Evaluation of *Acacia Mangium* in Structural Size at Green Condition

Gaddafi Ismaili, Badorul Hisham Abu Bakar and Khairul Khuzaimah Abdul Rahim

Abstract—*Acacia mangium* is one of the most popular choices in the reforestation and rehabilitation of abandoned shifting cultivation areas dated back to the 70's. This paper looks into the evaluation of mechanical strength and physical properties in structural size at green condition for *Acacia mangium*. The mechanical strength properties tests were referred to the modulus of rupture, modulus of elasticity and tensile strength. Meanwhile, physical properties determination referred to basic density and moisture content. At green condition, *Acacia mangium* had been identified under the strength group SG6. It was found that strength value of modulus of rupture was higher than the tensile strength value with 44% stronger in bending compared to in tension. At the structural size, the mean value for moisture content and basic density at green condition were reported with 73.03% and 0.54g/cm^3 respectively.

***Keywords*:** Modulus of rupture, modulus of elasticity, tensile strength, basic density and moisture content

I. Introduction

Acacia mangium (Fabaceae: Mimosoideae) is a perennial tree native to Australia and Asia. Common names for it include Black Wattle, Hickory Wattle and Mangium. The species was selected for this study as a result of some factors. One of the main factors is due to its fast growing characteristics. Besides that, it is also one of the major plantation species in Malaysia. Successful plantations of this species were reported from Sabah [4]. In Sarawak, this species is most widely used in the reforestation and rehabilitation of abandoned shifting cultivation areas [12]. This is because the species is very adaptable to a wide range of soil types that it even thrives on degraded sites where shifting cultivation had been practiced, on hill slopes overgrown with weeds like *Imperata* and *Eupatorium* species, and in areas subjected to seasonal flooding or areas leveled by tractors [21].

Structural usage of the timber is definitely one of the potential areas to explore [4]. A detailed knowledge of the growth and structure of wood is essential to the design of efficient timber structures. Nevertheless, an understanding of its characteristics may help engineer and designer to appreciate the behavior of wood as a constructional material [20]. Consequently, the purpose of this study is to evaluate *Acacia mangium* in structural size at green condition associated to the mechanical strength characteristic.

II. Materials and Methods

Materials and sampling methods

A total of 29 *Acacia mangium* trees were collected from Sabal Reforestation Plot. The age of the trees was about 23 years old. From these trees, a total of 323 samples were recovered. From those 323 samples, only the results from 50 samples at green condition were selected randomly and presented. The remaining samples are still in the process of air-drying and will be utilized for further studies.

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Selection of trees carried out for the samples were done at random basis. Then, the felled trees were sawn to logs form with length about 2.1m. Some allowance was given for the planning and air-drying process. Subsequently, the logs were marked and then sawn to 127 x 127mm flitches. The logs were firstly sawn at two opposite's sides (Figure 1) to relieve the stress from the logs. Consequently, this was to avoid the flitches from bending outward when they were sawn through the middle of the logs.

Figure 1: Sawing of logs to flitches forms.

Next, the flitches undergo the machining process. During this process, flitches are ripped to sample pieces. The ripped samples were also given some allowance for the planning and air-drying process. From these green samples, 50 samples were taken to undergo the planning process to a target size of 50 x 100 x 2000mm. Balances of samples are stacked properly for air-drying process (Figure 2).

Figure 2: Samples undergoing air-drying process.

Testing methods

Mechanical Strength properties

There were two types of strength test conducted namely structural bending test and structural tensile test. Testing was done in accordance to the British Standard BS 5820:1979. The testing room condition was maintained at room temperature of 23 ± 3°C. Bending test was conducted using an Instron Universal Testing Machine, which has a loading capacity of 200kN (Figure 4) with a loading rate of 8mm/min. The support span for this test was 1800mm, and its loading span was 600mm. Samples were places on rollers, which are at a free support condition. The values of modulus of rupture and modulus of elasticity were electronically calculated by the machine.

Figure 3: Structural bending test.

On the other hand, the tensile test was conducted using Maekawa Horizontal Tensile Machine with a capacity of 1000kN (Figure 4). The test samples were loaded using gripping devices, which will permit as far as possible the application of uniform tension without inducing bending. Distance between both grips was 1000mm, and the applied load was at a continuous speed rate of 6mm/min. The formula (1) to obtain the values of tensile strength is shown below:

$$TS = \frac{P_{\max}}{bh} \qquad (1)$$

Where TS = Tensile strength (N/mm^2)
P_{max} = Max Load (N)
b = Breadth (mm)
h = Height (mm)

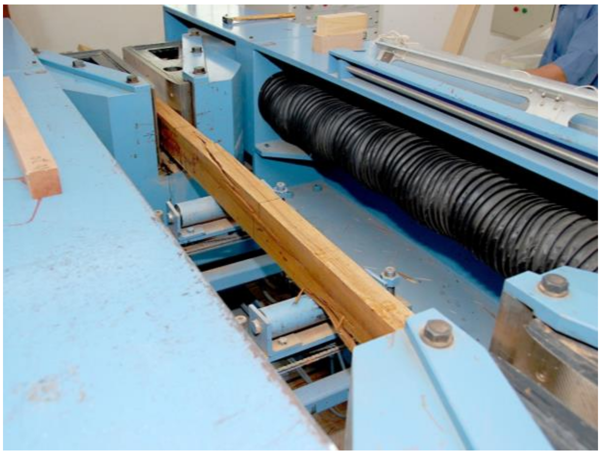

Figure 4: Structural tensile test.

