MECHANICAL PROPERTY EVALUATION OF BAMBOO FIBER REINFORCED EPOXY COMPOSITE

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Report submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATED TO MY BELOVED PARENTS, FAMILY, AND FRIENDS..

THANK YOU FOR ALL YOUR SUPPORT, IDEAS, AND COOPERATION..

ALL OF YOU ALWAYS IN MY HEART FOREVER..

ACKNOWLEDGEMENTS

First of all, I want to thank The Almighty Allah SWT for the beautiful life that has been given to me in the past 22 years and the present. I am very thankful to be given the time and chances to finally complete this research.

I would like to express my sincere gratitude to my supervisor Mr. Mohd Ruzaimi Bin Mat Rejab for his invaluable guidance, continuous encouragement and constant support in making this research possible. He has always support me in times when I faced difficulties during completing this research and constantly giving the best advice to help me. I am always impressed with his effort in putting up with my attitude and still treated me well as his student after giving him such a difficult time. I apologize for the hard times. I also want to thank Dr. Ahmad Syahrizan Bin Sulaiman who have given his best in making me understand how this research has to be done and have guided me throughout the research.

My sincere thanks go to all staff of the Mechanical Engineering Department, UMP, who helped me in many ways whenever I needed. Thanks for always putting up the best effort in helping me to finish this research.

The best thanks goes to my family especially to my parent. I am very thankful to have them as my father and mother because they never gave up on me and constantly support me morally and financially which are things that I needed the most in order to complete this research. But most of all, thanks for the love and attention that they gave to me which I will cherish until the end of time. Thanks for never stop believing in me although I have let them down so many times. Thanks for always pray for my success and happiness in the past, present and the future. Thanks for everything.

ABSTRACT

Natural fiber has emerged as a renewable and cheaper substitute to synthetic fiber which is use as reinforcement material. The main objective of this study is to investigate the performance of bamboo fiber reinforced epoxy composite and to investigate the mechanical property of bamboo fiber reinforced composite with different fiber orientation. This analysis was carried out by using commercial Finite Elements software (ALGOR) to evaluate the behavior of the composite. Tensile and flexural test was carried out to obtain tensile and flexural strength of the composite. Three type of composite with different fiber orientation were tested in this project. Unidirectional composite was found had a higher tensile strength and multidirectional composite had higher flexural strength. From the observation, increasing the number of layer in the composite, the value of tensile strength will decrease but the value o flexural strength will increase. Thus, the tensile strength of bamboo fiber composite is depends on the degree of the orientation of the fiber. For the flexural strength of bamboo fiber composite, it depends on the number of layer or thickness of the composite.

ABSTRAK

Indikasi kajian menunjukkan fiber semulajadi merupakan alternatif bagi menggantikan fiber sintetik sebagai bahan penguat. Fiber semulajadi merupakan unsur yang boleh diperbaharui dan jauh lebih murah berbanding dengan fiber sintetik. Objektif yang utama dalam kajian ini adalah untuk menyelidik prestasi gabungan gentian buluh dengan epoxy serta menyelidik sifat mekanikal komposit itu dengan susunan gentian yang berbeza. Analisis ini dijalankan menggunakan software yang biasa digunakan dalam industri iaitu ALGOR. Ujian lenturan dan tegangan dijalankan untuk mendapakan kekuatan lenturan dan kekuatan tegangan. Tiga jenis komposit yang menpunyai susunan gentian yang berbeza telah diujikaji dalam projek ini. Komposit yang mempunyai satu arah susunan gentian mempunyai kekuatan tegangan yang paling tinggi manakala komposit yang mempunyai banyak arah susunan gentian mempunyai kekutan lenturan yang paling tinggi. Daripada pemerhatian, dengan penambahan bilangan lapisan dalam komposit, nilai kekuatan tegangan akan berkurangan sebaliknya nilai kekuatan lenturan akan bertambah. Ini menunjukkan, kekuatan lenturan bagi komposit gentian buluh bergantung kepada arah susunan gentian buluh itu. Untuk kekuatan lenturan pula, nilainya bergantung kepada bilangan lapisan gentian atau ketebalan komposit itu.

