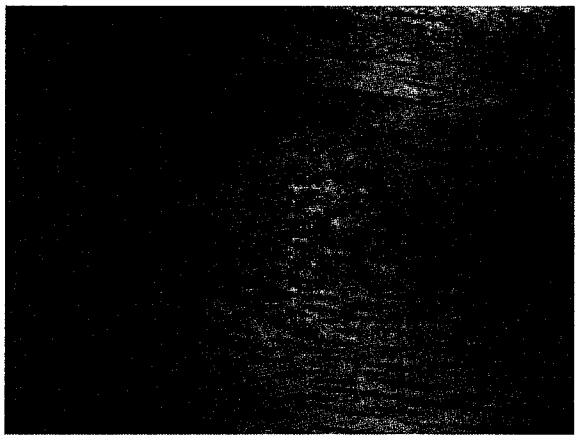
4.6.3.7.9 Base the comparison of turning properties on the proportions of Grades No.1, 2 and 3 pieces present.

APPENDIX

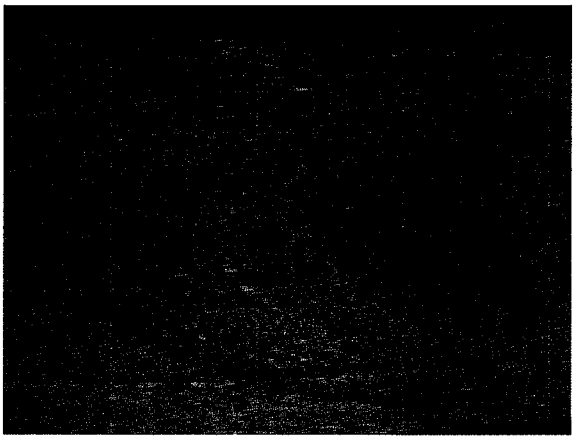
Planing defects

Raised grain

Fuzzy grain

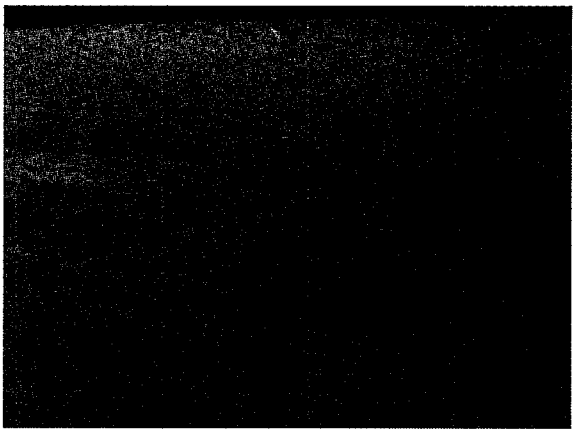


Torn grain

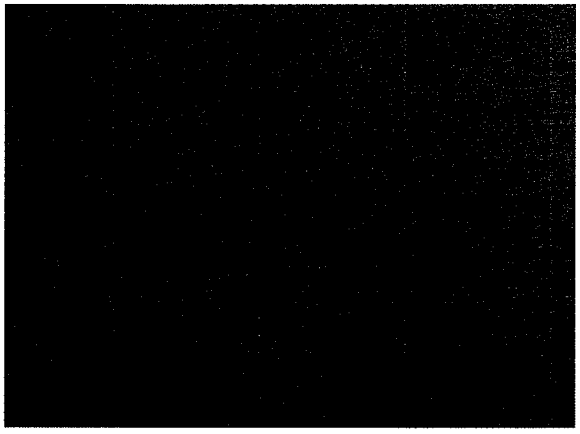


Chip marks

Sanding defects

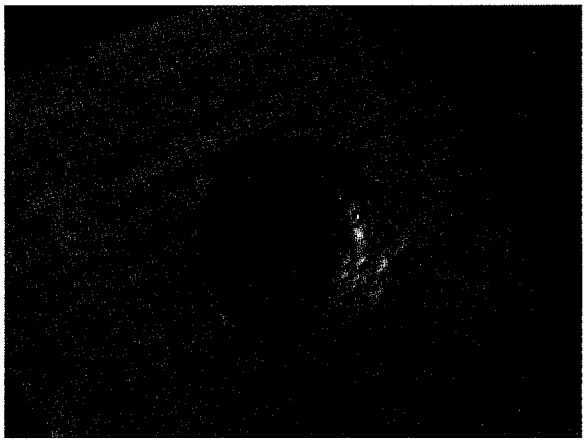


Scratching

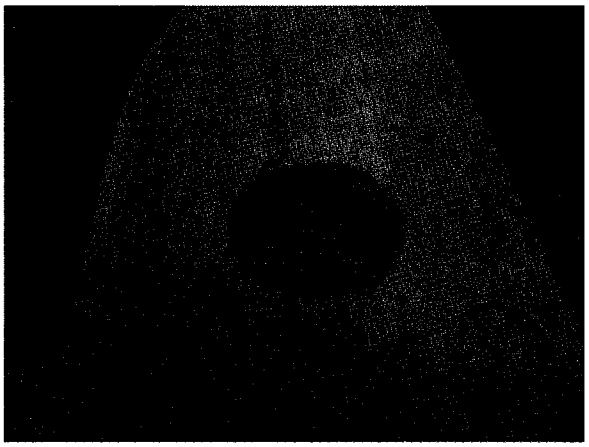


Fuzzing

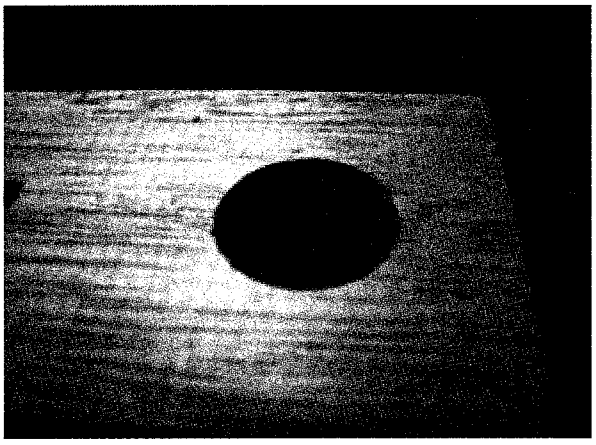
Boring defects



Crushing

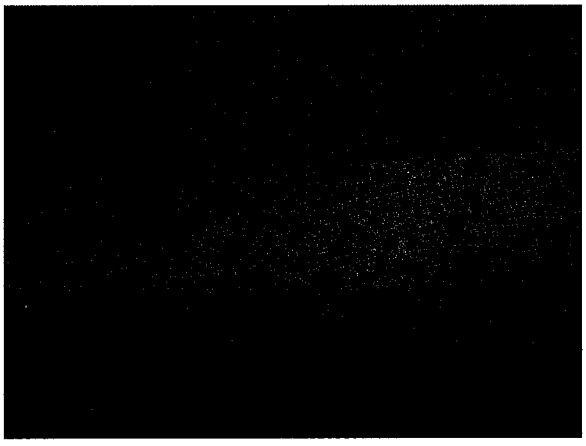


Tear-outs



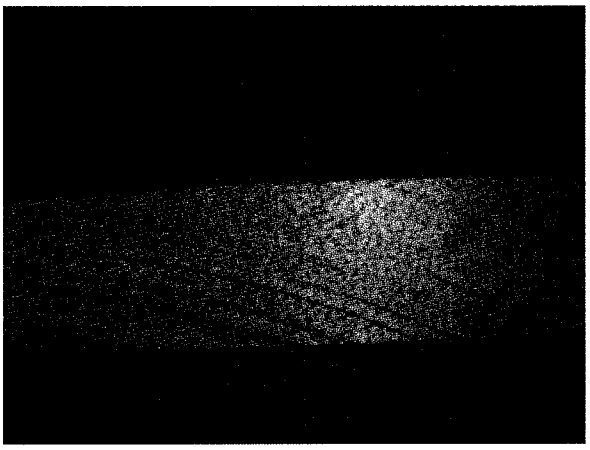
Fuzziness

Shaping defects

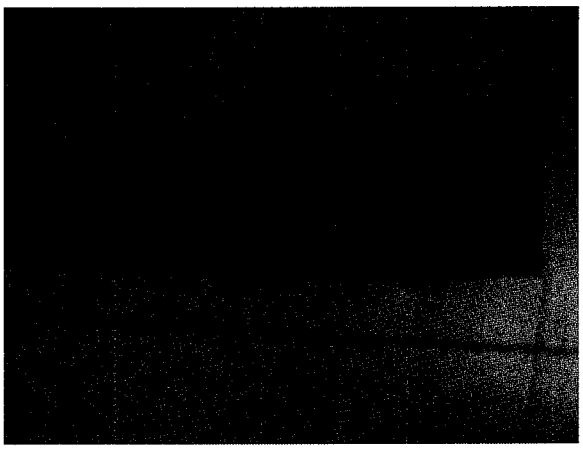


Raised grain

Fuzzy grain

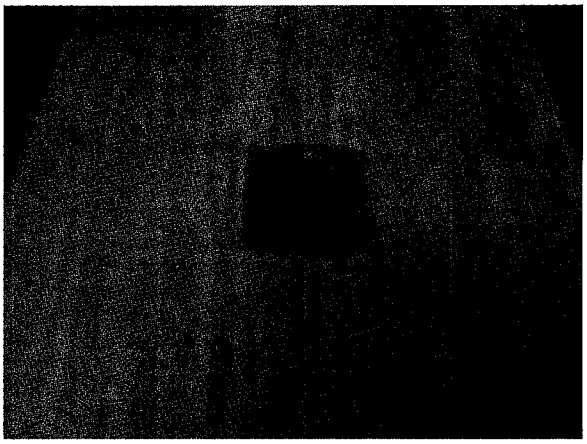


Chipped grain



Rough-end grain

Mortising defects

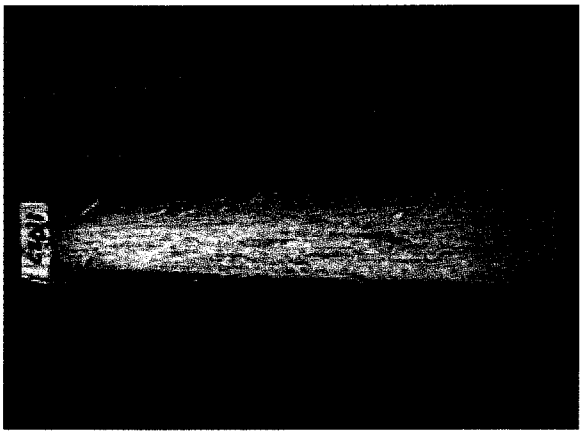


Crushing

Tearing

Turning defects

Fuzzy grain



Torn grain

Sawing Forms

Form 4.1 Log measurements

Log recording sheet #1								
Log ID No.	Log collection ID	Top end Ø (mm)		Butt end Ø (mm)		Log length (mm)	Heartwood radius (top) (mm)	No. of growth rings
		Long	Short	Long	Short			

(Cont'd.)

Top-end check	Butt-end check	Ring shake (mm)		Eccentricity (mm)		Warp (mm)		Remarks
Length (mm)	Length (mm)	Length (top)	Length (butt)	Top	Butt	h_1	h_2	

Form 4.2 Knots and knot locations

Log recording sheet #2			
Log ID :			
Knot No.	l	L_2	d
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Form 4.3 Saw specifications

Test information

Test:	Band-mill description:
Test date:	Saw description:
Test species:	Band-wheel diameter:
Mill location:	Revolution of band-saw:

Saw-tooth profile

Pitch	:	Hook angle	:
Gullet depth	:	Sharpness angle	:
Shape	:	Side-clearance angle	:
Number of teeth	:	Back-clearance angle	:
Kerf width	:		

Kerf measurements

Tooth No.	Kerf (mm)		Kerf (mm)* *If re-sharpening required
1st		1st	
10th		10th	
20th		20th	
30th		30th	
40th		40th	
50th		50th	
..		..	
..		..	
250th		250th	
260th		260th	

Form 4.4 Sawn-timber recording form

LOG ID No.:

Board No.	Target size (mm)					Stickers (mm)		Scantling (L×W×T)	MGR grade
	50 × 150	50 × 100	25 × 100			25 × 25	50 × 50		

Form 4.5 Moisture contents and defects recording form

LOG ID No.:

Board No.	Moisture content (%)			Bow (mm)	Spring/ crook (mm)	Other sawing defects	Remarks
	No. 1	No. 2	No. 3				

Form 4.6 Measurements of sawing time

Slab No.:

Sawing condition	Sawing time (sec)

Slab No.:

Sawing condition	Sawing time (sec)

Form 4.7 Measurements of thickness of sawn boards

Slab No.:

	Measurement position (mm)		
Sawing condition	1	2	3

Form 4.8 Determination of moisture content

Slat No.	Green weight (g)	Oven-dry weight (g)	M.C. (%)

Form 4.9 Determination of density

Slat No.	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)	Weight (g)	Density ($g\ cm^{-3}$)

Form 4.10 Table of power consumption

Sawing condition	P_o (Kw)	P_{max} (Kw)	P_{nmax} (Kw)	W (Kwh)	W_o (Kwh)	W_n (Kwh)	t (sec)	Precise feed speed (m min^{-1})

Form 4.11 Surface roughness measurements

R_a = mean arithmetic deviation of profile
R_{max} = maximum roughness
R_z = mean peak-to-valley height

Slat No.	Along grain			Across grain		
	R_a	R_{max}	R_z	R_a	R_{max}	R_z

Machining Forms

Form 4.12 Sample labelling form

Test species: **Date:**

Flat sawn			Quarter sawn		
No	Sample No.	Log ID No.	No	Sample No.	Log ID No.
1			1		
2			2		
..			..		
..			..		
..			..		
..			..		
23			23		
24			24		
25			25		

Form 4.13 Visual grading forms

Form 4.13.1 Planing test

Kind of test: **Planing** Date:

Species: Feed speed (m min^{-1}):

Spindle speed (rpm): Knives: Sharpness angle:

No.	Sample No.	Defect free	Raised grain	Fuzzy grain	Torn grain	Chip marks	Remarks
1							
2							
..							
..							
..							
..							
..							
49							
50							
Total							
Avg.							

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.2 Sanding test

Kind of test: **Sanding** Date:

Species: Feed speed (m min^{-1}):

No.	Sample No.	Defect free	Scratching	Fuzzing			Remarks
1							
2							
..							
..							
..							
..							
..							
49							
50							
Total							
Avg.							

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.3 Boring test

Kind of test: **Boring** Date:

Species: Bit:

Spindle speed (rpm).:

No.	Sample No.	Defect free	Crushing	Tear-outs	Fuzziness	Smoothness	Remarks
1							
2							
..							
..							
..							
..							
..							
49							
50							
Total							
Avg.							

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.4 Shaping tests

Form 4.13.4.1 Shaping test, side-grain cuts

Kind of test: **Shaping** Date:

Side-grain cuts

Species: Spindle speed (rpm).:

No.	Sample No.	Defect free	Raised grain	Fuzzy grain	Chipped grain	Rough-end grain	Remarks
1							
2							
..							
..							
..							
..							
..							
49							
50							
Total							
Avg.							

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.4.2 Shaping test, end-grain cuts

Kind of test: **Shaping** Date:

End-grain cuts

Species: Spindle speed (rpm).:

No.	Defect free	Raised grain	Fuzzy grain	Chipped grain	Rough-end grain	Remarks
1						
2						
..						
..						
..						
..						
..						
49						
50						
Total						
Avg.						

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.5 Mortising test

Kind of test: **Mortising** Date:

Species:

Spindle speed (rpm).: Chisel:

No.	Sample No.	Defect free	Crushing	Tearing	Smoothness	Remarks
1						
2						
..						
..						
..						
..						
..						
49						
50						
Total						
Avg.						

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.6 Turning tests

Form 4.13.6.1 Turning test— air-dry condition

Kind of test: **Turning— air-dry condition** Date:

Species: Knife:

Spindle speed (rpm).:

No.	Sample No.	Defect free	Fuzzy grain	Torn grain	Roughness	Remarks
1						
2						
..						
..						
..						
..						
..						
49						
50						
Total						
Avg.						

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.13.6.2 Turning test— 12% EMC

Kind of test: **Turning— 12% EMC** Date:

Species: Knife:

Spindle speed (rpm).:

No.	Sample No.	Defect free	Fuzzy grain	Torn grain	Roughness	Remarks
1						
2						
..						
..						
..						
..						
..						
49						
50						
Total						
Avg.						

Grade 1: excellent; Grade 2: good; Grade 3: fair; Grade 4: poor; Grade 5: very poor.

Form 4.14 Moisture content and density determinations

Species:

Date:

No.	Sample No.	Initial weight (g)	Oven-dry weight (g)	Length (cm)	Width (cm)	Thickness (cm)	MC (%)	Density (g cm^{-3})
1								
2								
..								
..								
..								
..								
..								
49								
50								

Form 4.15 Surface roughness measurement

Planing condition:
Date:

No.	Sample No.	R_{a1}	R_{a2}	R_{max1}	R_{max2}	R_{z1}	R_{z2}
1							
2							
..							
..							
..							
..							
..							
49							
50							

Form 4.16 Table of power consumption

Planing condition:
Date:

Sample No.	P_o (Kw)	P_{max} (Kw)	P_{nmax} (Kw)	W (Kwh)	W_o (Kwh)	W_n (Kwh)

Chapter 5

Accelerated Laboratory Decay Test

5.1 Scope

This test method covers the accelerated laboratory decay test to evaluate the natural decay resistance of tropical plantation timber species against selected fungi (dominant and aggressive wood-decaying fungal species) found in the country. This test method may also be used to evaluate the resistance of wood products or other organic materials subjected to decay by wood-destroying fungi.

5.2 Referenced Document

5.2.1 ASTM D 1413. Test Method for Wood Preservatives by Laboratory Soil-Block Cultures.

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

5.2.3 EN 350-1. 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.

5.2.4 EN113. Wood Preservatives – Test Method for Determining the Protective Effectiveness against Wood Destroying Basidiomycetes - Determination of Toxic Values.

5.2.5 JIS K 1571. Test Method for Determining the Effectiveness of Wood Preservatives and their Performance Requirements.

5.3 Definitions

5.3.1 *Decay Resistance*: The ability of the timber to withstand certain wood-decaying fungal attack under favourable conditions.

5.3.2 *Test Blocks*: Actual timber species tested for determining natural decay resistance.

5.3.3 *Reference Test Block*: Wood test blocks consisting of comparably low decay resistance wood or sapwood. The blocks shall be subjected to decay in the manner and at the same time as the actual test blocks, and the progress of their decay shall be used as a guide for terminating the incubation with the respective fungi.

5.4 Equipment

5.4.1 *Equipment for Preparing Test Specimens.* Band-saw, cross-cut saw, planer.

5.4.2 *Equipment for Measurement.* Analytical balance capable of weighing to 0.01 g /0.001g; oven capable of adjusting temperature to 60 ± 1 °C.

5.4.3 *Equipment for Preparing Fungal Cultures.* Autoclave—sterilizer for killing germs; laminar flow—clean bench for manipulating and inoculating fungi; incubator for growing fungus in culture bottles (capable of adjusting temperature to 25 ± 2 °C; culture bottles, 250—300 ml; Petri dishes, 100 mm diameter; forceps; cork-borer/scalpel; transfer needles.

5.5 Preparation of Test Materials

5.5.1 *Preparation of Test Blocks*

5.5.1.1 Test blocks from the selected timber species shall be obtained from the heartwood only, as no sapwood is known to be durable when conditions are favourable for decay fungi.

5.5.1.2 Conversion of planks from the logs is detailed in Figure 5.1. Planks converted shall to be air-dried to around 15% MC to prevent occurrence of molds and stains. At least four sticks about three-quarter distance away from the pith measured along the radius of the heartwood shall be sampled from one log, and subsequently three test blocks shall be obtained, labelled and kept for testing.

5.5.1.3 At least five or up to 20 logs (trees) shall be sampled for the study.

5.5.1.4 At least 20 test blocks (randomly selected) shall be included for each test fungus.

5.5.1.5 The samples shall be sawn into block specimens 25 by 25 by 9 mm in size, with the 9-mm dimension in the grain direction (see Figure 5.1).The block shall be from timber with normal growth rate and density, and be free of knots and abnormal amounts of resins or gums, and be without visible evidence of fungal infection.

5.5.2 *Preparation of Reference Blocks*

5.5.2.1 At least 16 reference blocks of the same dimensions as the test blocks shall be prepared from timber species of low decay resistance for each test fungus.

5.5.3 *Test Fungi*

5.5.3.1 Dominant and aggressive rotting fungi in the respective countries. (In Malaysia, we propose *Lentinus sajor-caju.*)

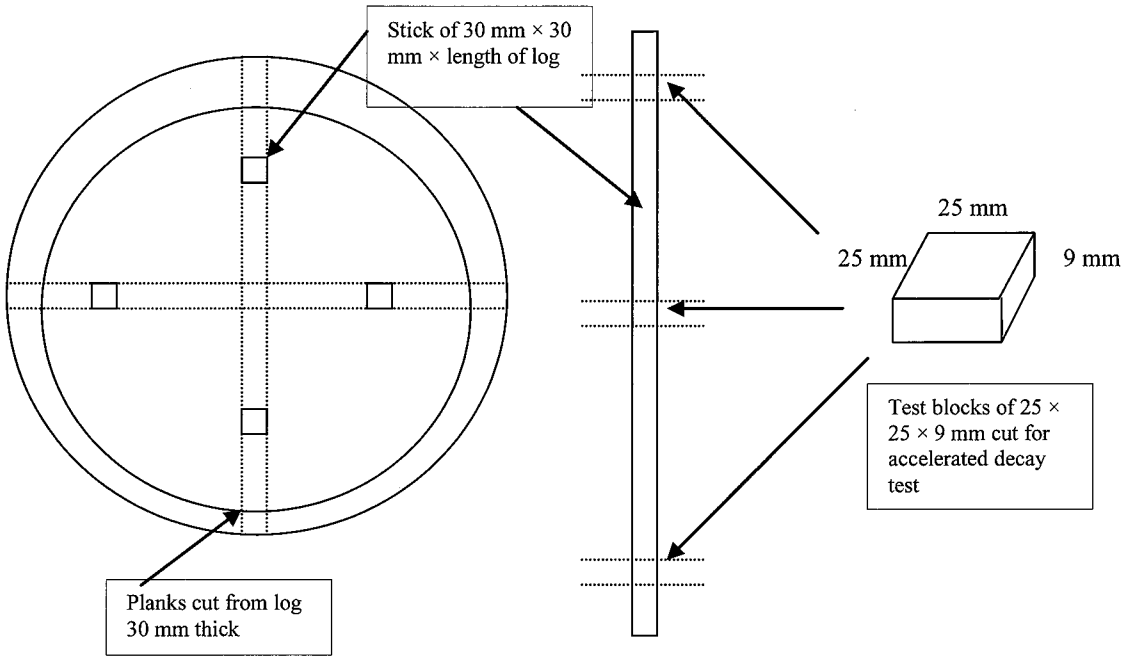


Figure 5.1 Preparation of test samples from log

5.5.3.2 For testing hardwoods: Include either *Gloeophylum trabeum* Pers. ex. Fr. (ATCC No. 11539) and/or *Trametes versicolor* (L. ex. Fr.) Pilat. (ATCC No. 42462) also for comparison.

5.5.4 *Culture Media*

5.5.4.1 Malt agar substrate (2% malt extract and 2% agar) by weight or an equivalent nutrient shall be used for the stock test tube cultures and for Petri dish cultures of the test fungi.

5.5.4.2 The culture media prepared shall be steam sterilized in an autoclave at 121 °C for 15–20 min.

5.6 Test Procedures

5.6.1 *Culturing of Decay Fungus*

5.6.1.1 Prepare Petri-dish subculture of the respective fungus with the desired medium to provide enough inocula for culture bottles for test.

5.6.1.2 Practice of aseptic techniques: All necessary equipment, glassware, media etc. shall be autoclaved at 121 °C for 20 min. (Not applicable to disposable sterile Petri dishes.)

5.6.1.3 Wash and clean hands with aseptic soap, wear proper and clean attire such as lab coats, disposable gloves etc. before starting subcultures.

5.6.1.4 Prepare 2% malt extract and 2% agar by weight and steam sterilized at 121 °C for 15–20 min.

5.6.1.5 Working in a laminar flow, transfer into Petri dish approximately 30 ml (100 mm diameter Petri dish) of the warm medium. Let medium cool and solidify. It is advisable to further sterilize the medium under UV lamp for 15 min or more on the clean bench as added precaution against contamination before starting subculture.

