PRELIMINARY STUDY ON WATER ABSORPTION AND SWELLING FOR PLAIN AND HONEYCOMB RUBBER WOOD

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ABSTRACT: Rubber wood receives good reviews such as minimal shrinkage and high durability. In composites, rubber wood is often used in the form of wood dust or flour as the filler, but has yet been employed as a honeycomb core in the sandwich composites. Since the rubber wood honeycomb composite is targeted to replace plywood in the furniture industries in Malaysia, a country with high humidity, it is important to investigate its water absorption and swelling condition. It is because the surface area will be highly increased when it is designed into the honeycomb. The plain and honeycomb rubber wood as well as plain plywood were immersed into the water for seven days. Their weight, volumes and density for before and after the immersion were compared and analysed. The honeycomb wood absorbed the highest percentage of water with the minimum volume change compared to the plain rubber wood and plywood. Due to the honeycomb design of the rubber wood, its density maintain as the lowest among the specimens.

KEYWORDS: *Rubber Wood; Honeycomb; Composite; Water Absorption; Swelling*

1.0 INTRODUCTION

Honeycomb is a multifunctional prismatic and ultra-light cellular material [1-3]. The initial idea of honeycomb has been adapted from the hexagonal design of the beehive of the honey bees. The array of interconnected network of the honeycomb cells have been aggressively redesigned to create auxetic [4-5] and hierarchical structures [6-8] in order to fulfill the various requirements such as vibration reduction, sound isolation and fire retardant [9-11].

Historically, rubber wood or Hevea Brasiliensis arrived in Malaysia and Singapore from Sri Lanka by the British Colonial Office. This has driven Malaysia into the wood industry [12]. Therefore, rubber wood has become a relatively low price source of renewable raw material because it makes full use of plantation trees after the trees have completed the latex producing cycle after 25 to 30 years [13-14]. Rubber wood is a very important raw material for furniture and composite panel industry in South East Asian countries including Thailand and Malaysia [15]. The advantages of using rubber wood are low cost, low density, low energy consumption and biodegradability [16].

There have been researches going on for rubber wood. For instance, Majumdar and co-workers researched on the effect of age and height of the rubber tree on the physical and mechanical properties [17]. Study by Nayeri et al. [18] focused on the effect of resin content and pressure on the performance of rubber wood kenaf composite. In addition, long term water absorption and dimensional stability of recycled polypropylene and rubber wood flour composites was investigated by Homkhiew and his co-researchers [16]. Moreover, fabrication of a green wood composite by Ruayruay and Khongtong on impregnating natural rubber into the rubber wood [19]. Even load-bearing capability of heat-treated rubber wood furniture components had been investigated [20]. Research on water absorption and thickness swelling behaviours on oil palm trunk and rubber wood where rubber wood showed lowest water absorption thus was able to maintain its dimensional stability after the ten-day water immersion [13]. Popularly, the rubber wood is used in the form of wood dust or flour as filler in the thermoplastic composite. To the best knowledge of the authors, there has been no knowledge on the rubber wood as honeycomb core in the composite structure despite the advantages offered by the rubber wood.

Plywood is also one of the commonly used wood materials for furniture. However, the multiple processes involved In producing plywood such as long hot press to increase the wood compression ratio causes the low productivity of plywood. This drawback has hindered the plywood manufacturing industry in terms of meeting the demand [21-23].

The motivation of this research is to replace plywood with rubber wood to opt for lower density wood. Besides, the rubber wood is designed into honeycomb shape. It can greatly reduce the density yet offer relatively good mechanical performance to the composite. Although there is a major challenge when using natural composite, that is the mechanical properties of the honeycomb composites such as bending stiffness and strength to weight ratio will be reduced by moisture diffusion when they are exposed to wet and high humidity environment such as in Malaysia during service. Throughout the long service time, the amount of water absorbed will affect the performance and life span of the products.

Therefore, the present work is focused on the moisture uptake and dimensional change in plain and honeycomb core made of rubber wood. The result will be compared with the actual product made of solid plywood to determine the wood that has higher dimensional resistance after water absorption. After that, their densities are compared to choose a low density wood. This paper aims to experiment on its geometrical stability to investigate whether the rubber wood honeycomb core is a suitable material to replace existing plywood.