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LIST OF SYMBOL

ε	Strain
σ	Stress
σ_f	Flexural Strength
E_f	Modulus of Elasticity
P	Load
L	Length of Test Specimen
b	Width of Test Specimen
d	Depth of Test Beam
D	Deflection
V_f	Volume Fraction
ρ	Density
I	Section Moment of Inertia
S	Section Modulus

LIST OF ABBREVIATIONS

FEM	Finite Element Method
FEA	Finite Element Analysis
DIG	Digital Image Processing
DG	Dendrocalamus Giganteus
CFRP	Carbon-fiber reinforced polymer composites

CHAPTER 1

INTRODUCTION

1.1 Project Background

Composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. [1]

There are two categories of constituent material: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. [1]

The combination of bamboo fiber as the reinforcement material and epoxy as the matrix material is to become bamboo fiber reinforced epoxy composite. This composite will be tested to investigate their mechanical properties.

1.2 Objectives

The objectives of the project are as follows:

1) To investigate the performance of bamboo fiber reinforced epoxy composite.
2) To investigate the mechanical property of bamboo fiber reinforced epoxy composite with different fiber orientation.

1.3 Scopes

In order to achieve the objectives notified earlier, the following scopes have been recognized:

1) Determination of mechanical property of bamboo.
2) Design the composite according to the step and dimension using Solid Work software.
3) Analysis the composite according to the step and dimension using ALGOR software (Tensile and Flexural Test).
4) Compare the mechanical property of composite with different fiber orientation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years there has been a fast growth in using renewable natural fiber as reinforcements in composite materials. [2] With the increasing global energy crisis and ecological risks, natural fibers reinforced polymer composites have attracted more and more research interests owing to their potential of serving as alternative for artificial fiber composites. Compared with conventional glass fibers or carbon fibers, natural fibers have many advantages like renewable, environmental friendly, low cost, lightweight, high specific mechanical performance. [3]

2.2 Bamboo as an Engineering Material

In consequence of the consumers choosing industrialized products, among other effects, activities are suppressed in rural areas or even in small towns, and renewable materials are wasted and causing permanent pollution. In this sense, it becomes obvious that ecological materials satisfy such fundamental requirements, making use of agricultural by-products such as rice husk, coconut fibers, sisal and bamboo and therefore minimizing energy consumption, conserving non-renewable natural resources, reducing pollution and maintaining a healthy environment. Bamboo is one material, which will have a tremendous economical advantage, as it reaches its full growth in just a few months and reaches its maximum mechanical resistance in just few years. Moreover, it exists in abundance in tropical and subtropical regions of the globe.

The energy necessary to produce 1m^3 per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete, has been compared with that of bamboo. It was found that for steel it is necessary to spend 50 times more energy than for bamboo. The tensile strength of bamboo is relatively high and can reach 370MPa. This makes bamboo an attractive alternative to steel in tensile loading applications. This is due to the fact that the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel.

The structural advantage, over other engineering materials is studied in terms of modulus of elasticity, E, and density, q, using the material selection method shown in Fig. 2.1. In this figure the line presenting the equation $C = E_{1/2}/q$ applies to the properties of bamboo. Materials, which have a better performance than bamboo, are situated above the line and those, which have a worse performance, are below the line. It can be seen that only timber from palm-trees and balsas are in the same range as bamboo whereas steel, concrete and aluminum are located far below the line. The closed area for each material shows the variation of the available data for the same. [4]