5.6.1.6 Using a sterile scalpel (sterilization can be done by dipping in 90% ethanol and flame over), cut the fungus inoculum of between 5 mm and 10 mm square from the growing edge of a growing Petri dish culture. Transfer it onto the centre of the new media in Petri dish with a sterile transfer needle and close the cover.

5.6.1.7 Seal cover with parafilm and label accordingly the date of culture and fungus species.

5.6.1.8 Incubate at 25 ± 2 °C until 90% fungal colonization on medium surface.

5.6.2 *Preparation of Culture Bottles for Decay Test*

5.6.2.1 Steam sterilize at 121 °C for 20 min all culture bottles with the caps loosened.

5.6.2.2 Prepare enough volume of 2% malt extract and 2% agar by weight and steam sterilized in an autoclave at 121 °C for 15–20 min.

5.6.2.3 While warm, pour enough volume of the medium into the culture bottles (about 1/3 volume of bottle), working on a clean bench. Let medium cool and solidify. It is advisable to further sterilize the medium under UV lamp for 15 min or more on the clean bench as added precaution against contamination before inoculation.

5.6.3 *Inoculation of Culture Bottles*

5.6.3.1 Using a sterile scalpel (sterilization can be done by dipping in 90% ethanol and inflaming), cut the fungus inoculum of between 5 mm and 10 mm square from the growing edge of a growing Petri dish subculture. Transfer it onto the centre of the new medium in culture bottle with a sterile transfer needle and close the cover.

5.6.3.2 Close cap slightly loosened and label accordingly the date of inoculation and fungus species.

5.6.3.3 Incubate at 25 ± 2 °C and 70 ± 5% relative humidity until complete colonization of medium surface.

5.6.4 *Preparation of Test Blocks and Reference Blocks*

5.6.4.1 Label the prepared blocks clearly with pencil or waterproof ink.

5.6.4.2 Both test blocks and reference blocks shall be conditioned in the oven at 60 ± 2 °C and their weights determined until constant. Their weights are recorded as R_1.

5.6.5 *Sterilizing of Test Blocks and Reference Blocks*

5.6.5.1 *Steam-sterilization method*: Put the conditioned and weighed test blocks into tightly closed containers and steam them at 121 °C for 20 min.

5.6.5.2 *Gas-sterilization method*: Put both the conditioned and weighed reference and test blocks arranged neatly with spaces in between in a closed desiccator together with a small beaker of propylene oxide (in the ratio of 2 ml propylene oxide: 1,000 ml container volume) beside for 24 hr after which open the cover in a closed fume hood to aerate before taking out the blocks aseptically to be kept in a germ-free atmosphere for at least 48 hr to exhaust the gas from the blocks.

5.6.6 *Introducing Test Blocks and Reference Blocks to Culture Bottles*

5.6.6.1 After sterilization, place the cooled blocks in the culture bottles, with cross-section face down on the colonized surface of medium by test fungus with sterile forceps or transfer needle.

5.6.6.2 Allow for aeration of culture bottles by closing caps slightly loosened.

5.6.6.3 Label accordingly the date of exposure of test blocks and test blocks identity on the cap or bottle.

5.6.7 *Incubation of Culture Bottles*

5.6.7.1 Place the bottles in a dark growth room.

5.6.7.2 Control the temperature at 25 ± 2 °C and relative humidity at 70 ± 5%.

5.6.8 *Removal of Reference Blocks for Weight Loss Study*

5.6.8.1 Two reference blocks per fungus shall be removed at weekly intervals, i.e. starting at the 8th week of exposure test to determine the weight loss.

5.6.8.2 Withdraw and carefully brush off any surface fungi. Condition the blocks in an oven at 60 ± 2 °C until constant weight is achieved and record the weights as R_2.

5.6.9 *Termination of Test*

5.6.9.1 The test shall be terminated when 50% weight loss in the reference blocks is attained, or at the end of 16 weeks exposure. If 50% weight loss does not appear attainable in 16 weeks, the severity of the test or the selection of reference wood must be considered inadequate, since the test fungi and prescribed procedure will ordinarily cause a 50% loss in a non-durable wood.

5.6.10 *Conditioning of Test Blocks after the Test*

5.6.10.1 All test blocks shall be removed after the test. Carefully brush off surface mycelia.

5.6.10.2 Special precaution shall be taken not to lose their ID.

5.6.10.3 Condition the test blocks in an oven at 60 ± 2 °C until constant weight is achieved. Record the weight as R_2.

5.6.11 *Calculation of Weight Loss (%)*

$$\text{Weight loss, \%} = [(R_1-R_2)/R_1] \times 100$$

5.6.12 *Interpretation of Results*

5.6.12.1 The percent weight losses in the test blocks provide a measure of the relative decay susceptibility or, inversely, of decay resistance of the wood or material.

Table 5.1 Decay susceptibility classification

Average weight loss (%)	Average residual weight (%)	Resistance class against 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 o r less	Slightly resistant or non-resistant

5.7 Forms

5.7.1 *Form 5.1*: Test blocks conditioning record
5.7.2 *Form 5.2:* Test blocks exposure test record
5.7.3 *Form 5.3:* Reference blocks record

Forms

Form 5.1 Test blocks conditioning record

Timber species:
Part of tree/ block dimensions:
Conditioning of test blocks before exposure to decay fungus
Temperature: 60 ± 2 °C (until constant weight)

Sample ID	Initial weight (g)	Weight 1 (g)	Weight 2 (g)	Weight 3 g)	Final weight (g)

Conditioning of test blocks after exposure test
Temperature: 60 ± 2 °C (until constant weight)

Sample ID	Initial weight (g)	Weight 1 (g)	Weight 2 (g)	Weight 3 (g)	Final weight (g)

Form 5.2 Test blocks exposure test record

Timber species:
Date started:
Date finished:
Substrate:

Sample ID	Initial weight (g)	Fungus species	Final weight (g)	Weight loss %

Form 5.3 Reference blocks records

Timber species:
Part of tree/ block dimensions:

Sample ID	Fungus	Weeks	Initial weight (OD) (g)	Final weight (OD) (g)	Weight loss %

Chapter 6

Treatability

6.1 Scope

This procedure is used to determine the treatability (permeability) of a timber species by undergoing a Full Cell Process with the schedule of treating the timber samples up to refusal point whereby absorption of wood preservative solution into the wood is at its maximum. The method also covers the technique adopted in determining preservative penetration pattern in treated wood.

However, in the event of non-availability of the required equipment to carry out a Full Cell Process, a simpler method is proposed to estimate the treatability by using laboratory vacuuming method. The user must be cautioned that the alternative method can only provide a rough estimation and is by no means an accurate one.

6.2 Referenced Documents

6.2.1 MS360: 2006. Treatment of Timber with Copper/Chrome/Arsenic Wood Preservatives – Specification (Third Revision).

6.2.2 MS1921: 2006. Treatment of Roof, Ceiling and Timber Roof Components with Copper-Chrome-Arsenic Preservatives for Indoor Above Ground Use.

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

6.2.4 AS/NZS 1605: 2000. Methods for Sampling and Analyzing Timber Preservatives and Preservative-treated Timber.

6.2.5 AS 1604.1-2000. Specification for Preservative Treatment Part 1: Sawn and Round Timber.

6.3 Definitions

6.3.1 *Treatability/Permeability*: Ability of the timber to absorb as much as possible the preservative solution when subjected to a Full Cell Process.

6.3.2 *Penetration Pattern*: How the preservative distributes itself inside the timber when subjected to the Full Cell Process.

6.3.3 *Full Cell Process*: A treatment process whereby timber is subjected to various treatment phases, namely initial vacuum, flooding with preservative, hydraulic pressure, draining of preservative and final vacuum.

6.3.4 *Refusal*: A point whereby no more wood preservative solution can enter the wood when subjected to the Full Cell Process.

6.3.5 *Net Dry Salt Retention*: The actual amount of wood preservative in dry form retained in the wood treated measured in kg m^{-3}.

6.4 Equipment

6.4.1 *Equipment for Preparing Test Specimens*: Band-saw, cross-cut saw, planer.

6.4.2 *Equipment for Measurements*: Analytical balance capable of weighing to 0.01 g, veneer caliper to measure dimensions of timber sample, hygrometer of range 1.000 to 1.050 to determine the specific gravity of preservative solution, stereo microscope with a graduated eyepieces that can perform measurement on the subject to 0.1 mm.

6.4.3 *Equipment to Conduct Full Cell Process Pressure Treatment:* Pressure treatment plant.

6.4.4 *Preservative Chemicals and Reagents:* Copper Azole or CCA wood preservative, chromazurol S indicators (chemical solution).

6.4.5 *For Alternate Method:* Portable vacuum pump, desiccators.

6.5 Preparation of Test Materials

6.5.1 Timber samples from the selected timber species shall be obtained from the heartwood only. Since all sapwood are easily treatable, there is no necessity to determine the treatability of the sapwood.

6.5.2 Conversion of planks from the logs is detailed in Figure 6.1. Planks converted shall be air-dried to about 15% MC with preventive measures taken to prevent occurrence of molds, stains and insect attacks. At least four sticks about three-quarter distance away from the pith measured along the radius of the heartwood shall be sampled from one log, and subsequently two test samples shall be obtained from each stick, labelled and kept for testing.

6.5.3 At least five or up to 20 logs (trees) shall be sampled for the study.

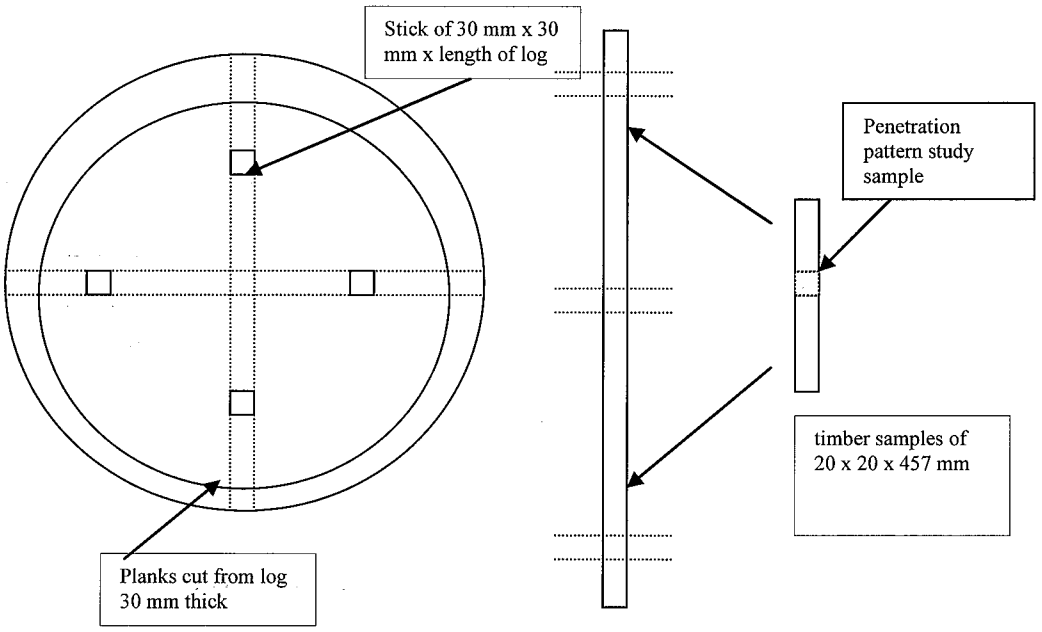


Figure 6.1 Preparation of test samples from log

6.5.4 At least 20 timber samples shall be selected from at least five trees.

6.5.5 Timber samples shall be end-coated with glossy paint / epoxy to prevent wood preservative uptake from the transverse section rather than the lateral section.

6.5.6 Each timber sample shall be labelled with a unique serial number, while the dimensions, initial weight (immediately before treatment) and final weight (immediately after treatment and wiped dry) shall be recorded accordingly to facilitate calculation of preservative uptake.

6.6 Test Procedure

6.6.1 *Full Cell Process*

6.6.1.1 *Initial vacuum*

Timber samples shall be subjected to a vacuum of not less than -85 kPa for a period of 60 min.

6.6.1.2 *Flooding with preservative*

Maintain the vacuum while preservative is pumped into the treatment cylinder.

6.6.1.3 *Pressure period*

Timber samples shall be subjected to a hydraulic pressure of not less than 200 psi (14 bars) for a period of 120 min.

6.6.1.4 *Draining of preservative*

Preservative shall be drained from the treatment cylinder after the pressure period.

6.6.1.5 *Final vacuum*

Timber samples shall then be subjected to a final vacuum of not less than -85 kPa for a period of 30 min. This is to remove excess preservative and reduce vomiting after the timber is removed from the treatment cylinder.

6.6.2 *Alternative Method (Vacuuming in Desiccator)*

6.6.2.1 Timber samples of dimensions 20 mm × 20 mm × 100 mm are selected as detailed in 6.5.1 and Figure 6.1

6.6.2.2 Samples are arranged in a desiccator and submerged in preservative solution / water as in Figure 6.2 and subjected to vacuuming at -85 kPa for 60 min.

6.6.2.3 The weight difference before and after vacuuming is taken as the amount of fluid that has entered the timber (density of water taken as 1.0 g cm^{-3}).

6.6.2.4 All calculations are similar to those for the Full Cell Process.

6.6.3 *Data Recording and Calculation*

6.6.3.1 *Weights of timber samples*

Weight of each and every timber sample shall be recorded immediately before and after the treatment process (W_1 and W_2 respectively).

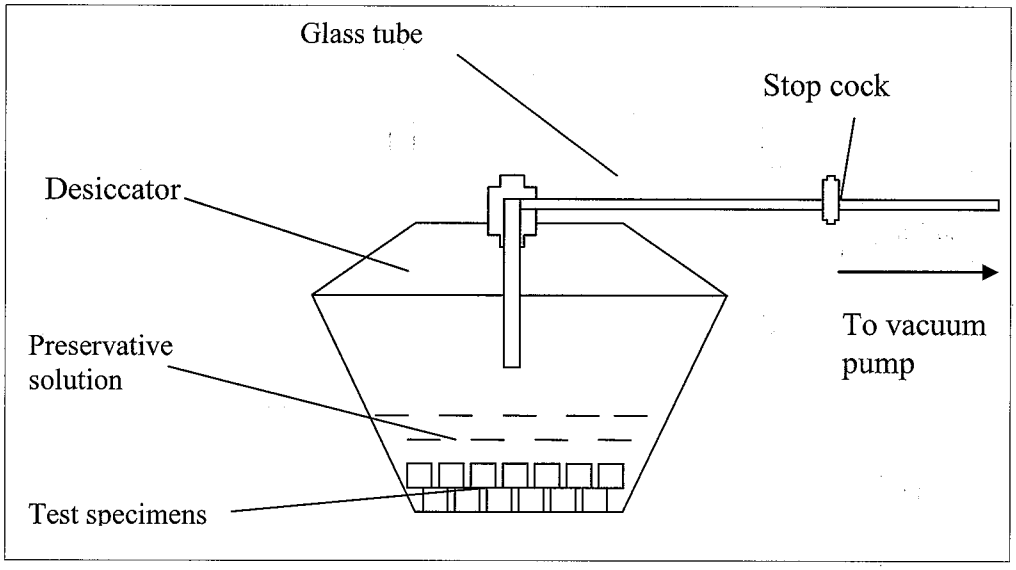


Figure 6.2 Wood permeability test – vacuum desiccator set-up

6.6.3.2 *Volume of timber samples*

Dimensions of each and every timber sample shall be recorded to facilitate volume calculation (V).

6.6.3.3 *Density of wood preservative*

Specific gravity of wood preservative can be determined by hygrometer in the range of 1.000 to 1.100 (G).

6.6.3.4 Treatability, in $\ell\ m^{-3}$.

$$\text{Treatability} = \frac{(W_2 - W_1)}{G * V} \times 1000$$

6.6.4 *Penetration Pattern Determination*

6.6.4.1 *Timber sample preparation*

A middle section of the dried treated timber sample of about 5.0 cm shall be cut as in Figure 6.1.

6.6.4.2 *Colorimetric test reagents preparation*

Spot test for active preservative elements or compounds like copper, pentachlorophenol, boron, fluoride and tin can be found in Australian/New Zealand Standard AS/NZS 1605: 2000. An example of spot test for copper is appended in Appendix 6.1.

6.6.4.3 *Measurement and description of penetration pattern*

Depth of penetration is referred to as the least perpendicular distance from the edges. The penetration pattern shall be described as fully penetrated, continuous band of xx mm, scattered, patchy, confined to pores, etc.

6.7 Interpretation of Results

6.7.1 *Permeability Classification*

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

6.7.2 *Depth of Penetration and Penetration Pattern*

Depth of penetration can be measured by following Sections 6.6.4.2 and 6.6.4.3. The depth of penetration can be used to gauge whether the timber when trested by the Full Cell Process meets the requirements as given in Appendix 6.2.

6.7.3 *Interpretation of Treatability and its Conversion to Dry-Salt Retention*

Example of calculation:

- If the treatability of the timber species is 180 ℓ m^{-3}
- If the concentration of the preservative is 8 % W/W (8 kg of wood preservative dissolved in water to make up 100 litres and density of water is taken as 1.0 g cm^{-3})

Thus, the maximum net dry-salt retention (Ret) achievable is

$$\text{Ret} = \frac{180 * 8}{100} \text{ kg m}^{-3}$$

$$= 12.4 \text{ kg m}^{-3}$$

In case the actual dry salt retention of the treated timber needs to be determined, the treated timber sample can be sent and analysed in a laboratory having facilities to conduct atomic absorption spectrometer (AAS) test.

6.7.4 *Gauging the Net Dry-Salt Retention against the Requirements in the Standards*

- Appendix 6.2 shows the required minimum net dry salt retention and minimum depth of penetration required for CCA-treated timber to be used in different hazard conditions.
- Similar requirements for different common and effective wood preservatives can also be found in standards like the Australian and New Zealand standards.
- Thus the treatability data collected will determine whether the timber species can be treated to meet the minimum requirements for applications in different hazard classes.
- In case the treatability of the timber species does not allow the timber to be treated to a retention required by the standard, methods to improve preservative loading like pre-steaming, incising or even the Oscillating Pressure Method may be looked into.

6.8 Treatment Record

Form 6.1 may be used to record the treatment.

Form 6.1 Treatment record

Project name:

Species code:
Common name:
Botanical name:
Preservative:
Concentration (%):

Treatment process:
Schedule:
Initial vacuum(85 kPa) : (Min)
Pressure (1400 kPa) : (Min)
Final vacuum(85 kPa) : (Min)

Specimen Dimensions:

Date treated:

Conducted by:

Specimen No.		M.C. (%)	Initial weight (g)	Final weight (g)	Loading (g)	Salt loading (g)	Vol. (ml)	Part of tree	Retention (kg m^{-3})	Denisty (kg m^{-3})	Remarks
Source	Serial No.										

N
Mean
S.D.
C.L.

Appendix 6.1

Determination of Preservative Penetration by Spot Tests

Determination of Copper Penetration in Timber Treated with Copper-based Preservatives*

Principle

Copper is determined visually on the end-grain of a freshly prepared timber surface by the rapid formation of a deep blue to blue-black colour.

Reagent–Stock solution

Dissolve 0.5 g chromazurol S (eriochromazurol S) and 5.0 g of sodium acetate in 100 m ℓ of water.

Procedure

Spray the test solution over a freshly prepared end-grain of a test piece. A deep blue to blue-black colour indicates the presence of copper. With some species, it is necessary to use a hand lens to examine the tested surface in order to distinguish a satisfactory result.

*Extracted from AS/NZS 1605: 2000. Methods for Sampling and Analyzing Timber Preservatives and Preservative-treated Timber.

Appendix 6.2
(normative)

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 (e.g. lyctids)	Framing, flooring, furniture, interior joinery	-	-
H2	Inside, above ground	Protected from wetting and leaching	Borers and termites	Framing, flooring, and similar uses 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 fill	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.

Chapter 7

Basic Veneer Properties

7.1 Scope and Field of Application

7.1.1 This guideline details the methodology for the determination of basic properties of veneer derived from plantation wood. Two types of veneer are produced, namely rotary-peeled veneer and flat-sliced veneer. The veneer yield, shrinkage, surface roughness and peeler checks are some of the basic properties determined. Sampling of logs shall be carried out as outlined in *Chapter 1: Sampling Trees and Allocation of Logs* found in this manual.

7.1.2 The methodology is meant to be practical and repeatable so that the results would be representative of the plantation species studied. This method will serve as a harmonized means towards establishing some of the basic veneer properties of plantation wood.

7.2 Referenced Documents

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

7.2.2 ISO 4288:1996. Rules and Procedures for Assessment of Surface Texture.

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

7.2.4 JIS B0651:1996. Geometrical Product Specifications–Surface Texture: Profile Method–Nominal Characteristics of Contact (Stylus) Instruments.

7.2.5 JIS B0601:2001. Geometrical Product Specifications–Surface Texture: Profile Method Terms, Definations and Surface Texture Parameters.

7.2.6 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.

7.3 Definitions

7.3.1 For the purpose of this guideline, the definitions given in AS/NZ 2098.6, ISO 4288, ISO 1302, JIS B0651 and JIS B0601: Method 6 apply.

7.3.2 The length of peeled veneer shall be the dimension measured along the direction it is peeled.

7.4 Equipment / Chemicals

7.4.1 *Rotary-Peeled Veneer*

7.4.1.1 Spindleless rotary lathe, capable of peeling veneer thickness of 0.5–3.0 mm.

7.4.1.2 Measuring tape, fabric type, able to measure up to 5-m length with 1-mm readability.

7.4.1.3 Vernier caliper, able to measure up to 200 mm with 0.01-mm readability.

7.4.1.4 Micrometer screw gauge, able to measure up to 25 mm with 0.001-mm readability.

7.4.1.5 Drying oven, capable of maintaining a constant temperature of 155–160 °C.

7.4.1.6 Profilometer, capable of tracing 0.5–2 mm sec^{-1} and with a 5 μm 90° stylus tip.

7.4.1.7 Measuring microscope capable of measuring to within ± 0.01 mm.

7.4.1.8 Hotplate with temperature control.

7.4.1.9 200-ml beaker.

7.4.1.10 Petri dish with diameter of about 70 mm and height of 20 mm.

7.4.1.11 Paraffin wax.

7.4.1.12 Propanol.

7.4.1.13 Methylene blue.

7.4.2 *Flat-Sliced Veneer*

7.4.2.1 Slicer, capable of producing veneer thickness of 0.5–3.0 mm.

7.4.2.2 Hot water storage tank for pretreatment of logs prior to slicing.

7.4.2.3 Measuring tape, fabric type, able to measure up to 5-m length with 1 mm readability.

7.4.2.4 Vernier caliper, able to measure up to 200 mm with 0.01-mm readability.

7.4.2.5 Micrometer screw gauge, able to measure up to 25 mm with 0.001-mm readability.

7.4.2.6 Drying oven, capable of maintaining a constant temperature of 155–160 °C.

7.4.2.7 Profilometer, capable of tracing 0.5–2 mm sec^{-1} and with a 5 μm 90° stylus tip.

7.5 Preparation of Test Materials

7.5.1 For each veneer thickness, six logs from six trees are taken as shown in Chapter 1 on sampling.

7.5.2 Green logs are usually stored in a water tank until they are ready for conversion to veneer. The length of the log is normally cut to either 1.3 m or 2.6 m.

7.5.3 The veneer test sheets shall be oven-dried according to the following recommended schedules:

(i) Temperature of 155–160 °C for 12–14 min (thickness of 0.5–1.5 mm)

(ii) Temperature of 155–160 °C for 20–23 min (thickness of 2.5–3.0 mm)

The dried veneer test sheets shall be cooled to room temperature before preparing the test specimens.

7.5.4 Form 7.1 is used to record the data on the logs and veneers.

7.6 Rotary-Peeling Procedure

7.6.1 Prior to peeling, the log is debarked and measurements of its length and mean diameter at both ends are taken.

7.6.2 The log is rounded off to remove any asymmetrical portions and its diameter recorded. The veneers obtained at this stage are collected and portions having complete width (as illustrated in Figure 7.1) are recovered for the final determination of veneer yield.

