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Strength group of Engkabang jantong as fast-growing indigenous species timber in Sarawak

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Abstract: Engkabang jantong is one of fast-growing indigenous species of Sarawak. Due to shortage of the source for heavy hardwood in the timber industries, an effort had been carried out to identify alternative species. Small clear sample is the most suitable for strength properties test. This paper aimed to acquire the strength group of fast-growing indigenous of Engkabang jantong compared with *Acacia mangium* as reference point. Strength properties at green and dry conditions are required namely bending parallel to grain, compression stress parallel to grain, shear parallel to grain and modulus of elasticity. The MS 544: Part 2 (2001) was used for strength group identification by converting the ultimate stresses obtained from strength properties into basic and grade stresses. It was founded that, Engkabang jantong of Sarawak classified under strength group SG6 as compared to *Acacia mangium* classified under strength group SG5.

Key words: Bending parallel to grain; Compression stress parallel to grain; Shear parallel to grain; Modulus of elasticity; Basic stress; Grade stress

1. Introduction

Engkabang jantong with biological name *Shorea marcophylla* is very well-known among the Iban people in Sarawak. The tree group which comprising of twenty species of a sub-family *Shorea* in Dipterocarpaceae in Sarawak (Smythies, 1985; Anderson, 1980). In Brunei, Engkabang jantong is appearing to correspond to a local species' group as Kawang and Tengkawang in Indonesia (Ashton, 2006). This confusion is recognizable between researchers and between Sarawak and Indonesia (Hotta, 1997). Engkabang jantong is well-known to produce big nuts known as illipe nuts to produce the illipe nut butter (Lee et al., 1997). The habitat of Engkabang jantong is found mainly in tropical lowland rainforest trees, especially in secondary growth frequently along rivers and in areas, which are periodically inundated. This species is known as one of the fastest growing species of the genus (Ashton, 1998).

The tree diameter can reach up to 50 m tall, and 130 cm diameter (SFD, 2011). The tree is lightweight reddish and yellowish timber. The timber is a light hardwood with a density of 0.415 to 0.625 g/cm^3 air-dry (MTC, 2006). According to Gan et al. (1998) from FRIM, the density at air-dry is ranged from 0.385 to 0.755 g/cm^3. The texture is rather coarse, and the grain is straight to shallowly interlock and somewhat lustrous. It does not have any distinctive odour or taste (Gan et al., 1998). Mechanical properties at air-dry condition given that for MOE and bending parallel to the grain are 7900 N/mm^2 and 46 N/mm^2, respectively. Furthermore, the compression strength for perpendicular and parallel to grain are 2.21 N/mm^2 and 24.50 N/mm^2, respectively. Meanwhile for shear strength is 6.30 N/mm^2 (HAIFOR, 2010).

Study conducted by Gan et al. (1998) showed that at green condition the MOE, bending parallel to the grain and compression parallel to grain are 9300 N/mm^2, 50 N/mm^2 and 25.6 N/mm^2, respectively. Meanwhile, at air-dry condition MOE, bending parallel to the grain and compression parallel to grain are 10200 N/mm^2, 63 N/mm^2 and 34.5 N/mm^2, respectively. *Acacia mangium* (Fabaceae: Mimosoideae) is a perennial tree native to Australia and Asia. Common names for it include Black Wattle, Hickory Wattle and Mangium. This species is selected for this study as a reference point. At the green soaked volume the density value ranges from 0.420 to 0.483 g/cm^3 meanwhile at the dry condition it varies between 0.5 to 0.6 g/cm^3 (Logan and Balodis, 1982; Peh and Khoo, 1984; Peh et al., 1982; Razali and Kuo, 1991; Sasaki and Razali, 1989)

). *Acacia mangium* at green condition reported with 114% of moisture content (MC) and 0.51 g/cm^3 of basic density (Alik, 1999). The MOE, bending parallel to the grain and compression stress parallel to grain at green condition were reported to be with 10900 MPa, 86.4 Mpa and 36.80 MPa, respectively and classified under Compressive Strength Group C, (Alik, 1999). It is understood that density of timber is relatively reflected the strength of the timber; however it should not be the definite measurement of its strength (Ismaili et al., 2015). Some physical testing have to be conducted to reveal and confirmed

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the timber strength group as identified from its density by performing small clear sample testing (Rahman, 1988).

The strength properties results can be compared and to be concluded by identifying its strength group classification based on Malaysian Standard MS544: Part 2 requirements. The strength group classification is based on strength properties results from compression parallel to grain test, shear parallel to grain test, bending parallel to grain and modulus of elasticity in two conditions at green and air-dry. Strength group classification is depended on grade stresses results, i.e. grade select, grade standard and grade common. There are seven categories of strength group, namely SG1, SG2, SG3, SG4, SG5, SG6 and SG7. In timber engineering practice, the ultimate stresses obtained from the tests are reduced by applying arbitrary factors (Thomas, 1948) to obtain what is called working stresses or permissible stress. These arbitrary reduction factors account for variability of timber duration, and conditions offloading, and factor of safety (Rahman, 1988).

