Addis Ababa University

Addis Ababa Institute of Technology

School Of Mechanical and Industrial Engineering

Fabrication and Characterization of False Banana Fiber Reinforced Gypsum Composite

By:

Ashenafi Abuye

October, 2017

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfilment for the Degree of Master of Science in Mechanical Engineering (Design Stream)

By

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Co-Adviser: Ato Araya Abera (Ph.D. Candidate)

Addis Ababa, Ethiopia

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SCHOOL OF GRADUATE STUDIES

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Approved By Board of Examiners

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DECLARATION

This is to certify that the thesis prepared by Ashenafi Abuye, entitled by Fabrication and characterization of false banana fiber reinforced gypsum composite and submitted in partial fulfilment of the required for the degree of masters of Science (Mechanical and Industrial engineering) compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

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This thesis has been submitted for examination with my approval as a university advisor.

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Abstract

The increase of environmental pollution and lack of resources have resulted in great research interest of materials that are friendly to our health and environment. In Southern part of Ethiopia, false banana covers a significant parts of land. Natural fiber from false banana is widely available fiber in Ethiopia. This research focuses on Fabrication and Characterization of Chopped Short False Banana Fiber Reinforced Gypsum Composite. Experimental investigation has been carried out to find out the effect of false banana fiber at different weight percentages of 5, 20, 30 and 40 to modify gypsum resin. 100 KN servo hydraulic universal testing machine was used to test specimen. Modifying gypsum resin through false banana fiber improves mechanical and physical properties—and this was the main focus of this study. The finding was that 20 wt.% of false banana fiber mixed gypsum gave optimum properties and was found out to be better than other weight percentages combinations. The new false banana fiber composite was compared with glass fiber reinforced epoxy composite and manufactured using hand lay-up techniques. The addition of false banana fiber has improved tensile, flexural and impact properties of gypsum resin, increasing water absorption of the material. According to the results, false banana fiber can be a potential candidate for use in natural fiber reinforced composite and is intended to improve its mechanical and physical properties. When compared to glass fiber reinforced epoxy resin composite (table 12 and 13), it has less mechanical properties. These composites can be applied as false ceiling and wall partitioning for internal house parts of construction materials.

Key words: False banana fiber, Gypsum, Mechanical properties, Water absorption, hand lay-up technique and improved mechanical properties.

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List of Abbreviations and Acronyms

ASTM	America Society for Testing and Material
hr.	hour
min	minute
mm	millimeter
PE	polyethylene
UTM	Universal Testing Machine
μ m	micrometer
in	inch
FBF	False Banana Fiber

CHAPTER 1 - INTRODUCTION

1.1 Background of the Study

Currently, worldwide environmental and economic interests motivate researchers in designing new materials whose significant portion is based on natural renewable resources in order to avoid further pressure on the environment.

A composite is a material prepared by combining two or more different material in such a way that the resultant material advanced with properties to any of its parental ones. They are the most promising materials nowadays. These materials can be used for a variety of applications: - such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances etc. For instance, polymeric composites have high strength and stiffness, light weight, low cost, low density, high toughness, and high corrosion resistance. [1]

Composite materials have great potential to improve the traditional materials like mud, wood, metal and concrete which have their own weaknesses such as heavy weight, chemical attack and poor durability. In addition, costly imported partition walls are out of the reach of most people. So the need for another high quality locally made material has become a necessity. Therefore, a new composite wall partition and false ceiling made from natural fiber are proposed in this research. Natural fiber reinforced composites have advantage over common reinforcing composites such as those using glass and carbon fibers. They also minimize the opposing impact on the environment. [5]. False banana fiber (FBF), a ligno-cellulosic fiber, obtained from the pseudo-stem of false banana plant (Musa sepientum), is a bast fiber with relatively good mechanical properties. Natural fiber (NF) from false banana is among widely used natural fibers in southern parts of Ethiopia.

In the past few decades, gypsum has been used as a finishing material for walls and ceilings. Due to its excellent performance [2], gypsum has made attractive appearance and its healthful contribution to living conditions have made most popular finishing material for applications. In addition, the availability in subsoil, relative low cost, easy handling and mechanical characteristics are suitable for different applications, making the gypsum a widely used construction material. However, gypsum has some undesirable characteristics, such as heaviness, brittleness: - impeding exterior application. Heaviness and brittleness may be appreciably reduced by combining gypsum with mineral particles or natural fiber. [2]

A lot of researches have been conducted on natural fiber reinforced polymer composites but researches on false banana fiber based polymer composites -on an isotropic gypsum resin composites is very rare. Against this background, the present research work has been undertaken-, with the objective of investigating the Mechanical and physical characterization of different fiber ratio Composites. In this study, false banana fiber reinforced with gypsum to create new composite materials like wall partition and false ceiling, thereby improving fiber weight composition in gypsum. [2]

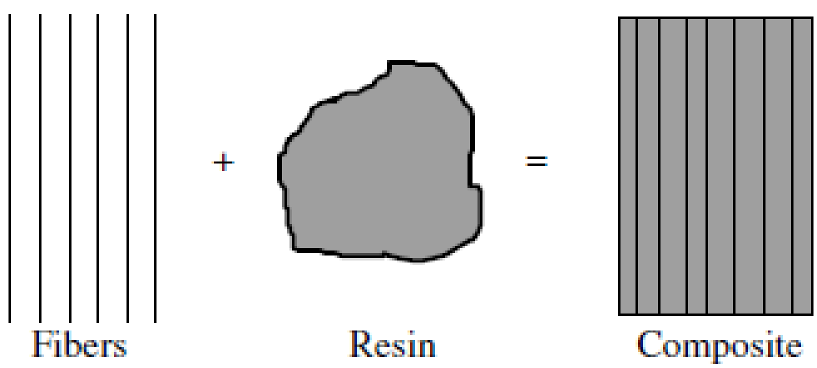


Figure 1 How New Material Will be created [5]

1.2 Problem Statement

Some researchers studied the mechanical properties of composite materials but, studying the mechanical and physical properties becomes vital because the properties of composite materials are different from manufacturers to manufacturers due to the incorporated manufacturing methods. Ethiopia has a considerable amount of false banana plant (especially in southern part of Ethiopia), which has a great potential for the use of structural material. However, the contribution of false banana plant for agro-economic sector of the country is negligible.

Moreover, as result of lack of awareness of this plant and unavailability of experimental tools, research on contribution of false banana fiber has not been conducted before. On the other hand, large amount synthetic fibers are used for floor board (matting) and for false ceiling. However, these synthetic fibers can cause environment pollution both during fiber extraction and fiber disposal of composite materials.

Global warming has forced researchers to enhance the quality products for energy saving. Hence, researchers are on the upper hand to block the problem associated with the climate change, maintaining temperature inside the commercial buildings as well as houses, where heat reduction is important aspects. Natural false banana fiber mixed gypsum composites are expected to reduce heat and associated problems.

1.3 Objectives

1.3.1 Major Objectives

- The overall objective of this research is to fabricate and characterize false banana fiber reinforced gypsum composite.

1.3.2 Specific Objectives

- Fabrication of short false banana fiber reinforced gypsum composite;
- To study mechanical properties (tensile, flexural and impact) of short false banana fiber reinforced gypsum composite;
- To study physical properties (water absorption) of short false banana fiber reinforced gypsum composite;
- To approve percentage composition of false banana fiber and gypsum;
- To compare properties of false banana fiber reinforced gypsum composite with glass fiber reinforced epoxy resin composite.

1.4 Scope of the Study

The overall scope of the study is to fabricate and characterize false banana fiber reinforced gypsum composite and testing of mechanical (tensile, flexural and impact) and physical (water absorption) properties using universal testing machine (UTM) and to compare with glass fiber reinforced epoxy resin composite.

1.5 Limitation of the Research

- ✓ The Experiment was not done by computerized electrohydraulic universal material testing machine.
- ✓ Compression samples were fabricated but not tested because of limitation of testing UTM

1.6 Thesis Organization

This thesis focuses on the Fabrication and Characterization of Short Chopped False Banana Fiber Reinforced Gypsum Composite, with results and discussion. This research document comprises Six- chapters:

Chapter 1 This chapter introduces the background of natural fiber composite materials objectives, Problem Statement, Scope and limitations.

Chapter 2: All relevant research papers regarding natural fiber composite materials are reviewed, ranging from polymer types, fiber types, and composite's mechanical properties to physical properties. Recent researches on false banana fiber reinforcement on polymers are also widely and deeply reviewed.

Chapter 3: In this chapter, the methods, materials and fabrication for the preparation of test specimen are discussed; also experimental analysis of mechanical and physical properties of chopped false banana fiber reinforced gypsum composite have been examined and discussed.

Chapter 4: This chapter discusses experimental conditions, experimental setup such as universal material testing machine and band saw.

Chapter 5: In here results and discussion of the characterization of composite material, mechanical and physical properties are performed well and discussed in detail.

Chapter 6: This chapter contains the conclusion, future work and appendix of this thesis.

