# Engineering Properties of Fast Growing Indigenous Timber in Sarawak Compare to Acacia Mangium: Aras

**Gaddafi Bin Ismaili**

***Abstract*— An effort has been taken to explore fast-growing indigenous of Aras as optional species besides Acacia mangium that prone to a number of diseases. Basic information on engineering properties viz; mechanical and physical properties from different species, and conditions were acquired from strength property's test namely, modulus of rupture, modulus of elasticity, impact bending, and compression stress parallel to grain. Meanwhile, for physical properties test namely moisture content and density. The test samples were prepared in small clear specimens according to British Standard, BS373.1957. Specimens condition which is referred to as green condition and air-dry condition. Data obtained from this study is very useful for utilization in furniture and engineering construction industries. In this study Aras was compared to Acacia mangium as the reference point use for observation. The results from the study indicated that, Aras gave the average percentage difference of mean for mechanical and physical property with 35% toward the results obtained by Acacia mangium.**

***Index Terms*— Modulus of rupture, Modulus of elasticity, Impact bending, Compression stress parallel to grain, Moisture content, Density.**

## I. INTRODUCTION

*Acacia mangium* is a species from the Fabaceae family. This species is native to northern Queensland in Australia, through Papua New Guinea into the Indonesian provinces of Irian Jaya and Maluku. It adapted with the wide range of soils in moist tropical lowlands [1]. In Malaysia, the planting of *Acacia magnium* on a commercial basis in plantations was instituted in 1962 [2]. In timber industry, *Acacia mangium* timber is very well known to produce attractive furniture and cabinets, door frames, window parts, mouldings, and sliced veneers [3]. Aras is known by the local in Sarawak where it botanical name is *Ilex cissoidea*. In Sabah, it was known as *bangkulatan* and *morogis*. Whereas in Peninsular Malaysia, this species also known as *timah-timah*. *Ilex cissoidea* is categorized in Aquifoliaceae family that commonly found throughout temperate and tropical regions of the world, mainly in South East Asia [4]. Generally, log production in Malaysia is mainly to accommodate of huge demand for general utility timber for industrial purposes. They go into cores of plywood and make up the major constituent of fibreboard, particleboard, interior construction wood, and other low grade use. Several species have been identified for this purpose and include *Shorea* spp. (Light Red Meranti group), *Hopea* spp., *Dryobalanops* spp., *Endospermum malaccense*, *Hevea brasiliensis, etc.* Many of these species would be included in reforestation and enrichment planting schemes within the Permanent Forest Estate (PFE). The species would have rotations of about 30-35 years [5]. Meanwhile for high quality timbers are grown for veneers, panelling, furniture, *etc.* [2]. Sarawak consists of numerous indigenous species of fast growing timber. From this species, several had been identified to be potential species for light wood industries utilisation and for engineering structural design purposes that can be optional species after *Acacia mangium*. The potential species are referred to Engkabang jantong, Aras, Terbulan, Kelampayan, Sawih, Benuang and, etc. Each of these species had it own characteristic and behaviour for its engineering properties viz; physical or mechanical properties. Therefore, effort had been carried out to conduct study on the potential fast growing indigenous species as optional species after *Acacia mangium* to accommodate the huge demand in light wood industries.

**Manuscript Received on December 2014.**
**Dr. Gaddafi Ismaili**, Department of Civil Engineering, University Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.

## II. PREPARATION OF SPECIMENS

Two timber species were collected from Sabal Reforestation Plot. The species were randomly selected and identified at the site. Selected trees were healthy, with straight bole and age between 20 to 25 years old. Three sections of log were made for ease sampling namely, bottom, middle and top parts of tree bole. The log of about 1.53m in length was then ripped through the pith to obtain two flitches and then be machined into boards. The boards were subsequently machined to produce exactly 20mm square sticks of small clear specimens. The sticks were visually grade, and only defect free green as well as air-dry samples are cut into specified length and tested. The green condition samples were first to be tested while for air-dry condition samples stacked properly for air-drying process. The air drying process is depending on the type of species, and this process can take more than nine months. A total of 190 timbers specimens were used for mechanical, and physical properties test both in each testing condition.

