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Physical and Mechanical Properties of Cassava-Bamboo Composite Lumber

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Abstract: The study was carried out to determine the physical and mechanical properties of composite lumber made from cassava (*Mahinot esculenta* Crantz) and bamboo (*Bambusa vulgaris*) in different ratios which is 100% cassava with 0% bamboo, 75% cassava with 25% bamboo, 50% cassava with 50% bamboo, 25% cassava with 75% bamboo and 0% cassava with 100% bamboo. The tests samples for determining the strength properties were divided into two categories namely mechanical testing and physical testing. Basic density of the samples was carried out for physical testing. The lowest basic density was in samples with 100% cassava which is 0.49 g/cm^3 and highest in samples with 100% bamboo which is 0.68 g/cm^3. Two tests for the mechanical testing are bending test and compression test. In bending test, modulus of elasticity (MOE) and modulus of rupture (MOR) were both highest for samples with 100% bamboo which the reading of MOE was 16794.03 N/mm^2 and 122.52 N/mm^2 for MOR. Similar to the bending test, compression test is the highest for the samples with 100% bamboo which are 65.58 N/mm^2. From statistical analysis, the basic density, static bending can compression strength give significant value at 95% confidence interval.

Keywords: *composite lumber, cassava-bamboo, basic density, bending test, compression test*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) has now become the fourth major energy source in the tropics after rice, sugar and maize [1]. In 2004, the total production of cassava were more than 200 million tons worldwide [2]. In African, Asian and Latin American, the amount of cassava produced exceeds 82 million tons per year. The largest cassava producing countries are Nigeria, Brazil, Thailand, Democratic Republic of Congo and Indonesia [3]. Cassava has been grown in Malaysia for quite some time. Malaysia has been a supplier and exporter of cassava products since the 1970s.

Bambusa vulgaris belongs to the Bambusae family which is the widely grown bamboo around the tropics. This species is easy to grow due to its adaptability to agroclimatic conditions, easily response to vegetative propagation, vigorous growth and quick recovery of clumps after felling. Besides, this bamboo species has high culm strength, can be utilized in various ways and high pulping quality [4].

In recent times, the timber industry is facing problem for the production of timber products due to the shortage of raw materials. Timber species such as meranti (*Shorea* sp.), kapur (*Dryobalanops* sp.) and other tropical hardwood are declining in supply due to environmental awareness. According to Malaysia Timber Industry Board, export for major timber products in Malaysia is more than RM 11 billion on 2017. This industry was even listed as Top 10 export product from Malaysia.

Therefore, to protect this industry from slumped, alternative materials and resources are needed to replace timber in wood-based products. For future use, the timber industry can manipulate non-wood lignocellulose sources species such as palm, coconut, kenaf, bamboo and cassava as raw material for the wood processing industry [5].

This study aims to use cassava and bamboo to produce a composite product known as cassava-bamboo composite lumber (CBCL). Also, this study is also conducted to study the physical and mechanical properties of the composite product whether it is suitable to be introduced as a new composite product.

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EXPERIMENT

Sample Preparation

The cassava stems obtained from the Tuaran, Sabah. 50 stems of cassava plant were used in this study. While for bamboo, the samples of *Bambusa vulgaris* were collected from Hutan Simpan Kawang. The number of bamboo samples taken was ten (10) stems.

Before the sample preparation process, bamboo and cassava stem was heated using palm oil for the pre-treatment process to increase the life-span of the cassava stem and bamboo [6]. However, the temperature should reach 80°C before bamboo, and cassava stem was put into the oil. After that, the samples were left until the oil temperature reaches 160°C. When this temperature is reached, the samples are left to be heated for 60 minutes in that temperature.

In the process of preparing samples, tubers of cassava and bamboo are cut to the predetermined size. The length of cassava stalks is cut equally regarding length, width and thickness (Figure 1). For bamboo samples, it was cut into the parts of the predetermined section as in Figure 2.