2. Preparation of specimens

Twelve years old planted species of *Acacia mangium* and Engkabang jantong were collected from Sabal Reforestation Plot were used in this study; Selected of defect free and healthy tree, with straight bowl approximately 7.5 m of height with the diameter at breast height over bark of the tress ranged from 240 mm to 340 mm. The planed samples were cut approximately 0.3m from the ground level. The logs were then planed and machined to 20 x 20 mm for static bending tests, compression parallel to the grain test, and shear parallel to grain test. For both conditions (air-dry and green) of sample, only the selected small clear sample for which is a defects free sample was used for analysis. The small clear test is in accordance to the British Standard BS 373: 1957. The green condition samples were first to be tested whilst for air-dry condition samples stacked properly for air-drying process. This air-dry process is depending on the type of species sample, and this process can be more than nine months. A total of 190 timber samples were used for the bending tests at green and air-dry conditions. A total number of 825 of defect free timbers specimens which is approximately $0.0992m^3$ are used for strength properties test in both conditions for each test.

2.1. Ultimate stress of strength properties determination

The determination of strength properties for green and 19% air-dry conditions were obtained from destructive test (DT). Four strength properties were acquired i.e. bending parallel to grain, compression parallel to grain, shear parallel to grain (tangential and radial directions) and modulus of elasticity. The average shear parallel to grain was from tangential and radial. The testing was done in accordance to the British Standard BS 373: 1957. For static bending test, a specimen 20 x 20 x 300 mm in length is supported over a span of 280mm, and the test is carried out by the three-point bending method. Compression test results were conducted with 20 x 20 x 60 mm specimen to determine maximum result. For shear parallel to grain test specimen dimensions of 20 x 20 x 20 mm is used. For shear parallel to grain at radial direction, the direction of shearing is in the parallel to the longitudinal of grain direction where the plane of shear failure is parallel to the radial direction. At tangential direction is vice versa where the plane of shear failure is parallel to the tangential direction.

2.2. Basic and grade stresses determination

The results that were obtained from ultimate stress of strength properties obtained from small clear specimen cannot be used directly in timber design (Ismaili et al., 2015). For structural used, it has to be converted in to basic and grade stresses that are calculated by using the probability values and multiplied with the safety factors as in Table 1.

Table 1: Probability values and factor of safety for determination of basic stresses (Rahman, 1988)

Property	Probability value	Formula	Factor of Safety
Bending	1 in 100	$\bar{x} - 2.33\sigma$	2.5
Compression parallel to the grain	1 in 100	$\bar{x} - 2.33\sigma$	1.5
Shear parallel to the grain	1 in 100	$\bar{x} - 2.33\sigma$	2.5
Mean modulus of elasticity	-	$\bar{x}$	1.0
Minimum modulus of elasticity	1 in 100	$\bar{x} - 2.33\sigma$	1.0
where, $\bar{x}$ = mean ultimate stress, σ = standard deviation			

This basic stress shall be applicable to structural use in timber design (Ismaili et al., 2015). From air-dry condition to obtain air-dry basic stresses it should be 19 percent moisture content (Rahman, 1988). The air-dry basic stresses will be calculated by the formula, as in:

$$\underset{\text{(Air-dry)}}{\text{Basic Stress}} = \frac{S_3}{\text{mean ultimate stress}} \times \underset{\text{(Green)}}{\text{Basic Stress}} \quad (1)$$

Using Madison's formula to estimate the ultimate stress at 19 percent moisture content will be calculated by the formula, as in:

$$\log S_3 = \log S_1 + \frac{(M_1 - M_3)}{(M_1 - M_2)} \log \frac{S_2}{S_1} \quad (2)$$

where S_3 is the ultimate stress at 19 percent moisture content, S_1 is the ultimate stress at fibre saturation point at 25 percent moisture content and assumed to be equal to green stress, S_2 is the ultimate stress from air-dry test, M_1 is assumption of fiber saturation point at 25 percent, M_2 is the air-dry moisture content from test, and M_3 is the maximum moisture content for dry condition at 19 percent. The results obtained from green and air-dry basic stresses were multiplied by the strength ratio to acquire stress grades select, standard, and common.

Table 2: Strength ratios (Pun et al., 1997)

Property	Select Structural %	Standard Structural %	Common Structural %
Bending, tension and compression parallel to grain	80	63	50
Shear	72	56	45
Modulus of elasticity	Same as the basic value for all grades		

Table 3: Mean results for strength properties between *Acacia mangium* and Engkabang jantong species at green and air-dry conditions