CHAPTER 2 - LITERATURE REVIEW

2.1 Composite Materials

A composite is a material prepared by combining two or more different materials. The resultant material is capable with properties advanced to any of its parental ones. Composites have been a field of great interest in the last two decades and a lot of researchers are working in this area. This becomes very important to discuss the prominent works related to the polymer composites and their properties. The purpose of literature review is to provide background information on the issues to be considered in this research and to emphasize the relevance of the present study. Various aspects of polymer composites have been considered with reference to development as well as characterization of polymer composites. Existing literature related to the physical and mechanical properties of the composites have been reviewed. Knowledge gap in the earlier investigations has been presented to frame the need for and objectives of the present work. [3]

Natural fiber reinforced polymer composites have raised a great attention and interest among scientists and engineers in recent years with regard to issues of developing environmental friendly materials. They are high specific strength and modulus materials, low priced and are easily available. It is known that natural fibers are non-uniform with irregular cross-sections which make their structures quite unique and much different with man-made fibers such as glass fibers, carbon fibers etc. Various researchers have worked on the natural fibers containing polyolefin, polystyrene, and polyester resins. Properties like low cost, light weight, high specific strength, free from health hazard are the unique selling points of these composites. Though the presence of hydroxyl and other polar groups in the natural fibers leads to the weak interfacial bonding between the fibers and the hydrophobic polymers, these properties can be significantly improved by interfacial treatment. [3]

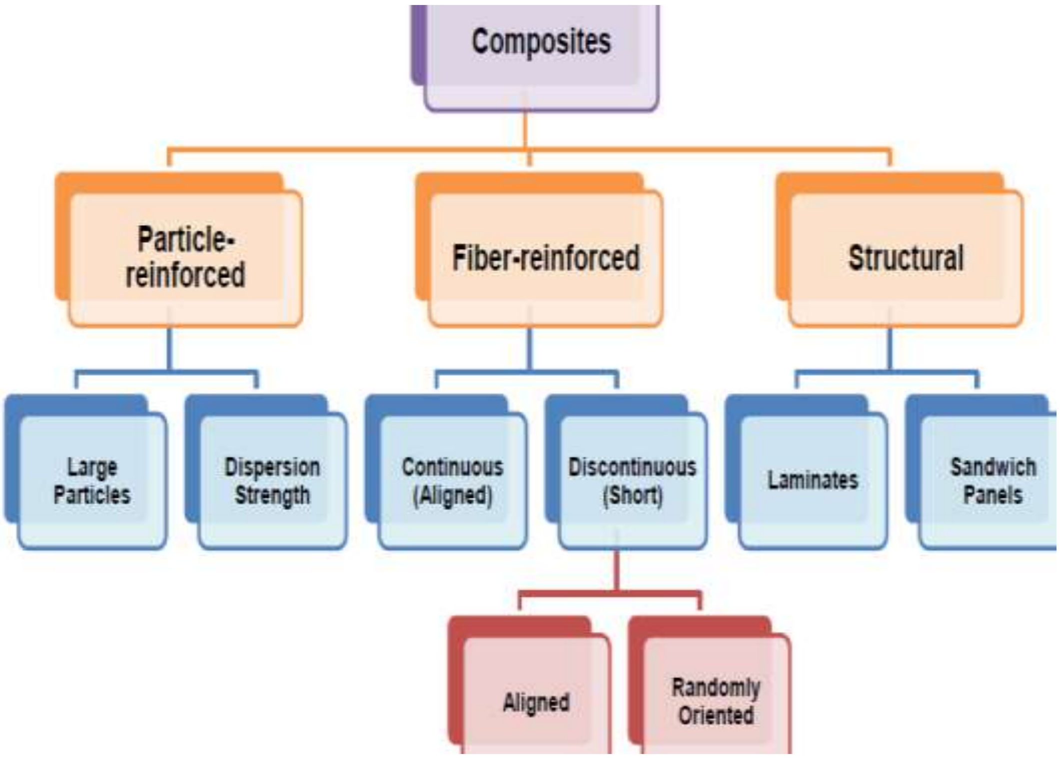


Figure 2 Classification of composites

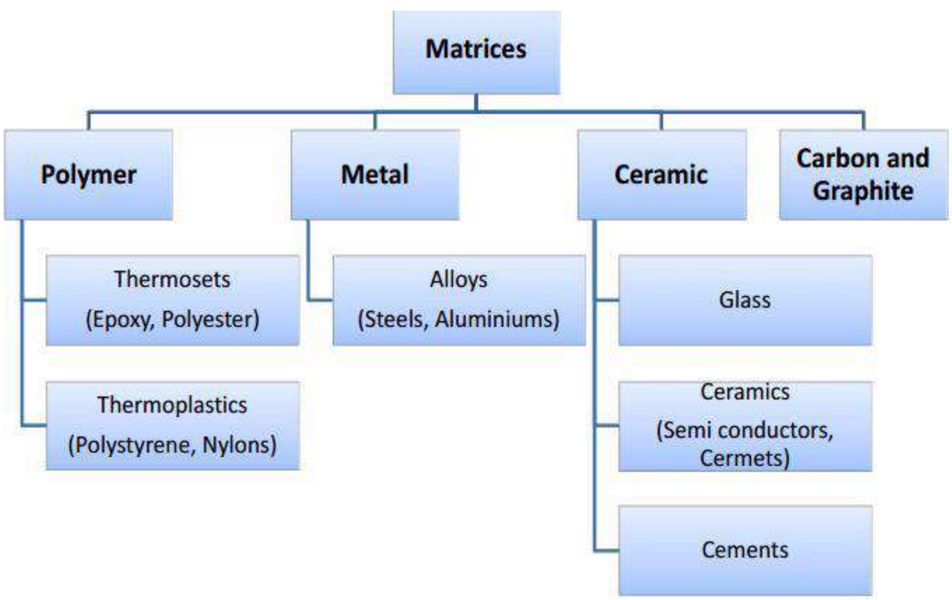


Figure 3 Classification of matrices

2.2. Classification of the Fiber

2.2.1. Synthetic Fiber

Synthetic fibers are fibers which are artificial. The most common synthetic reinforcements are glass, carbon, aramid and boron fibers. Typical fiber diameters range from 5 μ m (0.0002 in.) to 20 μ m (0.0008 in.). The diameter of a glass fiber is in the range of 5μm to 25 μ m, a carbon fiber is 5 to 8 μ m, an aramid fiber is 12.5 μ m, and a boron fiber is 100 μ m. Because of this thin diameter, the fiber is flexible and easily conforms to various shapes.

The most widely used fiber materials in fiber-reinforced plastics (FRP) are glass, carbon, aramid, and boron as stated above. Glass is found in abundance; so glass fibers are the cheapest among all other types of fibers. There are three major types of glass fibers: E-glass, S-glass, and S2-glass.

Some of the common types of reinforcements include:

• Continuous carbon tow, glass roving, aramid yarn

• Discontinuous chopped fibers

• Woven fabric

• Multidirectional fabric (stitch bonded for three-dimensional properties)

• Stapled

• Woven or knitted three-dimensional performs

Continuous fibers are used for filament winding, braiding and weaving applications. Continuous fibers are used with most thermoset and thermoplastic resin systems. Chopped fibers are used for making injection molding and compression molding compounds. Chopped fibers are made by cutting the continuous fibers. In spray-up and other processes, continuous fibers are used but are chopped by machine into small pieces before the application.

Woven fabrics are used for making prepares as well as for making laminates for a variety of applications (e.g. boating, marine, and sporting). Preforms are made by braiding and other processes and used as reinforcements for RTM (resin transfer molding) and other molding operations. [4, 8]

2.2.2 Natural Fiber

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap and completely or partially recyclable. Plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, false banana (enset) etc., as well as wood, used from time immemorial as a source of lignocelluloses fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and other man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products etc. [5,6]

As a drawback, natural fibers exhibit low transverse and compressive strength. Natural fibers are also sensitive to environmental factors such as temperature and moisture. Generally, rising moisture content lowers the mechanical properties of a composite. As a result, different research has been conducted to increase fiber matrix adhesion through different technique like treating the fiber surface with chemicals. [5, 6, 7].

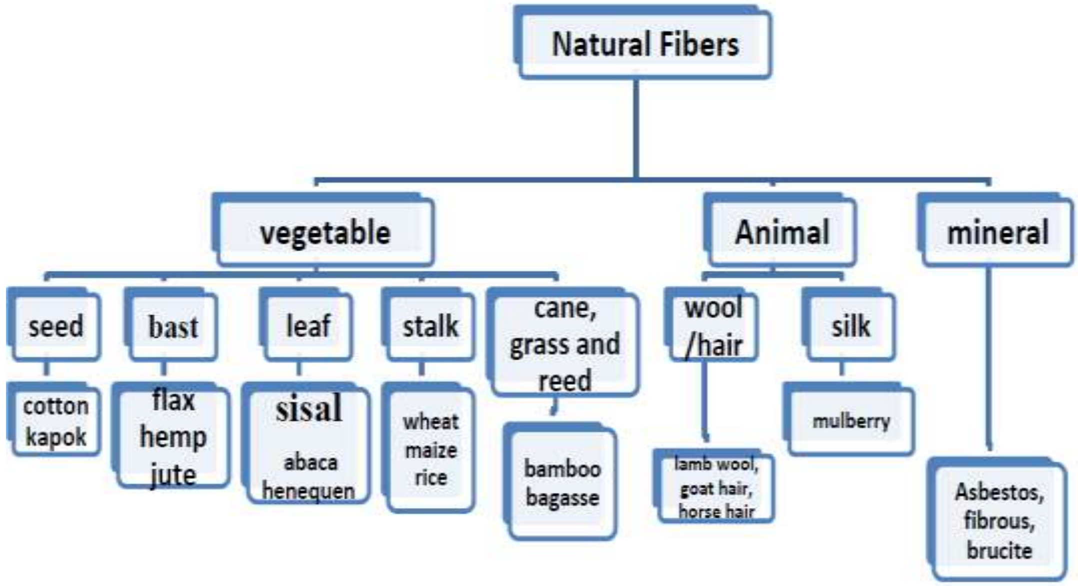


Figure 4 Classification of Natural Fibers

Fiber-reinforced composite materials can be divided into two main categories.

1. Short Fiber-Reinforced Composites

Short fibers are used as random and aligned way as composite is an isotropic component where its strength, varies with direction of the force applied. The fibers are chopped to a required length and are used as reinforcement. The fibers' properties are to be analyzed before using composites, as reinforcement alters all the properties of composites. Particles of minerals or stones are also used as reinforcement. The adhesion/compatibility between matrix and reinforcement will play an important role in determining performance of the composite. [2]

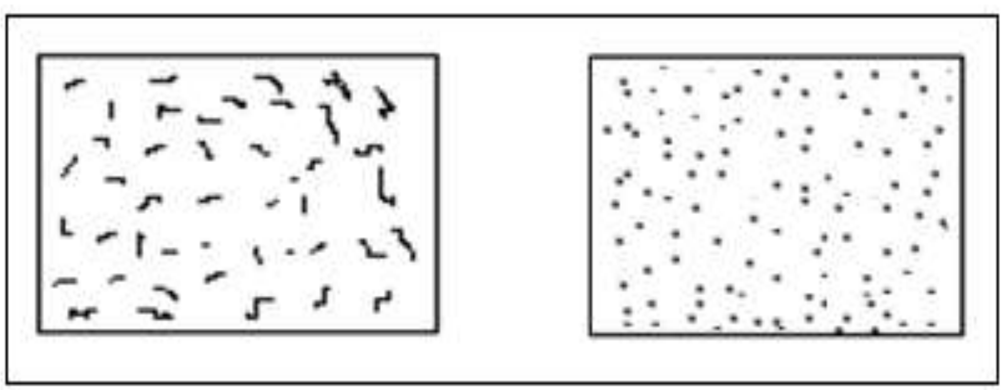


Figure 5 Short fibers reinforced composites. [2]

