BENDING PROPERTIES OF HARDWOOD TIMBERS FROM SECONDARY FOREST IN PAPUA NEW GUINEA

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EDWIN P & OZARSKA B. 2015. Bending properties of hardwood timbers from secondary forest in Papua New Guinea. The wood processing industry is one of the key economic sectors of Papua New Guinea (PNG), generating significant income from export earnings. It has the potential to meet PNG's socio-economic needs in the long term if managed in a sustainable way. Currently, most timber harvesting is heavily concentrated within the secondary (regrowth) forest. The transition from primary forest timber to secondary growth timber poses various challenges. Secondary growth timber differs in properties and processing characteristics from the same species from virgin, primary forest. Thus, wood processing companies require technical information of the differences to facilitate the transition and to optimise the processing of this newly available resource. Therefore, a collaborative research was undertaken by the University of Melbourne and PNG University of Technology with the aim of creating a basic catalogue of PNG secondary forest timber characteristics. This paper describes the first stage of the study, which aims to determine wood density and bending properties [modulus of elasticity (MOE) and modulus of rupture (MOR)] of 10 selected hardwood timbers from secondary forest in PNG. These timbers are available for the timber industry for processing. Test results revealed that the properties of timbers from the secondary forest differed substantially from those of the primary forest. There was high degree of variability between and within species with regard to density, MOE and MOR. Statistically, the degree of variability of MOE was moderately distributed within species than between species. The variability of MOR was greater between species than within species. Preliminary data provided a foundation for further studies using laboratory test assessments and would allow enhancing the application of PNG timbers for continued development of the timber processing industry.

Keywords: Primary forest, underutilised species, strength properties, modulus of elasticity, modulus of rupture, timber industry

INTRODUCTION

Increasing demand has put pressure on available timber resources in Papua New Guinea (PNG) and more timber is currently harvested from previously cut-over forests (Venn et al. 2004). Consequently, timber is sourced from secondary forests rather than from primary forests. It is expected that by 2020, heavy commercial logging of primary forest will significantly reduce timber resources such that 78% of timber will be sourced from logged-over forest (Shearman et al. 2006).

The transition from primary forest to secondary growth timbers poses various challenges to timber processors. Secondary growth timber differs in character from the same species from virgin, primary forest. Thus wood processing companies require technical information on the differences to facilitate the transition and to optimise the processing of this newly available resource (Ozarska & Molenaar 1998).

Information of PNG timber species has been compiled from primary forest timber and does not account for the differing characteristics of secondary forest timber. To further complicate the data, the difference varies from species to species. Thus generalisations cannot be applied across the available timber species. A new catalogue of timber qualities, at least for the popular species, defining technical specifications of secondary growth timber is required. Accurate

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and updated information is a vital element of successful timber processing industry in PNG (Forest Products Research Centre 1978).

Demand for relevant technical information to support timber choices and the application of appropriate technologies is required as processing technology develops and the industry continues to mature. The advent of secondary growth timber not only increases choices and options but also expands the need for sound technical analysis. Quality information is important for processing, manufacturing, utilisation, marketing and identification of opportunities for the industry to advance with technological applications (Ozarska 2009).

Inspired by the above requirements, a comprehensive research study was undertaken by PNG University of Technology in collaboration with the University of Melbourne with the aim of creating a foundational catalogue of PNG secondary forest timber characteristics.

Initially, the study focused on determination of mechanical properties and natural durability of timbers. This paper describes the first stage of the study, which is aimed at determining wood density, modulus of elasticity (MOE) and modulus of rupture (MOR) of 10 selected PNG hardwood timbers available to the timber industry.

MATERIALS AND METHODS

All timber species selected for testing were hardwood timbers from PNG. They were collected from various timber companies located at Madang, Lae and Vanimo of the Momase region. It is important to mention that most timber companies in this region harvest trees from natural forest. Therefore, all wood samples collected were sourced from natural forest.

According to Mack (1979) and ASTM D143 (ASTM 1994), eight samples per board of the timber species were significant for conducting static bending test. Table 1 shows the total number of boards and replicates tested for each of the 10 species.

The location represents the whereabout of both large and portable timber millers. The boards were collected upon availability of specified timbers at the mill sites.

The properties of the timbers were tested at the Wood Technology Laboratory, University of Melbourne, according to two standard methods for testing small clear specimens: (1) Australian methods for mechanically testing small clear specimens of timber (Mack 1979) and (2) ASTM D 143–94 Standard methods of testing small clear specimens of timber (ASTM 1994).In addition, Australian/New Zealand standard AS/NZS 1080.3:2000 was used for determination of density and moisture content (AS/NZS 2000).