2.0 MATERIAL PREPARATION AND EXPERIMENTAL SET UP

Two pieces of rubber wood and a piece of plywood sized 75 mm x 60 mm x 8 mm were prepared. One of the rubber woods was cut with the laser cutter to form hexagonal honeycomb core as shown in Figure 1. Both of the rubber woods and plywood were dried in the air circulating oven for 2 hours at 105 + 3 °C or until a constant weight was reached. After that, they were cooled in a desiccator to room temperature.

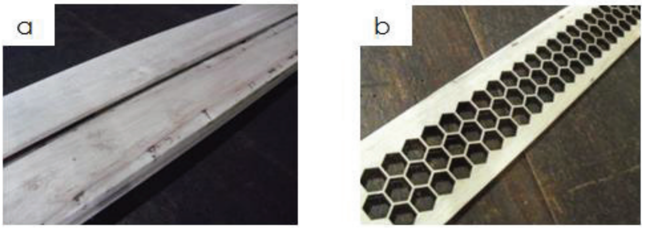

Figure 1: (a) Plain and (b) honeycomb rubber wood

A water bath was prepared for the immersion of the woods at 23 ± 2 °C. The initial weight and measurements for dimension in terms of length, width and thickness of the plain and honeycomb rubber wood were taken for before and after the water immersion. After seven days, the rubber woods were removed from the water bath and the access water on the surface was lightly dried with a cloth. Then, the rubber woods were immediately weighed and the dimensional measurements taken to avoid water vaporization due to long exposure to the environment. These results were later compared with the plywood which also went through the same testing procedures as in Figure 2. The tests were carried out according to the procedures stated in ASTM C272. The results have been recorded in Table 1, Table 2 and Table 3 calculated from the Equations (1), (2), (3) and (4) as stated.

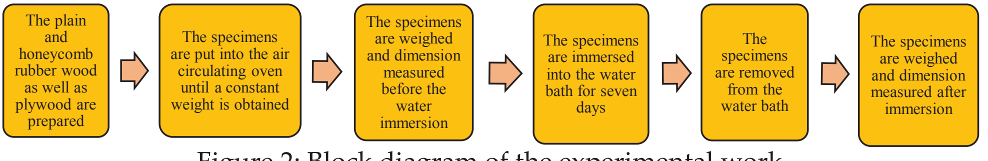

Figure 2: Block diagram of the experimental work

Table 1: Water absorption for plain and honeycomb rubber wood

Specimens	Dry Weight, W_{dry} (g)	Wet Weight, W_{wet} (g)	Weight Change, (g)	Weight Change, (%)
Plain Rubber Wood	23.49	36.58	+ 13.09	+ 55.73
Honeycomb Rubber Wood	5.05	8.70	+ 3.65	+ 72.28
Actual Product (Plain Plywood)	13.10	20.06	+ 6.96	+ 53.13

Table 2: Dimensional changes for plain and honeycomb rubber wood

Specimens	Length, *l* (mm)		Width, *w* (mm)		Thickness, *t* (mm)			Volume, V (mm^3)	Volume Change (mm^3)	Volume Change (%)
	Before	After	Before	After	Before	After	Before	After		
Plain Rubber Wood	71.40	72.67	61.65	61.68	8.45	9.08	37195	40699	+ 3504	+ 9.42
Honeycomb Rubber Wood	75.25	77.80	54.04	54.28	7.23	7.34	29401	30997	+ 1596	+ 5.43
Actual Product (Plain Plywood)	76.23	76.90	34.73	35.71	9.25	9.43	24489	25896	+ 1407	+ 5.75