2. Continuous Fiber-Reinforced Composites

Continuous reinforced materials will often constitute a layered or laminated structure. The drawback with the following technique is difficulty in workability, as fibers are continuous and they render the application of matrices and fibers slurry in molding process. The structure forms a layer or laminate structure which have tendency to detach from the mother composite when an impact force is applied, application of continuous fibers is therefore limited to certain products. [2]

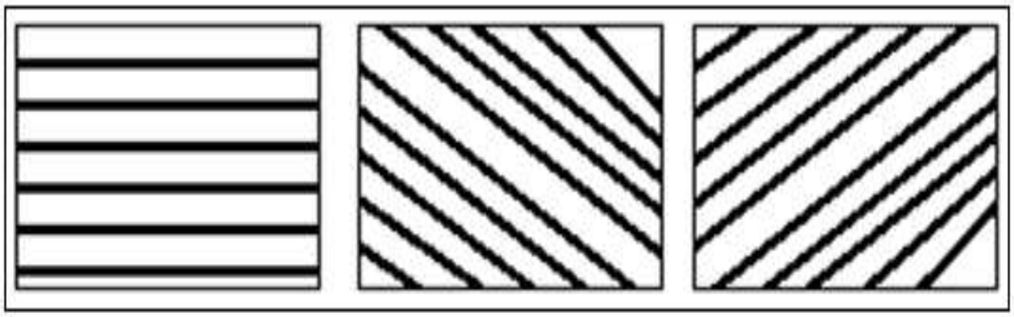


Figure 6 Continuous fibers reinforced composites. [2]

2.2.2.1. False Banana (Enset) Plant

Ethiopia has a considerable amount of false banana plant. In Southern parts of Ethiopia, most areas of land are covered with false banana plant which has a great potential in structural material use. Besides, the contribution of false banana plant for agro-economic sector of the country is negligible. The fibers are extracted from false banana plant by hand and dried in sunlight for 12 hours until all the moisture is removed from the fiber. The dried fibers are made in the configuration of woven fabric. *Enset* is farmed in a mixed system along with grain crops, coffee and others. It is a attractive plant, related to and resembling the banana tree, but taller, thicker and with no bananas (which gives rise to its English language name “the false banana”). This plant is the main source of food in the southern region of Ethiopia especially for the “Guarage and kambata” peoples. One of the well-known foods is “kocho”, a solid staple a bit like heavy bread, which is eaten with milk, cheese, cabbage, meat and/or coffee. This plant is also a major source of fiber, which the people call it kancha. They use it for making rope and a mat.

Figure 7 False banana (Enset) plant

2.2.2.2. False Banana Fiber

Reinforcements are part of composite which provide the strength and stiffness to the composite materials. The reinforcements can be fibers, particulates, or whiskers. The former is very common one. Reinforcing fibers are found in different forms, long continuous fibers, woven fibers and short chopped fibers. Each configuration results in different properties. The properties strongly depend on the way the fibers are laid in the composites materials. [4]

In composite material, one of the main components is the reinforcement material that is fiber. So enset fiber is a natural fiber which is extracted from local enset plants. The fiber obtained from this plant has whitish in color, in average 1 m to 1.50 m long and it is a strong fiber. In this paper, enset fiber was used as reinforcement.

Using enset fiber and the other part of enset plant, the Guarage and kambata peoples prepare mats for different purpose depending on the size of the mat. Most of the time, the mat is used to decorate their house specially the floor. This woven material is strong and costs less in price. [5]

Figure 8 Enset fiber (kancha) [5]

2.2.2.3. Extraction Process of Enset Fiber

The extraction of the fiber was not taken place as the main objective. Rather it is a byproduct. The main reason for extraction process is during the search for food. The processes are discussed as follows according to the observation this researcher made.

- ✓ Cut the enset plant which is ready for (4-5 years) for the process, from the ground level.
- ✓ Cut the outer two layers of the plant into smaller pieces.
- ✓ Attach the smaller piece on an inclined plane wood and hold it with right leg.
- ✓ Between the right leg and the inclined plane wood, scrap it with a tool made from wood to squeeze the size.
- ✓ The one which is left on the inclined plane will be the fiber and the one which is left on the ground will be the food.

In the figure below, the cross section of the enset plant and the extraction process of the food is shown.

Figure 9 Cross section of Enset plant   Slice of the layer

Figure 10 Extraction of the food and the fiber [5]

2.3. Properties of Natural Fibers

Density determines the weight of the composite. The higher the density is the higher the weight and vice versa. Its performance of the fiber depends on its strength to weight ratio. The composite should possess lower density with higher strength. Natural fibers have density in the range of 1.4 to 1.6.

Table 1 Selected Properties of Natural and Synthetic Fibers [9]

Fiber	Density (g/cm^3)	Tensile strength (MPa)	Specific tensile strength (MPa)	Elastic modulus (GPa)	Specific elastic modulus(MPa)
Cotton	1.5-1.6	400	250-267	55-126	3.5-8.1
Kenaf	1.45	930	641	53	36.5
Sisal	1.5	511-635	341-423	9.4-22	6.3-14.7
E-glass	2.5	2000-3500	800-1400	70	28
Carbon	1.4	4000	2857	230-240	164-171

Table 2 Properties of Selected Natural Fiber [8]

Property	hemp	flax	sisal	jute
Density (g/cm3)	1.48	1.4	1.33	1.46
Modulus (GPa)	70	60-80	38	10-30
Tensile strength(MPa)	550-900	800-1500	600-700	400-800
Elongation to failure (%)	1.6	1.2-1.6	2-3	1.8

Table 3 Properties for Glass Fiber Epoxy Resin [21]

Parameter	Value
Density (g/cc)	2.6
Tensile modulus	81.4 GPa
Shear modulus (GPa)	15
Fiber strength (GPa)	3.45
Elongation	4.88%

Table 4 Properties of Banana and Pineapple Fiber. [11]

Properties	Banana fiber	Pineapple fiber
Cellulose (%)	63–64	81-12
Micro febrile angle	11	14-8
Hemi cellulose (%)	6 - 19	16-19
Lignin (%)	5-10	4.6-12
Moisture content (%)	10-11	11-12
Density (kg/m3)	1350	1440
Lumen size (mm)	5	2-3
Tensile strength (MPa)	529-914	413-1627
Young's modulus (GPa)	27-32	60-82

2.3.1. Physical Property of False Banana Fiber

Density (g/cm3) 1.4 – 1.6, elongation at break (%) 4-6, cellulose content (%) 37.93 - 69.51, modulus of elasticity (GPa) 5433, Young's modulus (GPa) 67.3, tensile strength 543 MPa, diameter (25.87 µm) and Poisson ratio 0.25. [Internet]

2.4. Matrix Materials

Matrix is part of the composite material in which it surrounds the fibers and thus protects those fibers against chemical and environmental attacks. For fibers to carry maximum load, the matrix must have a lower modulus and greater elongation than the reinforcement.

Matrix is a material which condenses two or more than two components in itself. In case of natural fiber, reinforced composite material and matrix bind the fibers together. It transfers applied load to these fibers. Various types of materials are generally used as matrix material such as metal matrix, ceramic matrix, carbon graphite matrix, glass matrix and polymer matrix. Among these, polymer matrices are currently being used to a larger extent because of their enormous advantages. [2]

Polymer matrix materials include thermosets such as epoxy, phenol and vinyl ester; or thermoplastics such as polyether ketone and polyethersulphone. Metal matrix materials are made by dispersing a reinforcing material into a metal matrix.

Polymer matrix composites are used in modern day structural applications due to their significant advantages such as resistance to corrosion, resistance to chemicals, and high strength to weight ratio, low thermal and electrical conductivity, and low moisture absorption. [2]

The requirements for the matrix in natural fiber reinforced polymer composite are:

- To bind the fibers together, and protect their surfaces from damage during fabrication in the service of life of the composite;
- Melting point should be lower than the degradation temperature of the fibers;
- To keep the fibers dispersed and separated so as to avoid any catastrophic propagation of cracks and subsequent failure—to transfer stresses to the fibers efficiently by adhesion and/or friction, when the composite is under load;
- To be thermally compatible with the reinforcement; and
- To be chemically compatible with the fibers over a long period.

2.4.1. Gypsum as Matrix

Gypsum is a very soft sulfate mineral composed of calcium sulfate bi-hydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$. It can be used as fertilizer. It is the main constituent in many forms of plaster and is widely mined. As a mineral, it is alabaster, which has been used for sculpture by many cultures including ancient Egypt, Mesopotamia and the Nottingham alabasters of medieval England. It forms as an evaporate mineral and as a hydration product of anhydrite. The resin-hardener mixture is used for binding various layers of fiber. Gypsum ($CaSo_4.2H_2O$ gives the best binding property under standard room temperature. [2]

Figure 11 Gypsum powder

2.4.2. Properties of Gypsum

Table 5 The Properties of Gypsum Used. [12]

No.		
1	Workability time (min)	60-90
2	Final setting time (min)	150
3	Compressive strength (MPa)	2.5
4	Flexural strength (MPa)	1
5	Dry density (kg/m3)	650-100
6	1000 micrometer (% passing)	100
7	150 micrometer (% passing)	60
8	Chemical formulation	$CaSO_4 \cdot 1/2H_2O$

Table 6 The Properties of Gypsum [14]

Type	water content %	compressive strength (MPa)	Density (g/cm^3)	SO3 content (%)
ABS	2.5	11.3	2.597	72.4

2.5. Previous Research Works

The following researchers have conducted researches on natural fibers. Some of them are listed as follows:

Al-Hayat Getu Temesgen1 and Omprakash Sahu2 - they have studied the Process Ability Enhancement of False Banana Fiber for Rural Development. They focus on physical, chemical and tensile strength properties. [10]

Č. Mizera1,*, D. Herak2, M. Muller3 and P. Hrabě4- have observed the mechanical behavior of polymeric composite with fibers of false banana (enset ventricosum). This study focused on the analysis of the deformation characteristics of the polymer composite with continuous phase in the form of two-part epoxies and discontinuous phase (reinforcing particles) in the form of fibers of false banana (enset ventricosum). At last, they test the tensile strength by using laboratory and optical microscope. They determined tension force and deformation. **Result** – a deposition of the fibers in composite materials and their size is visible. [1]