		Condition	Bending parallel to grain (N/mm2)	Compression Stress parallel to grain (N/mm2)	Shear // to grain-Tangential direction (N/mm2)	Shear // to grain-Radial direction (N/mm2)	Modulus of Elasticity (N/mm2)
Acacia mangium	Mean	Green	88.7	37.3	11.8	10.8	11421.1
	SD		11.9	5.0	1.9	1.4	2307.8
	CV%		13.4	13.4	15.7	12.7	20.2
	Nos.		41.0	41.0	41.0	41.0	41.0
	Mean	Air-dry (19%)	96.0	41.7	11.6	10.1	12064.5
	SD		13.9	6.8	1.2	1.3	1922.1
	CV%		14.4	16.2	10.3	12.6	15.9
	Nos.		43.0	43.0	43.0	43.0	43.0
Engkabang jantong	Mean	Green	49.6	24.3	6.4	5.7	7143.7
	SD		8.6	3.9	0.8	0.9	1167.2
	CV%		17.4	16.0	12.4	15.5	16.3
	Nos.		46.0	46.0	46.0	46.0	46.0
	Mean	Air-dry (19%)	64.3	35.8	8.6	7.9	8007.3
	SD		7.9	3.9	1.5	0.9	1068.1
	CV%		12.2	11.0	17.3	11.8	13.3
	Nos.		35.0	35.0	35.0	35.0	35.0

Table 4: Green and Air-dry Grade Stresses and Modulus of Elasticity

Species	Strength Group	Condition	Bending Parallel to the Grain [N/mm²]				Compression Parallel to the Grain [N/mm²]				Shear Parallel to the Grain [N/mm²]				Modulus of Elasticity [N/mm²]	
			Basic	Select	Standard	Common	Basic	Select	Standard	Common	Basic	Select	Standard	Common	Mean	Minimum
Acacia mangium	SG5	Green	24.4	19.5	15.3	12.2	13.1	13.7	10.8	8.6	3.0	2.4	1.9	1.5	11421	6044
		Dry (19%)	26.3	21.0	16.5	13.1	19	15.2	12	9.5	2.9	2.3	1.8	1.4	12065	6368
Engkabang jantong	SG6	Green	10.2	8.2	6.4	5.1	8.3	6.6	5.2	4.1	1.6	1.3	1.0	0.8	7143.7	4424.0
		Dry (19%)	13.7	10.9	8.6	6.8	12.6	10.1	8.0	6.3	1.9	1.5	1.2	1.0	8007.3	4714.8

3. Results and discussion

The results for ultimate stress of strength properties in Table 3 were that to be converted to obtain the results in Table 3 to acquire for basic and grade stresses. In Table 4 shows that Engkabang jantong at green condition the mean compression parallel to grain had result the grade stresses basic, select, standard, and common were 8.3 N/mm², 6.6 N/mm², 5.2 N/mm², and 4.1 N/mm², thus contributed the grade stresses to be classified under SG6 compared to *Acacia mangium* with SG4. The mean of shear parallel to grain for grade stresses basic, select, standard, and common with 1.6 N/mm², 1.3 N/mm^2, 1.0 N/mm^2, and 0.8 N/mm^2, respectively thus classified under SG5 compared to *Acacia mangium* with SG2. Bending parallel to grain's basic stress was 10.2 N/mm^2 with the grade stresses of select, standard, and common with 8.2 N/mm^2, 6.4 N/mm^2, and 5.1 N/mm^2, respectively and fall under SG6 compared to *Acacia mangium* with SG2. Moreover, the minimum modulus of elasticity's grade stress was 4424.05 N/mm^2 with mean modulus of elasticity 7143.7 N/mm^2 and classified under SG6 if compared to *Acacia mangium* with SG5. At green condition, Engkabang jantong was classified under SG6 compared to *Acacia mangium* with SG5.

At 19% air-dry condition, Engkabang jantong's basic stress for compression parallel to grain was reported at 12.6 N/mm^2 had contributed the grade stresses of select, standard, and common with 10.1 N/mm^2, 8.0 N/mm^2 and 6.3 N/mm^2, respectively and classified under SG5 compared to *Acacia mangium* SG4. Shear parallel to grain with the grade stresses basic, select, standard, and common were 1.9 N/mm^2, 1.5 N/mm^2, 1.2 N/mm^2, and 1.0 N/mm^2, respectively and fall under SG5 compared to *Acacia mangium* with SG2. Engkabang jantong's basic stress for bending parallel to grain was 13.7 N/mm^2 thus gave the results for grade stresses of select, standard, and common were 10.9 N/mm^2, 8.6 N/mm^2 and 6.8 N/mm^2, respectively thus classified under SG6, compared to *Acacia mangium* SG3. Furthermore, for minimum Modulus of Elasticity, the grade stress was 4714.8 N/mm^2 with mean modulus of elasticity 8007.3 N/mm^2 and classified under SG6, relatively close to *Acacia mangium* with SG5. At 19% air dry condition, Engkabang jantong was classified under was classified under SG6, which was close to *Acacia mangium* with SG5. This can be concluded that, for both green and 19% air-dry conditions, Engkabang jantong can classified under SG6, and it was relatively close to *Acacia mangium* with SG5.

4. Conclusion

The basic and grade stresses for strength groups can be used to facilitate the design, stocking and supply of timber for structural purposes [24]. Engkabang jantong can be recommended mainly for general utility for furniture making and other non-structural applications. The result from small clear must be first derived into permissible stresses before it can be used for structural design purposes with the appropriate modification factors given in British Standard CP 112:1967 or Malaysian Standard MS544: Part 2. From this study Engkabang jantong has been classified under the strength group SG6 compared with *Acacia mangium* that classified under SG5.

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