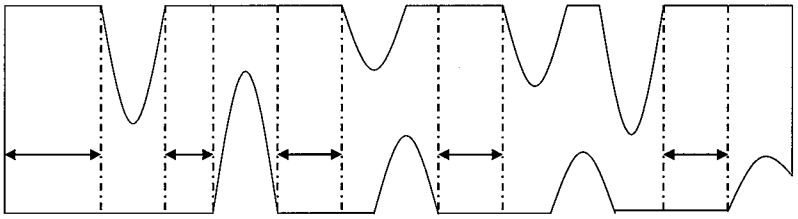


Figure 7.1 Pieces of veneer with full width recovered from rounding stage

7.6.3 The peeling knife shall be newly sharpened and free from defects.

7.6.4 The settings to obtain the desired thickness are made by adjusting the knife position and bedplate. For face and core veneer, the thickness shall be 0.5–1.5 mm and 2.0–3.0 mm respectively.

7.6.5 The final diameter of log core is set at about 4 cm.

7.6.6 The peeled veneer is labelled and reeled.

7.6.7 Where available, the use of an online veneer clipper is recommended for obtaining the desired veneer dimensions. A proper veneer labelling system is employed with the last digit in running sequence from the outer to the inner part of the log.

7.7 Flat-Slicing Procedure

7.7.1 Prior to slicing, the dimensions of the prepared block are measured.

7.7.2 The log is trimmed to a block with two parallel sides.

7.7.3 The blocks are soaked in hot water at temperature of 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.

7.7.4 The settings to obtain the desired thickness are made by adjusting the knife position and bedplate. For face veneer and flooring applications, their thicknesses shall be 0.5–1.0 mm and 2.5–3.0 mm respectively.

7.7.5 Slicing commences on one parallel side until unacceptable defects such as dead knots, holes and 'uneven surfaces' are detected. Then the block is switched over to the other parallel side.

7.7.6 When unacceptable defects in the veneer appear again, another two parallel sides perpendicular to earlier sides are cut.

7.7.7 If the block size permits, another two parallel sides are cut at 45° to any existing two sides. The cutting and slicing process can continue until no more acceptable veneers can be obtained.

7.7.8 Each sliced veneer will be labelled according to the block number.

7.8 Sampling Procedures

7.8.1 *Peeled Veneer*

Veneer test sheets are taken from three circumferential positions (outer, mid and inner) as illustrated in Figure 7.2. The veneer test sheet from the inner and outer positions will be the last and the first veneer pieces respectively. The position of the mid-sample may be determined thereafter.

7.8.1.1 A hole of about 5–10-mm diameter is drilled perpendicularly from the edge to almost 25 mm from the centre of the logs prior to peeling (Figure 7.2). The 5–10-mm diameter holes appearing on the veneer will relate linearly to the radius of the log. Figure 7.3 shows an example of the cutting pattern of the veneer to '2-circumference' length and the veneer from the log representing the outer, mid-and inner positions. The identity of the mid-sample is given by: (outer + inner) / 2.

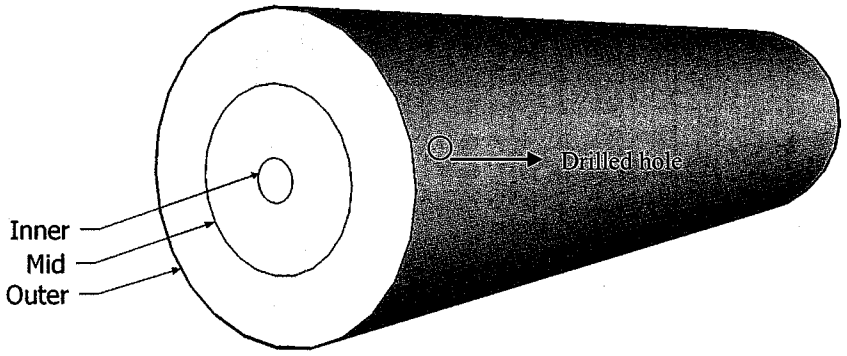


Figure 7.2 Locations of the three circumferential positions for taking representative veneer samples

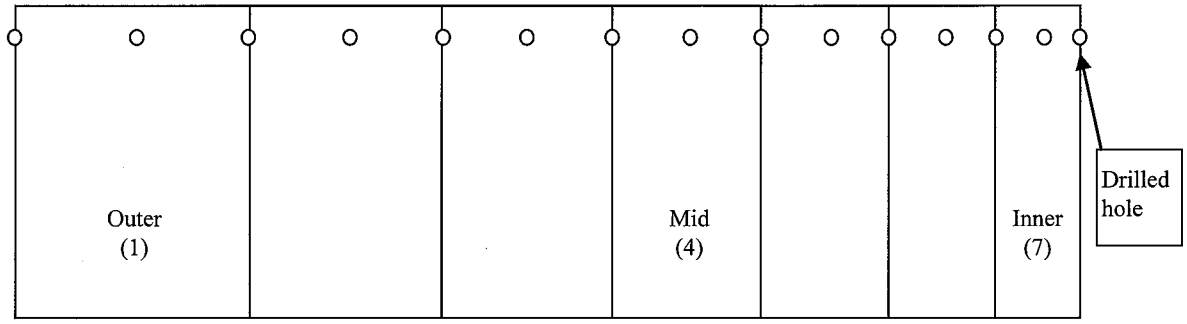


Figure 7.3 Example of veneer cut to length of '2-circumference' and veneer yield = 7 pieces

Figure 7.4 Shows the result of stacking the '2-circumference' -length veneers with veneer yield = 9 and the locations of the outer, mid- and inner samples.

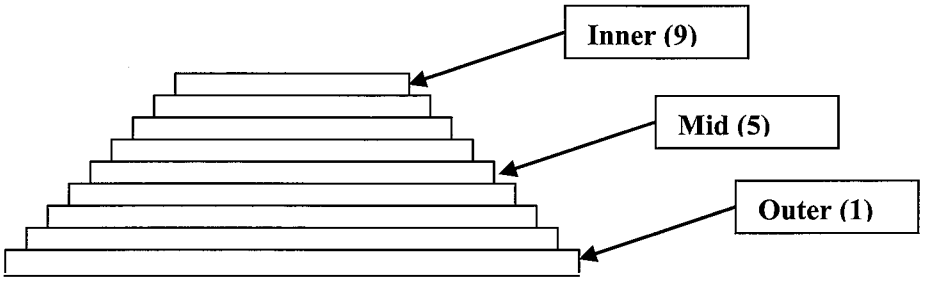


Figure 7.4 Locating the three representative veneer samples after stacking in numbering order for an example with veneer yield = 9

7.8.1.2 If the option in Section 7.6.7 is adopted, and the log is peeled and clipped to N pieces of veneer of constant dimensions with numbering from 1 to N (outer to inner), the identities of the veneer samples representing the outer, mid- and inner sections of the log are as follows:

Outer = 1

Mid = $\frac{N}{4}\left(\frac{3R+r}{R+r}\right)$, 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)

7.8.1.3 For the determination of depth of peeler checks and surface roughness, test specimens of 50 mm × 25 mm and 100 mm × 100 mm are prepared from each selected veneer test sheet respectively as in Figure 7.5.

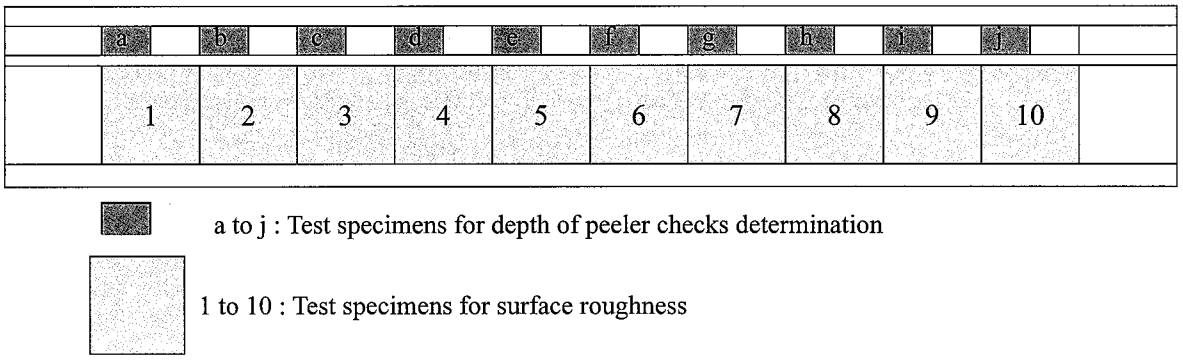


Figure 7.5 Sampling of samples for surface roughness and depth of peeler check determination

7.8.2 *Sliced Veneer*

A minimum of five veneer test sheets are randomly sampled from each block.

7.8.2.1 For sliced veneer, surface roughness test, test specimens of 50 mm × 25 mm are prepared from each selected veneer test sheet.

7.8.3 Where possible, avoid taking test specimens with knots, machine marks and knife marks.

7.9 Computations of Yield

7.9.1 *Yield Recovery of Veneer from Peeling Process*

Volume of log: The volume (m^3) of each log (V_l) is calculated based on the log length and diameter measurements:

$$V_l = \pi \times \frac{L}{4} \times \left[\frac{D_s + D_l}{2}\right]^2 \times 10^{-6} \quad \text{..... Eqn. 7.1}$$

where, L= length of log (cm)
D_s= mean diameter of small end (cm)
D_l= mean diameter of large end (cm)

Volume of rounded log: The volume (m^3) of the rounded log V_r is calculated as follows:

$$V_r = \left[\pi \times L \times \frac{D_r^2}{4} \times 10^{-6}\right] \quad \text{..... Eqn.7.2}$$

where, L= length of log (cm)
D_r= diameter of round-up log (cm)

Volume of peeler core: The volume (m^3) lost as peeler core (V_c) is computed using the diameter and length of the peeler core:

$$V_c = \left[\pi \times L \times \frac{D_c^2}{4} \times 10^{-6}\right] \quad \text{..... Eqn.7.3}$$

where, L = length of log cm)
D_c = diameter of peeler core (cm)

Volume of veneer recovered from rounding stage: The volume (m^3) of recovered veneer (V_w) with complete width obtained during rounding off is calculated as follows:

$$V_w = [\, t \times W \times L_w \times 10^{-6} \,] \quad \text{..... Eqn.7.4}$$

where, t = thickness of veneer (cm)
W = width of veneer (cm)
L_w = total length of veneer with complete width (cm)

Volume of peeled veneer: The volume (m^3) of peeled veneer (V_p) is computed as follows:

$$V_p = [\, t \times W \times L_p \times 10^{-6} \,] \quad \text{..... Eqn.7.5}$$

where, t = thickness of veneer (cm)
W = width of veneer (cm)
L_p = total length of veneer after peeling (cm)

Volume of veneer shrinkage: The volume (m^3) of veneer shrinkage (V_{sh}) is calculated as follows:

$$V_{sh} = [S_t \times t \times S_l \times (L_w + L_p) \times W \times 10^{-6}] \quad \text{..... Eqn.7.6}$$

where, S_t = thickness shrinkage (%)
t = thickness of veneer (cm)
S_l = lengthwise shrinkage (%)
L_w = total length of recovered veneer with complete width (cm)
L_p = total length of veneer after peeling (cm)
W = width of veneer (cm)

Peeled veneer yield: The yield of veneer (Y_p) is expressed as the percentage (%) of the log volume and calculated as:

$$Y_p = \frac{V_w + V_p - V_{sh}}{V_l} \times 100 \quad \text{..... Eqn.7.7}$$

7.9.2 *Yield Recovery of Veneer from Slicing Process*

Volume of prepared block: The volume (m^3) of the prepared block (V_b) is calculated as follows:

$$V_b = [\, A_b \times L_b \times 10^{-6} \,] \quad \text{..... Eqn.7.8}$$

where, A_b = cross-section area (cm^2)
L_b = length of block (cm)

Volume of sliced veneer: The volume (m^3) of the sliced veneer (V_S) is calculated as follows:

$$V_s = [\, \sum L_{sv} \times W_{sv} \times T_{sv} \times 10^{-6} \,] \quad \text{..... Eqn.7.9}$$

where, L_{SV} = length of sliced veneer (cm)
W_{SV} = width of sliced veneer (cm)
T_{SV} = thickness of sliced veneer (cm)

Sliced veneer yield: The yield of sliced veneer (Y_s) as expressed as a percentage (%) is calculated as:

$$Y_s = \frac{V_s}{V_b} \times 100 \quad \text{..... Eqn.7.10}$$

7.10 Determination of Veneer Attributes

7.10.1 *Shrinkage*

Shrinkage on the freshly peeled veneer test sheets is measured as shown in Figure 7.6. Two points of about 20 cm apart are accurately measured using a vernier caliper for lengthwise shrinkage determination. Another three points across the veneer width are marked and the thicknesses measured accurately with a digital micrometer screw gauge for thickness shrinkage determination. The dimensions are measured again after drying.

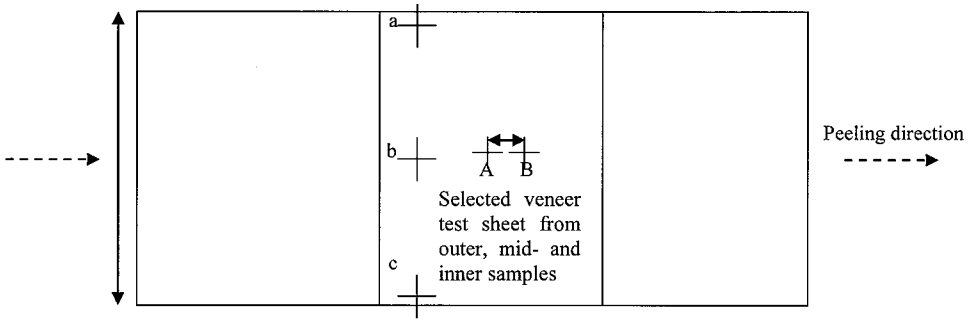


Figure 7.6 Shrinkage tests on freshly peeled veneer samples

The shrinkage values are expressed as percentages (%) as shown in the formulae below:

$$\text{Lengthwise shrinkage (\%)} = \frac{L_1 - L_2}{L_1} \times 100 \quad \text{..... Eqn. 7.11}$$

where, L_1 = distance AB on green veneer (mm)
L_2 = distance AB on oven-dried veneer (mm)

$$\text{Thickness shrinkage (\%)} = \frac{T_1 - T_2}{T_1} \times 100 \quad \text{..... Eqn. 7.12}$$

where, T_1 = thickness of green veneer (mm)
T_2 = thickness oven-dried veneer (mm)

7.10.1.1 Form 7.2 is used to record the data.

7.10.2 *Depth of Peeler Checks*

This is determined on 10 test specimens measuring 50 mm × 25 mm (Figure 7.7) taken from each veneer test sheet.

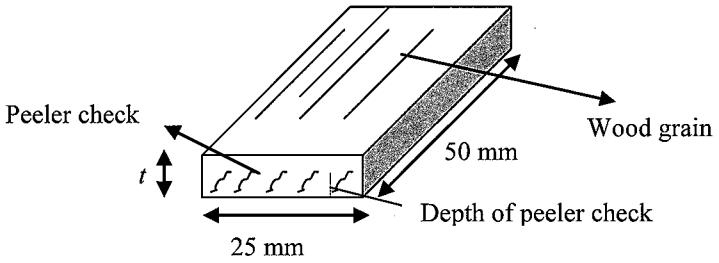


Figure 7.7 Peeler checks sample

7.10.2.1 Measuring microscope, capable of measuring to within ± 0.01mm shall be used.

7.10.2.2 Determination of the depth of peeler checks is carried out as specified in *AS/NZS 2098.6:1996 Methods of Test for Veneer and Plywood, Method 6: Depth of Peeler Checks in Veneer and Plywood.*

7.10.2.3 The percentage (%) depth of peeler check penetration (P_c) is calculated as shown in the formula below:

$$P_c = \frac{d}{t} \times 100 \quad \text{..... Eqn. 7.13}$$

where, d = average depth of peeler checks (mm)
t = thickness of veneer (mm)

7.10.2.4 The results are recorded in Form 7.3.

7.10.3 *Veneer Surface Roughness*

This is determined on ten test specimens measuring 100 mm × 100 mm taken from each veneer test sheet.

7.10.3.1 Suitable stylus type profilometer capable of providing the following test settings:

- Tracing speed: 0.5–2 mm sec^{-1}
- Cut-off value: 2.5 mm
- Stylus tip diameter: 5 μm
- Tip angle: 90°
- Tracing length: 15 mm
- Measuring force on surface: 4 mN

7.10.3.2 Before the test, the profilometer has to be calibrated against a standard reference plate and subsequently after every 100 measurements.

7.10.3.3 For each test specimen, surface roughness measurements are conducted across the grain orientation on both sides of the veneer using a stylus type profilometer as illustrated in Figure 7.8.

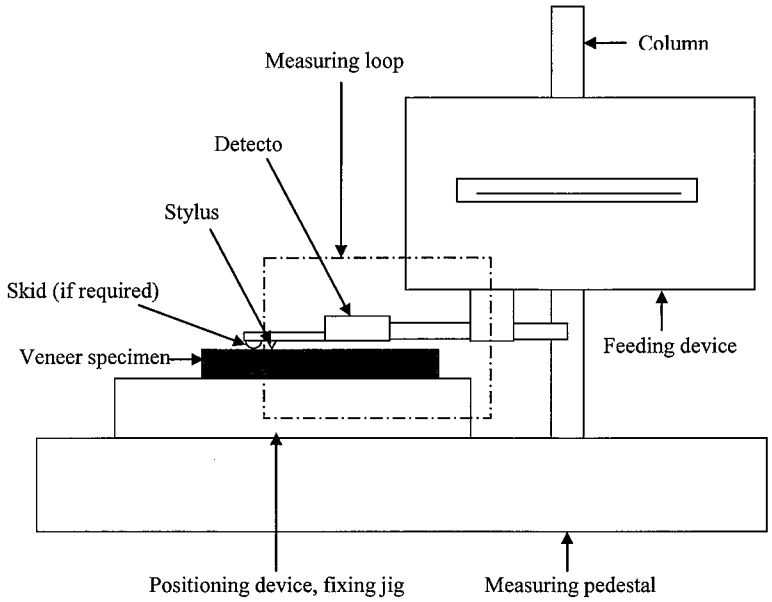


Figure 7.8 Set-up for surface roughness test

7.10.3.4 The test data to be collected are R_a (mean arithmetic deviation of profile), R_z (mean peak to valley height) and R_{max} (maximum roughness).

7.10.3.5 The data are recorded in Forms 7.4 and 7.5.

Forms

Form 7.1 Data on logs and veneers

Species:
Date:

Log ref.	Log dimensions					Peeler core diameter (cm)	Veneer				
	Initial			Rounded			Dimensions			No. of full sheets	Veneer ref. range
	Length (cm)	Diameter 1 (cm)	Diameter 2 (cm)	Length (cm)	Diameter (cm)		Thickness (mm)	Length (cm)	Width (cm)		
A										12	A1-A12
B										9	B1-B9
C										10	C1-C10
D										24	D1-D24
E										13	E1-E13
F										14	F1-F14

Form 7.2 Shrinkage recording form

Species:
Date:

Log ref.	Veneer test sheet No.	Thickness (mm)						Length perpendicular to the grain (mm)	
		Green			Oven-dried				
		a	b	c	a	b	c	Green, L_1	Oven-dried, L_2
A	1 (outer)								
	7 (mid)								
	12 (inner)								
B	1								
	5								
	9								
C	1								
	5								
	10								
D	1								
	15								
	24								
E	1								
	8								
	13								
F	1								
	9								
	14								

Form 7.3 Peeler checks recording form

Species:
Date:

Veneer thickness (mm)	Log ref.	Sample No.	Outer		Mid		Inner	
			Total No. of checks	Average depth of checks (mm)	Total No. of checks	Average depth of checks (mm)	Total No. of checks	Average depth of checks (mm)
1.5	A	1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						
		1						
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						

Form 7.4 Surface roughness of peeled veneers

Species:
Log ref.: A
Veneer thickness: 1.5 mm
Date:

Position	Sample No.	Side 1			Side 2		
		R_a (μm)	R_{max} (μm)	R_z (μm)	R_a (μm)	R_{max} (μm)	R_z (μm)
Outer	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
Mid	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
Inner	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Form 7.5 Surface roughness of sliced veneers

Species:
Log ref.: G
Veneer thickness: 0.6 mm
Date:

Veneer test sheet No.	Sample No.	Side 1			Side 2		
		R_a (µm)	R_{max} (µm)	R_z (µm)	R_a (µm)	R_{max} (µm)	R_z (µm)
1	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
2	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
3	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

Chapter 8

Drying Characteristics

8.1 Scope

8.1.1 This document specifies methods for evaluating the drying characteristics of plantation timbers. Four drying tests are proposed: air-drying test (ADT), drying-rate test (DRT), quick-drying test (QDT) and drying-schedule test (DST).

8.1.2 The results obtained are meant for comparing the drying characteristics of the timbers with other timber species and to develop drying schedules for the timbers using conventional steam-heated drying system.

8.2 Referenced Document

8.2.1 Forestry and Forest Products Research Institute, Japan. 2004. Testing Methods of Various Wood Properties of Fast-Growing Tropical Timbers. Technical Report of the Project Development Committee No. 13. 85 pp.

8.3 Definitions

8.3.1 *Plantation Timber*: Timber obtained from planted stock which is representative of a distinctive age group, stand density, clone, soil type, silvicultural treatment, etc.

8.3.2 *Air Drying*: Stacking timber under shed on stickers and drying naturally under the prevailing weather conditions.

8.3.3 *Drying Rate*: The rate of drying timber under constant conditions.

8.3.4 *Quick Drying*: Classifying defect characteristics of timber dried at 100 °C in a natural convection oven, and using these to set the initial drying temperatures for the timber.

8.3.5 *Drying Schedule*: A set of operating temperatures to control the drying of timber in a conventional steam-heated kiln.

8.4 Equipment

8.4.1 Laboratory-designed small chamber (operating temperature 30–95 °C, control accuracy ±2 °C; operating humidity 45–95% RH, control accuracy ±5% RH).

8.4.2 Natural convection oven (operating temperature 100–105 °C, control accuracy ±2 °C); forced convection oven (operating temperature 100–105 °C, control accuracy ±2 °C).

8.4.3 *Balances*: Electric balance—measuring MC (moisture content) specimens (weighing range 0–3,000 g, minimum readability 0.01g); electric balance—measuring test boards (weighing range 0–20,000 g; minimum readability 0.01 g).

8.4.4 *Measuring Instruments*. Vernier caliper (maximum length 200 mm, minimum readability 0.05 mm) to measure width of QDT samples; thickness gauge/caliper (maximum length 50 mm, minimum readability 0.05 mm); micrometer to measure deformation of QDT sample (minimum readability 0.01 mm).

8.4.5 *Climate Datalogger*: Temperature range 0–60 °C (accuracy ±2 °C), relative humidity 20–100% (accuracy ±5%); or thermo-hygrometer (either one can be used).

8.4.6 Silicon grease with caulking gun/bitumen paint (either one can be used).

8.4.7 Hammer and cleaver knife.

8.5 Test Board Preparation

8.5.1 *Sample Logs and Sawing Pattern*

8.5.1.1 Prepare up to 20 logs. The logs shall be obtained from Batches 4 and 5 as described in *Chapter 1: Sampling Trees and Allocations of Logs*. The length of log shall be 2,200 mm.

8.5.1.2 For logs with diameter of more than 300 mm, prepare test boards for drying tests by sawing from Flitches 1 to 5 as shown in Figure 8.1. Prepare one flat-sawn board using Flitch 1 for quick-drying test. For Flitch 2, two diagonal-sawn boards of 60 mm are cut: one board is used for air-drying test while the other board is ripped into two 30-mm boards for drying-schedule test and air-drying test. Flitch 3 is cut into two quarter-sawn 60-mm boards: one board is used for air-drying test, while the other is ripped into three 30-mm boards for air-drying test, drying-rate test and drying-schedule test. Prepare 60-mm air-drying board from Flitch 4, and the balance is ripped into two 30-mm boards for air-drying test and drying-rate test. Prepared from Flitch 5 30-mm flat-sawn board for drying-schedule test. If the log diameter is less than 300 mm, Flitches 1 and 5 may be omitted. However, the test boards for all the tests must be prepared from Flitches 2 to 4.