Thomas Gebre1, Jegan Raj2-have observed fabrication and study of mechanical properties for false banana and bamboo fibers reinforced bio-compos. They studied mechanical (tensile test, impact test, hardness test and flexural test) and physical (water absorption) properties false banana and bamboo fiber with epoxy resin (cy-230) using L scale on Digital Rockwell hardness testing machine and universal testing machine. **Result** –the tensile strength of false banana and bamboo fibers epoxy composites decreases at 40wt% fiber loading. Flexural strength decreases with increase in false banana and bamboo fibers wt. % in epoxy resin. So the fabricated composites are of good quality with appropriate bonding between the fiber and resin. [3]

Idiris Mehamud1*, Jegan Raj1, Cheru Zeleke1 and Thomas Gebre1-have conducted on fabrication and Mechanical Property Evaluation of Ethiopia Banana Fiber Reinforced Polymer Composites. They focused on banana and epoxy by testing mechanical properties such as tensile test, impact test and flexural test using scanning electron microscope (SEM). **Result** – when resin and fiber ratio increases also strength increases. [17]

Stephen K. Kimutai, Joan J. Kiptarus have worked on comparative Study of Composite Made from Enset False Banana Fibers and Polyethylene with Block Board. He studied on false banana and polyethylene of mechanical (bending test, impact test and compression test) and physical (water absorption) properties using universal testing machine. [18]

Juan David Pardo1 Rafael Andrés Robayo2 – they studied on Lightweight composites based on gypsum with reinforcement of rice husk and polystyrene**, Result-** the reinforcement with rice husk fibers improves the mechanical strength and the toughness. It is possible to obtain lightweight gypsum base composites with improved mechanical properties and resistance to cracking by their reinforcement with rice husk fibers. [19]

K.Alagarraja1, A.Dhamodharan2, K.Gopinathan3, R.Mathan Raj4, K.Ram Kumar5. - On Banana/pineapple fiber + epoxy resin [20]

Ermiyas Sisay pursued his studies on design and analysis of thick partition wall for building from local composite "enset" fiber, Enset fiber + epoxy resin , **Result** – enset fiber can be potential candidates for use in natural fiber reinforced polymer composites for non-load bearing partition wall. [5]

Jindal has observed that tensile strength of bamboo-fiber reinforced plastic composite is comparatively equivalent to that of the mild steel, whereas their density is only 12% of that of the mild steel. Hence, bamboo composites can be extremely useful in structural applications. [3]

Jain and Kumar have investigated that a uniform strength can be achieved in all directions of the composites by using multidirectional orientation of fibers. [3]

But this research paper focused on fabrication and characterization of the false banana fiber reinforced gypsum composite with better testing of mechanical (tensile, flexural and impact) and physical (water absorption) properties using universal testing machine (UTM).

CHAPTER 3 - MATERIALS, METHODS AND FABRICATION

3.1. Materials

3.3.3. False Banana Fiber

The fiber of enset is cheapest in the country. It is used to make ropes and mats and uses range from fencing to house construction, etc.

For this thesis work--false banana (enset) fiber as reinforcement, the study areas are in southern part of Ethiopia. The extraction of the fiber was not taken place as the main objective. Rather the fiber is a byproduct.

Figure 12 Harvesting enset plant Extraction process Extracted fiber

3.2. Gypsum

This researcher has used Abay Gypsum as matrix. It is purchased from the local shops in Addis Ababa, Ethiopia. It is one of the most exciting polymer type and is used in advance to produce composite material with different reinforcing elements. Its extensive use is mainly for its suitable mechanical properties and adhesion, good possibility of utilizing addition- type reaction as well as for low cure shrinkage and low cost.

3.3. Sample Preparation Method

3.3.1. Preparation of Short False Banana Fiber and Gypsum

The given false banana fiber has been cut into fiber length, with 10cm using a pair of scissors and finally the chopped fiber is obtained. Then it is mixed with gypsum powder.

Figure 13 Chopped short fiber (10cm) gypsum powder

3.3.2. Weight and Volume Fraction of the Fiber and the Matrix Content of the Composite

Fiber Mass Fraction

Fiber mass fraction is defined as

$M_f = \frac{Mass\ of\ fibers}{Total\ mass}$ ……………………………………………………........Equation 1

The mass of matrix is

$Mm = \frac{Mass\ of\ matrix}{Total\ mass}$ ....…..Equation 2

Fiber Volume Fraction

Fiber volume fraction is defined as

$$V_f = \frac{volume\ of\ fiber}{Total\ volume}$$ ……………………………………...……………Equation 3

The volume of matrix is given as

$$Vm = \frac{volume\ of\ matrix}{Total\ volume}$$ …………………….……..……………………Equation 4

Mass Density of a Ply

$$\rho = \frac{Total\ mass}{Total\ volume}$$ ……………………………….…...……………………Equation 5

$$\rho = \frac{mass\ of\ fiber}{total\ volume} + \frac{mass\ of\ matrix}{total\ volume}$$

$$= \frac{volume\ of\ fiber}{total\ volume}\ \rho_f + \frac{volume\ of\ matrix}{total\ volume}\ \rho_m$$

$\rho_c = \rho_f V_f + \rho_m V_m$ = density of composite ……………...…………..……. Equation 6

$\rho_f = V_f * \rho_c =$ density of fiber …………………………………………… Equation 7

$\rho_m = V_m * \rho_c =$ density of matrix ………………………..………………Equation 8

$M_c = \rho_c * v_c$ = mass of composite ………………………………………Equation 9

$M_f = V_f * M_c$ = mass of fiver ………………….…………………….Equation 10

$M_m = V_m * M_c =$ mass of matrix ....…..Equation 11

3.3.3. Calculation to Find the Mass Composition of the Composite Material

3.3.3.1. Mechanical Properties

The use of composite materials in the different fields is increasing with different period of time due to their improved properties. Many engineers and scientists are working together for a number of years to identify the alternative solution for the high solution materials.

In the present studies on natural fiber, like false banana (enset) fiber reinforced to the gypsum to create new composite materials and their effect on mechanical and physical properties are evaluated and their properties are compared to glass fiber reinforced epoxy composite.

For tensile test – Sample dimension (250 * 30* 3) mm, and Mold dimension (300 *200 *3) mm when ρ_f =1.4g/cm^3 ρ_m =2.32 g/cm^3, according to ASTM D3039 standard.

Table 7 Compositions of Gypsum Filled With False Banana Fibers

Designation of Composition	Composition (%)		Mass (g)			No. of Samples
	Gypsum	Fiber	Gypsum	Fiber	Total	
FBF5	95	5	388.85	20.466	409.31	3
FBF20	80	20	307.59	76.89	384.48	3
FBF30	70	30	257.54	110.37	367.91	3
FBF40	60	40	210.82	140.54	351.36	3

For flexural test –sample dimension (180* 25 * 5) mm, and mold dimension (300 *200 *5) mm when ρ_f =1.4g/cm^3 ρ_m =2.32 g/cm^3 according to ASTM D3410 standard

Table 8 Compositions of gypsum filled with false banana fibers

Designation of Composition	Composition (%)		Mass (g)			No. of Samples
	Gypsum	Fiber	Gypsum	Fiber	Total	
FBF5	95	5	648.09	34.11	682.2	3
FBF20	80	20	512.64	128.16	640.8	3
FBF30	70	30	429.24	183.96	613.2	3
FBF40	60	40	140.54	234.24	374.78	3

For Impact test – Sample dimension (55 * 10 * 10) mm, and Mold dimension (200 *100 *10) mm when ρ_f =1.4g/cm^3 ρm =2.32 g/cm^3

Table 9 Compositions of gypsum filled with false banana fibers

Designation of composition	Composition (%)		Mass (g)			No. of samples
	Gypsum	Fiber	Gypsum	Fiber	Total	
FBF5	95	5	216.03	11.37	227.4	3
FBF20	80	20	170.88	42.72	213.6	3
FBF30	70	30	143.08	61.32	204.4	3
FBF40	60	40	117.12	78	195.12	3

3.4. Composite Fabrication Process

Before the reinforcement of short false banana fiber to gypsum, the fiber volume fraction and matrix volume fraction of this composite material has to be determined. Next, the false banana fiber and matrix weight should be determined, then mixing them together by hand or by brush equally. The composite was cured at room temperature until it was dry. Finally, false banana fiber reinforced gypsum composite is fabricated.

3.4.1. Method of Fabrication

Hand lay –up technique (HLUT)

In this paper, a hand lay-up technique was used as fabrication method. It is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. Composite materials can be prepared by different methods. However, due to many reasons such as part size and shape, cost, familiarity with the technique and availability of tools, composite is fabricated using hand lay-up techniques. The hand lay-up is one of the oldest composite fabrication techniques and it belongs to the open mold category. The operator places the reinforcement and the resin mix manually on a mold and thereafter the resin-reinforcement mixture is compressed with a hand roller.

Figure 14 Hand Lay-up technique

In this process, short false banana fiber, gypsum and water are applied to the mold by weighting electronic balance at AAiT Mechanical Engineering Workshop. A roller is used to impregnate the fiber with the resin. Another resin and reinforcement layer is applied until a suitable thickness builds up. It is a very flexible process that allows the user to optimize the part by placing different types of fabric and mat materials. This process requires less capital investment and expertise and is therefore easy to use.

The schematic diagram for hand lay-up process is shown in figure below, where the thickness of the composite part is built up by applying a series of reinforcing layers and liquid resin layers. A roller is used to squeeze out excess resin and create a uniform distribution of the resin throughout the surface. By the squeezing action of the roller, homogeneous fiber wetting is obtained. The part is then cured mostly at room temperature and, once solidified; it is removed from the mold.