Wood samples were machined according to requirements of the Australian test method (AS 2006) and Mack (1979). The 20 mm × 20 mm × 300 mm specimens were cut in conformity to the testing sizes of static bending test. Small specimens of 20 mm × 20 mm × 20 mm were cut for determination of moisture content (MC) and air-dry density (AD) at 12% MC and basic density (BD). Prior to mechanical property testing, all samples were conditioned in a humidity chamber at 27 °C and relative humidity of 65 ± 5% for 8 weeks to achieve uniform 12% MC.

Testing was done using the universal testing machine (Yoshihara & Suzuki 2004). The MOE and MOR tests were performed using three point load stress test. Prior to the tests, data for each sample such as rate of load applied, specimen label and dimensions of wood were entered into the computer to enable automatic generation of graphical data during testing. A load rate of 1 mm s^{-1} was used.

RESULTS AND DISCUSSION

Density

Tables 2 and 3 indicate that density values for timber species from the secondary forest were lower than those from the primary forest. The ratio of secondary to primary forest ranged from 0.69 (pimeleodendron) to 1.30 (ebony) (Table 4). The densities of most secondary timbers were 80% and above those of primary timbers but the densities of mersawa and pimeleodendron fell below 80%, i.e. 77 and 69% respectively (Table 4). There were some species, however, with densities as high as the primary timbers but with low standard deviation values.

The discrepancies between the ratios of secondary to primary forest for various species could be due to the species being harvested at different locations with different growth

Table 1 Timber species and locations where they were collected

Timber	No of boards	Location
Instia bijuga (kwila)	8 (3 rpts, 24 pcs)	Lae
Pterocarpus indicus (rosewood)	8 (3 rpts, 24 pcs)	Lae, Madang
Pometia pinnata (taun)	8 (3 rpts, 24 pcs)	Lae, Madang
Anisoptera thurifera (mersawa)	6 (3 rpts, 8 pcs)	Lae, Vanimo
Pimeleodendron amboinicum (pimeleodendron)	6 (3 rpts, 18 pcs)	Lae, Madang
Disopyros spp. (ebony)	4 (3 rpts, 12 pcs)	Lae
Dracontemelon dao (walnut)	6 (3 rpts, 18 pcs)	Lae
Endospermum modulossum (basswood)	5 (3 rpts, 15 pcs)	Lae, Madang
Anthochephalus chinensis (labula)	5 (3 rpts, 15 pcs)	Madang
Flindersia pimelteliana (maple)	6 (3 rpts, 18 pcs)	Lae

rpts = Number of replicates (three replicates from each board), pcs = total number of pieces (specimens)

and climatic factors. The difference in density between secondary and primary forests was due to the growth factor. In this instance, secondary forest timbers grew faster than those of the primary forest, whereby the formation of woody cells was affected, resulting in thinner and narrower cells. The effects in wood cells are demonstrated by the physical properties of wood, i.e. lighter timbers which have lower densities.

Modulus of rupture

Table 2 shows that ebony, mersawa and pimeliodendron in the MOR category have lower measure of standard deviation from the population. Meanwhile maple experienced strong dispersion from its population mean. For MOE, ebony and taun reflected the least and strong standard deviations among the timber species. The MOR values indicated the relationship between density and MOR of tested species. Ebony, kwila, maple and taun had higher mean MOR values than other timber species.

Generally, high MOR values of timbers from the secondary forest indicate that these hardwood timbers can be processed for furniture and other structural applications. It must be noted that the values were based on 10 selected species only and more testing on other lesser-known species is required. Using a wide range of species is paramount for selection of specific timbers for various end-uses. In practice, in the process of selecting various timber species for high value wood products manufacturing (e.g. furniture), the sizes of the timber components should be calculated according to the strength of the timber (Ayarkwa et al. 2001).

Modulus of elasticity

Table 3 shows that MOE values of secondary timbers are generally lower than those from primary forest. Age and site productivity factors were considered as some of the elements that influenced the variation between primary and secondary growth timbers. Coefficient of variation values (Table 2) indicated significant deviations in MOE for the 10 timbers. Generally, the MOE values show that timbers harvested from the secondary forest are promising in terms of strength and stiffness and can be processed and utilised regardless of their location and age (Bodig 1985, Chen et al. 2009).