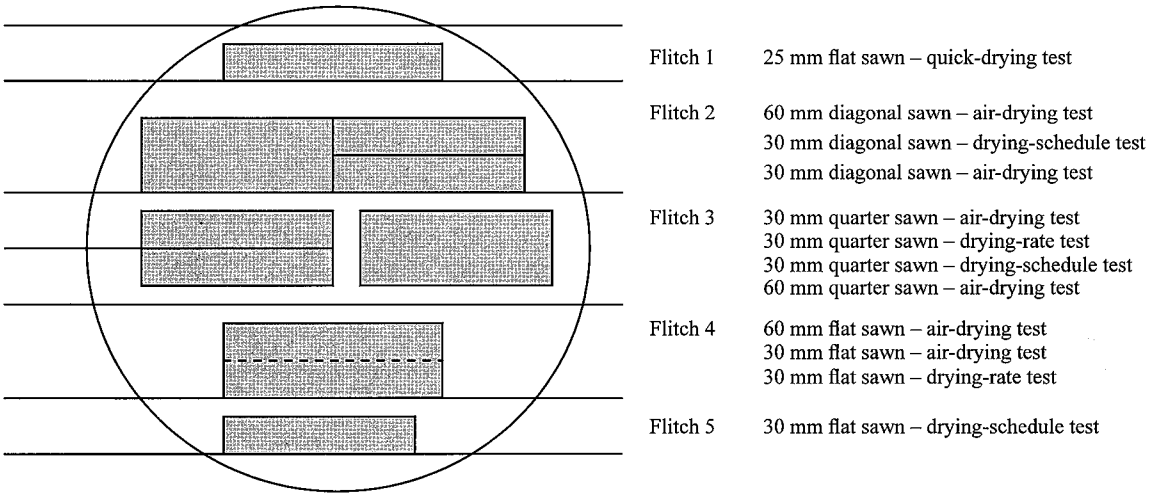


Figure 8.1 Sawing pattern for test specimens/boards

8.5.1.3 Boards used for the drying tests (air-drying, quick-drying, drying-rate and drying-schedule tests) must be sawn from the same log. Additional boards for drying-schedule test may be sawn from other logs to make up a charge. Mark the original numbers on the boards.

8.5.2 *Sawing*

8.5.2.1 Identify the boards that are to be processed to the final size for testing by writing the log number, sawing position number and longitudinal position number in the order shown in Figure 8.2. The boards may be recorded in Form 8.1.

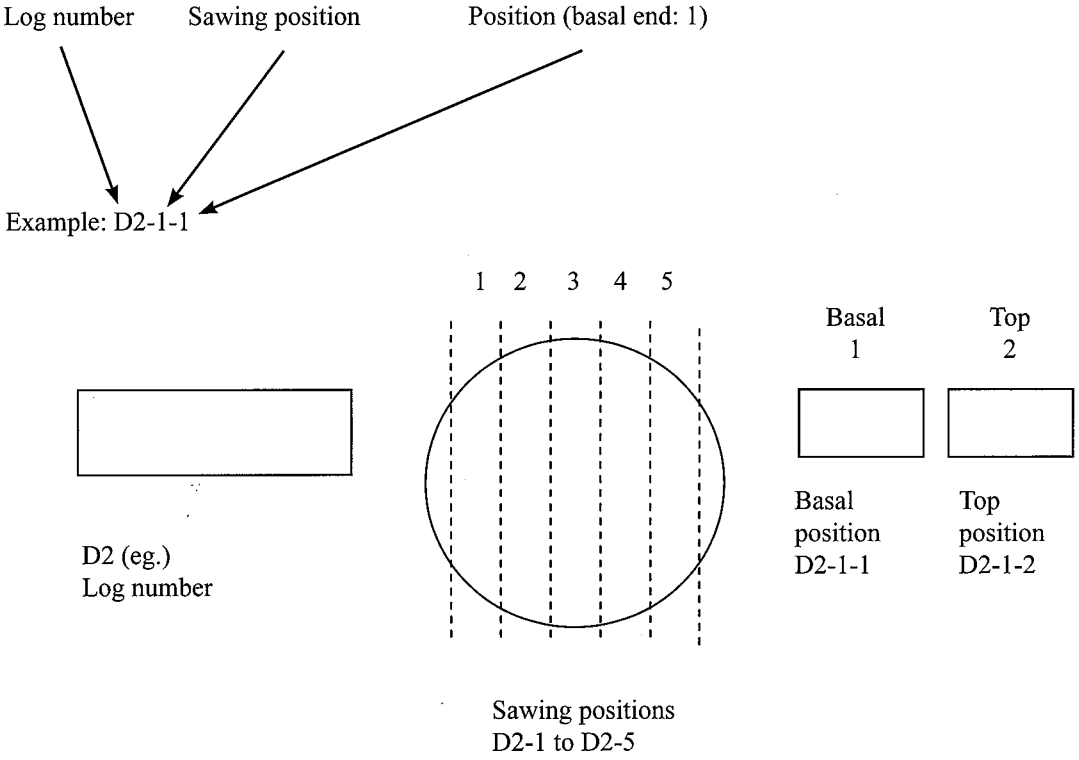


Figure 8.2 Marking of specimens

8.5.2.2 Specimens are cut from both ends of each test board for estimating moisture content (MC). Write the subnumbers (a,b,c) (MC specimens) from the top end on each sample as shown in Figure 8.3. (The procedure for determining MC is given in Appendix 8.1.)

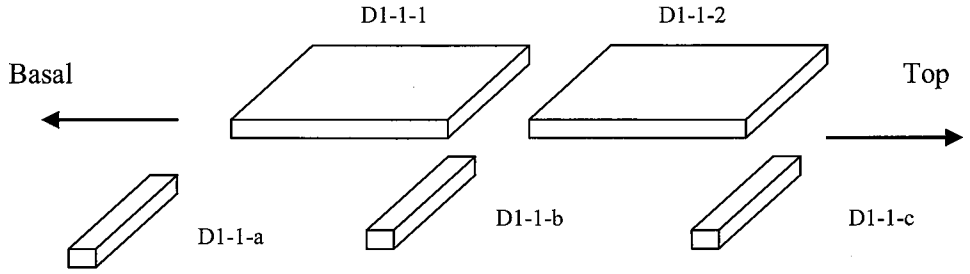


Figure 8.3 Specimens for moisture content estimation

8.5.2.3 Weigh each test board and measure the width and thickness at the centre of each test board using a vernier caliper and thickness gauge respectively. The measuring point of thickness differs depending on the grain or cut. For flat-sawn and diagonal-sawn boards, use one point at the centre of the sample. For quarter-sawn grain, use three points: one at the centre of the sample and two at 2 cm from both sides. Moisture content is calculated using the oven-dry method (Appendix 8.1, MS 873:2006).

8.5.3 *Nominal Sizes and Number of Test Boards*

The boards to be sawn from each log are given in Table 8.1. Test boards are planed to the respective test thicknesses.

Table 8.1 Summary of test boards to be prepared from each log

Board type	Flat	Diagonal	Quarter	Flat	Diagonal	Quarter	
Nominal size, (mm)	30 × 150	30 × 150	30 × 150	60 × 150	60 × 150	60 × 150	Length
Air drying	1	1	1	1	1	1	600
Drying-rate test	1		1				300
Quick-drying test*	1						200
Drying-schedule test**(× 3)	1	1	1				600

* The width of test boards for quick-drying test shall be 150 mm, all the other test boards may be narrower depending on the diameter of the log. For log diameter less than 300 mm a width of 120 mm may be used.

** Three trials are recommended (mild, moderate and severe).

8.5.3.1 *Air-drying test boards*

8.5.3.1.1 Two sizes: thickness 27 mm, width 150 mm, length 600 mm; and thickness 54 mm, width 150 mm, length 600 mm. Three grains: flat sawn, diagonal sawn, quarter sawn. Number of specimens: 2 sizes and 3 grains (2 × 3 = 6) are needed from each log.

8.5.3.2 *Drying-rate test specimens*

8.5.3.2.1 One size: thickness 30 mm, width 150 mm, length 300 mm. Two grains: flat sawn, quarter sawn. Number of specimens: 1 size and 2 grains (1 × 2 = 2) are needed from each log.

8.5.3.3 *Quick-drying test specimens*

8.5.3.3.1 One size: thickness 20 mm, width 100 mm, length 200 mm. One grain: flat sawn (defect-free as illustrated in Figure 8.4). Number of specimens: 1 size and 1 grain type (1 × 1 = 1) is needed from each log.

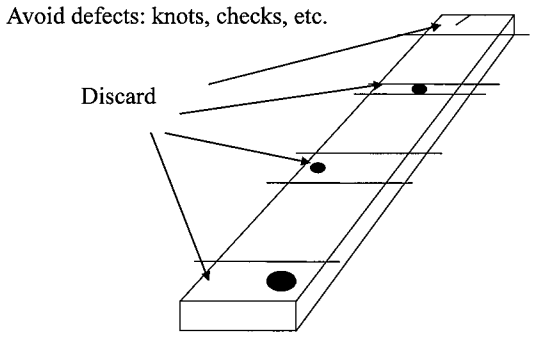


Figure 8.4 How to prepare test specimen for quick-drying test (clear sample without any defect)

8.5.3.4 *Drying-schedule test boards* (boards may be from different logs in Batches 4 and 5)

8.5.3.4.1 One size: thickness 27 mm, width 150 mm, length 600 mm (for diameter less than 300 mm width 120 mm). Three grains: flat sawn, diagonal sawn, quarter sawn. Number of specimens: 1 size and 3 grains (1 × 3 = 3) are needed from each log.

8.6 Test Procedures

8.6.1 *Air-Drying Test (ADT)*

8.6.1.1 The test is used to estimate the drying time, final moisture content and shrinkage. These are fundamental data for establishing an effective drying method, for example drying lumber by air drying only or in combination of air drying and kiln drying and so on, for any species. The test period is three to four months for boards 27 mm thick and nine to 12 months for boards 54 mm thick. Testing is completed when the weight of a specimen has changed by only 1 g in two weeks.

8.6.1.2 *Specimens*: Sizes of specimen are shown in Section 8.5.3.1.1. Both ends and the sides shall be sealed with silicon grease/bitumen paint before testing.

8.6.1.3 *Measurements*: Measure initial weight, width and thickness of specimens. These may be recorded in Form 8.2. During the test, interval times for measuring weight are usually every three days for two weeks, every seven days for three months and subsequently every two weeks until the end of the test. Measure the weight, width and thickness of all specimens each time. The location of each specimen in the stack shall be the same.

8.6.1.4 *Stacking*: Stack the specimens in an open site as shown in Figure 8.5. The specimens may be stacked in the same manner but without a cover over it, in an open shed (seasoning shed). The height of the foundation must be at least 20 cm to provide protection from splattering rain water.

8.6.1.4.1 Thickness of the stickers, which are made of dried timber or metal, is of uniform size. Stickers of uniform thickness of 25 or 30 mm square may be used.

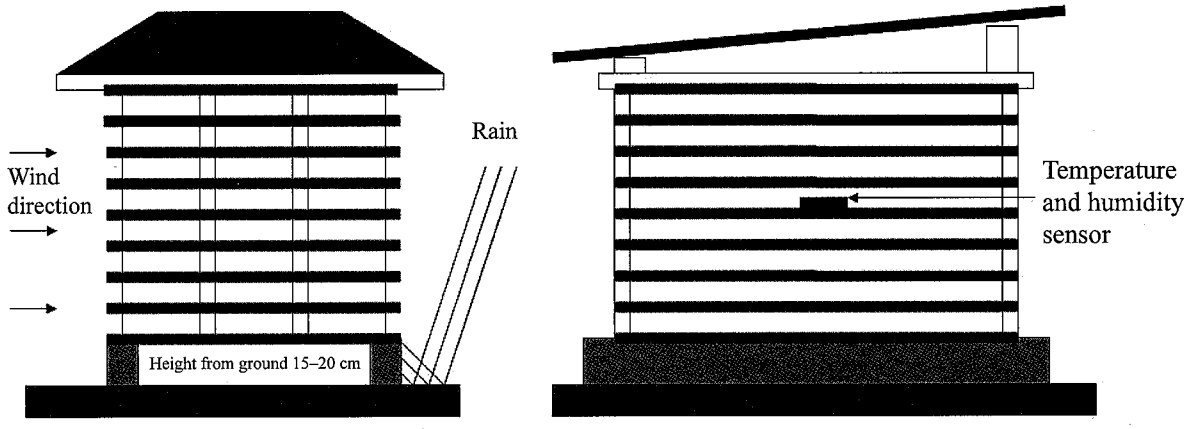


Figure 8.5 Air-drying stack

8.6.1.4.2 Place the specimens in the stack. Width and height of stack are limited to three boards per layer for 10 layers. Place a cover on the stack and fix it securely with wire. Decide on the direction of the stack according to the natural wind direction. Wind shall flow parallel to the stacks from the side edge of the stack.

8.6.1.4.3 Install a climate data logger/thermo-hygrometer at the centre of the stack (Figure 8.5).

8.6.1.5 *Observations*

8.6.1.5.1 Note and mark indicating the appearance time, length and width of all surface checks. These shall be written directly on the surface of the specimen.

8.6.1.5.2 Measure the amount of cup, twist and bow.

8.6.1.6 *Summary of results*

8.6.1.6.1 Calculate the moisture content and shrinkage. Test and calculate the density of specimens (Appendix 8.2).

8.6.1.6.2 Average moisture content is calculated using the oven-dry method for small samples, which are cut from the centre of a specimen as shown in Figure 8.6. Cut two small (about 25-mm length) samples. One is used for calculating the average moisture content; the other is used for calculating the moisture gradient.

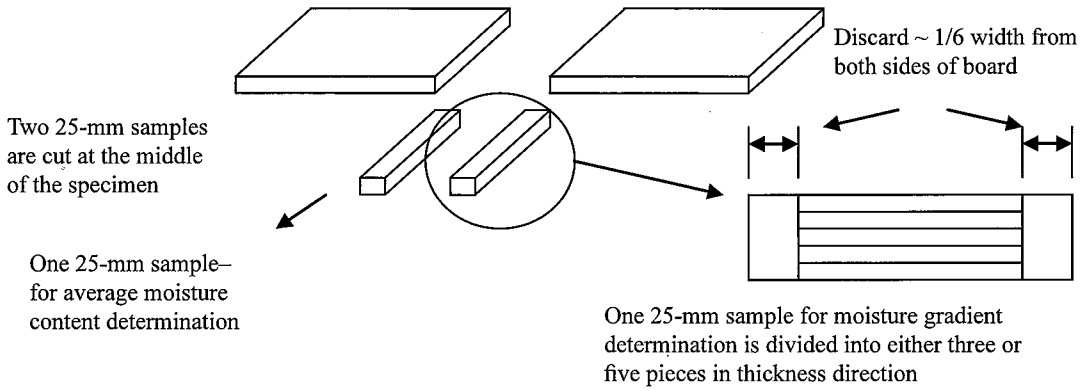


Figure 8.6 How to cut small specimens for moisture content determination at the end of air drying

8.6.1.6.3 Moisture gradient is calculated by dividing into three or five pieces (30-mm board – three, 60-mm board – five) as shown in Figure 8.6.

8.6.1.6.4 Drying curve is drawn using the values of moisture content, which is calculated based on the final moisture content.

8.6.1.6.5 Shrinkage curve is drawn using the values of shrinkage.

8.6.1.7 *Evaluation*

8.6.1.7.1 Estimate the drying time from 30 % MC to final air-dry MC. Calculate the shrinkage values of width and thickness at final air-dry MC.

8.6.2 *Drying-Rate Test*

8.6.2.1 The drying-rate test is used to estimate drying characteristics for drying specimens in a (forced-air oven) chamber, controlled at a constant temperature and humidity (humidity cannot be controlled in an oven). Evaluation of drying characteristics is made by comparing with other species tested under the same conditions. Testing period is four to seven days. Testing is completed when the weight of the specimen has changed by only 1 g in a day.

8.6.2.2 *Specimens*: Size of specimens is given in Section 8.5.3.2.1. Both ends and the sides shall be coated with silicon/bitumen paint before testing.

8.6.2.3 *Drying conditions*: These are controlled at a temperature of 60 °C and wet bulb temperature of 35 °C in a chamber. Air velocity in the chamber is about 1 m sec^{-1}.

8.6.2.4 *Measurements:* Measure the weight, width and thickness (measure at the centre) beforehand. These may be recorded in Form 8.3. Repeat measurements every four hours. Measure the weight, width and thickness each time.

8.6.2.5 *Summary of results*

8.6.2.5.1 Calculate the moisture content and shrinkage. Test and calculate the density of specimens (Appendix 8.2).

8.6.2.5.2 Average moisture content is calculated using the oven-dry method for a small sample cut from the centre of a specimen as shown in Figure 8.6.

8.6.2.5.3 Drying curve is drawn using the values of moisture content, which is calculated based on the final moisture content.

8.6.2.5.4 Shrinkage curve is drawn using the values of shrinkage. Oven-dry shrinkage is calculated using a small oven-dried sample.

8.6.2.6 *Evaluation*

8.6.2.6.1 Draw a drying curve and a shrinkage curve using the result values. Find the drying time from 15 to 10% MC of the specimen. Calculate coefficient k using Eqn. 8.1 below:

$$\frac{du}{dt} = k(u - u_e) \quad \text{..... Eqn. 8.1}$$

Note: du/dt: change of moisture content drying rate of final drying period (% hr^{-1})

k: coefficient of drying rate (hr^{-1})

$u–u_e$: change of moisture content (%)

8.6.3 *Quick-Drying Test*

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

8.6.3.2 *Specimens*: The size of the specimens shall be 20 mm (thickness) by 100 mm (width) by 200 mm (length) as shown in Figure 8.7 and in Section 8.5.3.3.1. In particular, both ends shall be newly cut and the surface should be finished with a planer. Unlike the other drying tests (air-drying and drying-rate tests), the coating on the ends is omitted for this test. Test specimens of poor quality are not appropriate. Only a flat-sawn grain board of heartwood shall be adopted. However, sapwood may be adopted as test specimens in such special case as when all the timber samples to be dried consist of sapwood. Timber with MC over 50% is used as test specimen when the specific gravity is moderate. This may be ignored for hard and heavy species with initial moisture content of not more than 45%. (It is difficult to determine in short the desirable MC because the moisture content of raw timber is not more than 45% in such hard and heavy species.)

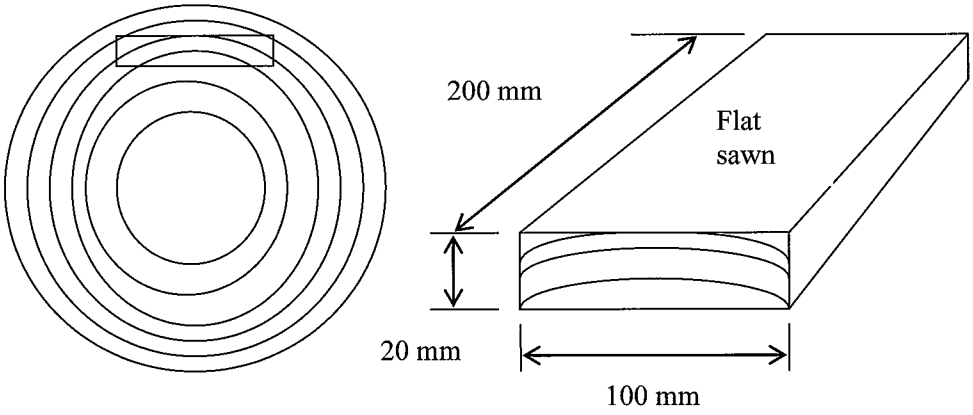


Figure 8.7 Size and grain of specimen

8.6.3.3 Each specimen is weighed for initial weight. Frequency of weighing and observation during the test is decided depending on the species and its initial moisture content: for softwood every 30 min or one hour and for hardwood every one or two hours.

8.6.3.4 Specimens are placed in an oven, previously adjusted to 103±2 °C, edgewise upright. Limit the number of specimens to three or four in a small natural convection oven and six or seven in a large one. Specimens shall be placed at more than 75 mm apart.

8.6.3.5 *Observations*

8.6.3.5.1 Specimens are to be observed each time for checks and the degrees of end and surface checks are rated according to the illustration in Figure 8.8. The purpose is to ascertain the highest rate possible of the end and surface checks (degree of end and surface checks) appearing at the initial stage of drying. If the checks begin to close, the frequency of weighing shall be reduced to every two to three hours.

8.6.3.5.2 After drying to the specified point, which is about 1% MC, it will be possible to observe honeycombing.

8.6.3.5.3 Another 15 to 30 hours is required for the purpose of obtaining the oven-dry weight to estimate the period required for the kiln drying.

8.6.3.5.4 When drying is complete, the specimen is cross-cut at the centre in order to observe cross-sectional deformation. The degree of internal checks is established based on Figure 8.9 (internal checks).

8.6.3.5.5 Measure the thicknesses of the board as shown in Figure 8.10 and calculate the difference between A and B. The degree of collapse is rated based on the classification in Table 8.2.

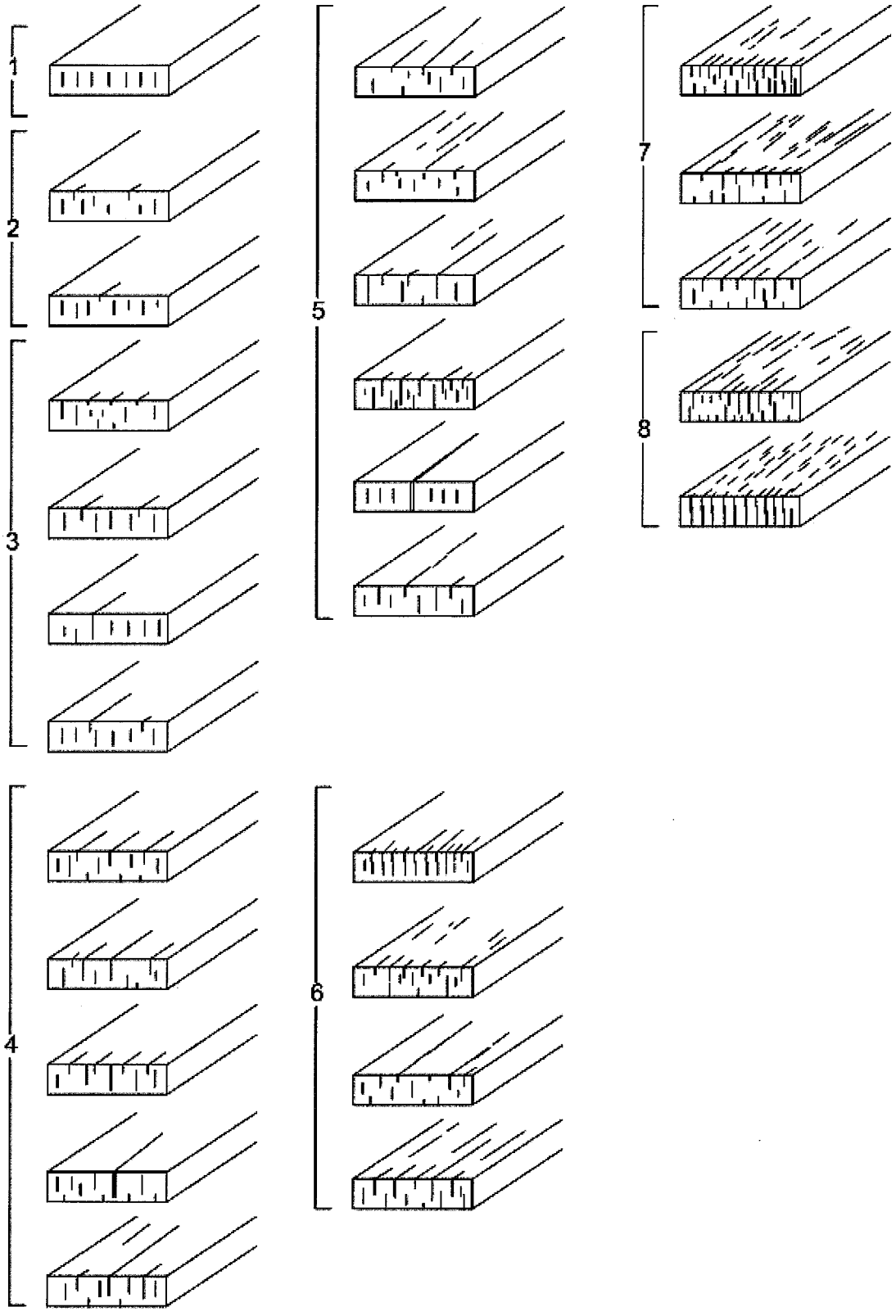


Figure 8.8 Comparison sheet for degrees of end and surface checks

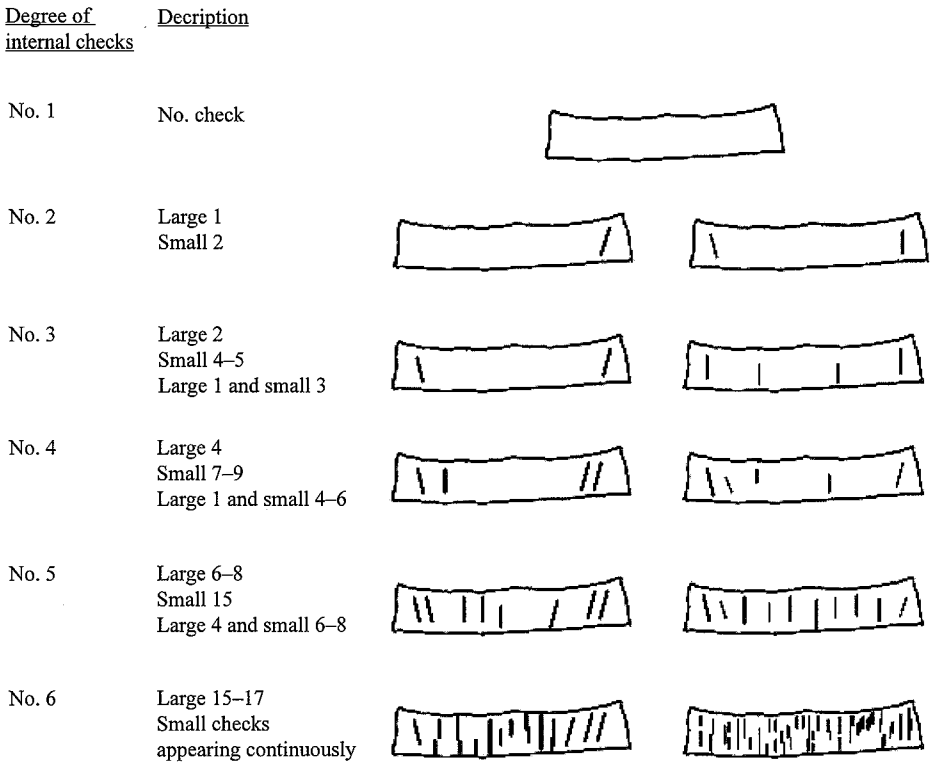


Figure 8.9 Comparison sheet for degree on internal checks

8.6.3.6 *Evaluation of defects*

8.6.3.6.1 Checks

A number of ways are used to assess the checks during the initial stage of drying (Figure 8.8). End checks extending to the surface, end splits, surface checks extending from the end and isolated surface checks may occur not only in number but also in length and shape. A certain correlation can be found between the drying conditions and degree of checks; these can be classified into eight degrees as shown in Figure 8.8. Checks appearing in the early stage of kiln drying are closely associated with the relative humidity. A test specimen with such isolated surface checks should be dried under high relative humidity. However, when only minor checks are found on the end there is little need to worry even in actual operations.