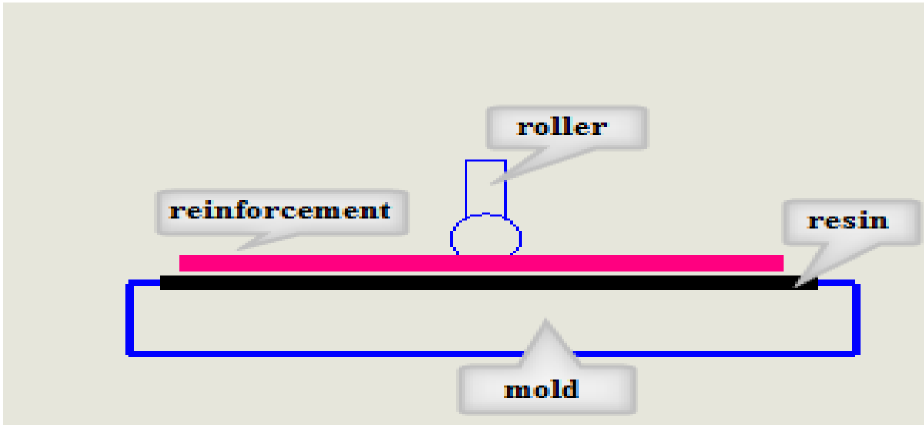


Figure 15 a typical schematic diagram for hand lay-up

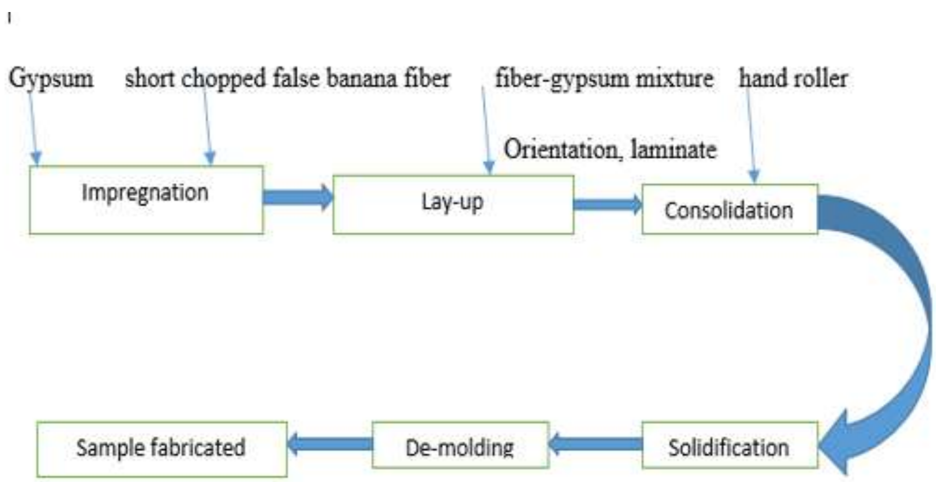


Figure 16 Flowchart of fabrication process of composite using HLU

3.4.2. Basic Processing Steps

The major processing steps in the hand lay-up process to prepare the short chopped false banana fiber reinforced gypsum composite are:

1. The mold is cleaned and prepared for use.
2. The fiber volume fraction and matrix volume fraction of this composite material has to be determined.
3. Next, the operator places or laid the reinforcement and matrix layer on the mold after weighting them.
4. Then, the reinforcement and the resin mix manually on a mold and thereafter the resin-reinforcement mixture are compressed with a hand roller.

5. Using brush, resin is uniformly distributed over the laminate and consolidation is made between the laminate and the mold.
6. Another resin and reinforcement layer is applied until a suitable thickness builds up.
7. After that, the part is allowed to cure at room temperature overnight.
8. Finally, false banana fiber reinforced gypsum composite is fabricated.

3.4.3. Advantages of the Hand Lay-Up Process

The wet lay-up process is one of the oldest composite manufacturing techniques with the following advantages:

- Very low capital investment is required for this process because there is a negligible equipment cost as compared to other processes.
- The process is very simple and versatile, any fiber type material can be selected with any fiber orientation.
- The cost of making a prototype part is low because a simple mold can be used to make the part. In addition, the raw material used for this process is resin, mat, and fabric material, which are less expensive.

3.4.4. Disadvantages of the Hand Lay-Up Process

The wet lay-up process has the following limitations:

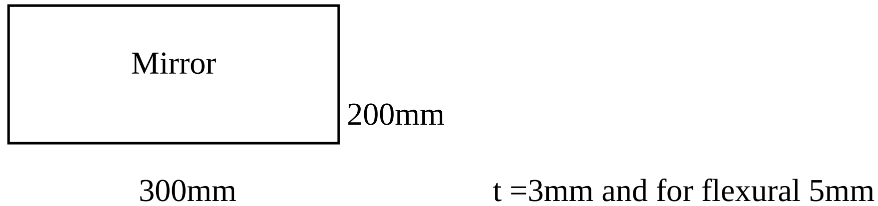
- The process is labor intensive.
- The process is mostly suitable for prototyping as well as for making large structures.
- The quality of the part produced is not consistent from part to part.
- The process is not clean. [5]

3.5. Preparing Sample Mold for Experimental Test

3.5.1. Dimensions of Mold

The samples are prepared by using the following mold dimensions, then cut into ASTM standard to test. For each property, there are three samples and taken the average one.

For tensile and flexural tests



For impact test

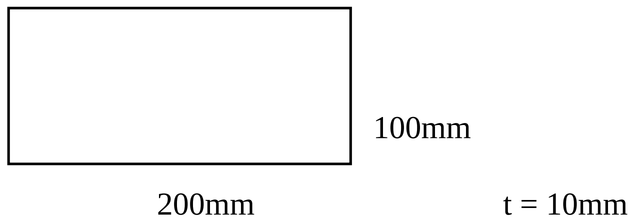


Figure 17 Dimension of Mold

Figure 18 Mirror mold

The following figures are prepared from false banana fiber and gypsum that represent the weight measurement and prepared samples of composite.

Figure 19 Gypsum and enset fiber weight for flexural sample

Figure 20 Prepared flexural sample to test   Impact sample to test

3.5.2. Dimension of Test Pieces

American Society for Testing of the Materials (ASTM) was used to prepare and conduct a test of this false banana fiber reinforced gypsum composite.

Tensile test

The tensile test is done by cutting the composite specimen as per ASTM: D3039 standard (sample dimension is 250 × 30 × 3 mm). A universal testing machine (UTM) (Model: WAW-100 is used for testing with a maximum load rating of 100 KN.

Composite specimens are tested; and the following results have been recorded:

- In each case, three samples are tested and the average results are determined and noted.
- The load is applied until the specimen breaks and break load, tensile strengths is noted.
- Tensile stress and strain graph is recorded or generated and
- Load vs. length graphs should be generated.

Impact Test:

The impact test set up consists of a pendulum which is dropped from an angle of 45 degree to impact the specimen and to fracture it. Charpy impact is employed in this impact work. The specimens are prepared as per ASTM:

(Sample dimension is 55× 10 × 10 mm). Capacity of machine is 17kg/m and it is 6701 type and has E5360 number in AAiT Mechanical Material Testing Laboratory.

Composite specimens have been tested and the following results are recorded:

- In each case, three samples are tested and the average is determined and noted.
- The specimen must be loaded in the testing machine to allow the pendulum until it fractures or breaks:
- The amount of Energy absorbed during the breaking of specimen is noted:
- Using the impact test, the energy needed to break the material is noted.

Flexural Test

The flexural test is done in a three-point flexural setup as per ASTM: D3410 standard (sample dimension is 180 × 25 × 5) mm at AAiT Mechanical Engineering Material Testing Laboratory. This test is carried out in the universal testing machine. A universal testing machine (UTM) (Model: WAW-100 is used for testing with a maximum load rating of 100 KN. When a load is applied at the middle of the specimen, it bends and fractures.

Composite specimens are tested and the following results are recorded:

- In each case, three samples are tested and the average is determined and noted.
- Breaking load is recorded
- Load vs. length graphs is generated.
- Stress vs. strain graph is generated

3.6 Physical Properties

3.6.1. Water Absorption of Composite

The water absorption tests of enset fiber reinforced gypsum composites were carried out through immersion in distilled water at room temperature. The samples were taken out periodically and after wiping out the water from the surface of the sample, they were weighed immediately using a precise electronic balance machine to find out the content of water absorbed. The specimens were weighed regularly at 2, 4, 6 and 24 hours. The water absorption is calculated by the weight difference. The percentage weight gain of the samples is measured at different time intervals by using the equation

(12). The mass of samples was taken after conditioning in 50% relative humidity. To measure moisture uptake, samples were immersed in deionized water for 24 hours.[3]

Table 10 Weight of the samples in water in different hours

Properties	Original Wt. of composite	After 2 hours (g)	After 4 hours(g)	After 6 hours (g)	After 24 hours (g)
Impact sample	240.3	354.6	357.8	359.2	366.5

We can convert the given mass in table above into percentage using following formula

$$WA\% = \frac{w2-w1}{w1} * 100 \quad \text{Equation 12}$$

Where , W2 = Weight of sample after soaking in water.

W1= Weight of sample before soaking in water

Table 11 Percentage of the samples in water

Properties of Composites	Original Wt. of Composite (g)	After 2 hours in water %	After 4 hours in water %	After 6 hours in water %	After 24 hours in water %
Impact sample	240.3	47.57	48.89	49.48	52.52

Figure 21 Samples immersed in water

CHAPTER 4 - EXPERIMENTS SET UP

4.1. Experimental Methods

For each test, three specimens are taken in order to show the repeatability of the results to minimize the experimental errors. After the composite laminates are prepared, next, test pieces are cut properly using circular band saw from the laminates.

The next task was experimental investigation through prepared test pieces on universal testing machine by varying a load from the dynamometer load cell. After each test, displacements at different load response are generated in a data acquisition system as an output.

The tensile test was conducted along the longitudinal direction of the FBFRGC on universal testing machine according to ASTM.

The flexural test was also conducted at the middle span of the specimen of the FBFRGC on universal testing machine according to ASTM.

The impact test set up consists of a pendulum which is dropped from an angle of 45 degree to impact the specimen and to fracture it. Charpy impact is employed in this impact work. The amount of energy absorbed during the breaking of specimen is noted. The specimens are prepared as per ASTM: D256 standards.

4.2. Experimental Conditions

4.2.1. Testing Conditions

The experiment was conducted at constant-strain-rate-values in quasi-static condition for tensile, impact and flexural testing under constant room temperature. Tensile test of the fabricated composite was conducted using electro hydraulic UTM at AAiT Mechanical Engineering Testing Laboratory condition (room temperature & humidity) at a cross head speed of 0.75mm/min. Similarly, the flexural (three point bending) test was also conducted on electro hydraulic universal testing machine using a cross head speed of about 1.5mm/min. During the test, load is continuously applied to all the specimens from dynamometer load cell until the specimen fails.

4.3. Experimental Setup

4.3.1. Universal Testing Machine (UTM) for Tensile and Flexural Test

All the mechanical tests were investigated using Computer Controlled Electro-Hydraulic Servo Universal Testing Machine model: WAW-100; which has a capacity of up to 100kN, with 0.01 – 500 mm /min test speed.

Figure 22 Universal Testing Machine (UTM) Tensile test

Figure 23 before bending after bending

4.3.2. Universal Testing Machine for Impact Test

The impact test set up consists of a pendulum which is dropped and it impacts the specimen and fracture it. Charpy impact is employed in this impact work. The specimens are prepared as per ASTM: 256 (sample dimension is 55× 10 × 10 mm). Capacity of machine is 17kg/m and it is 6701 type and has E5360 number at AAiT Mechanical Engineering Material Testing Laboratory.

