PLANTATION GROWN TROPICAL TIMBERS 1. WOOD PROPERTY AND PROCESSING EVALUATION PROCEDURES TO IMPROVE USAGE

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HASLETT, A.N. & YOUNG, G.D. 1990. Plantation grown tropical timbers 1. Wood property and processing evaluation procedures to improve usage. Knowledge of wood properties is essential to enable optimal use of tropical forest timber species and to ensure appropriate selection of species for plantation projects. This paper outlines a basic procedure for evaluating wood and processing properties of timber species. Tests are largely in accordance with international standards. Of particular interest is the sampling procedure and the way the various tests are integrated to yield practical information.

Key words: Wood properties - density - shrinkage - strength - durability - treatability - drying - working - plantation timber

Introduction

Tropical forests have the potential to meet much of the world's demand for timber but in recent years they have become increasingly subject to conservation pressures for reasons as diverse as protection of forest types, effect on the indigenous people's life style, and global warming. These pressures can only serve to increase the need for appropriate management of tropical forests and encourage correct use of the products arising from these forests.

Traditionally, a large proportion of the Asian tropical timber supply has come from a very limited number of species such as ramin (*Gonystylus bancanus*) and meranti (*Shorea* spp.) but now increased attention is being given to the numerous lesser known species available. A critical step towards the commercial use of these species is the acquisition of information on their wood properties and processing characteristics. This information facilitates the grouping of similar species for processing, marketing, and use, and ultimately ensures acceptance by the customer.

Wood property information is also important in tropical plantation forestry. Availability of this information prior to large scale forest establishment should play a critical part in selecting the species most appropriate for the envisaged final market. Fast-grown young plantation timber often exhibits significantly different wood properties from the timber of traditional mature stands of the same species; some examples of this are kamarere (*Eucalyptus deglupta*) and cadamba (*Anthocephalus chinensis*) (Haslett 1986). In addition to growth rate and age, local site factors can also significantly affect wood properties. For example, *Pinus caribaea* grown at high altitudes has lower wood density than when grown at low altitudes (Cown *et al.* 1983).

As with lesser known indigenous species, there is a need for full wood property and processing information prior to usage of a plantation resource to ensure correct processing and use.

Therefore it can be seen that the development of a procedure for identifying the properties of new timber species is essential for their efficient use. This publication describes the wood property and processing assessment procedures which have been used throughout the South Pacific by the Forest Research Institute for timber evaluation of both indigenous and plantation species.

Test procedures for evaluating timbers

Generally, the key wood properties for evaluating any new species are wood density, moisture content, heartwood proportion, strength, and durability. Of prime importance for some end-uses, "stability" may also be added to this list, that is assessing movement (shrinkage or swelling) under fluctuating atmospheric humidity. Wood anatomy studies are usually necessary only if there are unexpected difficulties in processes such as preservation, drying, machining, and pulping.

The wood processing properties requiring evaluation will depend on the expected end use of the timber, but generally evaluations will include sawmilling, preservation treatment, drying, and machining. In addition, commercial end use evaluation trials can give an early indication of acceptability to likely end users, as well as possible market values.

The evaluation procedure must yield commercially appropriate information. For example, if sawlogs are the expected product then density information should be based on likely commercial log lengths rather than at a set proportion of stem length. The procedure must also be relatively simple to conduct in the field and flexible enough to adapt to the requirements of each species/country situation. Above all, whilst meeting these requirements it must still yield reliable and representative results.

Wood properties

Basic physical properties

Density is important because it directly influences most other wood properties and final wood use. Most importantly, basic density (oven dry weight/green volume) and strength are directly related. Density also affects drying, preservation, machining, and pulping; so if density patterns are quantified it is often possible to predict the variation in other properties. Green density provides information on the weight of logs or freshly sawn timber and is important for transport cost and sometimes for transport methods (that is river transportation as rafts). Green moisture content is assessed because of its effect on drying properties. Heartwood proportions can affect sawing patterns, conversion factors, preservation, processing, and ultimately end uses if it is a particular colour or durability which is the required feature.