8.6.3.6.2 Collapse and honeycombing (internal checks)

Honeycombing that appears after the drying process can be classified into six degrees as shown in Figure 8.9. The collapse (spool-like deformation) of a cross-section is shown in Figure 8.10. The degree of deformation is classified into eight degrees according to the difference of thickness between A and B as shown in Table 8.2.

8.6.3.6.3 Table 8.3 describes the critical conditions of drying for both the initial conditions and the final temperatures for one-inch board based on each of the three defect classifications. The mildest conditions are selected from among such drying conditions as shown in each degree of defect in order to determine the applicable conditions for a specific species.

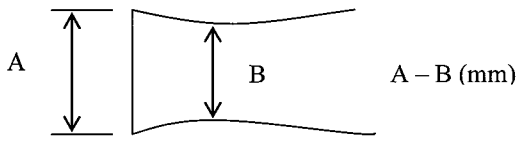


Figure 8.10 Measuring points (A and B) for thickness of board

Table 8.2 Degrees of collapse based on A – B in Figure 8.10

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

Note: B is measured between the points of maximum collapse.

8.6.3.7 *Estimation of the kiln-drying period*

8.6.3.7.1 To obtain an indication of the drying period, the DBT and WBT difference (or WBD, wet bulb depression) at the initial drying stage obtained from Table 8.3 are used, and the time needed to reduce the moisture content to 1% is employed to indicate the relative difficulty of moisture mobility. Each contribution is presumed to be equal.

Table 8.3 Drying conditions based on degrees of defects from the QDT results

Deformation	Degree	1	2	3	4	5	6	7	8
		Drying conditions (°C)							
Surface checks (appearing during initial stage of drying)	Initial DBT	70	65	60	55	53	50	47	45
	Initial WBD	6.5	5.5	4.3	3.6	3.0	2.3	2.0	1.8
	Final DBT	95	90	85	83	82	81	80	79
Cross-sectional deformation (spool-like deformation)	Initial DBT	70	66	58	54	50	49	48	47
	Initial WBD	6.5	6.0	4.7	4	3.6	3.3	2.8	2.5
	Final DBT	95	88	83	80	77	75	73	70
Internal checks (honeycombing)	Initial DBT	70	55	50	49	48	45	-	-
	Initial WBD	6.5	4.5	3.8	3.3	3.0	2.5	-	-
	Final DBT	95	83	77	73	71	70	-	-

DBT – Dry bulb temperature

WBD – Wet bulb depression (difference between dry bulb temperature DBT and wet bulb temperature WBT)

8.6.3.7.2 In estimating the actual kiln-drying schedule for one-inch board, the drying process must first be plotted on a graph as shown in Figure 8.11 in order to obtain the time needed to reduce the initial moisture content to 1%. Plotting a logarithm scale graph is convenient because the trend is linear when shown on a logarithm scale graph.

8.6.3.7.3 The relationship between the time needed to reduce the moisture content to 1% and the actual kiln-drying period is shown in Figure 8.12. The relationship between the actual kiln-drying time and the initial DBT and WBT difference (or WBD) determined in Table 8.3 is also presented in Figure 8.12.

8.6.3.7.4 Summarizing the descriptions presented thus far, the two kiln-drying periods established from the relationships can be averaged to yield an estimated actual kiln-drying duration for an unfamiliar species.

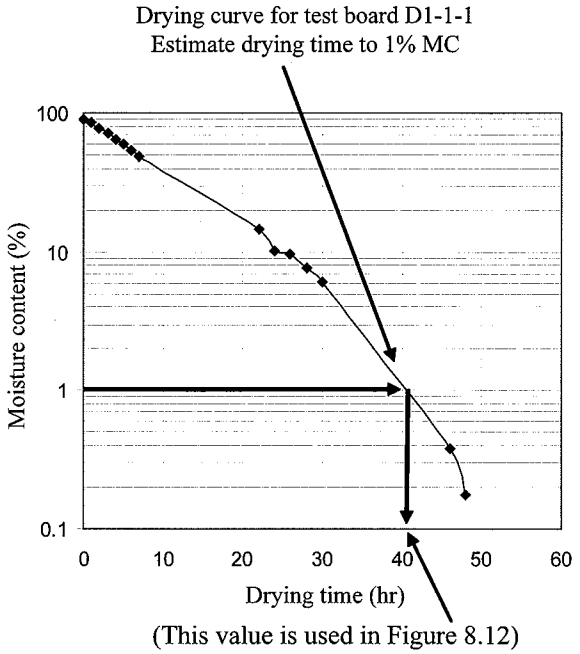


Figure 8.11 Plot of the drying process on a logarithm graph

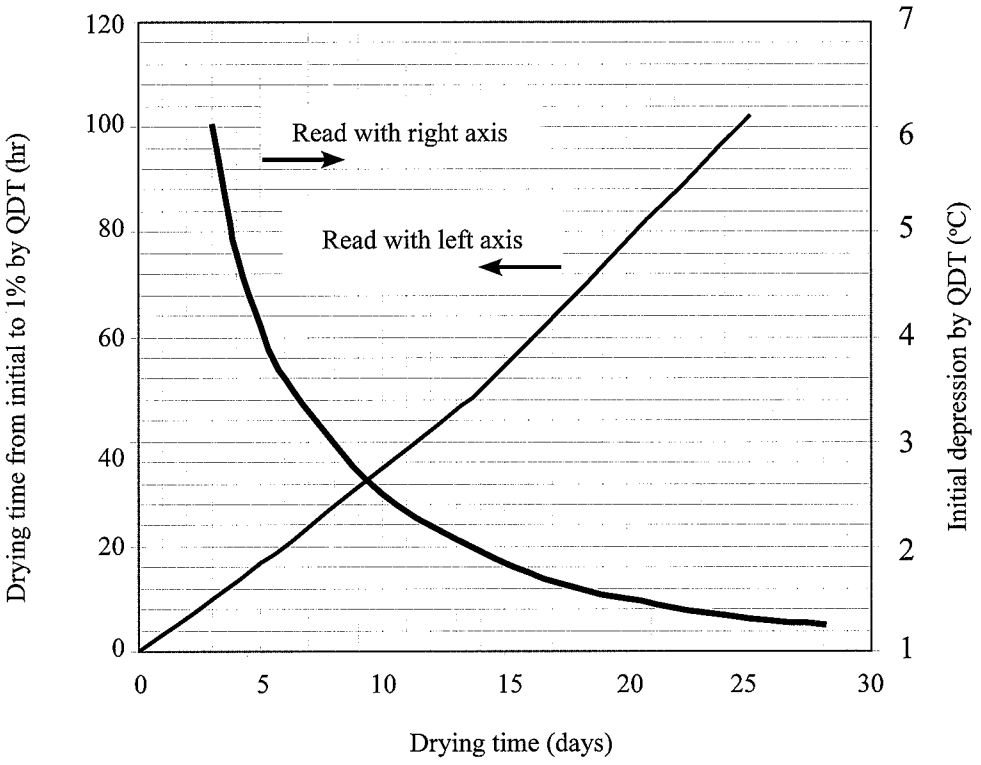


Figure 8.12 Estimation of drying time for one-inch (25-mm) timber from green to 1% MC by conventional steam-heated kiln drying

(Remarks: Left vertical column relates to the results of drying time from green to 1%. Right vertical column relates to the results of initial wet bulb depression.)

8.6.3.8 *Summary of results*

8.6.3.8.1 Deformations

Fill in the form with the results of test. For example, typical results of *Acacia mangium* are presented in Table 8.4.

Table 8.4 Deformation form

Results of QDT test / Sample No.	Classification of defects		
	Surface checks (1 - 8)	Collapse deformation (1 – 8)	Internal checks (1 – 6)
D1-1-1	1	7	5
D2-1-1	1	7	5
D3-1-1	1	5	4
D4-1-1	1	5	3
D5-1-1	1	6	5
D6-1-1	1	5	3
D7-1-1	1	6	4
D8-1-2	1	4	2
D9-4-2	1	7	5
D10-4-1	1	7	2
D11-5-1	1	7	2
D12-1-1	1	4	2
D13-4-2	1	2	1
D14-1-1	1	5	5
D16-4-1	1	6	5
D18-5-2	1	5	6
D18-5-1	1	5	3
D19-4-2	1	4	3
D20-5-1	1	2	2
D21-5-1	1	5	5
Results	1/8	7/8	6/6

Record the highest number (representing the worst case) in the result row.

8.6.3.8.2 Dry bulb temperature, wet bulb temperature and drying time (Table 8.5)

The critical conditions of drying (obtained from Table 8.3) based on the results of defect classifications (Table 8.4) are tabulated in Table 8.5.

Table 8.5 Dry bulb temperature, wet bulb temperature and drying time form

Results of QDT / No.	Initial dry bulb temperature, DBT (°C)	Initial wet bulb depression, WBD (°C)	Final dry bulb temperature (°C)	Drying time from IMC to 1% (hrs)
D1-1-1	48	2.5	70	40.5
D2-1-1	48	2.5	70	38
D3-1-1	49	3.3	73	43
D4-1-1	50	3.6	77	36.5
D5-1-1	48	3	71	38
D6-1-1	50	3.6	77	34.5
D8-1-1	49	3.3	73	42
D8-1-2	54	4	80	40.5
D9-4-2	48	2.5	70	41
D10-4-1	48	2.5	70	42
D11-5-1	48	2.5	70	45
D12-1-1	54	4	80	46
D13-4-2	66	6	88	44
D14-1-1	48	3	71	43
D16-4-1	48	3	71	40.5
D18-5-2	45	2.5	70	43.5
D18-5-1	50	3.6	77	35
D19-4-2	50	3.8	77	38
D20-5-1	55	4.5	83	48
D21-5-1	48	3	71	42
Results	45	2.5	70	34.5 – 48.0

Record the smallest number (representing the mildest) in the results row.
Note: IMC – Initial moisture content

8.6.3.8.3 Results of drying time and initial moisture content and drying times

These as described in Section 8.6.3.7 may be tabulated in a form. An example of *Acacia mangium* is presented in Table 8.6.

Table 8.6 Results of drying time and initial moisture content form

Sample No	Drying time from IMC to 1% (hr)	Results 1 (days)	Initial wet bulb depression (°C)	Results 2 (days)	Average (days)	Initial MC (%)
D1-1-1	40.5	11.5	2.8	8	9.85	91.0
D2-1-1	38	11	2.8	8	9.5	96.8
D3-1-1	43	12	3.3	6.8	9.35	92.1
D4-1-1	36.5	10.5	3.6	6	8.25	100.8
D5-1-1	38	10.6	3	8.5	9.05	83.8
D6-1-1	34.5	10	3.6	6	8	98.8
D7-1-1	42	12	3.3	6.8	9.35	94.9
D8-1-1	40.5	11.5	4	5	8.25	90.0
D9-4-2	41	11.6	2.8	8	9.8	99.1
D10-4-1	42	12	2.8	8	10	100.0
D11-5-1	45	13	2.8	8	10.5	93.2
D12-1-1	46	13.2	4	5	9.1	88.0
D13-4-2	44	12.8	6	3	8.9	85.8
D14-1-1	43	12.6	3	8.5	10.05	95.1
D16-4-1	40.5	11.5	3	8.5	9.5	110.3
D18-5-2	43.5	12.9	2.5	10	11.45	83.8
D18-5-1	35	10.5	3.6	6	8.25	95.9
D19-4-2	38	11	3.8	5.3	8.15	84.2
D20-5-1	48	13.5	4.5	4.5	9	96.5
D21-5-1	42	12	3	8.5	9.85	88.8
Results					12.0	83.8–110.3 Avg. 92.3

Note: Results 1 – obtained from relationship between kiln-drying time and drying time from green to 1% under QDT; Results 2 – obtained from relationship between kiln-drying time and initial WBD.

8.6.3.9 *How to construct a drying schedule*

8.6.3.9.1 Method A

8.6.3.9.1.1 Refer to Table 8.5 (dry bulb temperature, wet bulb temperature and drying time form) and Table 8.6 (results of drying time and initial moisture content form).

8.6.3.9.1.2 Select initial MC, initial DBT and initial WBD. Choose DBT from Table 8.7 to match the number in Table 8.5 (in this case 45 °C). Choose initial MC from Table 8.8 to match the number in Table 8.6 (in this case about 110%), WBD from Table 8.8 (for hardwood) to match the number in Table 8.5 (in this case 2 °C). Table 8.9 is for softwood.

Table 8.7 Combination of moisture content and dry bulb temperature

Moisture content (%)	Dry bulb temperature (°C)													
Initial MC-30	38	40	45	45	50	50	55	55	60	60	65	70	75	80
30–25	42	45	50	50	55	55	60	60	65	65	70	75	80	90
25–20	42	50	55	55	60	60	65	65	70	70	70	75	80	90
20–15	45	55	60	60	65	65	70	70	70	75	80	80	90	95
Under 15	50	65	70	80	70	80	70	80	70	80	80	80	90	95

Table 8.8 Combination of moisture content range and wet bulb depression (hardwood)

Initial MC of wood (%)	40	50	60	75	90	110	Wet bulb depression (°C)							
Range of MC for drying schedule	40-30	50-35	60-40	75-50	90-60	110-70	2	2	3	4	6	8	11	15
	30-25	35-30	40-35	50-40	60-50	70-60	2	3	4	6	8	12	18	20
	25-20	30-25	35-30	40-35	50-40	60-50	3	5	6	9	12	18	25	30
	20-15	25-20	30-25	35-30	40-35	50-40	5	8	10	15	20	25	30	30
	15-10	20-15	25-20	30-25	35-30	40-35	12	18	18	25	30	30	30	30
	under 10	under 15	under 20	under 25	under 30	under 35	25	30	30	30	30	30	30	30

Table 8.9 Combination of moisture content range and wet bulb depression (softwood)

Initial MC of wood (%)	40	50	60	75	90	110	Wet bulb depression (°C)							
Range of MC for drying schedule	40-30	50-35	60-40	75-50	90-60	110-70	1.5	2	3	4	6	8	11	15
	30-25	35-30	40-35	50-40	60-50	70-60	2	3	4	6	8	11	14	17
	25-20	30-25	35-30	40-35	50-40	60-50	3	5	6	9	11	14	17	22
	20-15	25-20	30-25	35-30	40-35	50-40	5	8	8	11	14	17	22	22
		20-15	25-20	30-25	35-30	40-35	8	11	11	14	17	22	22	22
			20-15	25-20	30-25	35-30	11	14	14	17	22	22	22	22
				20-15	25-20	30-25	14	17	17	22	22	22	22	22
					20-15	25-20	17	22	22	22	22	22	22	22
						20-15	22	22	22	22	22	22	22	22
	under 15	under 15	under 15	under 15	under 15	under 15	30	30	30	30	30	30	30	30

8.6.3.9.2 Method B (by drawing on a semi-logarithm scale graph)

8.6.3.9.2.1 Sample schedule is shown in Figure 8.13 and Table 8.10.

8.6.3.9.2.2 DBT line

(1) Choose the initial temperature (in this case 45 °C)
(2) Draw a line from green to 30% MC
(3) Choose the final temperature (in this case 70 °C)
(4) Draw a line from 10 to 15%.
(5) Draw a connecting line

8.6.3.9.2.3 WBT line

(1) Choose the initial wet bulb depression (in this case 2.5 °C)
(2) Draw a line from green to 2/3 of initial MC (i.e. 2/3 of 110% MC = 75% MC)
(3) Choose the final wet bulb depression from 20 to 30 °C (in this case 20 °C)

This number depends on the appearance of internal checks in the QDT test.
No internal checks: 30 °C, extensive internal checks: 20 °C

(4) Draw a line from 10 to 15%
(5) Draw a connecting line
(6) Construct steps for wet bulb depression changes
(7) Draw the respective wet bulb temperature

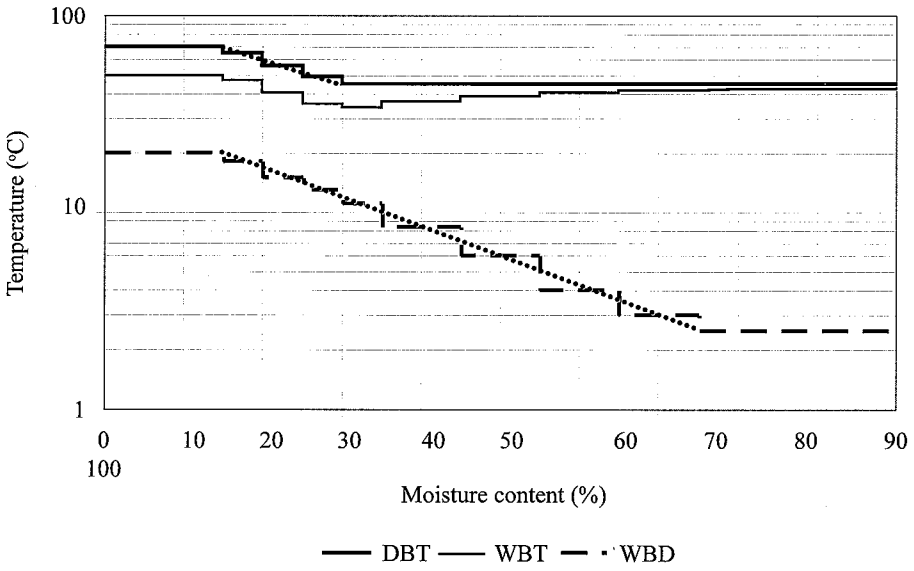


Figure 8.13 Drying schedule drawn following Method B

8.6.3.9.3 Construct a drying schedule based on the graph drawn using the QDT results in Figure 8.13 as shown in Table 8.10.

Table 8.10 Drying schedule for *Acacia mangium* using the QDT results

M.C	DBT	WBT	WBD	EMC	RH
(%)	°C	°C	°C	%	%
Above 75	45.0	43.0	2.0	18.3	89.0
75 to 65	45.0	42.6	2.4	19.1	86.0
65 to 55	45.0	41.6	3.4	15.1	81.0
55 to 45	45.0	40.2	4.8	13.0	74.0
45 to 35	45.0	38.1	6.9	10.9	64.0
35 to 30	45.0	35.0	10.0	8.4	52.0
30 to 25	48.0	35.4	12.4	7.2	43.0
25 to 20	56.0	37.0	19.0	6.3	40.0
20 to 15	65.0	47.0	18.0	5.2	37.0
15 to final	70.0	50.0	20.0	5.0	35.0
equalizing	70.0	60.5	9.5	7.6	64.0
conditioning	70.0	64.0	6.0	11.2	76.0

EMC – Equilibrium moisture content (%)
RH – Relative humidity (%)

8.6.3.9.4 In general, this schedule is comparatively mild and can be relied upon to give satisfactory results. This should be used as it is unless there are special considerations that some modifications are necessary, or until experience indicates that modifications can be made to provide an improvement.

8.6.4 *Drying-Schedule Test* (*DST*)

8.6.4.1 This test is important for establishing a good drying schedule. The fundamental schedule is decided by the QDT. At least three tests with different schedules (moderate, mild and severe) are needed. If a good drying schedule is derived by the DST, a practical drying method can be established quickly. The test periods are five to 20 days for specimens 27 mm thick, and 10 days to more than one month for specimens 54 mm thick. Testing is completed when the drying schedule is finished.

8.6.4.2 *Specimens.* Size of specimens is shown in Section 8.5.3.4.1. Both ends shall be coated with silicon/ bitumen paint to prevent water evaporation from the ends during test. Select board with mixed grain and slight defects. Prepare 10 to 20 specimens.

8.6.4.3 *Measurements.* Measure the initial weight, width and thickness of specimens and also for each time. Measurements are taken once a day.

8.6.4.4 Apply the drying schedule based on the QDT as shown in Table 8.10. Moisture content decreases with time and drying conditions (temperature setting) are changed according to the moisture content level.

8.6.4.5 If a continuous weighing system is available with the laboratory-design kiln, select a board for moisture control and set the value of moisture content. A board with moisture content value equivalent to the average moisture content plus the standard deviation of all the boards is preferred.

8.6.4.6 Stack boards in the laboratory-design kiln. Air flow inside the kiln is parallel to the stack from the one side.

8.6.4.7 The appearance time, length and width of all surface checks should be written directly on the surface of the specimen.

8.6.4.8 Cut the moisture content (MC) specimens at the centre of a board. Take two test strips 2 cm wide for measuring the average MC and distribution of MC (Section 8.6.1.6.2 and Figure 8.6).

8.6.4.9 *Summary of results*

8.6.4.9.1 Construct the drying curve based on the weight measurements at interval.

8.6.4.9.2 Quantify the defects, surface checks and distortion (cup, twist, bow).

8.6.4.9.3 Evaluate the defects to improve or modify the drying schedule.

8.6.4.9.3.1 If the test result is good, set the initial WBD of the drying schedule to a larger value. When the result is poor, set the initial WBD of the drying schedule to a smaller value. Repeat the same test at least three times.

8.6.4.9.3.2 When surface checks occur, set the initial WBD to a smaller value. When collapse and internal checks occur, set the final WBD of the drying schedule to a smaller value.

Forms

Form 8.1 Records of test boards and specimens for ADT, DRT, QDT and DST

Log No.	Drying log No.	ADT	DRT	QDT	DST

Form 8.2 Air-drying test – Data sheet*

Date:										
Time:										
Board No	Weight (g)	Thickness (I) (mm)	Thickness (II) (mm)	Thickness (III) (mm)	Width I (mm)	Width II (mm)	Length (mm)	Cup (mm)	Twist (mm)	Bow (mm)

* Form to be used for each measurement.

