



## **UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

### **TENSILE TEST AND FLEXURAL TEST ANALYSIS FOR BANANA PLANT STEM FIBER BEING REINFORCED WITH POLYESTER RESIN COMPOSITES**

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

By

VENURAJ A/L VISWANATHAN

B071610641

930330-01-6103

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING  
TECHNOLOGY

2019



**Faculty of Mechanical and Manufacturing Engineering  
Technology**

**TENSILE TEST AND FLEXURAL TEST ANALYSIS FOR  
BANANA STEM FIBER BEING REINFORCED WITH  
POLYESTER RESIN COMPOSITES**

**Venuraj A/L Viswanathan**

**Bachelor of Mechanical Engineering Technology  
(Maintenance Technology) with Honours**

**2019**

**TENSILE TEST AND FLXURAL TEST ANALYSIS FOR BANANA PLANT STEM  
FIBER BEING REINFORCED WITH POLYESTER RESIN COMPOSITES**

**VENURAJ A/L VISWANATHAN**

**A thesis submitted  
in fulfillment of the requirements for the Bachelor of Mechanical Engineering  
Technology (Maintenance Technology) with Honours**

**Faculty of Mechanical and Manufacturing Engineering Technology**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2019**

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

TAJUK: Tensile Test and Flexural Test Analysis for Banana Plant Stem Fiber being Reinforced with Polyester Resin Composites

SESI PENGAJIAN: 2019/2020

Saya **Venuraj A/L Viswanathan** mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Per Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.

- SULIT\* Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972.
- TERHAD\* Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.
- TIDAK TERHAD

Yang benar,

Disahkan oleh penyelia:

.....  
VENURAJ A.L VISWANATHAN  
Alamat Tetap:  
NO41, JALAN MANGGA 12, TAMAN  
KOTA MASAI, 81700 PASIR GUDANG  
JOHOR

.....  
KHAIRIL AMRI BIN KAMARUZZAMAN  
Cop Rasmi Penyelia

Tarikh: \_\_\_\_\_

Tarikh: \_\_\_\_\_

4. \*\*Sila tandakan (X)

\*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini

## DECLARATION

I declare that this investigation entitled “Tensile test, and flexural test for banana plant stem fiber being reinforced with polyester resin composites” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

## **APPROVAL**

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical and Manufacturing Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follows:

.....

(Ts. Khairil Amri Bin Kamaruzzaman)

## **DEDICATION**

For my beloved mother and father.

## ABSTRACT

Plantation waste such as banana plant should have a proper way of disposal after the fruits was harvested. Environmental awareness and decreasing in the petroleum resources worldwide have enhances many researchers to fully utilizing the natural fibers as it is more environmental friendly and sustainable compare to the existing conventional materials. Natural fiber reinforced polymer composites have many benefits such as inexpensive, low hazard to health, approximately high modulus strength , easily available, biodegradable, light weight, and renewable. However, the processing of the natural fiber requires a lot on energy and process for extracting the pure fibers. However this applications have same limitations for example the natural habits of the plant fibers that could not be changed when reinforced with polymer matrix such as high water absorption, controlled processing temperature, poor dimensional stability and poor wettability. Therefore, this project gives review on the plant fiber reinforced thermosetting polymer. This composite specimen is fabricated through hand lay-up method at where four different composition of banana stem fiber which are 0%, 5%, 10% and 15% are being reinforced with polyester resin. The specimens produced is then conducted Tensile Test and Flexural Test to obtain the Young's Modulus and Modulus of Flexural Strength values. The results obtained is being compare with the facts that given by the previous researchers so that the project findings can be used for the implementation of composite product in daily life such as the water tank.