Figure 24 UTM for impact tested sample

4.3.3. Band Saw for Cutting Purpose

The circular Band Saw is used for cutting purposes. The machine has a cutting speed of 500-1000m/min, with blade length of 2560mm and maximum work piece height of 230mm.

Figure 25 Band saw machine

CHAPTER 5 - RESULT AND DISCUSSION

5.1 Tensile Properties

The tensile test is carried out by cutting the composite specimen as per ASTM: D3039 standard (sample dimension is 250 × 30 × 3 mm). A universal testing machine (UTM) (Model: WAW-100 is used for testing with a maximum load rating of 100 KN. The different three composite specimen samples are tested and the average is taken and the samples are left to break until the ultimate tensile strength occurs. Stress–strain curve is plotted for determining tensile strength, Poisson ratio, shear modulus and elastic modulus. The sample graph is generated manually from the machine used for tensile test with respect to load and displacement at AAiT Mechanical Engineering Material Testing Laboratory.

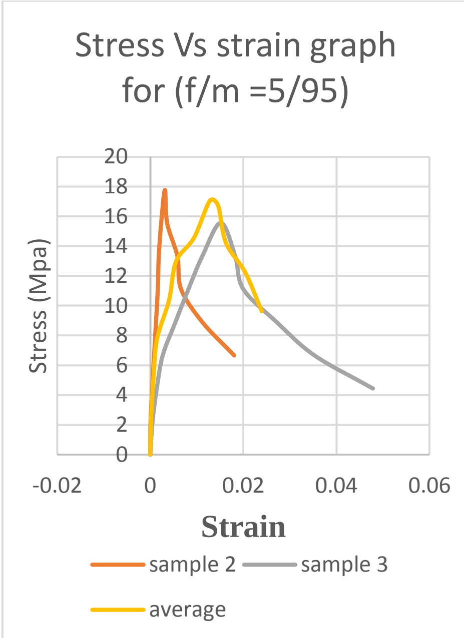
The results and discussion of tensile test are presented in figures below

f/m = 5/95 f/m = 20/80 f/m = 30/70 and f/m = 40/60

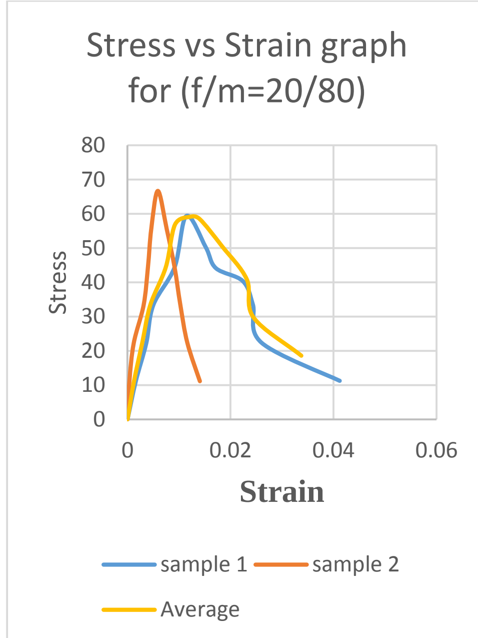
Figure 26 Specimens of composite material with Enset fibers and fibers in matrix

Where:- f/m represents:(f) for false banana fiber and (m) for matrix (gypsum) or fiber to gypsum ratio

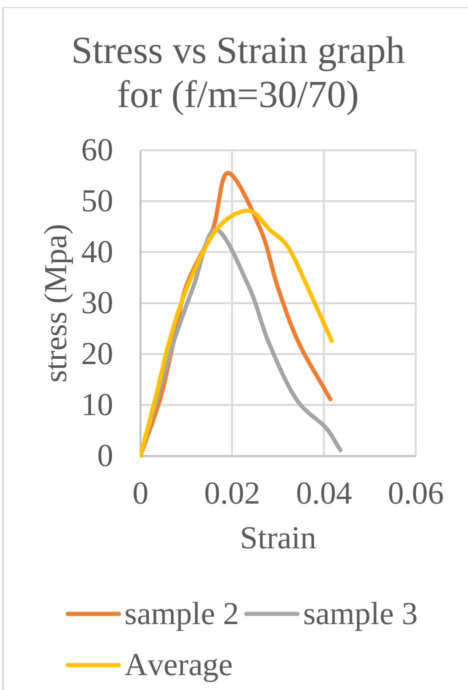
Tensile Test Graphs



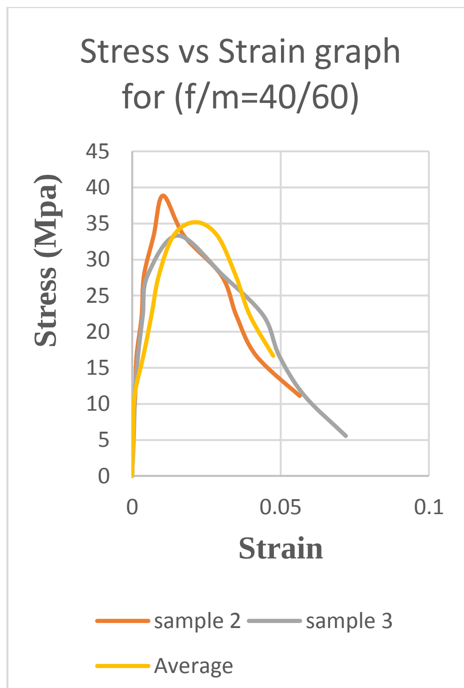
(a)



(b)

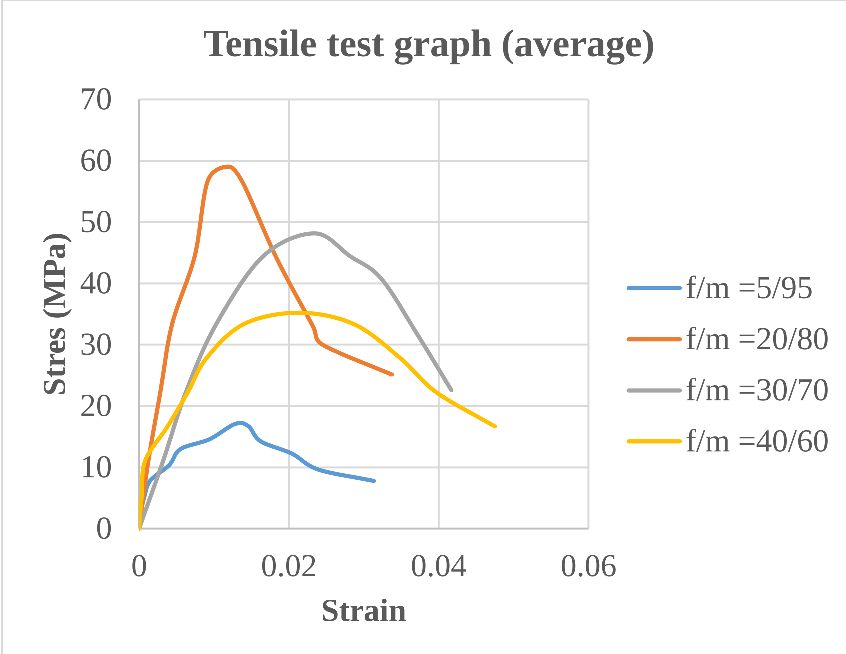


(c)



(d)

Figures 27 Tensile test graphs for each three samples



(e)

Figure 28 Stress-strain diagrams for different wt. % of false banana fibers on tensile test

Where: f/m = f stands for fiber and m stands for matrix

Table 12 Summary table for tensile test result (9, 21)

Samples of Composite	Length (mm)	Width (mm)	Thickness (mm)	F_{max} (KN)	Tensile strength (MPa)	Modulus Elasticity (MPa) E	Shear modulus (GPa) G	Poisson ratio (υ)
FBF-5	250	30	3	1.7	17.04	1331.019	0.55229	0.205
FBF-20	250	30	3	9.67	59.01	4879.548	2.25931	0.22
FBF-30	250	30	3	5.33	48.15	2056.471	0.83637	0.23
FBF-40	250	30	3	3.5	35.19	1652.43	0.66630	0.24
glass fiber with epoxy					2000	70,000	15	0.25

Using the following formulas and taking elasticity modulus result (E), calculate the values of G and υ ;

$\sigma = P/A$ ....Equation 13

$\Sigma = \frac{L2}{L1}$ ....Equation 14

$E = \frac{\text{stress}}{\text{strain}} = \sigma/\varepsilon$ ....Equation 15

$\upsilon = \upsilon_m * v_m + \upsilon_f * v_f$ ....Equation 16

$G = \frac{E}{2(1+v)}$..Equation 17

Discussion on Tensile Test Result

The results of tensile test of composites, which are shown in the above diagrams and table 12, are discussed below:

Figures (a) – (d) mentioned above represent that the tensile test results of various fiber compositions for the same three samples in each diagram; and on average, the total average is shown in figure (e). It is evident that the mechanical properties of the false banana fiber reinforced gypsum composites for 5, 20, 30 and 40 percentage of fiber compositions of tensile test are shown in table 12.

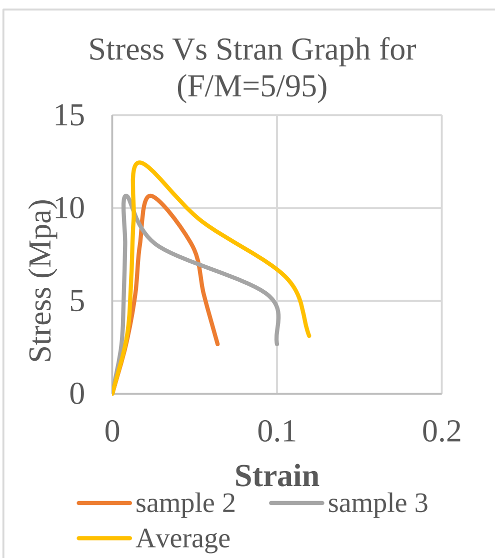
As considered from all diagrams, the same three samples were tested but the result was different. And this is the problem of manufacturing method and the distribution of fiber and gypsum.