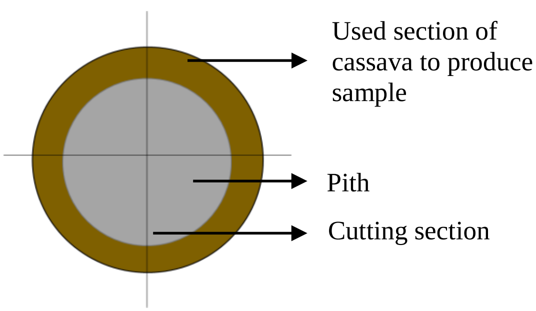

Fig 1 Cutting dimension of cassava stem

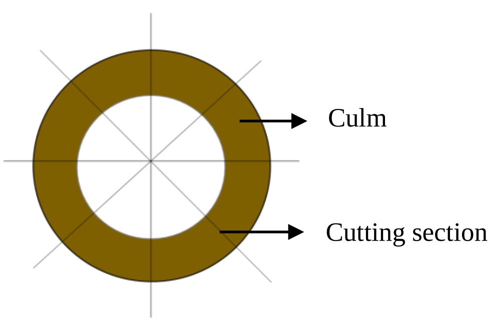

Fig 2 Cutting dimension of bamboo

The moisture content of the cassava tubers and the bamboo sticks standardized at 12%. The composite board were prepared according to different ratios which were 100% cassava, 70% cassava with 30% bamboo, 50% cassava with 50% bamboo, 30% cassava with 70% bamboo and 100% bamboo. The samples are glued together using polyvinyl acetate (PVAc) resin. Before being glued together, samples should be kept clean and dry without any dirt or foreign matter. The samples were left until the adhesive becomes dried and turns from liquid to solid. It eventually produces cassava-bamboo composite boards (CBCL).

Physical Testing

Physical tests conducted for CBCL samples were basic density tests. The sample size was 2 x 2 x 2 cm each. The initial weight is taken before being put into the oven at 102°C overnight. After 24 hours, the weight was recorded again, and the basic density of the samples can be calculated using the following formula:

Basic density (g/cm3) = (oven dry mass) / (green volume)

Mechanical Testing

Mechanical testing was carried out according to ISO standard that was done using Mechanical Testing Machine (MTM). Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were tested for static bending test. The sample size for MOE and MOR were 20 x 20 x 320 mm. The value of MOE and MOR were generated from the MTM machine. Besides that, using the same machine, the compression test parallel to the grain are also conducted.

Statistical Analysis

Data obtained from tests on physical and mechanical properties of CBCL are collected and analyzed. The results were analyzed using correlation analysis to find the relationship between the characteristics of CBCL.

RESULT AND DISCUSSION

Figure 3 shows the average of the basic density tests carried out on cassava-bamboo composite lumber that have different strip ratios. The basic density of CBCL is 0.49 g/cm^{3}for 100% cassava, 0.51 g/cm^3 for 75% cassava and 25% bamboo, 0.55 g/cm^3 for 50% cassava and 50% bamboo, 0.62 g/cm^3 for 25% cassava and 75% bamboo and 0.68 g/cm^{3}for only bamboo composite board.

Overall, the results of the basic density test carried out show the different ratio of cassava and bamboo in the CBCL increasing the basic density value of the sample studied when the bamboo strips increase. This is because from the result we can see the basic density of 100% cassava is lower than basic density of 100% bamboo. The basic density of *Bambusa vulgaris* in this study is comparable with the study done by Anokye *et al*., [7] which he concludes that density of *Bambusa vulgaris* are comparable with density of *Gigantachloa scortechinii* which is one of the widely used bamboo in Malaysia.

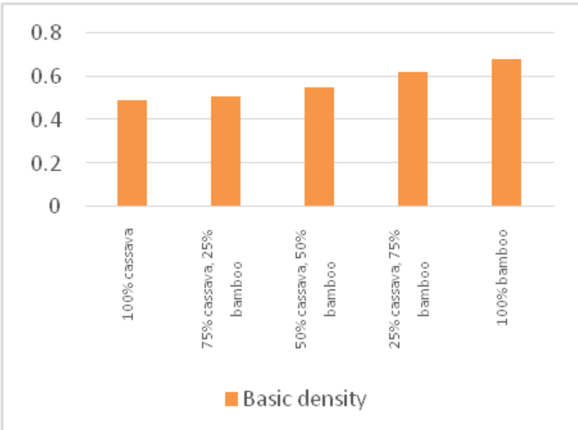

Fig 3 The basic density of cassava-bamboo composite lumber

In mechanical testing, there are two types of tests that have been carried out using a Mechanical Testing Machine (MTM). This mechanical test is conducted using the ISO 22157 standard. Mechanical test results obtained from static bending tests and parallel compression tests.

Through the results of the mechanical test obtained, the change regarding the strength of the CBCL is known. The result determined whether the different ratio of tuber and bamboo content in composite board gives different strengths.

Figure 4 shows the modulus of elasticity (MOE) and modulus of rupture (MOR) of static bending. The MOE of cassava-bamboo composite lumber increase with increasing composition of bamboo. At 100% cassava, the MOE was only 1834.22 N/mm^2, but with 100% bamboo, the MOE increases up to 16794.03 N/mm^2. The sample with 100% bamboo has almost 90% MOE higher than the cassava board. This is due to the density of the bamboo which were much higher than cassava stems. Besides, the MOE of 100% bamboo CBCL is comparable with air-dried bamboo which were the more than 18000 MPa as studed by Razak *et al*., [8].