Form 8.3 Drying-rate test – Data sheet**

Board No.	Date: Time:			Date: Time:			Date: Time:		
	Weight (g)	Width (mm)	Thickness (mm)	Weight (g)	Width (mm)	Thickness (mm)	Weight (g)	Width (mm)	Thickness (mm)

** Each data sheet is used for three sets of measurements.
Form is to be duplicated for measurements until test completed.

Appendix 8.1

STANDARD TEST METHOD FOR DETERMINATION OF MOISTURE CONTENT

Scope
This test method describes a procedure to determine the moisture content in wood using the oven-drying test.

References
MS 837:2006. Method for the Determination of Moisture Content of Timber.
BS EN 13183-1: 2002. Moisture Content of a Piece of Sawn Timber – Part 1: Determination by Oven Dry Method.

Definition
The moisture content, MC, is defined as the weight of water per unit weight of dry wood and expressed as a percentage. The MC of the test piece shall be calculated from the formula:

$$MC = \frac{m_i - m_o}{m_o} \times 100\% \quad \text{..... Eqn. 8.2}$$

or

$$MC = \left(\frac{m_i}{m_o} - 1\right) \times 100\% \quad \text{..... Eqn. 8.3}$$

where,
MC = the moisture content of wood, in percentage
m_i = the initial weight of test specimen, in grams
m_o = the oven-dry weight of test specimen, in grams

The dry state is defined as the state after the wood sample has been dried in an oven at 103±2 °C for such a duration that repeated weighing of the sample, at intervals of 2 hr, shows a difference in mass of 0.1 per cent or less.

Sampling
Perform according to the specific requirements for each type of testing.

Equipment
Equipment required are as follows:
Top loading balance (accuracy 0.01 g)
Electrically heated oven set at 103±2 °C
Cross-cut saw

Procedure
The test pieces obtained shall be weighed immediately after cutting. If the test pieces cannot be weighed immediately, they should be placed in a plastic bag or tightly wrapped in cellophane to protect them from moisture change until they can be weighed. Balance with accuracy 0.1 g is used if the mass of each test piece is likely to be more than 100 g in an oven-dry state, and balance with accuracy 0.01 g is used if the mass of the test piece is likely to be less than 100 g in an oven-dry state.
The test pieces shall then be dried in an oven set at temperature of 103±2 °C for 24 hr or until constant weight is obtained. Smaller specimens will take less time.
In order to obtain accurate results, test pieces should be kept in a desiccator before re-weighing.
Re-weigh the dry sections to obtain the oven-dry weights.
Calculate the moisture content using equations 8.2 or 8.3.

STANDARD TEST METHOD FOR DETERMINATION OF WOOD DENSITY

Scope

This test method describes a procedure for determining the density (ratio of mass to volume) of wood at the moisture content at the time of test (conventional density), at absolutely dry condition (oven-dry density) and at green volume (basic density, ratio of oven-dry mass to green volume).

Reference:

IS0 3131: 1975 (E) Wood—Determination of Density for Physical and Mechanical Tests.

Definition

The density of wood is defined as the weight per unit volume of wood and is expressed in kg m^{-3} or g cm^{-3}. The wood density of the test piece shall be calculated from the formula as follows:

Conventional Density (ρ_w)

The density of test pieces at the moisture content, *w,* at test is given by the formula:

$$\rho_w = \frac{W_w}{L_w B_w H_w} = \frac{W_w}{V_w} \quad \text{..... Eqn. 8.4}$$

where,

W_w = weight of the test piece (in g) at moisture content, *w*
L_w = length of the test piece (in cm) at moisture content, *w*
B_w = breadth of test piece (in cm) at moisture content, *w*
H_w = height of the test piece (in cm) at moisture content, *w*
V_w = volume of the test piece (in cm^3) at moisture content, *w*

Oven-dry Density (ρ_o)

The density of test pieces in the absolutely dry (oven-dry) condition, is given by the formula:

$$\rho_o = \frac{W_o}{L_o B_o H_o} = \frac{W_o}{V_o} \quad \text{..... .Eqn. 8.5}$$

where,

W_o = weight of the test piece (in g) in the absolutely dry condition, *o*
L_o = length of the test piece (in cm) in the absolutely dry condition, *o*
B_o = breadth of test piece (in cm) in the absolutely dry condition, *o*
H_o = height of the test piece (in cm) in the absolutely dry condition, *o*
V_o = volume of the test piece (in cm^3) in the absolutely dry condition, *o*

Basic Density (ρ_b)

The basic density of test pieces at a moisture content greater than or equal to the fibre saturation point (green volume) is given by the formula:

$$\rho_b = \frac{W_o}{L_{max} B_{max} H_{max}} = \frac{W_o}{V_{max}} \quad \text{..... Eqn. 8.6}$$

where,

W_o = weight of the test piece (in g) in the absolutely dry condition, *o*
L_{max} = length of the test piece (in cm) in the green condition
B_{max} = breadth of test piece (in cm) in the green condition
H_{max} = height of the test piece (in cm) in the green condition
V_{max} = volume of the test piece (in cm^3) in the green condition

Principle: The mass of the test piece shall be obtained by weighing and its volume by measurements of its dimensions. The density of wood shall be calculated by dividing the weight by its corresponding volume.

Equipment

a. Veneer caliper (accuracy 0.01 mm)
b. Top loading balance (accuracy 0.01 g)
c. Electrically heated oven set at 103±2 °C
d. Cross-cut saw

Procedure

The test pieces obtained after cutting shall be weighed immediately to an accuracy of 0.01 g. If the specimens cannot be weighed immediately, they should be placed in a plastic bag or tightly wrapped in cellophane to protect them from moisture change until they can be weighed.
Measure the sides of cross-section and length of test pieces along the axes of symmetry to the nearest 0.1 mm.
Oven dry the test pieces at 103±2 °C to constant mass.
Weigh the test pieces to obtain their oven-dry weights.
Measure again the dimensions of the test pieces to obtain their oven-dry volumes.
Calculate the density of test pieces according to Eqns. 8.4, 8.5 or 8.6.
Determine the moisture content according to Appendix 8.1.

Chapter 9

Finger and Laminate Joints in Non-Structural Timber Products

9.1 Scope

This guideline is intended to be used to evaluate the adhesive bonds in the finger joints and laminate joints of non-structural products from plantation timbers. Adhesives that meet the requirements are considered capable of providing adequate bond for use under the various conditions.

To evaluate the adhesive bonds in the finger joints, test specimens shall be subjected to bending and tension tests with different service conditions for dry and wet uses and shall meet the requirements as stated in Table 9.5.

To evaluate the adhesive bonds in the laminate joints, test specimens shall be subjected to block shear test with different service conditions for dry and wet use respectively and shall meet the requirements as stated in Table 9.6 while delamination test shall meet the requirements as stated in Table 9.7.

9.2 Referenced Documents

9.2.1 ASTM D5751-99: 1999. Standard Specification for Adhesives Used for Laminate Joints in Nonstructural Lumber Products.

9.2.2 ASTM D5572-95: 2003. Standard Specification for Adhesives Used for Finger Joints in Nonstructural Lumber Products.

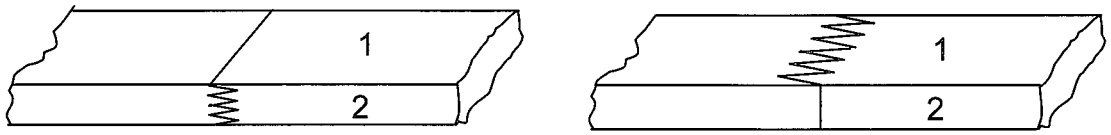
9.2.3 ISO 17087:2006(E). Specifications for Adhesives Used for Finger Joints in Non-structural Lumber Products.

9.2.4 JAS 2003, MAFF, Notification No. 234. Japanese Agricultural Standard for Glued Laminated Timber.

9.3 Definitions

9.3.1 *Bond*: Jointing of materials using adhesives.

9.3.2 *Finger Joint*: Joint formed by bonding two precut members shaped like fingers (see Figure 9.1).



a) Horizontal joint b) Vertical joint

Key:
1 Face
2 Edge

Figure 9.1 Finger joints

9.3.3 *Laminate Joint*: Joint made by bonding layers of adherents face to face or edge to edge to form thicker or wider stock.

9.3.4 *Dry-use Non-structural Adhesive*: Adhesive capable of producing sufficient strength and durability to make the bonded timber product serviceable in non-structural use, under conditions in which the equilibrium moisture content (EMC) of the timber does not exceed 18%.

9.3.5 *Wet-use Non-structural Adhesive*: Adhesive capable of producing sufficient strength and durability to make the bonded timber product serviceable in non-structural use, under conditions in which the equilibrium moisture content (EMC) of the timber may be 18% or greater.

9.3.6 *Elevated Temperature Testing*: Testing method designed to simulate conditions of short-term elevated temperature that might be experienced in transit, further processing, or in service.

9.3.7 *Equilibrium Moisture Content (EMC)*: Moisture content at which timber neither gains nor loses moisture to the surrounding air.

9.3.8 *Moisture Content (MC)*: Amount of water in the timber, usually expressed as a percentage of the mass of the oven-dry timber.

9.4 General Requirements

9.4.1 *General*

The cutting and the bonding operations of finger and laminate joints shall result in reliable and durable bonds of adequate strength within the appropriate service conditions. These general requirements shall be considered satisfied if the requirements in Sections 9.4.2 and 9.4.3 are fulfilled.

9.4.2 *Timber Species*

Any timber derived from a single species may be finger jointed or laminate jointed.

9.4.3 *Adhesives*

Non-structural finger-jointed or laminated timber shall be manufactured for use either in dry-use service condition or wet-use service condition as defined in Sections 9.3.4 or 9.3.5 respectively. The type of adhesive shall be chosen to maintain the finger- and laminate-joint strength and durability throughout the intended lifetime of the products.

Examples of adhesives for non-structural finger and laminate joints can be selected from Table 9.1.

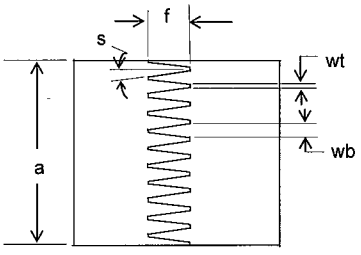
Table 9.1 Types of adhesive

Service condition	Type of adhesive*
Dry use (MC<18%)	Polyvinyl acetate, PVAc Emulsion polymer isocyanate, EPI
Wet use (MC≥18%)	Phenol-resorcinol formaldehyde, PRF Emulsion polymer isocyanate, EPI

*NOTE: Other adhesives as recommended by adhesive suppliers may be used should they meet the requirements of this manual.

9.4.4 *Finger-joint Geometry*

Finger joints are prepared using finger-joint cutter and composer. Figure 9.2 depicts a typical finger-joint configuration. The normal practice is to prepare test joints in cooperation with the manufacturer or equipment supplier having the necessary finger-joint cutter and assembly equipment. Such finger joints may vary in geometry and length from manufacturer to manufacturer, and it should be recognized that this variation could affect the performance of the bonded finger-joint assembly. When changes are made in the design of the industrially manufactured finger joint, the new design should be compared with a control design that has been used successfully.



Key:

a, height of joint	= 19 mm
f, length of finger	= 12 mm
W_t, width of finger tip	= 1 mm
W_b, width of finger base	= 3.5 mm
S, slope of finger	= 7°

Figure 9.2 Example of cross-section of a finger-joint specimen

9.5 Preparation of Test Specimens

Specimens are obtained randomly from different trees and may be quarter sawn, flat sawn or a mixture of quarter sawn and flat sawn. The specimens are cut to nominal size of 50 mm thick by 100 mm width and length not less than 3,000 mm for bending and tension tests and 1,200 mm for block shear and delamination tests.

9.5.1 *Bending and Tension Tests*

The cutting of specimens for finger joints shall be made according to Figure 9.3 and the number of test conditions for each type of adhesive as stated in Table 9.2.

9.5.2 *Block Shear Test*

The cutting of specimens for block shear test shall be made according to Figure 9.4 and the number of test conditions for each type of adhesive as stated in Table 9.3.

9.5.3 *Delamination Test*

The cutting of specimens for delamination test shall be made according to Figure 9.4 and the number of test conditions as stated in Table 9.4.

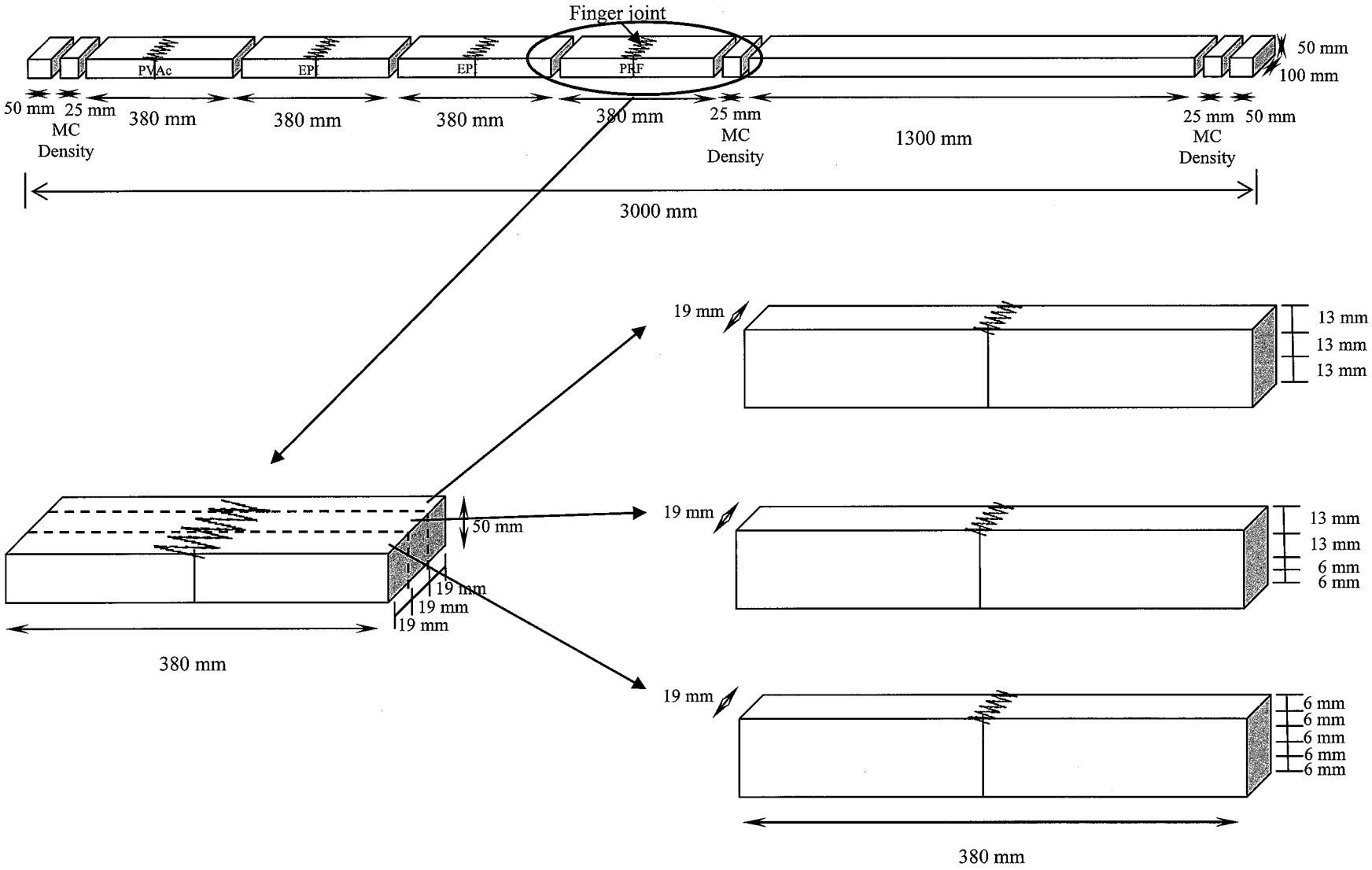


Figure 9.3 Preparation of specimens for bending and tension tests

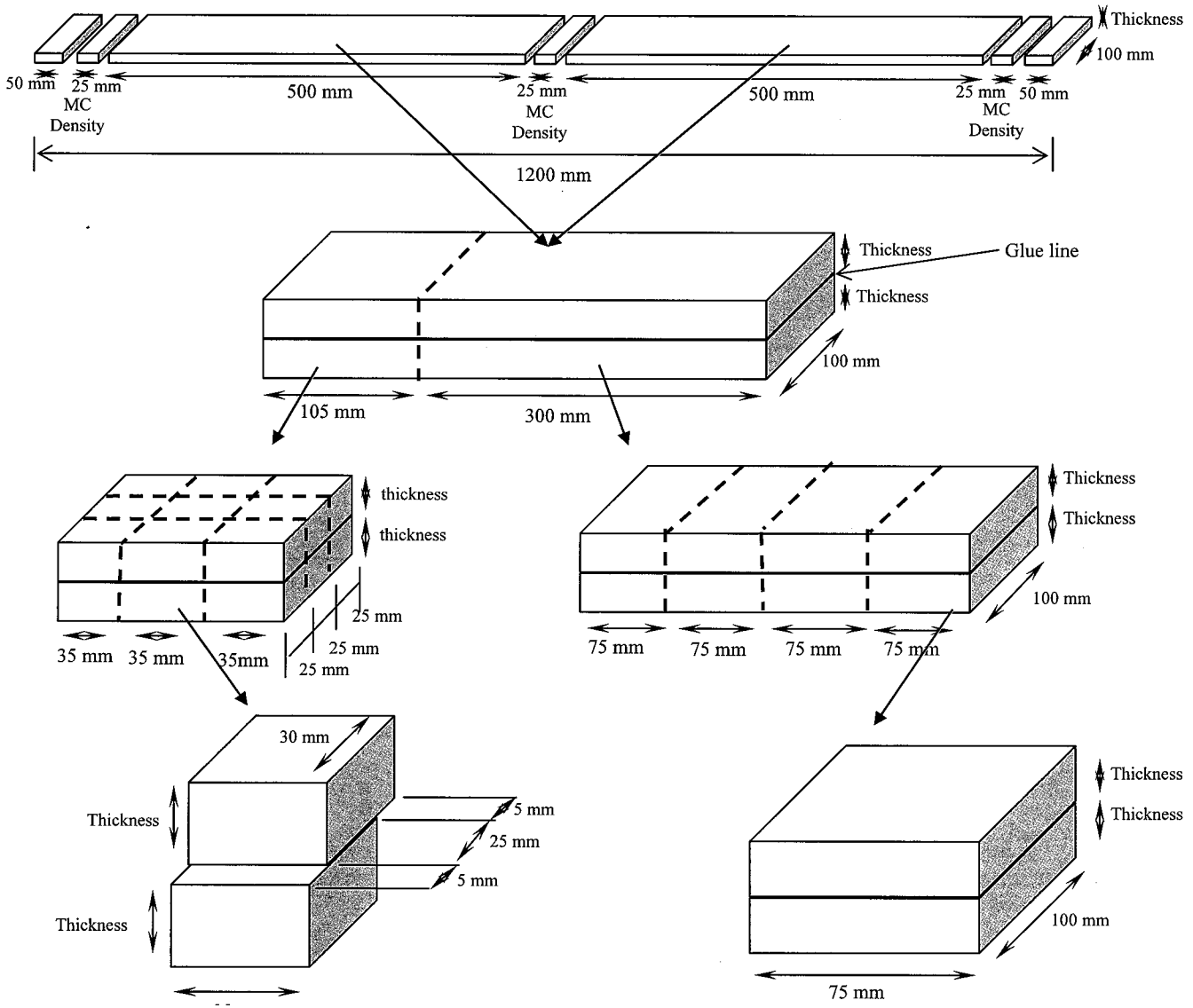


Figure 9.4 Preparation of specimens for block shear and delamination tests

Table 9.2 Summary of test conditions for different adhesives and test types (bending and tension)

Test	Specimen dimensions (mm)	Condition for each type of adhesive															
		Dry use								Wet use							
		PVAc				EPI				PRF				EPI			
Bending	13(d)×19(b)×362(L)	Dry		Water soak		Dry		Water soak		Dry	Boil	Vacuum-pressure		Dry	Boil	Vacuum-pressure	
Tension	6(d)×19(b)×254(L)	Dry	Water soak	Elevated temp.	Temp-humidity	Dry	Water soak	Elevated temp.	Temp-humidity	Dry	Boil	Elevated temp.	Vacuum-pressure	Dry	Boil	Elevated temp.	Vacuum-pressure

Table 9.3 Summary of test conditions for different adhesives for block shear test

Test	Test specimen dimensions (mm)	Condition for each type of adhesive															
		Dry use						Wet use									
		PVAc			EPI			PRF				EPI					
Block shear test	25 × 30 × thickness	Dry	Water soak	Elevated temp.	Dry	Water soak	Elevated temp.	Dry	Boil	Elevated temp.	Vacuum-pressure	Dry	Boil	Elevated temp.	Vacuum-pressure		

Table 9.4 Summary of test conditions for different adhesives for delamination test

Adhesive type*	Test specimen dimensions (mm)	Delamination test			
PVAc	75(W) × 100 (L) × thickness	Treatment I (6 hours)	Treatment II (24 hours)	Treatment III (Boil)	Treatment IV (Vacuum-pressure)
EPI					
PRF					

* Refer to Table 9.1·

9.6 Test Requirements

Test requirements for both finger and laminate joints are given in Tables 9.5, 9.6 and 9.7. The exposure conditions stipulated in each dry and wet-use condition are given in Section 9.11.

9.6.1 *Finger-jointed Test Specimens*

These specimens may be used to evaluate the properties of joints and are tested against the requirements in Table 9.5.

Table 9.5 Test requirements for finger joints

Service condition	Tension test			Bending test
	Strength (MPa)	Wood failure		MOR (MPa)
		Group average (%)	Individual minimum (%)	
		Hardwood	Hardwood	
Dry use				
Dry	13.8	30	15	13.8
Water soak	6.9	15	-	6.9
Elevated temperature (104 °C)	6.9	-	-	-
Temperature / humidity (65 °C, 16% EMC)	5.2	-	-	-
Wet use				
Dry	13.8	30	15	13.8
Boil	11.0	25	-	9.7
Elevated temperature (104 °C)	6.9	-	-	-
Vacuum-pressure	11.0	25	-	9.7

9.6.2 *Laminate-jointed Test Specimens*

These specimens may be used to evaluate the properties of lamination and are tested against the requirements in Table 9.6.

Table 9.6 Test requirements for laminate joints at 12% moisture content

Service condition	Laminate joint in shear			
	Strength (MPa)*		Wood failure	
	Group average**	Individual minimum**	Group average (%)	Individual minimum (%)
			Hardwood	Hardwood
Dry use				
Dry	5.32	2.66	30	15
Water soak	2.66	1.33	15	-
Elevated temperature (104 °C)	3.55	1.77	20	-
Wet use				
Dry	5.32	2.66	30	15
Boil	4.44	2.22	25	-
Elevated temperature (104 °C)	3.55	1.77	20	-
Vacuum-pressure	4.44	2.22	25	-

* For tests conducted in which the moisture content is less than or greater than 12%, the measured strength should be adjusted upward 3% for each 1% decrease in moisture content, or downward 3% for each 1% increase in moisture content.

** Values are based on the average shear strength of western hemlock at 12% moisture content.

9.6.3 *Delamination Test Specimens*

These specimens may be used to evaluate the properties of joints and are tested against the requirements in Table 9.7.

Table 9.7 Test requirements for delamination test

Accelerated treatment	Delamination ratio (%)	Ratio of delamination to the respective length
Treatment I	Less than 10%	Less than 1/3
Treatment II	Less than 10%	Less than 1/3
Treatment III	Less than 5%	Less than 1/4
Treatment IV	Less than 5%	Less than 1/4

9.7 Test Specimens

9.7.1 Suitable equipment shall be available for the production of finger joints or laminate joints.

9.7.2 Specimens used shall conform to the following requirements:

9.7.2.1 Moisture content within 10% and 12% prior to bonding.

9.7.2.2 Free of knots and decay.

9.7.2.3 Free of machining defects such as chipped grain, roller marks and coarse knife marks.

9.7.2.4 Free of drying effects such as case hardening, collapse and splits or checks.

9.7.3 The moisture content of specimen shall be measured by the oven-drying method to verify that it lies within the specified range.

9.7.4 Conditions and procedures for preparing and applying of adhesives, as well as for assembling, pressing and curing shall follow the instructions of the adhesive manufacturer.

9.7.5 Thirty (30) specimens shall be made available for each test group based on Figures 9.3 and 9.4.

9.7.6 Adhesive shall be applied such that all surfaces are evenly spread. This requirement can be assumed to be met if beads of adhesive are 'oozed out' on all surfaces around the joint when the end pressure is applied.