To examine the variation in properties two levels of survey intensity are used. The more intensive survey is done in a "typical" single stand which is within five years of the expected rotation age, with the purpose of identifying not only differences in physical properties between trees but also differences within trees. This survey involves collecting increment cores as well as felling the trees to collect 50 *mm* thick stem discs. The second less intensive survey involves collecting only increment cores with the objective of obtaining information on density variation between trees and between different stands or sites.

For the intensive survey 10 to 12 trees are assessed as this number also provides a valid sample for strength testing. Trees are chosen as being non-edge, non-leaning, and non-malformed and representative of the range of diameters in the stand. Before felling, diameter at breast height over bark (dbhob) is measured and two 5 *mm* diameter increment cores are taken from bark to pith at breast height. An identification code and the heart/sap boundary are immediately marked on each core before it is placed in a container to prevent drying and breakage.

In the laboratory the cores are assessed for heart/sap proportions and then, starting from the bark end and working to the pith, the cores are marked into either 5-ring or 50 *mm* sections. A 50 *mm* section is used when there are difficulties in distinguishing annual growth rings. Using the maximum moisture content method of Smith (1954), basic density is then assessed for each section of the core.

Once the trees are felled they are marked for sampling 50 *mm* wood property discs, a short 0.9 *m* billet for subsequent small clears strength testing, and, where necessary, sawlogs to yield test sawn timber. The 50 *mm* discs are taken from the butt and breast height (1.4 *m*) and above this at intervals determined by the likely future commercial log length (*e.g.* 2.5 and 5.0 *m* intervals for pulpwood and sawlogs, respectively). It is considered that relating the disc interval to log length yields results more commercially applicable than the commonly used method of sampling at growth intervals along the stem length (which may be biologically more satisfactory). Discs are cut until the stem diameter nears the likely minimum diameter that will be commercially used. A second set of discs is taken from the butt and from 10 and 20 *m* height to provide information on green moisture content and basic density. This second set of discs is immediately debarked and weighed in the forest before being measured for volume and oven dried in the laboratory. A schematic diagram of the sampling system is shown in Figure 1.