Physical properties

Moisture content determination

Moisture content determination was conducted directly after the processing was completed. This was to ensure that the moisture content inside the samples was properly conserved. At that point, the initial weights were taken. Then, samples were placed in the oven at 103±2°C until the constant weight was achieved. Afterward, the oven-dried weights were taken. Therefore, the moisture content values were determined by using the formula (2) below:

$$\text{Moisture content}, (\%) = \frac{W_i - W_o}{W_o} \times 100 \qquad (2)$$

Where W_i = Initial weight (g)
W_o = Oven-dry weight (g)

Basic density determination

Basic density determination test were conducted using the same samples used for moisture content determination test. Thus, the dimensions of the green samples were taken before they were placed into the oven to find out the green volumes. The values of the oven-dried were also needed to complete the formula used to determine the basic density as follows:

$$BD = \frac{W_o}{V_g} \qquad (3)$$

Where BD = Basic Density (g/cm^3)
W_o = Oven-dry weight (g)
V_g = Volume at green condition (cm^3)

III. Results and Discussion

Materials and sampling methods

The results of modulus of rupture, modulus of elasticity and tensile strength of structural size samples is shown in Table 1. The mean values of modulus of rupture, modulus of elasticity and tensile strength are 60.95N/mm^{2,} 13262N/mm^2 and 42.32 N/mm^2 with its coefficient of variation 16.16%, 10.89% and 22.67% respectively.

Table 1: Summary of results for *Acacia mangium* at green condition.

Statistical Analysis	Bending		Tensile	Basic Density	Moisture Content
	MOR	MOE	Tensile Strength		
	N/mm^2	N/mm^2	N/mm^2	g/cm^3	%
Mean	60.95	13262	42.32	0.54	73.03
STDEV	9.85	1444	9.60	0.05	11.93
CV%	16.16	10.89	22.67	8.83	16.33
n	25		25	50	

Note:
MOR = Modulus of rupture
MOE = Modulus of elasticity
Mean = Mean values
STDEV = Standard deviation
CV = Coefficient of variation
n = Number of specimens

The coefficient of variation is quit high for every result parameter mentioned with the exceptions on the modulus of rupture 10.89%. One of the main reasons is probably due to lacking in the number of specimens. Basically, if a higher number of specimens were used, the coefficient of variation would definitely be lower. Besides that, the occurrence of defects such as knots, sloping grain and inherent properties might reduce the strength values of timber. Based on the strength of green samples, the timber can be group in the SG 6 [6] which is in the same grouping with species such as Bindang (*Agathis* spp.), Jongkong *(Dactylocladus stenostachys*), Yellow Meranti (*Shorea* spp.), Mersawa (*Anisoptera* spp.), Durian (*Durio* spp.) etc. Therefore, the timber species may be recommended for structural applications.

Physical properties

Fiber-saturation point of most timber species is between the ranges of 25 to 30%. Therefore, timber samples would be considered to be in green condition when its moisture content value is above that range. For that reason, all specimens were considered to be in green condition with mean moisture content of 73.03% which ranges between 53.08% and 117%.

There was a marked increase in strength of timber species tested from green to air-dried condition [1]. The increment of strength with reduction in moisture is because of shortening and consequently, strengthening of hydrogen bonds linking together the microfibrils [13], [9]. Nevertheless, the effect of moisture is less significant on some mechanical properties of timber [18], [19], [15]. Thus, samples of air-dried condition of the timber will be tested.

Wood density provides a simple measurement of the total amount of solid-wood substances in a piece of wood [17]. The mean value of basic density was 0.54 g/cm^3 with the coefficient of percentage of 8.83%. Therefore, *Acacia mangium* is classified under Light Hardwood [7].

From the results, the coefficient of variation of most parameters is quit high. The occurrences of defects mainly big size knots promote to this matter. It is well known that the strength and stiffness of wood members containing knots is reduced due to the disruption of the grain in the region of the knot [22]. Knots influence the strength properties of a piece of wood to a varying degree depending on the size, position and type [11]. However, there is no difference in the effects between live and dead knot as far as stress grading of timber is concerned [9].

The location of knots affects the bending strength more because the distribution stress varies along the depth of a beam [10], [14]. Based on timber failures, out of the total number tested for structural bending, roughly 90% of the timber samples failure started from compression and finally ended with tension failures (Figure 5). The failures pattern was similar to the small clear specimens. A knot that is located close to the axis will have less effect on strength than the one located close to the edge. Referring to Figure 6, this is true especially for the edge subjected to tensile stresses since the effect is more in tension rather than in compression [2], [10].

Figure 5: Failure on bending specimens.

Figure 6: Failure on tensile specimens.

IV. CONCLUSION

The results obtained from structural size very much different with small clear specimen. This was due to the homogenous behavior in timber that been tested in structural size compared to small clear specimen or defect free sample. The differences can be identified where the small clear specimen recorded with modulus of rupture mean value 86.4N/mm^2 [3] which was 29.46% higher than the mean value obtained from structural size with 60.95N/mm^2. For modulus of elasticity, the small clear result obtained with 10900N/mm^2 [3] which was 17.81% lower than the result acquired from structural size with 13262N/mm^2.

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