9.7.7 For finger and laminate joints, lumber with various grain orientations (flat sawn or quarter sawn) shall be allowed to be used interchangeably.

NOTE: Any deviation in range of moisture content should show that there are no differences in the results obtained and if otherwise correlation shall be established.

9.8 Apparatus (General)

9.8.1 *Equipment*

The equipment used in this clause is for general use while that for specific use is listed under each test procedure in Sections 9.9, 9.10 and 9.11.

9.8.2 *Environmental Chamber*

Capable of conditioning specimens at (23 $\pm$ 2) °C and (65 $\pm$ 5) % relative humidity and capacity for at least 30 specimens well-spaced and supported on racks to allow free air flow.

NOTE:

a. If it is not possible to maintain this relative humidity in the laboratory, test pieces shall be tested immediately after conditioning or on their removal from the sealed vessels.

b. Correlation shall be established for specimens under individual local condition and ambient environment.

9.9 Test Procedures for Finger Joints

9.9.1 *Bending Test*

9.9.1.1 *Apparatus (universal testing machine)*

The machine shall have a capacity of not less than 1,000 kg in compression and shall be equipped for one-third-span, two-point loading for the bending test as described in 9.9.1.2 and shown in Figure 9.5.

9.9.1.2 *Procedure*

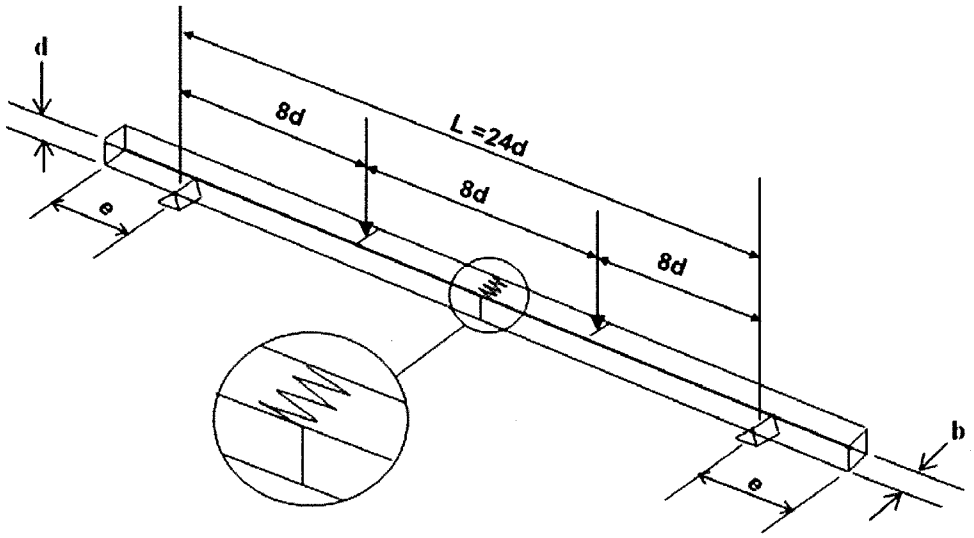
The finger-jointed specimen shall be cut with sufficient length for the joint to be centred at mid-span as in Figure 9.5, and with a distance between reaction points of at least 24 multiplied by the depth, *d*. Allow at least 25 mm (1 inch) at both ends of the specimen outside the reaction points (overhang) (see dimension *e* in Figure 9.5).

Apply the load with a continuous motion of the movable head at a rate of 12 mm min^{-1} ($\pm$ 10%), testing the specimens by one-third span, two-point loading with the load applied perpendicular to the face showing the fingers, as shown in Figure 9.5.

Report the stress at rupture values on Form 9.1 (Annex A). Also, report the measurements of specimen length (L), width or thickness (b) and depth (d), as well as finger length, width (base and tip) and slope.
Calculate the modulus of rupture MOR, in megapascals (MPa) as follows:

$$MOR = \frac{PL}{bd^2} \quad \text{..... Eqn. 9.1}$$

where,
MOR = modulus of rupture (MPa)
P = maximum load (N)
L = length of span between the reaction points ($24d$) (mm)
b = width of specimen (mm)
d = depth of specimen (mm)



Key:

L, length of specimen between reaction points	= 312 mm
b, width of vertical joint	= 19 mm
d, depth of specimen	= 13 mm
e, length of specimen outside reaction points	= at least 25 mm

Figure 9.5 Typical test specimen dimensions and set-up for bending test

9.9.2 *Tension Test*

9.9.2.1 *Apparatus (universal testing machine)*

The machine shall be equipped with grips of sufficient length to hold the specimen firmly, preferably with a minimum length of 63 mm and minimum width of 19 mm and capacity of test machine of not less than 1,000 kg.

9.9.2.2 *Procedure*

From a finger-jointed assembly, cut the tension test specimens measuring 6 mm (width) by 19 mm (height) with a length of 254 mm as shown in Figure 9.6.

Attach the specimen to the test machine and apply the load with a continuous motion of the movable head at a rate of 13 mm min^{-1}.

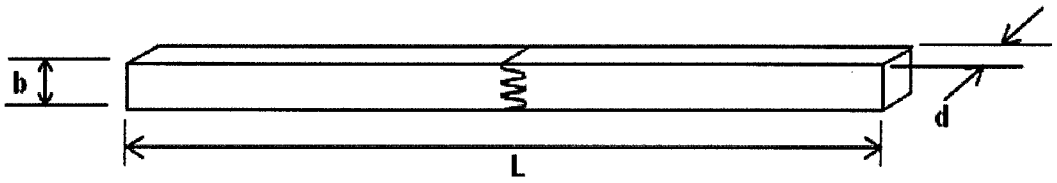
Report the tensile stress values, together with the estimated percentages of wood failure on the forms shown in Forms 9.2 and 9.3 for dry use or Forms 9.4 and 9.5 for wet use. Also, report the slope of the finger in degrees and the dimensions of each specimen to the nearest 0.1 mm: length of the finger f, width of the finger at the tip W_t and width of the finger at the base W_b (see Figure 9.2).

Estimate the wood failure at the finger joints visually to the nearest 5% (see Annex B for guidelines on reading wood failure). In addition, the failure mode and location of failure may be noted, i.e. as wood failure away from the joint, through the tips or follow the fingers.

Calculate the tensile stress TS, in megapascals (MPa) as follows:

$$TS = \frac{P}{bd} \quad \text{..... Eqn. 9.2}$$

where,
TS = tensile stress (MPa)
P = maximum load (N)
b = width of specimen (mm)
d = depth of specimen (mm)



Key:

L, length of specimen	= 254 mm
b, width of specimen	= 19 mm
d, depth of specimen	= 6 mm

Figure 9.6 Typical test specimen dimensions and set-up for tension test

9.10 Test Procedures for Laminate Joints

9.10.1 *Block Shear Test*

9.10.1.1 *Apparatus (universal testing machine)*

The machine shall have a capacity of not less than 6,810 kg in compression and shall be equipped with a shearing tool containing a self-aligning seat to ensure uniform lateral distribution of the load as shown in Figure 9.7, capable of maintaining a uniform rate of loading at 12.8 mm min^{-1} (± 10%).

9.10.1.2 *Procedure*

The test piece in the form as shown in Figure 9.4 shall be prepared in a manner that the glue line of the lamination shall be included. The moisture content of the test piece shall be 12 % (± 1%) when testing.

The block shear test shall be conducted using a testing machine with a capacity stated for compression as in Section 9.10.1.1 and the shearing device designed to set the shear surface parallel to the loading axis. The load shall be applied to the glue line until failure occurs. The load at failure is recorded and the wood failure percentage is evaluated. Report the results in Forms 9.6, 9.7 and 9.8.

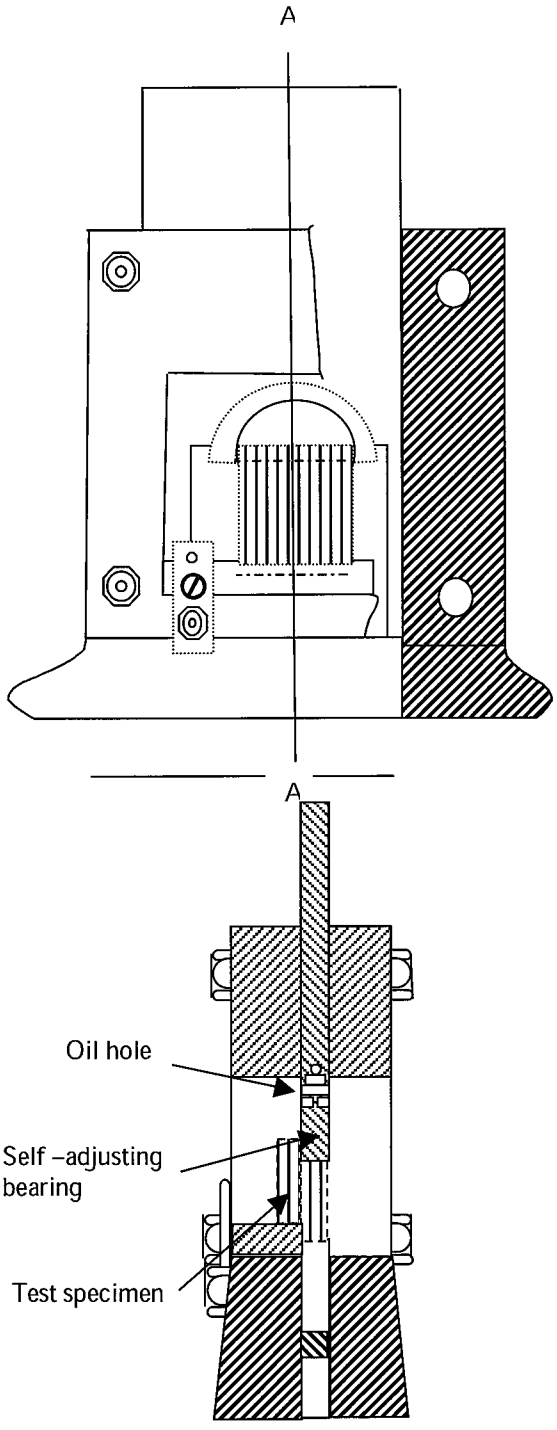


Figure 9.7 Shearing Tool

Calculate the shear strength, SS, in MPa, as follows:

$$SS = \frac{\bar{P}}{A} \quad \text{.....Eqn. 9.3}$$

SS = shear strength (MPa)
P = maximum load at failure (N)
A = glued area (mm^2)

9.10.2 *Delamination Test*

Test specimens shall be subjected to all accelerated treatments as stated in Sections 9.10.2.2, 9.10.2.3, 9.10.2.4 and 9.10.2.5 and shall meet the requirements as stated in Table 9.7.

9.10.2.1 *Procedure*

The test specimen shall be cut from laminated wood in the size of the actual cross section 75 mm in width and 100 mm in length as shown in Figure 9.4. The initial weight of the specimens shall be measured. Then test specimens shall be subjected to the accelerated treatments. After the accelerated treatments, the length of any delaminations longer than 3 mm and gaps of more than 0.05 mm at both ends of each specimen shall be measured. In the measurement of delamination, ruptures caused by dried splits shall not be considered as delamination. The weight of each specimen after the treatments shall be measured and recorded. The weight of specimens shall not be more than the initial weight prior to testing. In the case where the tested specimen weight is higher than the initial weight, further drying of about 1 hour is needed. Use Form 9.9 to record the data.

9.10.2.2 *Accelerated treatment I*

The test specimens, after being immersed in water at room temperature (10–25 °C) for 6 hr, shall be taken out of the water and dried at a thermostat-controlled temperature of 40 ± 3 °C with good air ventilation for 18 hr or longer.

9.10.2.3 *Accelerated treatment II*

The test specimens, after being immersed in water at room temperature (10–25 °C) for 24 hr, shall be taken out of the water and dried at a thermostat-controlled temperature of 70 ± 3 °C with good air ventilation for 18 hr or longer.

9.10.2.4 *Accelerated treatment III*

The test specimens, after being immersed in boiling water for 4 hr and then cooled in water at room temperature (10–25 °C) for 1 hr, shall be taken out of the water and dried at a thermostat-controlled temperature of 70 ± 3 °C with good air ventilation for 18 hr or longer.

9.10.2.5 *Accelerated treatment IV*

The test specimens immersed in water at room temperature (10–25 °C) shall be applied a vacuumed pressure of 0.084 MPa for 5 min and then applied a high pressure of 0.51 ± 0.03 MPa for 1 hr. This process shall be repeated twice. After that test pieces shall be taken out from the water and dried at a thermostat-controlled temperature of 70 ±3 °C with good air ventilation for 18 hr or longer. The moisture content after drying shall be made below the moisture content before testing.

9.10.2.6 *Evaluation*

The delamination ratio shall be calculated by the following equation:

$$\text{Ratio of delimination (\%)} = \frac{\text{total of the length of delamination on both ends}}{\text{total length of glue line on both ends}} \times 100\% \text{ .... Eqn. 9.4}$$

9.11 Exposure Conditions

The exposure conditions stipulated here are applicable to samples for dry and wet use respectively. These conditions are spelt out in Tables 9.5 and 9.6 in which the expected minimum values of the finger and laminated joints after a series of exposure conditions are given in the same table.

9.11.1 *Dry Test*

9.11.1.1 *Procedure*

Following the prescribed curing period for the adhesive being tested, condition or dry one group of the specimens to within ± 1% of the original moisture content (MC) of <18%.

9.11.2 *Water-Soak Test (Three-cycle)*

9.11.2.1 *Apparatus (soaking tank)*

The tank shall have a capacity meeting the requirements such that all of the specimens are at least 50 mm below the water-level for the duration of the soak cycles.

9.11.2.2 *Procedure*

Place the specimens in water at 23 ± 2 °C in the soak tank, separated by stickers, wire screens or other suitable means in such a manner that all surfaces are freely exposed to the water. Weigh down the specimens so that all specimens are at least 50 mm below the surface of the water. Keep the specimens immersed for a period of 4 hr, followed by drying at a temperature of 41 ± 2 °C for a period of 19 hr, with sufficient air circulation to reduce the moisture content of the specimens to within ± 1% of the original MC. Repeat this procedure twice more for a total of three cycles. Following the third cycle, conduct the tests in the dry condition at 23 ± 2 °C.

9.11.3 *Elevated Temperature (104 °C) Test*

9.11.3.1 *Apparatus (oven)*

With sufficient air circulation to remove moisture from the oven chamber and capable of meeting all the following temperature requirements: 41 ± 2 °C, 65 ± 2 °C, 104 ± 2 °C and 110 ± 2 °C.

9.11.3.2 *Procedure*

For finger joints: Place one group of specimens in an oven at 104 ± 2 °C and hold for 6 hr. Remove the specimens individually and immediately wrap each in two layers of polyvinylidene chloride (PVDC) wrap. Place the wrapped specimens in a single layer in an oven at 110 ± 2 °C and hold for a minimum of 12 min and maximum of 20 min. Remove them from the oven one specimen at a time, and test within 30 sec without removing the PVDC wrap. Conduct the test in a room with an ambient temperature of 23 ± 2 °C.

For laminate joints: Test the specimens for the effect of elevated temperature by heating the specimens to 104 ± 3 °C for 6 hr. The oven shall be located near to the testing machine while the specimens shall be removed one at a time and tested immediately.

9.11.4 *Temperature/Humidity (65 °C, 16% EMC) Test*

9.11.4.1 *Procedure*

For finger joints: Place one group of specimens to equilibrium at 27 ± 2 °C and 80 ± 5 % relative humidity (equivalent to 16% EMC). Wrap each specimen in two layers of polyvinylidene chloride (PVDC) wrap and place in a single layer in an oven at 65 ± 2 °C and hold for a minimum of 12 min and maximum of 20 min. Remove them from the oven one specimen at a time, and test within 30 sec without removing the PVDC wrap. Conduct the test in a room with an ambient temperature of 23 ± 2 °C. Note that the temperature of a specimen 15 sec after removal from the oven will be approximately 60 °C. This cool-down rate is based on actual tests on specimens.

9.11.5 *Boil Test (Two-cycle)*

9.11.5.1 *Apparatus (boiling tank)*

The tank shall have a capacity meeting the requirements so that all of the specimens are at least 50 mm below the water-level for the duration of the boil cycles.

9.11.5.2 *Procedure*

Place one group of specimens in a tank of boiling water, separated by stickers wire screens or other suitable means in such a manner that all surfaces are freely exposed to the water. Weigh down the specimens so they remain immersed by at least 50 mm during the boil cycle. Boil for 4 hr. Dry for 20 hr at 65 ± 2 °C with sufficient air circulation to lower the MC of the specimens to the original MC, within an allowable variation of ± 1%. Determine the MC by removing a specimen at 18, 19 and 20 hr and testing with a moisture meter until the MC reading is in the desired range, or predetermine the time required to reach the desired MC by running trials. Repeat the 4-hr boil cycle. Then remove the specimens and cool in running water at 18 °C to 27 °C for 1 hr. Remove the specimens from the water and place them in a plastic bag to keep them wet. Test while wet within 1 hr.

9.11.6 *Vacuum-Pressure Test*

9.11.6.1 *Apparatus (vacuum-pressure vessel)*

The vacuum-pressure vessel shall have capacity of meeting the requirements so that all of the specimens are at least 50 mm below the water-level for the duration of the vacuum-pressure cycle.

9.11.6.2 *Procedure*

Place 30 specimens in a pressure vessel, separated by stickers, wire screens or other suitable means in such a manner that all surfaces will be freely exposed to the water. Weigh down the specimens and fill the vessel with water at 18 to 27 °C so that all specimens are immersed by at least 50 mm. Produce and maintain a vacuum of at least 84.4 kPa for 30 min. Release the vacuum and follow immediately with pressure of 517 ± 14 kPa for 30 min. Remove the specimens from the vessel and place in a plastic bag to keep them wet. Test while wet within 1 hr. Dry to less than 8% MC for clear reading of the wood failure.

Annex A

Report Forms

This annex provides report forms that are intended to be used to record test results and to provide an easy reference to determine whether the specimens prepared under test satisfy the requirements.

a) A report form for the bending test is given in Form 9.1.
b) Report forms for the tension test are given in Forms 9.2, 9.3, 9.4 and 9.5.
c) Report forms for the block-shear test are given in Forms 9.6, 9.7 and 9.8.
d) A report form for the delamination test is given in Form 9.9.

Form 9.1 Bending test for dry use and wet use

Test specimens dimensions:

a) length, L: b) width, b: c) depth, d:

Loading speed:

Finger dimensions

a) finger length, f: b) width (tip), W_t: *c)* width (base), W_b: d) slope, s:

Specimen No.	MOR (dry use) (MPa)		MOR (wet use) (MPa)		
	Dry	Water soak	Dry	Boil	Vacuum-pressure
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
Required avg. MOR (MPa)	13.8	6.9	13.8	9.7	9.7
Passed?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Meet dry-use requirement? Yes_____ No_____			Meet wet-use requirement? Yes_____ No_____		

Form 9.2 Tension test for dry use (dry test and water soak test)

Test specimens dimensions:

a) length, L: b) width, b: c) depth, d:

Loading speed:

Finger dimensions:

a) finger length, f: b) width (tip), W_t: c) width (base), W_b: d) slope, s:

Specimen No.	Dry		Water soak	
	Strength (TS) (MPa)	Wood failure (WF) (%)	Strength (TS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
Required avg. TS (MPa)	13.8	-	6.9	-
WF (%) group avg.	-	30	-	15
WF (%) individual	-	15	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet dry-use requirement? Yes_____ No_____				

Form 9.3 Tension test for dry use (elevated-temperature [104 °C] test and temperature/humidity [65 °C, 16% EMC] test)

Specimen No.	Elevated temperature (104 °C)		Temperature/humidity (65 °C, 16% EMC)	
	Strength (TS) (MPa)	Wood failure (WF) (%)	Strength (TS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
Required avg. TS (MPa)	6.9	-	5.2	-
WF (%) group avg.	-	-	-	-
WF (%) individual	-	-	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet dry-use requirement? Yes_____ No_____				

Form 9.4 Tension test for wet use (dry test and boil test)

Specimen No.	Dry		Boil	
	Strength (TS) (MPa)	Wood failure (WF) (%)	Strength (TS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
Required avg. TS (MPa)	13.8	-	11.0	-
WF (%) group avg.	-	30	-	25
WF (%) individual	-	15	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet wet-use requirement? Yes_____ No_____				

Form 9.5 Tension test for wet use (elevated-temperature [104 °C] test and vacuum-pressure test)

Specimen No.	Elevated temperature (104 °C)		Vacuum-pressure	
	Strength (TS) (MPa)	Wood failure (WF) (%)	Strength (TS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
Required avg. TS (MPa)	6.9	-	11.0	-
WF (%) group avg.	-	-	-	25
WF (%) individual	-	-	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet wet-use requirement? Yes_____ No_____				

Form 9.6 Block-shear test for dry use

Specimen No.	Dry		Water soak		Elevated temperature (104 °C)	
	Strength (SS) (MPa)	Wood failure (WF) (%)	Strength (SS) (MPa)	Wood failure (WF) (%)	Strength (SS) (MPa)	Wood failure (WF) (%)
1						
2						
3						
4						
5						
6						
7						
8						
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25						
26						
27						
28						
29						
30						
Required individual SS (MPa)	2.66	-	1.33	-	1.77	-
Required avg. SS (MPa)	5.32	-	2.66	-	3.55	-
WF (%) group avg.	-	30	-	15	-	20
WF (%) individual	-	15	-	-	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Meet dry-use requirement? Yes_____ No_____						

Form 9.7 Block-shear test for wet use (dry test and boil test)

Specimen No.	Dry		Boil	
	Strength (SS) (MPa)	Wood failure (WF) (%)	Strength (SS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
Required individual SS (MPa)	2.66	-	2.22	-
Required avg. SS (MPa)	5.32	-	4.44	-
WF (%) group avg.	-	30	-	25
WF (%) individual	-	15	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet wet-use requirement? Yes_____ No_____				

Form 9.8 Block-shear test for wet use (elevated temperature [104 °C] test and vacuum-pressure test)

Specimen No.	Elevated temperature (104 °C)		Vacuum-pressure	
	Strength (SS) (MPa)	Wood failure (WF) (%)	Strength (SS) (MPa)	Wood failure (WF) (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
Required individual SS (MPa)	1.77	-	2.22	-
Required avg. SS (MPa)	3.55	-	4.44	-
WF (%) group avg.	-	20	-	25
WF (%) individual	-	-	-	-
Passed?	Yes/No	Yes/No	Yes/No	Yes/No
Meet wet-use requirement? Yes_____ No_____				

Form 9.9 Delamination test

a) Adhesive (s) used: b) Treatment:

Specimen No.	Total length of delamination at both ends (mm)	Total length of glue line at both ends (mm)	Ratio of delamination (%)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
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23			
24			
25			
26			
27			
28			
29			
30			
Delamination ratio shall meet the requirements of the respective treatment in Table 9.7			
Meet requirements? Yes_____ No_____			

Annex B

Reading Wood Failure in Finger Joints

1. General

The types of failure that occur in finger-jointed specimens due to tension loading can be roughly classified into six modes. The failure mode of each specimen should be based on the written and graphical descriptions given in Table 9.8.

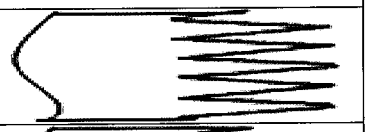
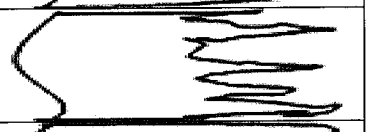
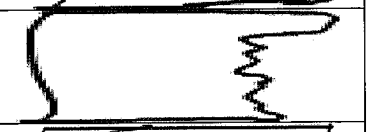
Failure modes 1 and 2 require the evaluator to make a distinction between less than 70% wood failure and more than 70% wood failure. This is often a difficult quantity to judge from an oblique angle. In difficult cases, it is suggested that the fingers be cut off at their roots so that the failed surfaces of the finger can be viewed directly.