## **ABSTRAK**

*Kesedaran sisa perladangan seperti tumbuhan pisang perlu mempunyai cara pelupusan yang betul selepas buah itu dituai. Kesedaran alam sekitar dan pengurangan sumber petroleum di seluruh dunia telah meningkatkan banyak penyelidik untuk menggunakan serat semula jadi kerana ia lebih mesra alam dan berterusan berbanding dengan bahan konvensional sedia ada. Serat semulajadi bertetulang polimer rencam mempunyai banyak manfaat seperti murah, rendah bahaya kepada kesihatan, kekuatan modulus yang tinggi, mudah didapati, biodegradasi, berat ringan, dan boleh diperbaharui. Walau bagaimanapun, pemprosesan serat semulajadi memerlukan banyak tenaga dan proses untuk mengekstrak gentian tulen. Walau bagaimanapun, aplikasi ini mempunyai had yang sama contohnya tabiat semulajadi gentian tumbuhan yang tidak boleh berubah apabila diperkukuh dengan matrix polimer seperti penyerapan air yang tinggi, suhu pemprosesan terkawal, kestabilan dimensi yang lemah dan rendah basah. Oleh itu, projek ini memberi kajian pada gentian serat bertetulang termosetting polimer. Spesimen komposit ini direka melalui kaedah lay-up tangan di mana empat komposisi yang berbeza serat stem pisang iaitu 0%, 5%, 10% dan 15% diperkukuh dengan resin poliester. Spesimen yang dihasilkan kemudiannya dijalankan ujian tegangan dan ujian lentur untuk mendapatkan nilai kekuatan lentur dan modulus Young. Keputusan yang diperolehi adalah dibandingkan dengan fakta yang diberikan oleh penyelidik sebelum ini supaya penemuan projek boleh digunakan untuk pelaksanaan produk komposit dalam kehidupan harian seperti tangki air.*

## **ACKNOWLEDGEMENT**

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Mr Khairil Amri Bin Kamaruzzaman from the Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this project. Heartful gratitude and thanks to all my friends who help me throughout to completing this project.

Particularly, I would also like to express my deepest thanks to Mr Azizol Ikhwan bin Mohd, the technicians from material testing laboratory Faculty of Mechanical and Manufacturing Engineering Technology. Besides that, I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) especially Faculty of Mechanical and Manufacturing Engineering Technology to give me a chance to apply my engineering knowledge and improve the existing skills by conducting this project.

Special thanks to my father, mother and siblings for their moral and financial support in completing this project as per requirement of the university syllabus. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

## TABLE OF CONTENT

<b>DECLARATION.....</b>	
<b>APPROVAL.....</b>	
<b>DEDICATION.....</b>	
<b>ABSTRACT.....</b>	<b>i</b>
<b>ABSTRAK.....</b>	<b>ii</b>
<b>ACKNOWLEDGEMENT.....</b>	<b>iii</b>
<b>TABLE OF CONTENT.....</b>	<b>iv</b>
<b>LIST OF TABLES.....</b>	<b>vii</b>
<b>LIST OF FIGURES.....</b>	<b>viii</b>
<b>LIST OF ABBREVIATIONS.....</b>	<b>x</b>
<b>1.0 CHAPTER 1 INTRODUCTION .....</b>	<b>1</b>
1.1 Project Background .....	1
1.2 Problem Statement .....	2
1.3 Objective .....	3
1.4 Work Scope .....	4
<b>2.0 CHAPTER 2 LITERATURE REVIEW .....</b>	<b>5</b>
2.1 Introduction .....	5
2.2 Polymers .....	5
2.2.1 Thermoplastic.....	10
2.2.2 Thermoset.....	12
2.2.3 Elastomer.....	13
2.3 Polyester Resin .....	16