## III. MECHANICAL PROPERTIES

The testing conducted by using destructive test (DT) and results were obtained from two different timber conditions, i.e. green and air-dry conditions. Five testing results of mechanical properties were acquired i.e. modulus of rupture, modulus of elasticity, compression stress parallel to grain, and impact bending.

### A. Static bending test

Testing was done in accordance to the British Standard BS 373: 1957 [6]. Bending test was conducted using an Instron Universal Testing Machines with loading capacity of 50kN. A specimen 20 x 20 x 300mm in length is supported over a span of 280mm, and the test is carried out by three-point bending method. Samples were placed 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. The formulae to determine the fibre stress, Modulus of Elasticity (MOE) and bending strength or Modulus of Rupture (MOR) are as follows:

$$MOE = \frac{L^3}{4WT^3}\frac{\Delta F}{\Delta \ell} \quad (1)$$

where, $L$ : Span (mm)

$\frac{\Delta F}{\Delta \ell}$ : Slope of graph (Nmm$^{-1}$)

$W$ : Width (mm)

$T$ : Depth (mm)

$MOE$ : Modulus of Elasticity (Nmm$^{-1}$)

$$MOR = \frac{3}{2}\frac{FL}{WT^2} \quad (2)$$

where, $F$ : Maximum load (N)

$L$ : Span (mm)

$W$ : Width (mm)

$T$ : Depth (mm)

$MOR$ : Modulus of Rupture (Nmm$^{-1}$)

### B. Impact bending test

This test was made to determine impact force and work done (energy) to break the specimen. A specimen of 20 x 20 x 300mm in length is prepared according to French Standard. The test specimen is placed on two supports 240mm apart. The striking edge of the hammer and the supports are rounded with radius of 15mm. A pendulum strikes against the test specimen in the centre and breaks it. The weight of the pendulum is 10kg and height of fall 1m so the striking energy available is 10kgfm. This test is made to determine impact force and work done (energy) to break the specimen. These can be calculated by formulas as follows:

$$W = mg(h_1 - h_2) \quad (3)$$

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)

$$E = \frac{W}{bd} \quad (4)$$

where, $E$ : Energy absorbed in impact bending (J mm$^{-2}$)

$W$ : Work in impact bending (J)

$b$ : Width of the specimen (mm)

$d$ : Height of the specimen (mm)

### C. Compression stress parallel to grain

This test is made on 20 x 20 x 60mm specimen in which special care has been taken to ensure that end-grain surfaces are parallel to each other and normal to the longitudinal axis. The specimen is placed between two compression platen and the rate of upper platen descent 0.6mm/min is used. The property determined is the maximum compression strength parallel to grain. The values of compression stress at maximum load were electronically calculated by the machine. Compression stress at maximum load is calculated by using the formula as follows:

$$\text{Compressive stress at maximum load} = \frac{F}{A} \quad (5)$$

where, $F$ : Maximum load (N)

$A$ : Cross-sectional area (mm$^2$)

## IV. PHYSICAL PROPERTIES

The testing conducted by using non-destructive test (NDT) and results were obtained from two different timber conditions, i.e. green and air-dry conditions. There are two testing results acquire namely moisture content and density.

### *A. 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 are taken. Then, samples are placed in the oven at 103 ± 2°C until the constant weight was achieved. The percentage of moisture content is calculated on the dry weight basis. Therefore, the moisture content values are determined by using the formula as follows:

$$X = \frac{W_1 - W_0}{W_0} \times 100 \quad (6)$$

where, $X$ : Moisture content (%)

$W_1$ : Weight of sample at test (g)

$W_0$ : Weight of sample, oven-dry (g)

### *B. Density*

Basic density determination test are conducted using the same samples used for moisture content determination test. Thus, the dimensions of the green samples are taken before they are placed into the oven to find out the green volumes. The specimens were calculated from the ratio of oven-dried weight to green volume. Water displacement method was used to get the green volume, and the dry weight was measured using an electronic balance. The values of the oven-dried are also needed to complete the formula used to determine the basic density as follows:

$$\rho_b = S_1 \rho_w \left(1 + \frac{X}{100}\right) \quad (7)$$

where, $\rho_b$ : Specific density at test (g/cm$^3$)

$S_1$ : Specific gravity (g/cm$^3$)