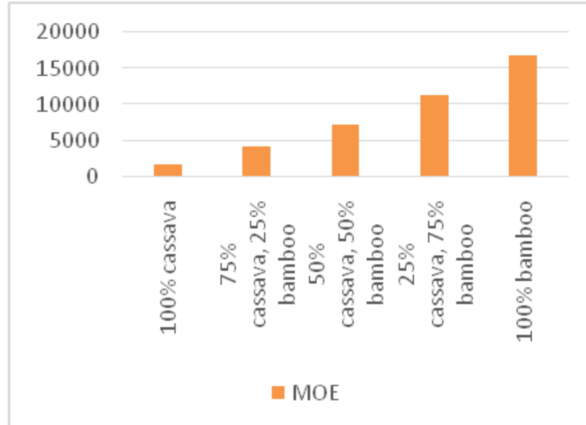

Fig 4 The MOE (N/mm^2) of cassava-bamboo composite lumber

It is similar to the MOR result which can be observed from Figure 5 where the highest MOR was in the 100% bamboo which is 122.52N/mm^2. The MOR strength increase with the increasing bamboo content which is similar to the value of MOE.

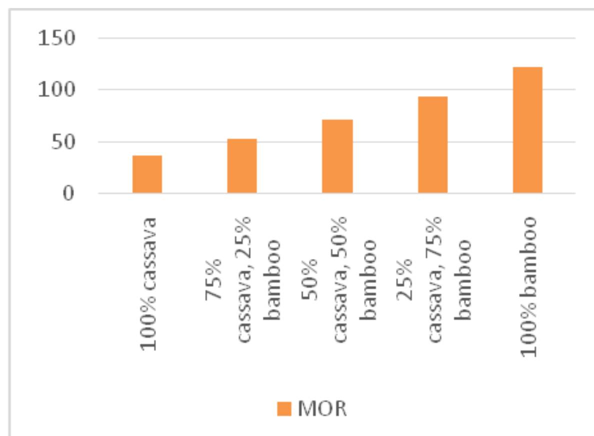

Fig 5 The MOR (N/mm^2) of cassava-bamboo composite lumber

The result for parallel compression test as in Figure 6. Similar to MOE and MOR, the value for compression test increase with increasing bamboo content in the composite lumber. For composite lumber with 100% cassava, the compression value is only 32.86 N/mm^2 compared to 100% bamboo with 65.58 N/mm^2. The value of compression parallel to the grain of bamboo in this study was comparable with the value of air-dried *Bambusa vulgaris* as determined by Razak *et al*., [8].

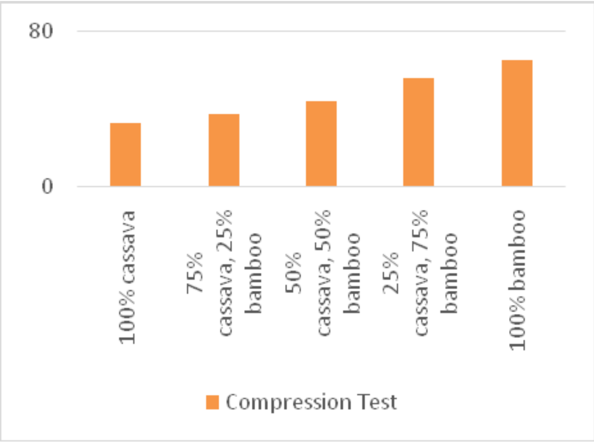

Fig 6 The compression test value (N/mm^2) of cassava-bamboo composite lumber

Table 1 shows the correlation between CBCL with all the properties tested. All the properties of CBCL were significantly related to each other. That is why the result indicates that the density, MOE, MOR and compression increases with increase use to bamboo in the composite lumber.

Table 1 Correlation between the properties of CBCL

	Basic density	MOE	MOR	Compression
Basic density	1	0.9683*	0.9642*	0.9538*
MOE		0.9928*	0.9974*	0.9833*
MOR			0.9912*	0.9820*
Compression				1

*significant at p≤0.01

CONCLUSION

The physical tests that have been carried out concluded that different ratio of cassava and bamboo affected the physical characteristics of the composite lumber. The value of the base density of the composite board studied increases when more bamboo mixed in the composite board. It was found that the use of bamboo and cassava wood is suitable to be used as composite lumber. This was evident by the value shown in the mechanical tests. In static bending tests and compression test, results show relatively high values at 100% bamboo ratio compared to other strip ratios. Based on the studies conducted, it can be seen that the CBCL is capable of replacing other timber products using logs or sawn timber. This can be seen based on the results of the mechanical tests as well as the physical tests obtained. The composite wood can be used as a board for the floor, as a base material for wood furniture and so on.

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