2. Procedure to determine wood failure of finger joints

The following procedure has been shown to be helpful in determining the wood-failure percentage of finger joints:

a) Do not estimate the wood-failure percentage of specimens with localized defects such as knots, knot holes, burls and voids in the bonded area.
b) Work in a location where direct outside light does not fall on the specimens.
c) Select a light source and use it consistently. A dual-element desk lamp equipped with one 15-W daylight and one 15-W cool white tube is recommended.
d) When reading wood failure on finger joints, hold the specimen with the length of the fingers perpendicular to the line between the light source and the eye.
e) Dyes are sometimes helpful in distinguishing wood failure from light-coloured adhesives.
f) Magnification, rotation of the specimen and variation of the incident angle of the light on the surface are often necessary to distinguish shallow wood failure from adhesive failure, especially when the adhesive is light-coloured or transparent. Magnification may or may not be used to make the actual estimate of the wood failure; however, the practice should be consistent. After rotation, always reposition the specimen to the standard position before making the estimate of wood failure.
g) Mentally divide the surface into quadrants for estimating the areas of various forms of failure.
h) Estimate total wood-fibre failure of each specimen to the nearest 5%, with a maximum of 100% of the total bonded test area.
i) For accuracy and consistency, special care should be taken in the middle range from 30 to 85% where most of the difficulty occurs.
j) The colour of the adhesive and recognition of shallow wood failure affect the estimate.
k) If the percentage of wood failure is high and the failure is mostly on the side of the adhesive layer, the grain orientation can be a factor.
l) Record any indications of poor spread, lack of adhesive transfer or other bonding problem.

Table 9.8 Failure mode criteria

Mode	Description	Example
1	Failure mostly along the bondline surface of the joint profile with poor wood failure of any kind. (Wood failure < 70%)	
2	Failure mostly along the bondline surface of the joint profile with good wood shear failure. (Wood failure > 70%)	
3	Failure mostly along the joint profile but with some failure at the finger roots or scarf tips. Good overall wood shear failure along the joint profile surfaces.	
4	Mostly tensile wood failure at the finger-joint roots or scarf tips and with high overall wood failure. Little failure of any kind along the joint profile.	
5	Failure beginning at the joint (possibly due to a stress riser) and progressing away from the joint. Essentially 100% wood failure.	
6	Failure away from the joint (not influenced by the joint). All-wood failure.	

Chapter 10

Chemical Properties

10.1 Scope

This section describes the procedures to determine the contents of the major components of wood and its extractives in terms of solubles in polar and non-polar solvents. It also includes the determinations of tannins and sugars in barks.

10.2 Referenced Documents

10.2.1 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., editors).

10.2.2 Anonymous. 2004. Determination of Sugars. Testing Methods of Various Wood Properties of Fast-Growing Tropical Timbers. Technical Report of the Project Development Committee No. 13. Forestry and Forest Products Research Institute, September 2004 , p. 84.

10.2.3 Malaysian Standard MS 837: 2006. Solid Timber – Determination of Moisture Content.

10.2.4 TAPPI Test Method T 204 – OM 88. Solvent Extractives of Wood and Pulp.

10.2.5 TAPPI Test Method T 207 – OM 93. Water Solubility of Wood and Pulp.

10.2.6 TAPPI Test Method T222 – OM 88. Acid Insoluble Lignin in Wood and Pulp.

10.2.7 TAPPI Test Method T 223 – CM 84. Pentosans in Wood and Pulp.

10.2.8 Wise, Murphy & D'Addico. 1946. Holocellulose in Wood. Paper Trade Journal : 122 # 2, p. 35.

10.3 Definitions

10.3.1 *Major Components of Wood* : Lignin, cellulose and carbohydrates (normally called hemicelluloses). Extractives are solvent soluble, non-volatile materials in wood.

10.3.2 *Major Components of Bark* : 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.

10.4 Equipment

10.4.1 *Moisture Content:* Weighing bottle, desiccator, analytical balance capable of measuring up to 0.000 g, drying oven capable of maintaining a temperature of 105 ± 2 °C.

10.4.2 *Water Solubles, Oils and Waxes, and Total Extractives:* Desiccator, 250 ml round-bottomed flask, heating mantle, Soxhlet extractor, reflux condenser, rotary evaporator, analytical balance capable of measuring up to 0.0001 mg, drying oven capable of maintaining a temperature of 103 ± 2 °C.

10.4.3 *Acid Insoluble Lignin:* 2,000-ml filtering flask, 30-ml filtering crucible (porosity F), adaptor, siphon tube, 1,000-ml Erlenmeyer flask, reflux condenser, 100-ml beakers, glass rod, pipette, burette, hot plate, analytical balance capable of measuring up to 0.0001 g, drying oven capable of maintaining a temperature of 105 ± 2 °C, constant temperature water bath 20 ± 1 °C, watch glass.

10.4.4 *Holocellulose :* Fritted glass crucible (porosity 1), desiccator, 250-ml round-bottomed flask, constant temperature water bath 20 ± 1 °C, reflux condenser, dropping funnel, analytical balance capable of measuring up to 0.0001 mg, drying oven capable of maintaining a temperature of 105 ± 2 °C.

10.4.5 *Pentosans:* 350-ml round conical flask, 250-ml separatory funnel, Graham condenser, three- and two-way connecting tubes, adjustable heater, pipette, 500-ml measuring cylinder and 250-ml volumetric flask.

10.4.6 *Tannins:* 10-, 25- and 100-ml volumetric flasks, 0.1–1.0-ml micro-pipettes, Procter's filter bell, analytical balance capable of measuring up to 0.0001 g, vacuum drier, UV-VIS spectrophotometer.

10.4.7 *Sugars:* 10- and 100-ml volumetric flasks, 0.1–1.0-ml micro-pipettes, centrifuge with 15- and 40-ml tubes, 20-ml glass sample tubes, analytical balance capable of measuring up to 0.0001 g, vacuum drier, UV-VIS spectrophotometer.

10.5 Chemicals

10.5.1 *Moisture Content:* Silica gel (blue) for drying.

10.5.2 *Water Solubles, Oils and Waxes, and Total Extractives:* Silica gel (blue) for drying, boiling stones, extraction thimble, deionized water, hexane and 2:1 benzene-ethanol (95%).

10.5.3 *Acid Insoluble Lignin:* Silica gel (blue) for drying, 72% sulphuric acid solution, 24 ± 0.1N, S.G. 1.6338 at 20 °C (prepared from addition of 665 ml of concentrated sulphuric acid of S.G. 1.84 into 300 ml of water and making up to 1,000 ml after cooling).

10.5.4 *Holocellulose:* Sodium chlorite, 10% acetic acid, ice bath, acetone, 2:1 benzene-ethanol (95%), silica gel (blue) for drying.

10.5.5 *Pentosans*: 13.2% hydrochloric acid, 0.1N potassium bromate, 0.1N potassium bromide, 10% potassium iodide, 0.1N sodium thiosulphate.

10.5.6 *Tannins*: Anhydrous sodium carbonate (special grade), catechin, Folin-Ciocalteu reagent.

10.5.7 *Sugars*: D-glucose, lead (II) acetate (special grade), phenol (special grade), sulphuric acid (0.1N).

10.6 Preparation of Test Materials

10.6.1 *Preparation of Specimens*

Specimens are collected from one-inch thick disc samples as shown in Figure 1.2 (Chapter 1 on sampling). The specimens are then reduced to size using a Wiley mill to pass through ASTM mesh-40 screen.

10.7 Test Procedures

10.7.1 *Determination of Moisture Content in Wood and Bark*

10.7.1.1 Weighing bottle is dried at 105 ± 2 °C in a drying oven for 1 hr, and weighed by a balance to 0.0001 g level after cooling the bottle in a desiccator for around 30 min. Silica gel (blue) should be placed at the bottom of the desiccator.

10.7.1.2 Wood meal (0.5 ± 0.1 g) or bark meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to the above bottle, dried at 105 ± 2 °C in a drying oven for 2 hr, and weighed using the same procedure as in 10.7.1.1.

10.7.1.3 Moisture content (MC) is calculated by the following equation:

$$MC = \frac{W - W_{od}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.1}$$

where W and W_{od} are the original and oven-dry weights of the wood meal respectively.

(See Appendix 8.1)

10.7.2 *Determination of Water Solubles in Wood*

10.7.2.1 A 250-ml round-bottomed flask is dried at 105 ± 2 ° C in a drying oven for 1 hr, and weighed by a balance to 0.0001 g level after cooling the bottle in a desiccator for around 30 min. Silica gel (blue) should be placed at the bottom of the desiccator.

10.7.2.2 Wood meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to a tarred Soxhlet thimble. Deionized water (100 ml) is placed in the tarred 250-ml round-bottomed flask equipped with a Soxhlet extractor and reflux condenser. The flask is heated in a heating mantle at 100 °C for 6 hr.

10.7.2.3 After the extraction, the solvent is evaporated to dryness using a rotary evaporator. The residue is dried at 105 ± 2 °C in a drying oven for 24 hr, and weighed using the same procedure as in 10.7.2.1.

10.7.2.4 The hot water solubility (HS) is calculated by the following equation:

$$HS = \frac{W_{residue}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.2}$$

where W_{od} and $W_{residue}$ are the oven-dry weights of the wood meal and residue respectively.

10.7.3 *Determination of Oils and Waxes in Wood*

10.7.3.1 A 250-ml round-bottomed flask is dried at 105 ± 2 °C in a drying oven for 1 hr, and weighed by a balance to 0.0001g level after cooling the bottle in a desiccator for around 30 min. Silica gel (blue) should be placed at the bottom of the desiccator.

10.7.3.2 Wood meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to a tarred Soxhlet thimble. Hexane (100 ml) is placed in the tared 250-ml round-bottomed flask equipped with a Soxhlet extractor and reflux condenser. The flask is heated in a heating mantle to boiling for 6 hr.

10.7.3.3 After the extraction, the solvent is evaporated to dryness using a rotary evaporator. The residue is dried at 105 ± 2 °C in a drying oven for 24 hr, and weighed using the same procedure as in 10.7.3.1.

10.7.3.4 The content of oils and waxes (OW) is calculated by the following equation:

$$OW = \frac{W_{residue}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.3}$$

where W_{od} and $W_{residue}$ are the oven-dry weights of the wood meal and residue respectively

10.7.4 *Determination of Total Extractives in Wood*

10.7.4.1 A 250-ml round-bottomed flask is dried at 105 ± 2 °C in a drying oven for 1 hr, and weighed by a balance to 0.0001g level after cooling the bottle in a desiccator for around 30 min. Silica gel (blue) should be placed at the bottom of the desiccator.

10.7.4.2 Wood meal (2.0 ± 0.1 g), weighed to the nearest 0.1 mg, and is transferred to a tarred Soxhlet thimble. 2:1 benzene-ethanol (95%) (150 ml) is placed in the tarred 250-ml round-bottomed flask equipped with a Soxhlet extractor and reflux condenser. The flask is heated in a heating mantle to boiling for 6 hr.

10.7.4.3 After the extraction, the solvent is evaporated to dryness using a rotary evaporator. The residue is dried at 105 ± 2 °C in a drying oven for 24 hr, and weighed using the same procedure as in 10.7.4.1.

10.7.4.4 The total extractive content (TE) is calculated by the following equation:

$$TE = \frac{W_{residue}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.4}$$

where W_{od} and $W_{residue}$ are the oven-dry weights of the wood meal and residue respectively.

10.7.5 *Determination of Acid Insoluble Lignin in Wood*

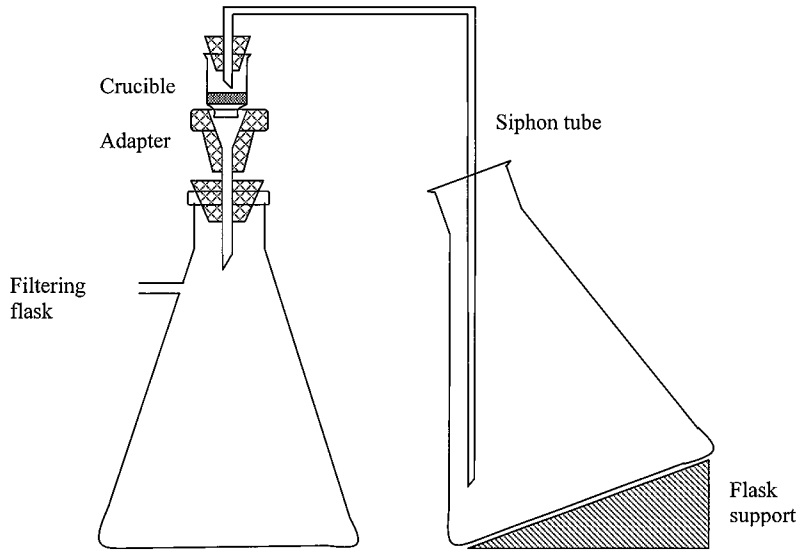


Figure 10.1 Lignin Filtration apparatus

10.7.5.1 Carefully pour 665 ml of concentrated sulphuric acid, S.G. =1.84, into 300 ml of water. After cooling, make up to 1,000 ml. Adjust the strength to 24 ± 0.1 N by titration with standard alkali or by measuring specific gravity.

10.7.5.2 Extractive-free wood meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to a beaker. Cold (10–15 °C) 72% sulphuric acid (15 ml) is added gradually in small increments while stirring and macerating the material with a glass rod. The beaker is being kept in a cold bath during dispersion.

10.7.5.3 Cover with watch glass and keep in the cold bath (≅ 20 °C) for 2 hr. Stir the material frequently to ensure complete dissolution.

10.7.5.4 Add about 300–400 ml of water to a flask and transfer the material from the beaker to the flask. Rinse and dilute with water to 3% concentration of sulphuric acid, to a total volume of 575 ml.

10.7.5.5 Boil the solution for 4 hr maintaining constant volume either by using a reflux condenser or by frequent addition of hot water.

10.7.5.6 Allow the insoluble material to settle by keeping the flask in an inclined position (Figure 10.1). If the lignin is finely dispersed, it may take overnight or a longer period to settle.

10.7.5.7 Without stirring up the precipitate, decant or siphon off the supernatant solution to a filtering crucible, then transfer the lignin quantitatively to the filter using hot water and a rod with rubber policeman.

10.7.5.8 Wash the lignin free of acid with hot water.

10.7.5.9 Dry the crucible with lignin in an oven at 105 ± 2 °C to constant weight. Cool in a desiccator and weigh.

10.7.5.10 The lignin content (LC) is calculated by the following equation:

$$LC = \frac{W_{lignin}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.5}$$

where W_{od} and W_{lignin} are the oven-dry weights of the extractive-free wood meal and lignin respectively.

10.7.6 *Determination of Holocellulose in Wood*

10.7.6.1 Extractive-free wood meal (1.0 ± 0.1 g) is transferred into a 250-ml round-conical flask followed by 100 ml of water, 1.5 g sodium chlorite and 5 ml of 10% acetic acid.

10.7.6.2 The mixture is placed in a boiling water bath. After 30 min, 5 ml 10% acetic acid are added. After a further 30 min, 1.5 g sodium chlorite are added.

10.7.6.3 Alternate addition of acetic acid and sodium chlorite at 30-min intervals is continued until a total of 6 g sodium chlorite has been added.

10.7.6.4 After the last addition of sodium chlorite, the mixture is heated for a further 30 min. The residue should be white.

10.7.6.5 The suspension is cooled in an ice bath and filtered into a tarred fritted glass crucible and washed with ice cold water, and rinsed with acetone.

10.7.6.6 The residue is air-dried. then placed in a desiccator and weighed daily until constant weight.

10.7.6.7 The holocellulose content (H) is calculated by the following equation:

$$H = \frac{W_{holocellulose}}{W_{od}} \times 100\ (\%) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn. 10.6}$$

where W_{od} and $W_{holocellulose}$ are the oven-dry weights of the extractive-free wood meal and holocellulose respectively

10.7.7 *Determination of Pentosans in Wood*

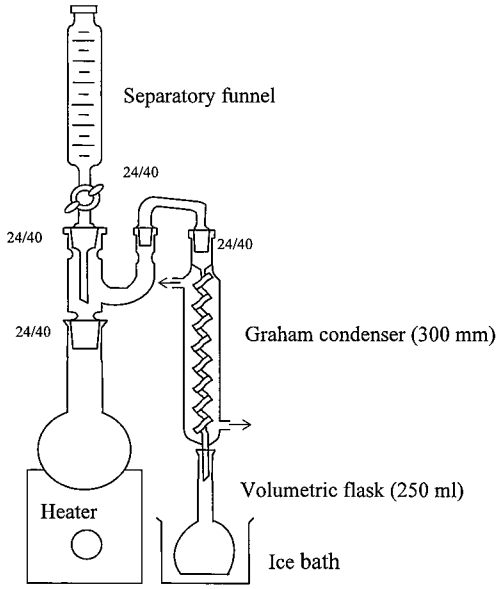


Figure 10.2 Distillation apparatus

10.7.7.1 Extractive-free wood meal (0.6 ± 0.001 g) is transferred into a 350-ml round-conical flask followed by 100 ml of 13.2% hydrochloric acid.

10.7.7.2 The mixture is distilled at a rate of 25 ml/10 min. and a further 25 ml of 13.2% hydrochloric acid is added every 10 min until 300 ml of distillate have been collected.

10.7.7.3 The distillate is mixed and checked that its volume in the cylinder is 300 ml. Water is added to make up if necessary.

10.7.7.4 The distillate (100 ml) is pipetted into a stoppered reagent bottle while 100 ml of 13.2% hydrochloric acid is placed into another bottle (blank).

10.7.7.5 The bottles are cooled to below 20 °C and 25 ml of 0.1 N potassium bromate followed by 10 ml 0.1N potassium bromide are added to each bottle. The mixtures are then left for an hour in the dark at 20 °C followed by 10 ml each of 10% potassium iodide solution.

10.7.7.6 After standing for 5–10 min, both of the solutions are titrated against 0.1 N sodium thiosulphate solution.

10.7.7.7 The pentosan content (P) is calculated by the following equation:

$$P = \frac{1.375 \times (M_{blank} - M_{unreacted})}{4.05 \times W_{od}} \times 100\ (\%) \quad \text{..... Eqn. 10.7}$$

where,

M_{Blank} is the amount of bromine in blank solution = volume 1 × normality of $Na_2S_2O_3$ soln. (bromine soln. added in excess)

$M_{unreacted}$ is the amount of bromine unreacted = volume 2 × normality of $Na_2S_2O_3$ soln.

W_{od} is the oven-dry weight of the specimen.

(see Appendix 10.1)

10.7.8 *Determination of Tannins in Bark*

10.7.8.1 Bark meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to a 500-ml Kjeldahl short-necked flask equipped with a reflux condenser. Deionized water (200 ml) is added and the flask is heated in a heating mantle at 100 °C for 3 hr.

10.7.8.2 After the hot water extraction, the bark meal is filtered through a glass filter (1G3) and the residue is washed with water.

10.7.8.3 The filtrate and washings are collected and the volume is adjusted to 250 ml with water. The solution obtained is used as the standard solution for subsequent determination of tannin content according to the Folin-Ciocalteu method. (The working curve is drawn using catechin as a standard sample.)

10.7.8.4 Catechin, fully dried in a vacuum drier (10 mg), is dissolved in water and the volume is adjusted to 100 ml.

10.7.8.5 Specific amounts (50, 100, 200, 300, 400 and 500 µl respectively) of the above solution are transferred to 10-ml volumetric flasks, 1 ml of Folin-Ciocalteu reagent is added to each flask, and the flask shaken vigorously.

10.7.8.6 Sodium carbonate solution (20 %, 5 ml) and water are added to each flask to adjust the total volume of the solution to 10 ml. The flasks are shaken vigorously again.

10.7.8.7 After 20 min, the absorbance at 735 nm is measured using air as a reference.

10.7.8.8 Working curve is drawn based on the data of absorbance of each catechin solution.

10.7.8.9 A small amount (1–2 ml) of the standard solution is transferred to a 10-ml volumetric flask, 1 ml of Folin-Ciocalteu reagent is added, and the flask is shaken vigorously.

10.7.8.10 Sodium carbonate solution (20 %, 5 ml) is added to the flask and water is added to adjust the total volume of the solution to 10 ml. The flask is shaken vigorously again.

10.7.8.11 After 20 min, the absorbance at 735 nm is measured using water as a reference solution.

10.7.8.12 Tannin content in the standard solution is calculated using the working curve and reported as a weight % on oven-dry bark meal.

10.7.8.13 The tannin content (TC) is calculated from the equation:

$$TC = \frac{100\ V_c}{W_{od}} \times 100\ (\%) \quad \text{..... Eqn. 10.8}$$

where V_c is obtained from the calibration curve and W_{od} is the oven-dried weight of the bark meal.

10.7.9 *Determination of Sugars in Bark*

10.7.9.1 Bark meal (1.0 ± 0.1 g), weighed to the nearest 0.1 mg, is transferred to a 500-ml Kjeldahl short-necked flask equipped with a reflux condenser, 200 ml of deionized water is added and the flask is heated in a heating mantle at 100 °C for 3 hr.

10.7.9.2 After the hot water extraction, the bark meal is filtered through a glass filter (1G3), and the residue is washed with water.

10.7.9.3 The filtrate and washings are collected and the volume is adjusted to 250 ml with water. The solution obtained is used as the standard solution for subsequent determination of total sugars according to the phenol-sulphuric acid method with slight modification. Pretreatment of the standard solution with lead(II) acetate aqueous solution is conducted to remove the influence of co-existing tannins on the determination of sugars. (The working curve is drawn using D-glucose as a standard sample.)

10.7.9.4 D-Glucose, fully dried in a vacuum drier (15 mg), is dissolved in water, and the volume is adjusted to 100 ml.

10.7.9.5 Specific amounts (1.0, 1.5, 2.0, 2.5 and 3.0 ml respectively) of the above solution are transferred to 10-ml volumetric flasks, water is added to adjust the total volume of the solution to 10 ml in each flask.

10.7.9.6 Two millilitres of each of the above solutions are transferred to a 20-ml glass sample tube, 80% phenol aqueous solution (0.05 ml) and sulphuric acid (0.1N, 5 ml) are added, and the mixture is allowed to stand for 35 min.

10.7.9.7 The absorbance at 490 nm is measured using water as a reference.

10.7.9.8 Working curve is drawn based on the data of absorbance of each glucose solution.

10.7.9.9 A small amount (1-2 ml) of the standard solution is transferred to a 10-ml volumetric flask, and water is added to adjust the total volume of the solution to 10 ml.

10.7.9.10 The above solution is transferred to an approximately 40-ml centrifuge tube, 1% lead(II) acetate (10 ml) is added and the mixture is allowed to stand for 20 min.

10.7.9.11 Centrifugation is performed at 18,000 rpm for 20 min to precipitate insolubles.

10.7.9.12 Two millilitres of the supernatant are transferred to a 15-ml centrifuge tube, 80% phenol aqueous solution (0.05 ml) and sulphuric acid (0.1N, 5 ml) are added, and the mixture is allowed to stand for 35 min.

10.7.9.13 Centrifugation is performed at 3,500 rpm for 5 min, and the absorbance of the supernatant at 490 nm is measured using water as a reference.

10.7.9.14 The sugar content in the standard solution is calculated using the working curve and reported as a weight % on oven-dry bark meal.

10.7.9.15 The sugar content (SC) is calculated from the equation:

$$SC = \frac{100\ V_c}{W_{od}} \times 100\ (\%) \quad \text{..... Eqn. 10.9}$$

where V_c is obtained from the calibration curve and W_{od} is the oven-dry weight of the bark meal

10.8 Reports of Results

The results may be tabulated using Form 10.1

Form 10.1 Tabulation of results

Timber ID	Moisture content (%)	Hot water solubility (%)	Ethanol - toluene solubility (%)	Hexane solubility (%)	Pentosans (%)	Lignin (%)	Hollocellulose (%)	Tannins in bark (%)	Sugars in bark (%)

Appendix 10.1

Determination of Pentosans

Notes :

(i) The pentosans are hydrolysed by boiling acid to pentoses which subsequently decompose into volatile furfural. Furfural is almost entirely distilled over under the conditions of the experiment.

(ii) Gram atom means the atomic weight in grams, e.g. 1 g of hydrogen, 23 g of sodium, 12 g of carbon, 80 g bromine. A normal solution of bromine contains 1 gram equivalent of bromine = atomic weight of bromine in g.

(iii) One repeating unit of pentosan (unit MW = 132, pentosans are polymeric) will quantitatively give one molecule of pentose (MW = 150). This in turn gives one molecule of furfural (MW = 96). Thus 1 g of furfural corresponds to 1.375 g pentosan.

(iv) Bromine may be directly titrated with sodium thiosulphate, but due to its volatility, excess potassium iodide is added, enabling bromine to displace atom by atom the iodide.

(v) 4.05 g atoms of bromine react with 1 g molecule of furfural.

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