Table 3: Density of specimens

Specimens	Density (kg/m^3)		
	Before	After	Difference
Plain Rubber Wood	631.54	898.79	267.25
Honeycomb Rubber Wood	171.76	280.67	108.91
Actual Product (Plain Plywood)	534.93	774.64	239.71

$$\text{Weight Change (\%)} = \frac{W_{wet} - W_{dry}}{W_{wet}} \text{ x } 100\ \% \qquad (1)$$

$$\text{Volume Change (\%)} = \frac{V_{after} - V_{before}}{V_{before}} \text{ x } 100\ \% \qquad (2)$$

$$\text{Density (Before) (kg/m}^3\text{)} = \frac{W_{dry}}{V_{before}} \text{ x } 106 \qquad (3)$$

$$\text{Density (Before) (kg/m}^3\text{)} = \frac{W_{wet}}{V_{after}} \text{ x } 106 \qquad (4)$$

3.0 RESULTS AND DISCUSSION

The plain and honeycomb rubber wood as well as plywood have been immersed into the water for seven days so that the maximum water absorption could be observed. A total of 55.73 %, 72.28 % and 53.13 % of water have been absorbed by the plain and honeycomb rubber wood as well as plywood respectively as shown in Table 1. In fact, the results showed a significant amount of water is being absorbed by the rubber wood. Rubber wood is a natural wood with high porosity with a strong capability of water absorption [13, 24]. The polar hydroxyl groups in the natural wood fiber enable the water uptake into the wood structure by forming hydrogen bonds with the water molecules [13, 25]. There is a large number of parenchyma tissues present in the natural rubber wood where it increases the water absorption [26-27]. It is because parenchyma tissues have large central vacuoles (voids) which allow the tissues to store water [28]. The difference of weight change for plain rubber wood and plywood is only 2.6 %. However, the difference of water absorption for plain and honeycomb rubber wood is 16.55 % where higher water absorption is observed in the honeycomb rubber wood. It could be explained that the higher surface area comes into contact with the water during the immersion [29]. Therefore, more water is being absorbed into the honeycomb rubber wood.

From the results in Table 2, it shows that the plain and honeycomb rubber wood as well as plywood have swelled up to 9.42 %, 5.43 % and 5.75 % respectively despite the considerably large amount of water uptake. It is because the water is mostly stored in the vacuoles of the parenchyma tissues minimizes its porosity in the rubber wood. Besides, the strong dimensional stability is due to the tough and rigid cell wall of the wood to provide tensile strength, structural support against mechanical stress as a result of large amount of water diffusion [30]. It is found that the difference in swelling between the two types of rubber wood is 3.99 % whereas the difference between the plain plywood and honeycomb rubber wood is only 0.32 %. The lowest volume change is observed in honeycomb rubber wood which is at 5.43 %.

Despite the highest weight change found in honeycomb rubber wood compared to the plain plywood and rubber wood, the honeycomb rubber wood has the minimum volume change among the specimens. The honeycomb rubber wood consists of many hollow hexagonal cells and it is common where it swells towards its surfaces that exposed to the water. One prediction could be made is the swelling grow towards its hollow cells creating smaller hollow cell diameter. Unlike the honeycomb rubber wood, the plain plywood and rubber wood structures are compact and not hollow; the swelling is forced externally towards its surface area [31]. Therefore, the swelling is seen higher for the plain plywood and rubber wood than the honeycomb rubber wood. From the experimental results, the honeycomb rubber wood is able to absorb higher amount of water yet lower swelling towards its external dimension which is a positive phenomenon compared to the plain rubber wood and plywood.

On the other hand, the densities of the plain plywood and rubber wood are considerably high compared to that of honeycomb rubber wood for both before and after the water absorption test. The difference of densities for the honeycomb rubber wood is also the lowest among the three specimens which is only 108.91 kg/m^3. Due to the honeycomb design of the rubber wood, the specimen is able to absorb water with minimum volume change and brings about relatively low densities of 171.76 kg/m^3 and 280.67 kg/m^3 for before and after the water immersion.

4.0 CONCLUSION

The plain and honeycomb rubber wood as well as plywood are immersed into the water for seven days. The honeycomb rubber wood absorbed the highest percentage of water which is at 72.28 % yet it has the highest resistance to the dimensional change where it only swelled up to 5.43 % compared to the plain rubber wood and plywood. Besides, the honeycomb design also enables the rubber wood to maintain as the lowest in density at 280.67 kg/m^3 after completing the test.

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