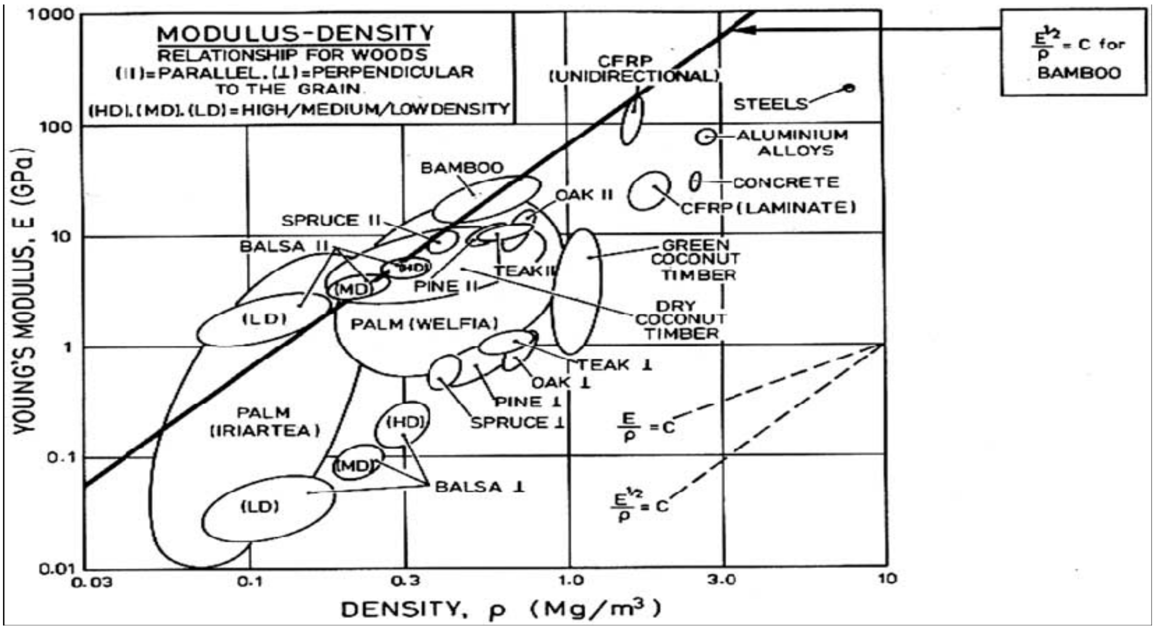

Figure 2.1: Performance of bamboo and other materials, in relation to their E and q, [4]

2.3 Basic Characteristics of Bamboo

Bamboos are giant grasses and not trees as commonly believed. They belong to the family of the Bambusoideae. The bamboo column, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers and low strength perpendicular to the fibers respectively.

Bamboo is a composite material, consisting of long and parallel cellulose fibers embedded in a ligneous matrix. The density of the fibers in the cross-section of a bamboo shell varies along its thickness. This presents a functionally gradient material, evolved according to the state of stress distribution in its natural environment. As seen in Fig. 2.2, the fibers are concentrated in regions closer to the outer skin. This is consistent with the state of stress distribution when the column is subjected to wind forces. In establishing the mechanical properties of bamboo, in the elastic range, the rule of mix for the composite materials is used. The properties of the fibers and matrix with their volumetric fractions are taken into account. Eq. (1) presents the calculation of the elasticity modulus, E_c, of the bamboo as a composite. In this equation E_f and E_m are elasticity modules and V_f and $V_m = (1 - V_f)$ are the volumetric fractions of the fibers and matrix respectively. In the development of Eq. (1), long, uniformly spaced and aligned fibers are assumed in addition to a perfect bonding between fibers and matrix. [4]

$$E_c = E_f V_f + E_m (1 - V_f) \tag{1}$$

In the application of Eq. (1) to the analysis of bamboo, the variation of the volumetric fraction of fibers, $V_f(x)$, with thickness should be taken into account. Considering that the $V_f(x)$ distribution follows an axis, x, with the origin at the internal wall and the maximum limit at the outer wall of the bamboo column, Eq. (2) can be written. The variation of $V_f(x)$, was determined using the digital image processing, DIP.

$$E_c = f(x) = E_f V_f(x) + E_m (1 - V_f(x)) \tag{2}$$

Using the DIP method, the variation of the fiber volume fraction of the bamboo shell was determined for 10 columns of different species. For each column, three samples were taken from the bottom, middle and the top part of the column, as shown in Fig. 2.4(a) for bamboo Dendrocalamus giganteus (DG).