2.4	Fibers .....	18
2.4.1	Synthetic Fibers.....	18
2.4.2	Natural Fibers.....	19
2.5	Banana Fibers .....	24
2.6	Composites .....	26
2.6.1	Polymer Matrix Composites .....	28
2.6.2	Natural Fibers Composites.....	29
<b>3.0</b>	<b>CHAPTER 3 METHODOLOGY .....</b>	<b>30</b>
3.1	Introduction .....	30
3.2	Objective review.....	31
3.3	Flow Chart.....	32
3.4	Data and Information Collection.....	33
3.5	Raw material Preparation .....	33
3.5.1	Extraction of Banana Stem Fiber .....	33
3.5.2	Alkaline Treatment.....	34
3.6	Sample Preparation / Fabrication .....	37
3.7	Mechanical Testing Method.....	44
3.7.1	Tensile Testing .....	44
3.7.2	Flexural Test.....	45
<b>4.0</b>	<b>CHAPTER 4 RESULTS AND ANALYSIS .....</b>	<b>47</b>
4.1	Introduction .....	47
4.2	Tensile Test .....	47
4.3	Flexural Test.....	61
4.4	Specimen Defects and Failure .....	66

<b>5.0</b>	<b>CHAPTER 5 CONCLUSION AND RECOMENDATION .....</b>	<b>69</b>
5.1	Conclusion.....	69
5.2	Recommendation.....	70
	<b>REFERENCES.....</b>	<b>72</b>
	<b>APPENDICES.....</b>	<b>76</b>

## LIST OF TABLE

Table 2.1: Types of Polymers and Its Acronym	7
Table 2.2: Polymer Applications	9
Table 2.3: Average Mechanical Properties of Thermoplastic	11
Table 2.4: Advantages and Disadvantages of Thermosets	13
Table 2.5: General Properties of Elastomer	15
Table 2.6: General List of Natural Fibers	19
Table 2.7: Mechanical Properties of Natural Fibers	21
Table 2.8: Comparison Between Natural Fibers and Glass Fibers	22
Table 3.1: Percentage of Composition Polyester Resin + Banana Stem Fiber	37
Table 4.1: Results of Tensile Test	46
Table 4.2: Condition of the Sample After Undergo Tensile Test	58
Table 4.3: Results of Flexural Test	59
Table 4.4: Condition of the Sample After Undergo Flexural Test	63
Table 4.5: Sample Defects During Process of Moulding the Specimen	66

## LIST OF FIGURES

Figure 1.1: Production of Banana in Malaysia	2
Figure 2.1: Branched polymer formation for radical polystyrene	8
Figure 2.2: Thermoset Molucules after Cross Linking	12
Figure 2.3: Types of elastomer structure	14
Figure 2.4: Unsaturated polyester resin chemical formula	17
Figure 2.5: Properties of polyester resin	18
Figure 2.6: Examples of Natural Fibers	21
Figure 2.7: Banana Fiber	24
Figure 2.8: Chemical Composition of Banana Plant Compared to Other Plant	25
Figure 2.9: Formation of Composites	26
Figure 2.10: Fabrication Process of The Polymer Matrix Composites	28
Figure 3.1: Flow Chart	32
Figure 3.2: Banana fiber extraction machine	34
Figure 3.3: Sodium hydroxide used for alkaline treatment.	35
Figure 3.4: Alkaline treatment on the fibers.	36
Figure 3.5: Drying process of the fibers under sunlight.	36
Figure 3.6: Mould used form the specimen.	38
Figure 3.7: Polyester resin and Methyl ethyl ketone peroxide.	38
Figure 3.8: LOCATITE 770-NC Frekote mould releasing agent.	41
Figure 3.9: Applying mould releasing agent on the mould surrounding.	41
Figure 3.10: Arrangement of banana stem fiber on open mould	42
Figure 3.11: Polyester resin pouring technique .	42