$\rho_w$ : Density of water 1000 kg/m$^3$



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

$X$ : Moisture content (%)

## V. RESULTS AND DISCUSSION

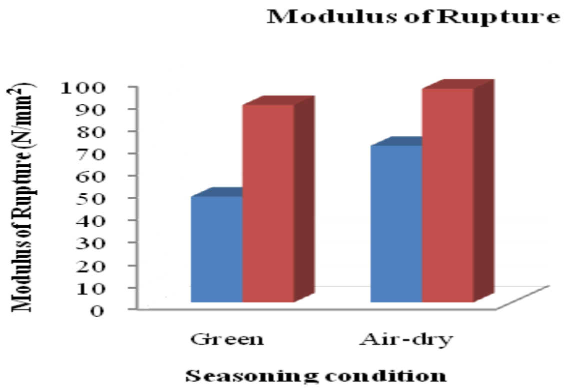
The results obtained from analysis were compared between Aras fast-growing indigenous species with exotic species Acacia mangium as the reference point. The comparison of mechanical and physical properties was based on the percentage different compared to Acacia mangium at green and air-dry conditions using statistical analysis. Mean results from each species from each property were converted into percentage based on its mean different compare to the mean obtained from Acacia mangium. Small percentage of different will be subjected to the closeness of the species toward the reference species.

### A. Bending properties

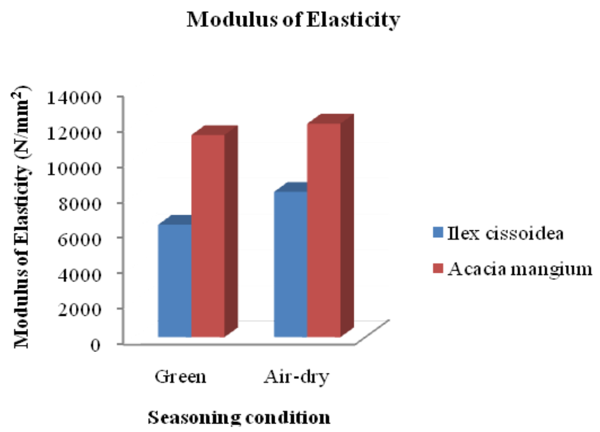
At green condition, Aras reported with modulus of rupture mean value of 47.54N/mm2. Comparatively, the modulus of rupture mean value for Acacia mangium was 46.38% higher than the average mean of indigenous species with its mean value of 88.66N/mm2 at green condition. Meanwhile, at air-dry condition, the mean value for Aras with 70.32N/mm2. The modulus of rupture mean value for Acacia mangium was 26.72% higher than Aras with mean value of 95.96N/mm2 for air-dry condition. The results of modulus of elasticity at green condition identified that Aras, with mean value of 6360.05N/mm2. Whilst, Acacia mangium recorded with 44.32% higher than the Aras with mean value of 11421.06 N/mm2 at green condition. At the air-dry condition, the mean value for Aras was 8213.66N/mm2 with the percentage different of 31.92% compared to Acacia mangium with its mean value of 12064.51N/mm2. The modulus of elasticity mean value for both indigenous and exotic species was increased from green condition to air-dry condition with the increment of 16.23% and 5.33%, respectively. The relationship between bending strength and modulus of elasticity can also be affected by the way in which the timber is dried [7]. The results obtained from impact bending test showed that the result from green condition slightly higher than the air-dry condition. Impact bending resistance may, in fact, decrease because the dry timber will not bend as far as green timber before failure, although it will generally bear a greater load [8]. At green condition, Aras reported with mean value of 1.97J. Meanwhile, Acacia mangium recorded 4.17J, which was 52.76% higher than the Aras. At air-dry condition, Aras recorded with mean value of 1.71J, whilst Acacia mangium reported 54.28% higher than the Aras with mean value of 3.74J. The results showed the decreased in mean value for both species from green condition to air-dry condition. For Indigenous species, it decreased to 13.20%, whilst Acacia mangium decreased to 10.31% from green condition to air-dry condition. This showed that, Indigenous species decreased more than 2.89% compare to Acacia mangium. The results for bending tests were tabulated in Table I and it was clearly presented in Fig. 1 and Fig. 2..