General

High ratio of ebony species is linked to testing of different species of *Diospyros*. In this case, the species selected for test was *Diospyros ferra* (black ebony), while the species tested by Bolza and Kloot (1977) was *D. papuana* (white ebony). Black ebony is denser and stronger than white ebony in terms of mechanical strength properties (Dowling 1998, Green et al. 2001). As a result, density, MOR and MOE of ebony from the secondary forest had

Table 2 Summary results for density, MOR and MOE values of 10 Papua New Guinea timbers

Species	No of specimens	Density (kg m^{-3})		MOR (MPa)		MOE (GPa)	
		AD	BD	Mean[a]	CV (%)	Mean[a]	CV (%)
Pometia pinnata (taun)	27	678	608	86.60	22.08	10.71	18.03
Flindersia laevicarpa (maple)	9	598	538	87.00	34.37	11.74	17.07
Endospermum modulosum (basswood)	9	339	304	52.92	5.87	7.76	21.71
Instia bijuga (kwila)	27	790	706	127.06	26.28	14.22	8.04
Diospyros spp. (ebony)	6	980	704	103.47	2.33	16.38	3.18
Anisoptera thurifera (mersawa)	9	635	568	77.38	4.84	12.20	32.39
Pimeleodendron amboinicum (pimeleodendron)	9	481	430	52.39	4.98	10.92	21.97
Pterocarpus indicus (rosewood)	27	573	512	62.69	26.91	10.73	8.17
Dracontemelon dao (walnut)	27	631	566	83.05	8.96	11.64	15.51
Anthocephalus chinensis (labula)	21	430	340	43.35	9.24	7.90	8.30

[a]Grand mean of all wood specimens tested; CV = coefficient of variation (standard deviation/mean); AD = air-dry density at 12% moisture content, BD = basic density, MOR = modulus of rupture, MOE = modulus of elasticity

Table 3 Comparison of properties of 10 secondary forest Papua New Guinea timbers with those of primary forest timbers published by Bolza and Kloot (1977)

Timber	Air-dry density (kg m^{-3})		MOR (MPa)		MOE (GPa)	
	This study	B & K	This study	B & K	This study	B & K
Pometia pinnata (taun)	678	695	86.60	106.18	10.71	14.34
Flindersia laevicarpa (maple)	598	562	87.00	85.49	11.74	11.44
Endospermum modulosum (basswood)	339	392	52.92	61.43	7.76	9.58
Instia bijuga (kwila)	790	828	127.06	146.86	14.22	17.99
Diospyros spp. (ebony)	980	754	103.47	102.04	16.38	15.17
Anisoptera thurifera (mersawa)	635	646	77.38	79.29	12.20	13.31
Pimeleodendron amboinicum (pimeleodendron)	481	623	52.39	95.15	10.92	16.00
Pterocarpus indicus (rosewood)	573	614	62.69	95.15	10.73	12.20
Dracontemelon dao (walnut)	631	541	83.05	81.36	11.64	11.44
Anthocephalus chinensis (labula)	430	468	43.35	43.37	7.90	8.00

B & K = Bolza and Kloot (1977); MOR = modulus of rupture, MOE = modulus of elasticity; air dry-density is at 12% moisture content

higher standard deviations than those from the primary forest.

Similarly, maple and walnut were different from the species that were tested by Bolza and Kloot (1977). *Flindersia pimelteliana* and *Dracontomelon mangiferum* tested at that time were from islands of PNG. However, the current species tested were from the mainland of PNG and their properties differed from the species found on the island (Eddowes 1977). Therefore, the higher ratios of these two species showed that different species of the same species group

Table 4 Ratio of secondary to primary forest timbers

Timber	Ratio of secondary to primary timbers		
	Density	MOR	MOE
Pometia pinnata (taun)	0.97	0.81	0.75
Flindersia pimelteliana (maple)	1.06	1.01	1.03
Endospermum modulossum (basswood)	0.86	0.86	0.81
Instia bijuga (kwila)	0.95	0.86	0.79
Disopyros spp. (ebony)	1.30	1.01	1.08
Anisoptera thurifera (mersawa)	0.77	0.97	0.92
Pimeleodendron amboinicum (pimeleodendron)	0.69	0.55	0.68
Pterocarpus indicus (rosewood)	0.93	0.66	0.88
Dracontemelon dao (walnut)	1.17	1.02	1.02
Anthochephalus chinensis (labula)	0.92	0.99	0.99

MOR = modulus of rupture, MOE = modulus of elasticity

had been tested and compared. Therefore, their density, MOR and MOE values showed significant differences.