As shown in table above, tensile strength, Modulus of elasticity, load and shear modulus in 20wt% of fiber composition is higher than the others 5, 30, and 40wt% of false banana fiber compositions. From this we can consider that when the fiber weight increases, it also increases tensile strength, modulus of elasticity, Load and shear modulus increase; however, after 20%wt fiber composition, they decrease. This decrease in tensile strength is due to the maximum void contents and weak interfacial adhesion in case of composites and manufacturing method (hand lay-up), And by itself, it is not suitable to fabricate— i.e. when the material is stressed in tension test, it tends to elongate and when the material elongates. And when the bond between false banana fibers and gypsum weakens, it leads to the loosening of false banana fibers and to fracture of material. However, poisons ratio increases with increasing fiber weight. So 20/80 specimen is better than the others false banana fiber composition.

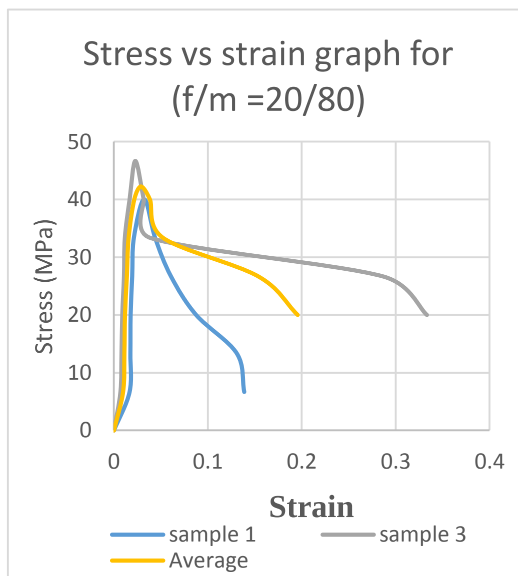
Finally, the result obtained was compared with glass fiber reinforced epoxy standard specimen that does not have any additives. As shown in table 12 above, the false banana fiber reinforced gypsum composite cannot be compared with glass fiber reinforced epoxy composite because glass fiber reinforced epoxy composite has very higher tensile properties.

5.2 Flexural Properties

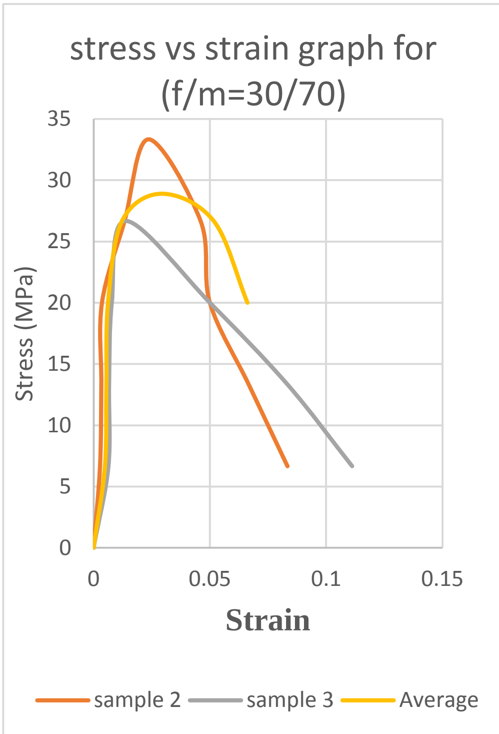
The flexural test is done in a three-point flexural setup as per ASTM: D3410 standard (sample dimension is 180 × 25 × 5) mm). A universal testing machine (UTM) (Model: WAW-100 is used for testing with a maximum load rating of 100 KN. When a load is applied at the middle of the specimen, it bends and fractures. Test results include load and displacement, stress vs. strain and load vs. displacement curve is plotted for the determination of flexural strength

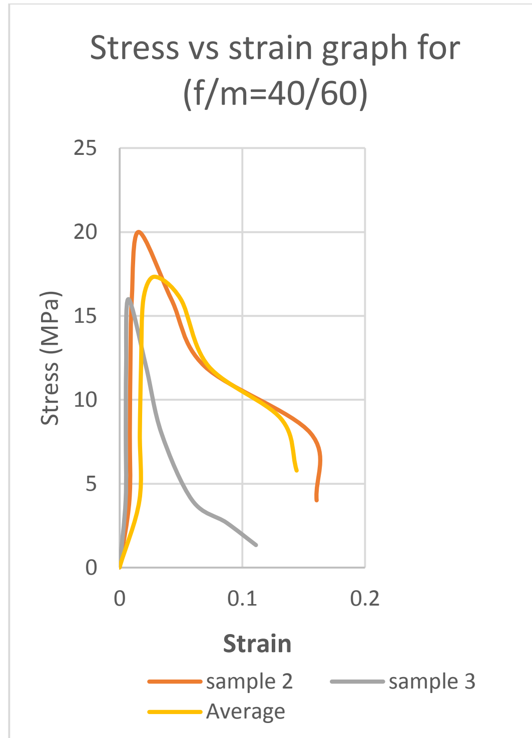


(f)



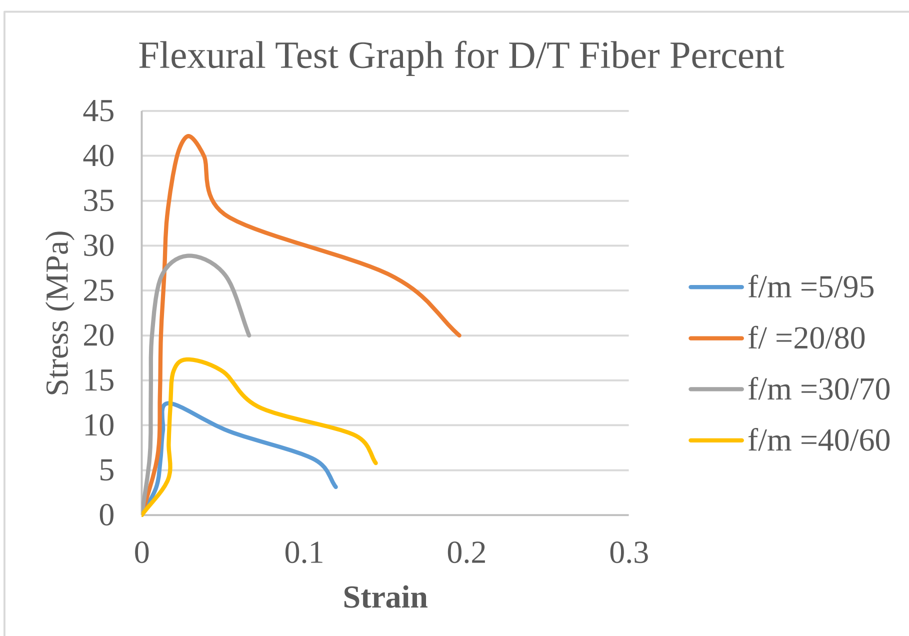
(g)





(h) (i)

Figure 29 flexural test graphs for each three samples



(j)

Figure 30 Stress-strain diagrams for different wt. % of false banana fibers on flexural

Table 13 Summary table for flexural test (9, 21)

Samples of Composite	Length (mm)	Width (mm)	Thickness (mm)	F_{max} (KN)	Flexural Strength (MPa)	Modulus Elasticity (MPa) E	Shear Modulus (GPa) G	Poisson Ratio (υ)
FBF-5	180	30	5	0.933	12.44	754.21	0.31295	0.205
FBF-20	180	30	5	3.166	42.22	1470.96	0.60285	0.22
FBF-30	180	30	5	2.166	28.88	983.61	0.39984	0.23
FBF-40	180	30	5	1.3	17.33	610.57	0.246197	0.24
Glass fiber with epoxy					2000	70,000	15	0.25

Discussion on Flexural Test Results

The results of flexural test of composites, which are shown in the above diagrams and table 13, are discussed below:

Figures (f) – (i) mentioned above represent that the flexural test results of various fiber compositions for the same three samples in each diagram and the total average is shown in figure (j). It is evident that the mechanical properties of the false banana fiber reinforced gypsum composites for 5, 20, 30 and 40 percentage of fiber compositions of flexural test are shown in table 13.

As shown in table above 13, flexural strength, Modulus of elasticity, load and shear modulus in 20wt% of fiber composition is higher than the others 5, 30, and 40wt% of false banana fiber compositions. From this we can consider that when the fiber weight increases, modulus of elasticity, load and shear modulus increase but after 20%wt fiber composition, they decrease. This decrease in flexural strength is due to the maximum emptiness contents and weak interfacial bond in case of composites i.e. when the material is stressed in tension test, it tends to elongate. And when the material elongates, the bond between false banana fibers and gypsum weakens, leading to the loosening of false banana fibers and to fracture of material. However, poisons ratio increases with increasing fiber weight. So 20/80 specimen is better than the others false banana fiber composition.

Finally, the result obtained was compared with glass fiber reinforced epoxy standard specimen which does not have any additives. As shown in table above, false banana fiber reinforced gypsum composite cannot be compared with glass fiber reinforced epoxy composite because glass fiber reinforced epoxy composite has very higher flexural properties.

5.3. Impact Properties

Three same samples are prepared to test for each fiber composition and the average of the three is taken. The specimens are prepared as per ASTM: D256 standards. A universal testing machine, at AAiT Mechanical Engineering Testing Laboratory was used for testing. The specimens are shown in Figure 24. The specimen must be loaded onto the testing machine to allow the pendulum until it fractures or breaks. Using the impact test, the energy needed to break the material is noted. The loss of energy during impact is the energy absorbed by the specimen during impact.