**Table I. The bending properties of Indigenous species**

| Species | Seasoning condition | Static bending | | Impact bending (Joule) |
|---|---|---|---|---|
| | | Modulus of rupture (N/mm$^2$) | Modulus of elasticity (N/mm$^2$) | |
| *Acacia mangium* | Green | 88.66 | 11421.06 | 4.17 |
| | Air-dry | 95.96 | 12064.51 | 3.74 |
| Aras | Green | 47.54 | 6360.05 | 1.97 |
| | Air-dry | 70.32 | 8213.66 | 1.71 |




(a)




(b)

**Figure 1. Comparison of (a) modulus of rupture and (b) modulus of elasticity at different seasoning condition**

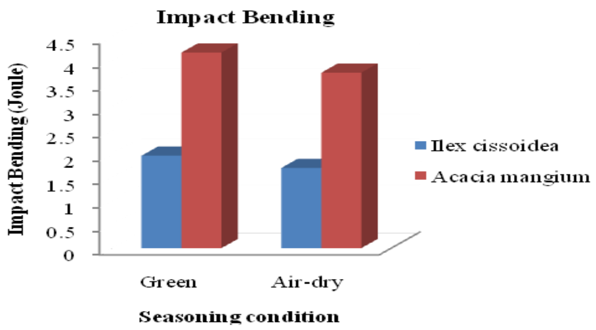



**Figure 2. Comparison of impact bending at different seasoning condition**

### *B. Compression stress parallel to grain*

The results from the compression stress parallel to grain at green condition, Aras reported with mean reading of 22.42N/mm2, while Acacia mangium was 39.92% higher than Aras with its mean value of 37.32N/mm2. Meanwhile, at air-dry condition Aras reported with the mean value of 34.15N/mm2. As a result, the mean value for Acacia mangium is 18.03% higher than Aras with its mean value of 41.66N/mm2. The mean value obtained from both indigenous and exotic species increase from green condition to air-dry condition by the average increment of 34.34% and 10.42%. It was concluded that the wood tested in compression and loaded in parallel to the grain stronger than when loaded perpendicular to the grain. The results for compressive stress were tabulated in Table II and it was clearly presented in Fig. 3.

**Table II. Compressive stresses parallel to the grain of Indigenous species**

| Species | Seasoning condition | Compression parallel to grain |
|---|---|---|
| | | Maximum crushing strength (N/mm$^2$) |
| *Acacia mangium* | Green | 37.32 |
| | Air-dry | 41.66 |
| Aras | Green | 22.42 |
| | Air-dry | 34.15 |