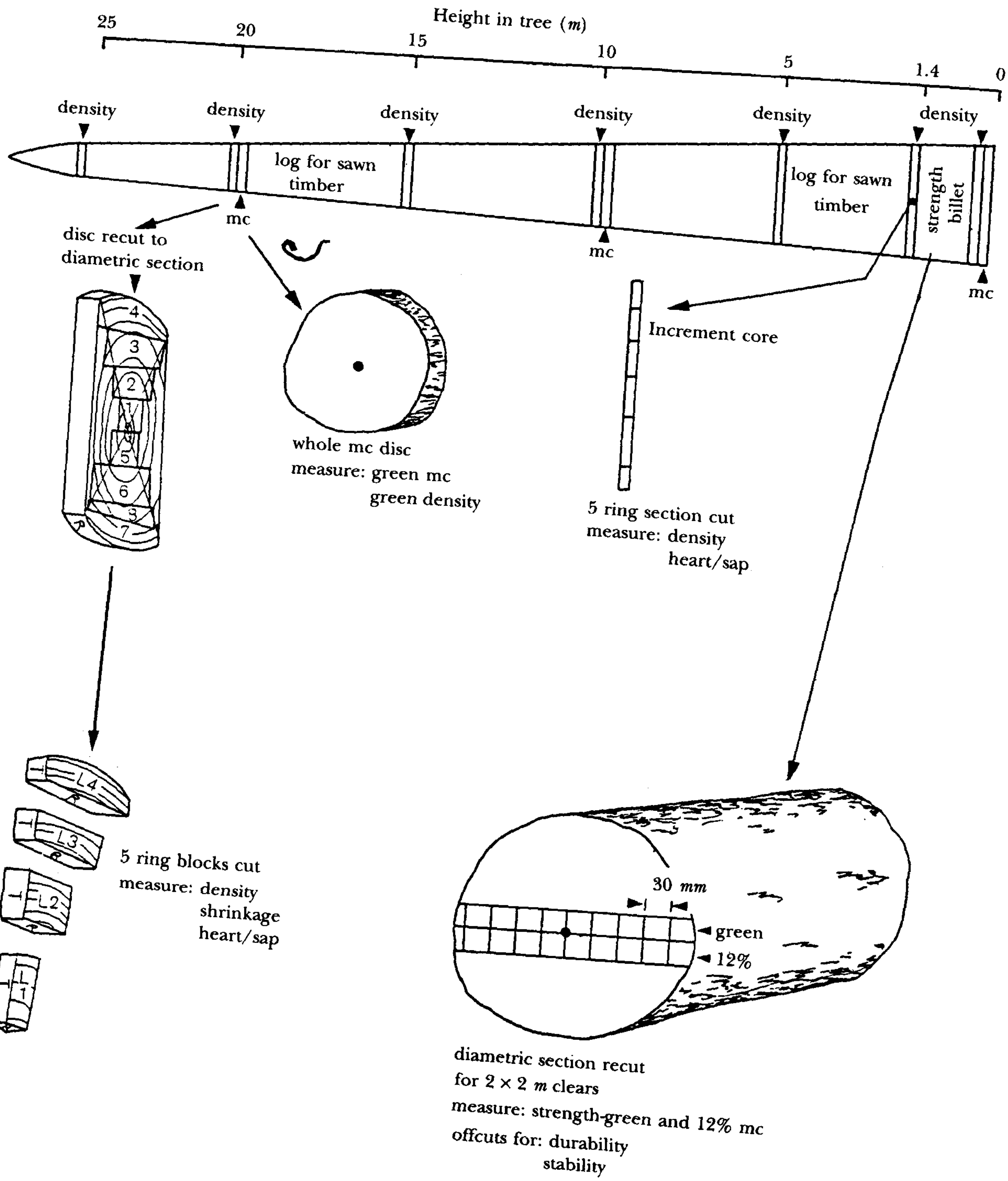

Figure 1. Typical sampling pattern for each test tree and procedure for sample preparation

From each of the other discs two diametrically opposed sectors are cut and divided into 5-ring or 50 *mm* wide blocks as shown in Figure 1. Where shrinkage characteristics are required, points are marked on each face of the blocks for dimensional measurements when green, after equilibration to 12% moisture content and after oven drying. Weights and volumes of the blocks are also measured at each of the above stages to give information on green, basic, and oven dry density. The individual block information identifies any radial and vertical trends within the tree for moisture content, shrinkage, and density. In addition, these properties are also calculated as weighted values for each disc and then for each log and whole tree.

Quantification of the relationship between tree and/or log density and the increment core density facilitates a simple, rapid, non-destructive means for the determination of tree and log density of other forest sites.

The less-intensive "increment core" survey uses the same tree selection criteria as the intensive study, although stand age can be as low as half the expected rotation length. Inclusion of younger stands can also facilitate identification of any relationship between tree age and density. From each stand approximately 30 trees have a single 5 *mm* diameter increment core taken from bark-to-pith at breast height and at right angles to any tree lean (to avoid reaction wood). The cores are handled by the procedure previously outlined to yield density data which then allows identification of between-tree and between-site density variation as well as any relationship between age and density.

Stability

Stability is a critical property in uses such as exterior joinery and furniture, and it is often necessary to confirm that plantation grown material has similar stability to traditional sources of a known stable timber for example teak (*Tectona grandis*). The test methods used recognise that movement can be either of a long term or short term nature.