The variation, $V_f(x)$, at the three loci of culms, is presented in Fig. 2.4(b). It is observed that the fiber distribution is more uniform at the base than at the top or the middle part. This phenomenon could be explained knowing that the bamboo is subjected to maximum bending stress due to wind and its own weight in the base. However, the differences between the distributions are not very significant. Therefore all the data presented in Fig. 2.4(b) were used to establish Eq. (3) where the mean volume fraction variation of fibers across the thickness of bamboo DG is presented:

$$V_f(x) = 49.83x^2 - 0.49x + 12.01 \quad (3)$$

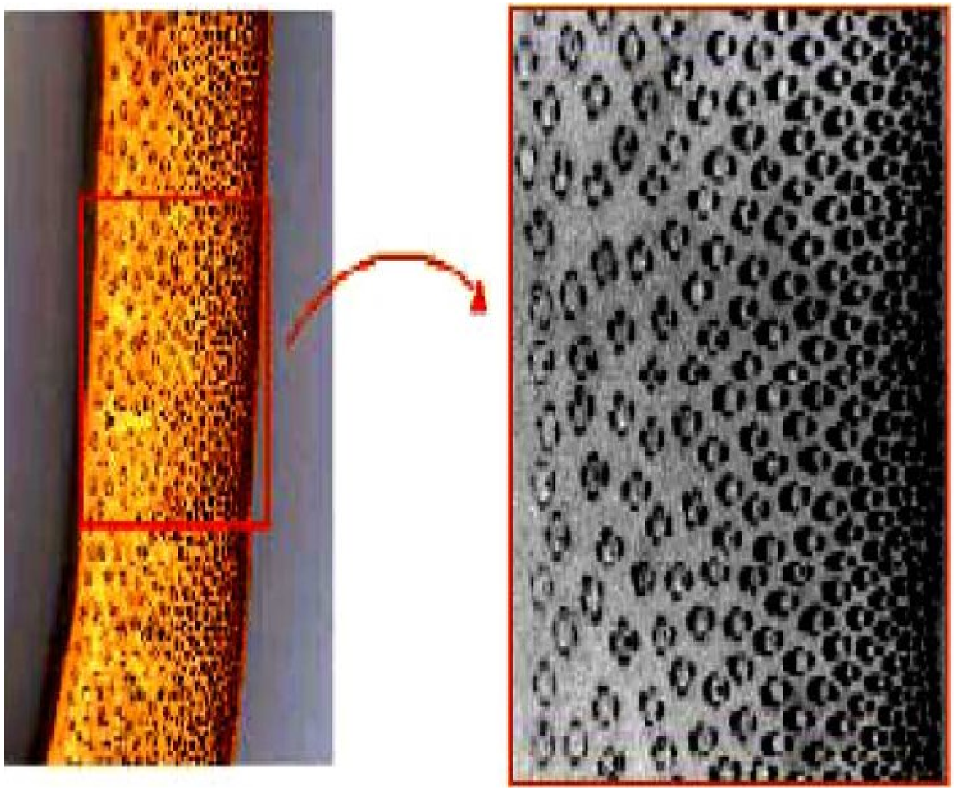

Figure 2.2: Non-uniform fiber distribution on cross-section of bamboo. [4]

Similar mathematical formulas have been developed for diameter and internodal length of the bamboo.

The international norm for the evaluation of the mechanical behavior of bamboo proposed by the international Bamboo Committee of INBAR is being adopted by ISO and should be available to the general public soon.