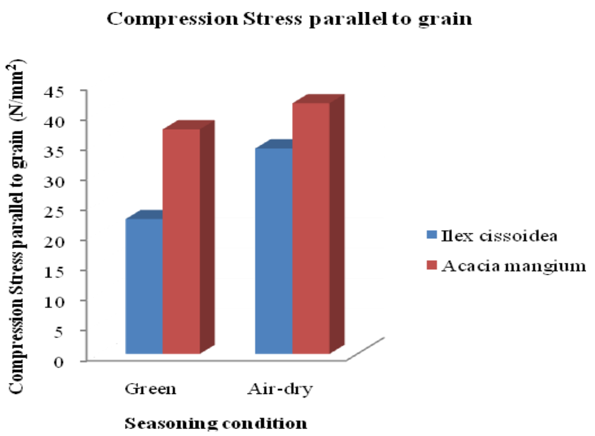


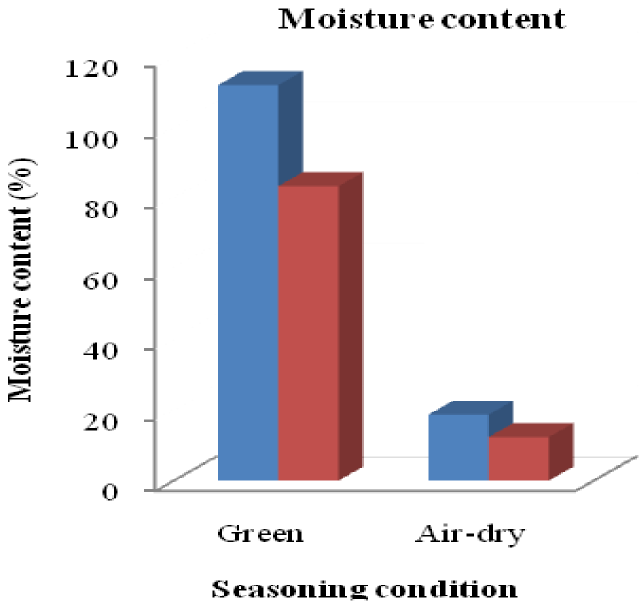

**Figure 3. Comparison of compression stress parallel to grain at different seasoning condition**

### C. Density and moisture content

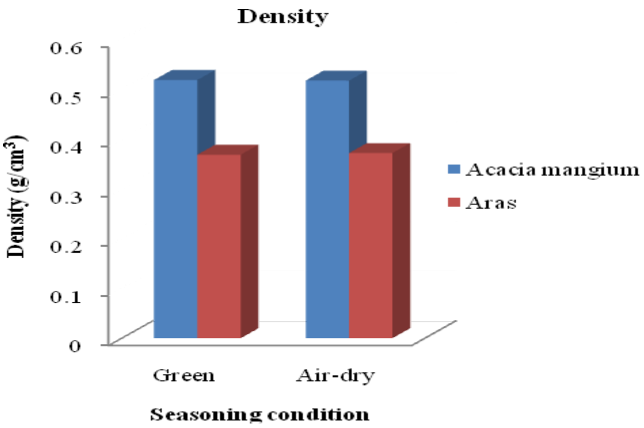
The moisture contents between species are rather different among the species, especially at the green condition. The green moisture content of the wood is variable within a tree and between trees and species [4]. The ability of species that can preserve certain percentages of moisture contents is directly depending on its wood cells. The strength and stability of timber are greatly influenced by its moisture contents. Timber will increase in strength as its dries, though this effect does not begin until the water within the cell has dried out. Not every strength property improves with the decrease in moisture content [8]. In the air-dry activities, it was difficult to achieve moisture contents in the vicinity of 15–19%, because some timber species tend to dry rapidly. Aras reported with mean value 83.32%. Obviously, *Acacia mangium* gave the higher reading compare to indigenous species with the mean reading of 111.93% of moisture content. From previous research, the mean moisture content for *Acacia mangium* was reported with 114% [9]. The mean readings at the air-dry condition showed that Aras with the mean reading of 12.33%. For exotic species of *Acacia mangium* the mean reading is 18.70% for moisture content. From the average mean at green condition, the exotic species gave very much in different of 25.56% compare to indigenous species. Meanwhile at the air-dry condition the difference was higher with 34.06%. For density, it showed that at green condition, Aras was reported with the mean reading of 0.3692g/cm3. For the moment, Acacia mangium recorded with mean reading of 0.5193g/cm3. At air-dry condition Aras mean reading of 0.37g/cm3 with the reduction of density from green condition to air-dry condition was 0.86%. For Acacia mangium, the mean reading also decrease at the air-dry condition with 0.06% reduction gave its mean reading of 0.5181 g/cm3. It was clearly shown that the condition: air-dry and green, of the timber was not slightly influenced to the timber density. This also was agreed that the air-dry and green densities are not very reproducible in the results. It was reported, greater the green density of wood, the lower the basic density [10]. A material having a low basic density has high moisture content and vice versa. The results for physical properties were tabulated in Table III and it was clearly presented in Fig. 4.

**Table III. Moisture content and density of indigenous specie**

| Species | Seasoning condition | Moisture content (%) | Density (g/cm$^3$) |
|---|---|---|---|
| *Acacia mangium* | Green | 111.93 | 0.5193 |
| | Air-dry | 18.70 | 0.5181 |
| *Ilex cissoidea* | Green | 83.32 | 0.3692 |
| | Air-dry | 12.33 | 0.3724 |



(a)



(b)

**Figure 4. Green and air-dry grade stresses and modulus of elasticity**

## VI. CONCLUSION

Aras identified as potential species after Acacia mangium and recommended as reference for light wood industries utilisation. It was found that the strength values for modulus of elasticity, modulus of rupture, and compression parallel to grain at green condition showed an increase at the air-dry condition. Meanwhile, the impact bending showed the decrease. The moisture content also showed a similar trend. For density, the results for indigenous and exotic species were not influenced by moisture content. It was found that, Aras give the average different of 45.95% of its engineering properties at green condition. Meanwhile, at air-dry the average mean different of 31.53% from Acacia mangium. Future investigations, involving mechanical and physical properties for more indigenous species could predict and identified the potential species for plantation for utilisation in light wood industries. All the results that were tested are concluded in Table IV as mean results.