Long term movement is best illustrated as the movement associated with the changes in moisture content that occur seasonally for example when wood is exposed first to dry conditions and later to wet conditions, or alternatively when timber is installed wet and further drying occurs. The amount of movement is dependent on the wood's shrinkage, its shrinkage intersection point, and its equilibrium moisture content properties. Long term movement is expressed as the percentage of movement when the moisture content of wood changes from equilibrium at 90% RH to equilibrium at 60% RH. This method was developed by Princes Risborough Laboratory (Anonymous 1965).

The Forest Research Institute (FRI), Rotorua, have developed a method (Harris 1961) for determining short term movement which can be illustrated by the dimensional responsiveness of weatherboards and exterior joinery that have been exposed to fluctuating weather conditions such as high humidity and dry sunny periods. Short term movement is most dependent upon the permeability of a wood to moisture and is measured by recording dimensional and moisture content increases when wood is taken from equilibrium at 65% RH and placed at 95% RH for only 24 hours. Average values are obtained after three separate cycles.

Both these tests are done using flat-sawn and quarter-sawn heartwood and require only 10 to 12, 6 or 8 *mm* thick specimens each. The samples are obtained from the strength billet.

Strength

To ensure efficient safe use of a timber species, strength properties should be taken into account when designing load-bearing timber components. For reasons of simplicity, economy and comparison of different sources of material, 20 × 20 *mm* clear strength specimens are used in preference to the in-grade testing of sawn timber sizes. To enable comparison with existing published data all the tests are done in accordance with British Standard BS 373:1957 (BSI 1957) with the actual tests conducted depending upon the individual species under consideration. Key tests include static bending, compression parallel to grain, shear, and hardness (Janka).

A minimum of five trees are required with 10 to 12 being preferable. Test material is resawn from the butt 0.9 *m* billet, and specimens are taken at 30 *mm* intervals from the bark to pith to bark as shown in Figure 1. Side-matched specimens are tested green and at 12% moisture content. Use of the diametric sampling system means that the total range of wood density is tested.

From these tests the relationship between each strength property and density is established. Using this relationship and basic density from the survey the mean species strength properties are calculated for each species. It is recognised that individual test values can vary considerably around the mean, but the calculated mean strength values are extremely useful for comparisons betwen countries and between related species.

Durability

Information on durability is necessary to determine the suitability of species for untreated exterior use and to assess the need for preservative treatment. Durability testing provides information on the average life of heartwood in the ground. This information is obtained both from outside graveyard tests of 20 × 20 *mm* stakes and from laboratory fungus cellar testing of 25 × 12.5 *mm* stakes.

Graveyard testing may take many years but use of fungus cellar testing, which maintains 28°*C* and 95% RH, can yield results approximately four times faster. For comparative purposes it is important to also include samples of a known species in the fungus cellar.

Testing should include heartwood material from at least five trees with 10 to 15 stakes being prepared. The stakes are recut from the strength billet.

Processing properties

Sawmilling

Two types of sawmilling study are used. In the basic study logs are sawn simply to provide timber for other processing studies, with observations being made on defects in the log, the effect of growth stress, surface finish quality, and blunting.

Alternatively, a detailed sawing study is done to determine sawn conversion factors, timber grade recoveries, and the relationship between log quality and sawn timber grade and value (the latter is ultimately aimed at formulating log grades). Such a detailed study requires a large number of logs containing the full range of log parameters. Before the logs are sawn (according to a standardised pattern), log parameters such as log and branch diameter, sweep *et cetera* are measured. During sawing a record is made of the location of each individual length of timber from within the log, so that after grading it is possible to establish the relationship between timber grade and log parameters. Cown *et al.* (1989) have described the development of log grades for plantation grown mahogany (*Swietenia macrophylla*).

Drying and kiln schedules

Using matched 0.6 *m* sample boards to compare shrinkage, checking, and drying time, and 2.4 *m* lengths to indicate warp and checking, the most appropriate drying technique is identified. Drying methods used in the evaluation can include air drying, low temperature predrying, and kilning at a range of temperatures. The procedure used depends upon available information on the drying characteristics of the species, as well as factors such as wood anatomy, density, and green moisture content.