Figure 3.12: Acrylic sheet placed on top of mould.	43
Figure 3.13: Specimen samples.	43
Figure 3.14: Tensile Test on Universal Testing Machine	45
Figure 3.15: Flexural Test on Universal Testing Machine	46
Figure 4.1: Graph of Tensile Strain (mm/mm) against Tensile Stress (Mpa) Composition of 100% Polyester Resin + 0% Banana Stem Fiber	50
Figure 4.2: Graph of Extension (mm) against Load (N) for composition of 100% polyester resin + 0% banana stem fiber	50
Figure 4.3: Graph of Tensile Strain(mm/mm) against Tensile Stress (MPa) for composition of 95% polyester resin + 5% banana stem fiber	51
Figure 4.4: Graph of Extension (mm) against Load (N) for composition of 95% polyester resin + 5% banana stem fiber	52
Figure 4.5: Graph of Tensile Strain(mm/mm) against Tensile Stress (Mpa) for composition of 90% polyester resin + 10% banana stem fiber	53
Figure 4.6: Graph of Extension(mm) against Load (n) for composition of 90% polyester resin + 10% banana stem fiber	54
Figure 4.7: Graph of Tensile Strain(mm/mm) against Tensile Stress (Mpa) for composition of 85% polyester resin + 15% banana stem fiber	55
Figure 4.8: Graph of Extension (mm) against Load (N) for composition of 85% polyester resin + 15% banana stem fiber	56
Figure 4.9: Graph of Maximum Stress against Percentage of Composition	57
Figure 4.10: Graph of Maximum Strain against Percentage of Composition	58
Figure 4.11: Graph of Young's Modulus against Percentage of Composition	59
Figure 4.12: Graph of Maximum Force (N) against Percentage of Composition	62
Figure 4.13: Graph of Modulus of Flexural Strength (MPa) against Percentage of Composition	63
Figure 4.14: Graph of Time at Break against Percentage of Composition	63
Figure 4.15: Sample specimen that break at the gripping place	67
Figure 4.16: Sample specimen that break into three pieces at the gripping place.	67
Figure 5.1: Polyester resin water tank used for irrigation process	71



## LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

$\sigma$	-	Stress
$\epsilon$	-	Strain
$E$	-	Young Modulus



## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Project Background**

Malaysia is a tropical country that produces a lot of fruits every year. Examples of the fruits are durian, banana, mango, duku and rambutan. Banana is the second most fruit that undergoes into production in Malaysia as shown in Figure 1.1. Those planted banana trees are cut down every year to produce enough banana to meet the demand in Malaysia. These banana trees are left to rot in the banana plantation. The rotting process release methane which is one of the greenhouse gases known as a pollutant.

It is worth to utilize fiber from banana trees since it is considered as one of the renewable resources in Malaysia and in the future the demand for banana stem fiber based will increase as green materials. Utilization of the banana stem fiber not only benefit the environment, but it will also reduce the overall resource and introduction of green technology to the rural areas. Each and every parts of the banana plant stem provides fibers with various strength.

In this investigation different composition of the polyester resin and banana plant stem fibers to form a composite material. Each composition of mixture can result in

different strength for the reinforced polymer composite. The composite polymer is then performed with physical test and mechanical test. At the end of the test, by reviewing the obtained result, a conclusion will be made whether this polymer composite reinforced with banana plant stem fiber is suitable to replace the usage of synthetic fibers as the reinforced composite.

Fruit name	Planted area (Ha)	Production	
		(metric tonne)	Value (RM'Million)
Star fruit	1,276	11,820	31.6
Papaya	3,403	49,760	68.4
Cempedak	11,158	56,631	130.2
Ciku	1,115	6,050	18.1
Dokong	16,130	32,420	97.3
Duku	5,775	27,680	65.0
Durian	104,655	300,470	1392
Guava	1,525	19,650	50.6
Langsat	6,925	25,660	69.3
Mango	9,760	25,510	83.5
Mangosteen	7,685	29,520	79.7
Jackfruit	3,962	27,459	63.2
Banana	29,790	294,530	476
Rambutan	25,460	82,740	171
Salak	1,190	4,530	15.8
Watermelon	11,750	238,050	309

**Figure 1.1:** Production of Banana in Malaysia

Source: (<https://scialert.net/abstract/?doi=jas.2011.3815.3820>)

## 1.2 Problem Statement

Polymers composite materials are one of the most advanced engineering materials. It has a high advantage against few mechanical properties such as corrosion resistance, low thermal expansion, higher stiffness and low weight which makes it suitable for various applications and the materials manufacturing in the field of automotive, aerospace, and

construction industries. Since that the demand on the composite materials starts to rise which brought to the insufficient supply of the raw materials.