Comparing density, MOR and MOE values obtained from this study with those by Eddowes (1977) and (Bolza & Kloot 1976) is important to define the wood properties of species from the secondary forest. The results in Table 3 indicate that seven of the timber species tested have lower MOR and MOE values. Labula remained constant in its MOR and MOE values of secondary forest to primary forest. Black ebony had higher density, MOR and MOE values compared with timber from the secondary forest. Likewise, maple and walnut also had higher density, MOR and MOE values. However, as previously stated, this is a result of different timber species of *Diospyros* used for the testing: white ebony from the primary forest and black ebony from the secondary forest. All other timber species showed decrease in MOE values compared with those from the primary data. The decrease in MOR and MOE values showed that considerable changes occurred in the physical, mechanical and chemical properties of wood (Winandy et al. 1984). Therefore, it is imperative that technical data on MOE and MOR values of changing forest cover is taken into account when harvesting, processing and manufacturing timbers from the secondary forest.

CONCLUSIONS

The results obtained from the bending property testing indicated significant variabilities within and between species. It is envisaged that the preliminary test results of MOE and MOR values will provide a valuable contribution to the knowledge on properties of PNG current timber resources and for PNG timber processing industries. The data may also provide a template for establishing strength groups for hardwood timbers. This may lead to the development of design values for manufacturing of engineered wood products in the future. The establishment of MOR and MOE values for timbers from secondary forest provides invaluable information of timber grading for specific end-uses and technical information base to support the timber industry needs for processing and manufacturing of PNG timbers.

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REFERENCES

AS (Australia Standard). 2006. *Timber Structures— Timber Properties and Their Requirements. AS 1720.2.* Standard Australia, Sydney.

AS/NZS (Australia and New Zealand Standard). 2000. *Timber—Methods of Test, Method 3: Density. AS/NZS 1080.3:2000.* Standards Australia International and Standards New Zealand, Straightfield.

ASTM (American Society for Testing and Materials). 1994. *ASTM D143-94. Standard Methods of Testing Small Clear Specimens of Timber.* ASTM, West Conshohocken.

Ayarkwa J, Yoshihikmo H & Sasaki Y. 2001. Predicting modulus of rupture of solid and finger-jointed tropical African hardwoods using longitudinal vibration. *Forest Products Journal* 51: 85–92.

Bodig J. 1985. *Timber Engineering. The Strength and Durability of Timber Structures.* Colorado State University Press, Colorado.

Bolza E & Kloot NH. 1977. *The Mechanical Properties of 81 New Guinea Timbers.* Technical Paper (Second Series) No. 11. CSIRO, Brisbane.

Chen Y, Barret JD & Lam F. 2009. Mechanical properties of Canadian coastal Douglas-fir and Hem-fir. An industry supply chain mapping. *Forest Products* 59: 44–55.

Dowling NE (ed). 1998. *Mechanical Behavior of Materials: Engineering Methods For Deformation, Fracture and Fatigue.* Second edition. Prentice Hall, London.

Eddowes PJ. 1977. *Commercial Timbers of Papua New Guinea: Their Properties and Uses.* Hebamo Press, Port Moresby.

Forest Products Research Centre. 1978. *Properties of Some PNG Woods Relating With Manufacturing Processes.* Bulletin No. 299. Forest Product Research Centre, Ibaraki.

Green DW, Winandy JE & Kretschmann DE. 2001. Mechanical properties of wood. Pp 4.1–4.45 in *Wood Handbook: Wood as an Engineering Material.* USDA Forest Service, Forest Products Laboratory, Madison.

Mack JJ. 1979. *Australian Methods for Mechanically Testing Small Clear Specimens of Timbe*r. Technical Paper (Second Series) No. 31. CSIRO, Brisbane.

Ozarska B. 2009. Engineering properties of selected young plantation-grown Australian hardwoods for furniture. *Forest Products Journal* 59: 27–30.

Ozarska B & Molenaar S. 1998. *Furniture From Young Plantation Grown Eucalypts—Engineering Properties of Young Eucalypts.* Forest and Wood Products Research and Development Corporation, Melbourne.

Shearman P, Bryan J, Ash J, Hunnam P, Mackey B & Lokes B. 2006. *The State of the Forest of PNG: Mapping the Extent and Condition of Forest Cover and Measuring the Drivers of Forest Change in the Period 1972–2002.* University of Papua New Guinea, Port Moresby.

Venn JJ, Mcgavin RL & Leggate WW. 2004. *Utilisation of Western Queensland Hardwoods as Speciality Timbers.* Forest and Wood Products, Melbourne.

Winandy JE, Rowell & Roger M. 1984. The chemistry of wood strength. Pp 211–255 in *Advances in Chemistry.* American Chemical Society, Madison.

Yoshihara H & Suzuki A. 2004. Shear stress/shear strain relation of wood obtained by asymmetric four-point bending test of side-tapered specimen. *Journal of Testing and Evaluation* 33: 6.