Treatability

Many of the plantation grown timbers exhibit lower natural durability than timber from natural forests of the same species, so preservative treatment is necessary to provide long term protection against insects or fungal decay.

Treatment trials include Bethell treatment of green and dry timber with copper-chrome-arsenate (CCA) salts, and boron diffusion treatment of green timber. The green pressure treatment is included to assess the efficacy of protection against insects and decay in internal situations and the treatment after drying for protection against decay in exterior unprotected situations. For some species green pressure but may also be acceptable for exterior uses. The following preservation treatment schedule is used for 25 *mm* thick material:

Initial vacuum	-85 *kPa*	10 *min*
Pressure	1380 *kPa*	60 *min*
Final vacuum	-85 *kPa*	20 *min*

After treatment samples are cut and spot-tested to indicate penetration and distribution of the copper. Where there is adequate penetration, sections are then chemically analysed to determine the content and balance of all the preservative elements.

Boron treatment involves dipping the green 50 *mm* thick timber in a solution which will give a charge retention of at least 5 $kg\,m^{-3}$ boric acid. Immediately after dipping the samples are stacked in a solid block and wrapped in plastic to allow diffusion. After eight weeks about one-third of each sample is removed for preservative analysis. Boric acid concentration in the entire cross-section of each sample is determined, and in the core (central ninth of the cross-sectional areas) of the 50 *mm* thick samples. Where there has been inadequate boron diffusion the samples are rewrapped and core analyses are repeated after a total of 12 weeks of diffusion.

Working properties

Working properties are of key concern for high value uses such as furniture and turnery. Tests are performed at 10 to 14% moisture content using standard tools and commercial machines operating within the range of settings and speeds recommended by their manufacturer. The most important tests are:

Boring - A 10 *mm* double-twist, brad-point bit is used at 3000 rpm. The quality of the hole is visually assessed by the smoothness of the cut and the degree of tear-out at the surface.

Planing - A planer with a two-knife cutting head is used at 6000 rpm and a range of feed speeds. Typically, knife cutting angles of 15°, 25°, and 35° are used and one edge of the wood is shaped to a bullnose pattern to assess moulding properties.

Turnery - Drawer knobs are turned at a range of settings on an automatic copy lathe and the knobs are graded according to sharpness of detail and smoothness of finish (the poorest point determining grade). The drawer knob shape includes a range of cutting angles and surfaces while being small enough to allow production of a large number of samples.

Commercial end user evaluation

The commercial suitability of a new species is evaluated by distributing timber to commercial end users for manufacture into items in which the timber could be used in the future. All users complete a questionnaire regarding the processes used, the working properties, and any inherent wood features that caused problems. In addition, users are asked to identify the types of products which could be manufactured from the timber supplied and what grades would be required as well as the price they would be prepared to pay for the timber. The findings are combined with the results of the wood properties evaluation to identify appropriate uses for the species.

Concluding remarks

The test procedures described are mainly in accordance with recognised international techniques. What is of particular interest is the way in which the results of tests of individual properties are linked together both in the field work and in the practical interpretation of the results. An example of this is how the density survey information is used to predict the average and the expected range of strength for the species. The procedure provides data which can be used for management of both new and existing forests. For example, by defining the relationship between increment core density and tree or butt log density, the forester has a simple and powerful means of segregating existing forests into density zones or incorporating wood density into a tree improvement programme.

The integrated sampling procedure for obtaining test materials means that the evaluations do not require a large number of test trees or a large volume of test material. For an indigenous timber species, availability of a large number of test trees may not pose a problem, but in the situation where the information is being used to assist in selecting new plantation species as few as five trees could be sufficient; this number could come from an area as small as an arboretum. Each study is customised depending on the species being examined, the quality or size of the existing resource, financial constraints, or on availability of existing information.

The success of this flexible approach is evident from the numerous studies already completed in countries throughout the South Pacific including Fiji, Western Samoa, Solomon Islands and Vanuatu.

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