The raw materials of the polymers were obtained from the natural gases combustions. Those combustions of the natural gases not only bring benefits in the production of the polymers but it also rises up the global warming issue by releasing the greenhouse gasses such as methane and carbon dioxide during the degradation of the polymers.

Aside from the environmental impact, the cost of the composite material is also an important factor, as glass and carbon fibers are relatively expensive to produce, and fluctuating oil prices mean unstable costs for the composite material as a whole. Fiber glass is an irritant. Skin irritation is generally associated with thick fibers which can be found in insulation wools and filamentous glass. Fiber glass may also cause irritation of the eyes and throat. If the exposure is sufficient, fiberglass may produce irritation dermatitis and difficulty in breathing which will further bring problem with the human respiratory system.

Besides the producing of polymers such as plastic were not easily to decompose in the soil. Therefore, this issues triggers the idea for developing a sustainable resource which is environmental friendly and recyclable. With the increasing in the capabilities of the engineering fields researchers starts to research on the polymer composites reinforced with the natural fibers.

Besides, the fiber reinforcement improves mechanical properties by increasing hardness, flexural ability, better tensile, and higher tensile modulus and impact strength,

and higher tensile modulus. Fibers in between the polymer composites hold the material together to resist deformation and breaking under stresses. Density of the fibers, length and width of the fibers, and adhesion strength between fiber and polymers as well as defects and variation within the fibers themselves are the several factors to be considered in the fiber reinforcement with the polymer composites.

### **1.3 Objective**

- To fabricate new composition of polyester resin reinforced with banana fiber in the fiber orientation of  $0^{\circ}/90^{\circ}$ .
- To test and analyse the new composition produced through tensile test and flexural test based on the ASTM standards.

### **1.4 Work Scope**

To fabricate a laminated polyester resin composite reinforced with banana plant fiber as a possible replacement for synthetic fibers in Malaysia such as glass fiber and carbon fiber. Next, is to test the specimens for determine the mechanical properties based on the ASTM standard.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

In this chapter some previous research are being reviewed to relate to this investigation. The polymers and natural fibers that are the main raw material being discussed in this chapter. Previous researches will be very helpful to know the material specifications, characteristics, advantages and disadvantages of selecting and using it.

#### **2.2 Polymer**

Polymers usage start to grow in the twentieth century at where on that time World War II was ongoing. The most commonly used polymers on that period of time are plastics. The needs of in the products of paints, fibers, elastomers, coatings, film and structural plastics enhance the growth of chemical industry to produce large amount of synthetic polymers (McKeen, 2009). Even though in today term most of the material can be manufactured by plastic which able to be moulded and formed into solid or semi solid objects except the fibers.

Polymers formed by covalent chemical bonding. The chemical bonding happens by joining between the large molecule known as macro-molecule and small repeating units known as monomers. The molecules of polymers consist of thousands or millions of atoms in the form of regular, irregular, crystalline regions or amorphous structures. Polymers are normally containing with the repetitive units of carbon atoms.

The arrangement of the polymers atom is normally in one-dimensional, two-dimensional or three dimensional molecules. The important group of polymers can be found in the last type of the atoms arrangements which normally can be detected in the natural fibers and in the manufacturing of man-made fibers (Grishnov, 2011).

Crude oil, natural gas, nitrogen and chlorine are the raw materials that used in the production of polymers. Ethylene, propylene, styrene and butadiene are formed from the basic petrochemicals is later processed into various kind of polymer materials. Polymers can be divided into three categories which are thermoplastic, thermoset and elastomers. Examples of the polymers with their categories has been shown in Table 2.1.

Thermoplastics are a polymer that can formed or deformed easily depends on the temperature changes because the molecular chain in the thermoplastic were connected apart from each other. Meanwhile thermosets are covalently bonded makes it is hard to formed or deformed into other shape (Gerdeen, et.al, 2005).