**Table IV. Mean results for Mechanical properties between indigenous and exotic species at green and air dry condition**

| | | | Indigenous Species | Exotic Species (Control) |
|---|---|---|---|---|
| | Property | Seasoning condition | Aras | *Acacia mangium* |
| Mechanical properties | Modulus of Rupture ($N/mm^2$) | Green | 47.54 | 88.66 |
| | | Air-dry | 70.32 | 95.96 |
| | Modulus of Elasticity ($N/mm^2$) | Green | 6360.05 | 11421.06 |
| | | Air-dry | 8213.66 | 12064.51 |
| | Compression Stress parallel to grain ($N/mm^2$) | Green | 22.42 | 37.32 |
| | | Air-dry | 34.15 | 41.66 |
| | Impact Bending (Joule) | Green | 1.97 | 4.17 |
| | | Air-dry | 1.71 | 3.74 |

## VII. ACKNOWLEDGMENT

The authors would like to gratefully acknowledge everyone involve in this project, especially to AFSID, Sarawak Forestry. Thank you all for your guidance and support.

## REFERENCES

1. Dorthe Jøker, 2000. *Acacia mangium* Willd, Danida Forest Seed Centre No. 3 Leaflet No. 3, Humlebaek, Denmark.
2. Krishnapillay B. and Abdul Razak Mohd Ali, 1998. Feasibility of Planning High Quality Timber Species in Peninsular Malaysia. In Proceeding of the Seminar on High Value Timber Species for Plantation Establishment-Teak and Mahoganies, 1-2 December 1998, Tawau, Sabah, pp. 91-101.
3. Mohd Hamami Sahri, Zaidon Ashaari Razali Abdul Kaderi and Abdul Latif Mohmod, 1998. Physical And Mechanical Properties of *Acacia mangium* and *Acacia Auriculiformis* from Different Provenances PertanikaJ. Trap. Agric. Sci. 21(2): 73 - 81 (1998)
4. Panshin, A.J. and De Zeeuw, C, 1980. Textbook of Wood Technology, Mcgraw-Hill, New York.
5. Krishnapillay, D.B., 1998, Case Study of The Tropical Forest Plantations In Malaysia, Forest Plantations Working Papers, Forestry Department, Food and Agriculture Organization of the United Nations.
6. British Standard, 1957. Methods of Testing Small Clear Specimen of Timber. British Standard Institution. BS 373: 1957, pp. 31.
7. Sven Thelandersson and Hans J. Larsen, 2003. Timber Engineering. John Wiley and Sons Ltd, West Sussex, England, pp. 30.
8. Keith R. Bootle, 1985, Wood in Australia: Type, properties and uses. McGraw-Hill Book Co. Australia. 29, pp. 60-61.
9. Alik Duju, 1999, Strength Properties of *Acacia mangium* Grown in Sarawak. TRTTC/STA, Forest Products Seminar, 12-14 October 1999, Kuching, Sarawak, Malaysia, pp.160.
10. Walker, J.C.F., 1993. Primary Wood Processing: Principles and Practice, 1st Edition. Chapman & Hall, London, pp. 72, 323, 346, 353, 362.

## AUTHORS PROFILE

**Dr. Gaddafi Bin Ismaili**, is graduated with PhD in Civil & Structural Engineering (Specialization in Timber Engineering) from Universiti Sains Malaysia in 2012. He also obtained Master in Science (Structural Engineering) from Universiti Sains Malaysia, Master in Science (Health, Safety and Enviroment) form Universiti Teknologi Malaysia, BEng (Hons) in Civil Engineering from Universiti Malaysia Sarawak, Diploma in Civil Engineering from Universiti Teknologi MARA. Have publish more than 10 index and impact factor journals. Currently carry out a research on fast growing timber species for 2 years. Registered engineer with BEM and IEM.