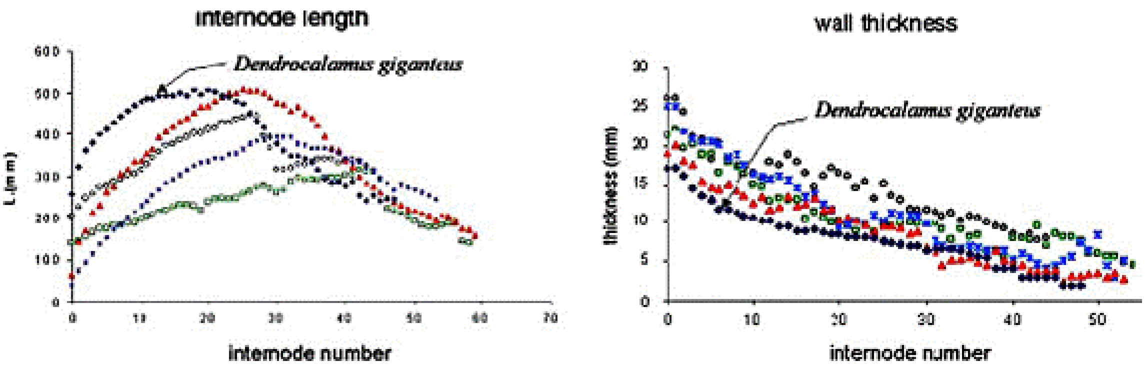

Figure 2.3: Variation of thickness and intermodal length along the whole bamboo column.[4]

2.4 Bamboo fiber

Bamboo belongs to the grass family Bambusoideae. It is a natural lingo-cellulosic composite, in which cellulose fibers are embedded in a lignin matrix. The average length of the bamboo fibers is about 2 mm, and average diameter between 10 and 20 µm. The hardness of the bamboo column mainly depends on the number of fiber bundles and the manner of their scattering. The percentage of fibers decreases from the bottom to the top of the column. [5]

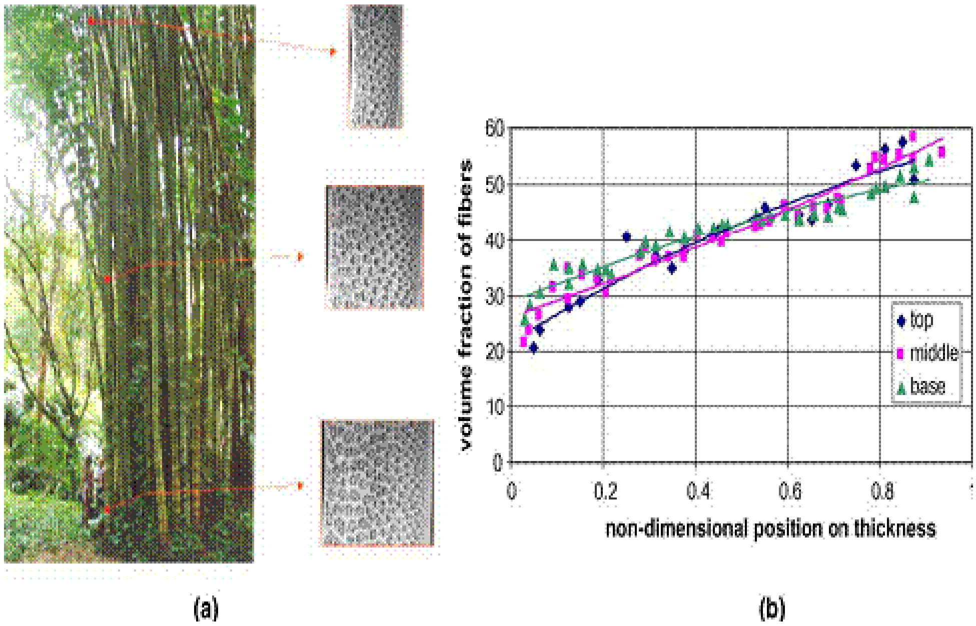

Figure 2.4: Fiber distribution across the thickness using DIP method along bamboo. (a) Location of samples for DIP along the bamboo shell length DG.(b) Fiber distribution across bamboo thickness at base, middle and top part of DG.[4]

The variation of the shell thickness, t, and intermodal distance, L, with the height of bamboo expressed in internode for the species Dendrocalamus giganteus (DG), Moso, Matake, Guadua and Phyllostachys pubescens is presented in Fig. 2.4. The internodal length is larger in the middle of the column. The thickness, however, decreases from the base to the top of the bamboo shell. Based on the obtained data, a mathematical formula, which relates the thickness, t, to the position of the internodes, n, is established for all species of bamboo studied. Eq. (4) gives the relation between t and n for bamboo DG. With the help of this equation the designer can choose the required thickness from the range of bamboo species DG.

$$t = -0{:}0003n^3 + 0.025n^2 - 0.809n + 16.791 \quad (4)$$