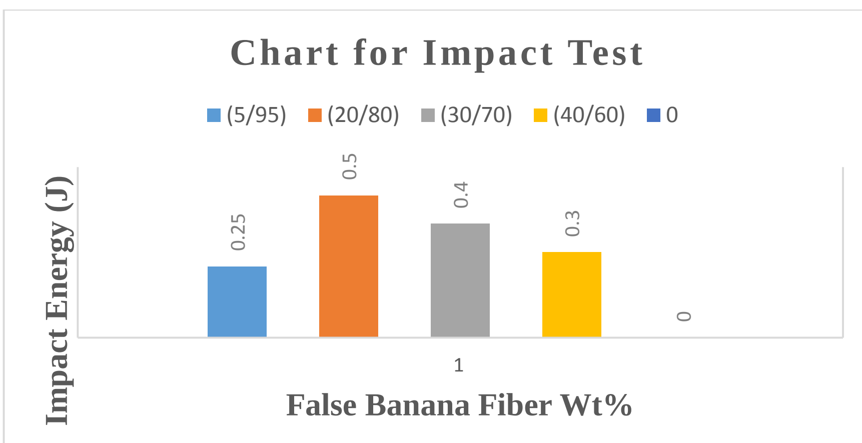


Figure 31 Chart that shows impact energy result

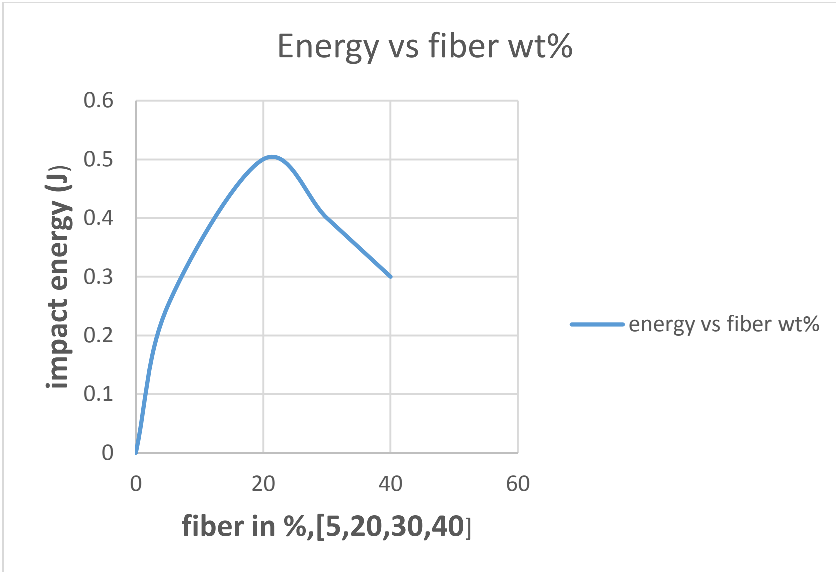


Figure 32 Effect of wt. % of false banana fibers on impact energy

Table 14 Impact properties of false banana fiber filled gypsum composite.

False Banana Fiber Wt.%	Dimensions (Mm)			Impact Energy (J)
	Length	Width	Thick	
Fbf-5	55	10	10	0.25
Fbf-20	55	10	10	0.5
Fbf-30	55	10	10	0.4
Fbf-40	55	10	10	0.3

Discussion on Impact Test Result

The loss of energy during impact is the energy absorbed by the specimen during impact. The values are arranged in Table 14. Figure 30 and 31 show a comparison between energy absorbed by the different combination of composites. The FBF-20% composition shows that very high impact strength (0.5J) compared to all other laminates. And FBF-30% composition shows higher one next to FBF-20 impact strength which has 0.4J impact energy. The FBF-5% composition shows very poor impact strength of 0.25 J. So the fiber weight of 20% composite is better than the others because much impact energy is observed on that range.

5.4 Physical Properties

5.4.1. Water Absorption

The water absorption test provides information about the adhesion between the fiber and the matrix in the interface region, as higher the adhesion (bond) between the matrix and the fiber fewer will be sites that could store water and will lead to lower water absorption.

The water absorption is calculated by the weight difference. The percentage weight gain of the samples is measured at different time intervals by using the following equation.

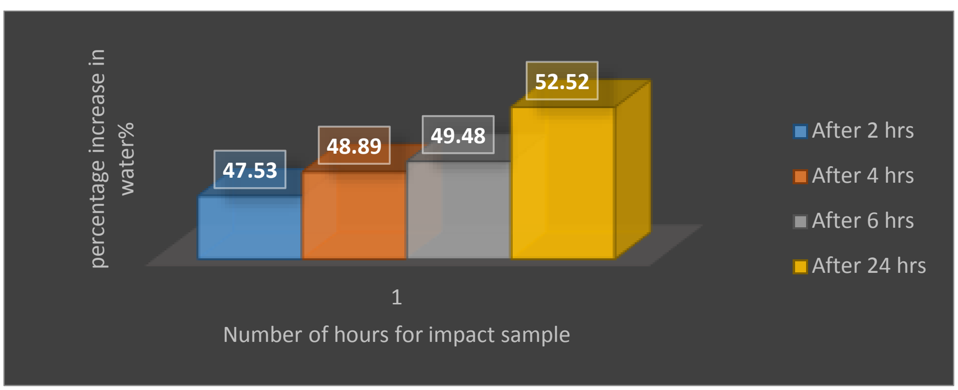
$$WA\% = \frac{W2-W1}{W1} * 100$$

Where , W_1=Weight of sample before soaking in water

W_2 = Weight of sample after soaking in water

Table 15 the water absorption is calculated by the weight difference.

Properties of Composites	Original Wt. of Composite (g)	After 2 hours in water %	After 4 hours in water %	After 6 hours in water %	After 24 hours in water %
Impact Test	240.3	47.57	48.89	49.48	52.52



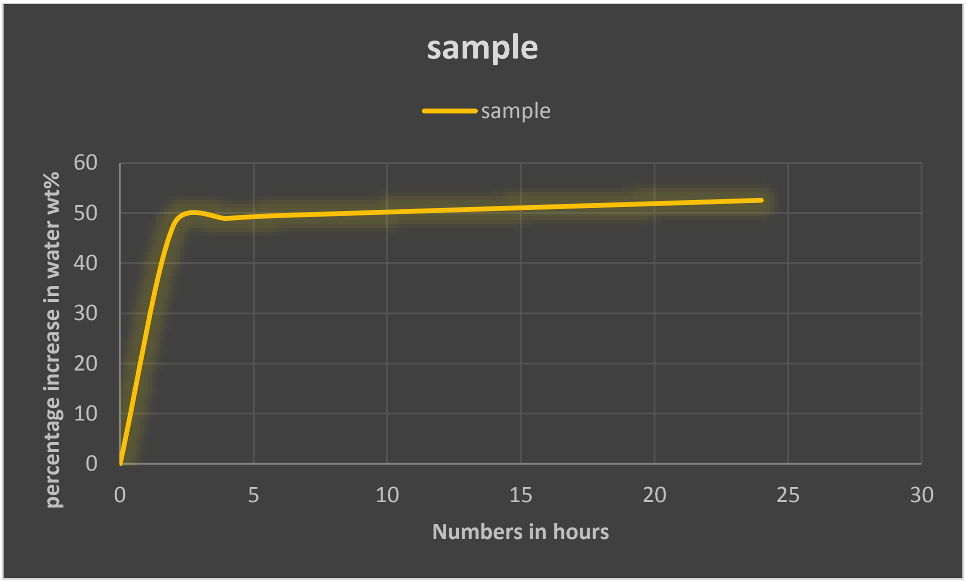


Figure 33 Sample in water absorption

5.4.2. Discussion on Water Absorption Test Result

As expected there was an increase in the rate of water absorption when the residue quantity of the composite was increased.

We can conclude that when samples (composites) stayed in water more hours, water absorption also increases at the intervals of every 2hrs, 4hrs, 6hrs and 24hrs. The higher the adhesion (bond) between the matrix and the fiber, the fewer will be the sites that could store water, leading to lower water absorption.

According to literature, a special treatment with alkalis like sodium hydroxide is at times given to this fiber, which can minimize water absorption of specimens. However, it is not necessary that much reducing absorption of water in this research because the fabricated materials of false ceiling and wall partition are for the purpose of internal parts of house as a construction materials. And painting outer part of the materials is necessary for both as a decoration of house and reducing water absorption.

CHAPTER SIX – CONCLUSION AND FUTURE WORK

6.1. Conclusion

The aim of this study was to set the mechanical and physical properties of the composite materials prepared from the fibers of the plant false banana (Enset Ventricosum) reinforced with gypsum. The false banana fiber was extracted manually from Ethiopian southern part false banana plant. Next, false banana fiber reinforced gypsum composite was manufactured for each weight ratio of 5/95%, 20/80%, 30/70%, and 40/60% where it was determined experimentally. All the numerous experimental test results were gathered from important information about chopped false banana fiber reinforced gypsum composite. Based on the test, results were obtained from the various tests carried out, and afterwards, conclusions were made:

A polymer matrix composite contains the chopped false banana fiber as a reinforcement was successfully fabricated and from the tensile, flexural and impact test results where it is found that 20/80 wt.% has better mechanical property among the other fiber-matrix composition. Tensile and flexural strength, Modulus of elasticity, load and shear modulus in 20wt% have better than the others 5, 30, and 40wt% false banana fiber compositions. So 20/80 specimen is better than the others false banana fiber composition.

Finally, the result obtained was compared with glass fiber reinforced epoxy standard specimen, of no additives. As shown in table 12 and 13, the false banana fiber reinforced gypsum composite cannot be compared with glass fiber reinforced epoxy composite because glass fiber reinforced epoxy composite has very higher mechanical properties but almost similar with other natural fibers like sisal fiber reinforced epoxy composite.

Therefore, from all the results and comparisons, we can conclude that the fabricated chopped false banana fiber reinforced gypsum composites have a good mechanical property and it is recommended to use it for light weight application, like for the production of false ceiling and wall partition which are used for house application as construction material.

6.2. Future Work

This researcher puts forward the following recommendations. Accordingly, the need for:

1. studying thermal insulation properties of false banana fiber reinforced gypsum composite
2. microstructure of short false banana fiber reinforced gypsum composite after each test will be examined by scanning electron microscope (SEM)
3. studying chemical properties of false banana fiber reinforced gypsum composite experimentally
4. Selecting appropriate manufacturing method rather than hand lay-up technique.

6.3. References

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6.4. Appendix

Appendix A

Sample Preparation

A B C D

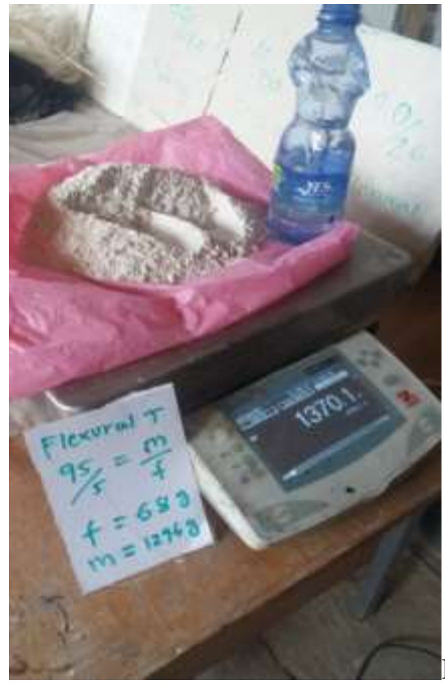
Sample Preparation Process: [A] False Banana Fiber,

[B] Gypsum Powder, [C] Water, [D] Mold

APPENDIX B

Wight to Prepare Specimens

E



F

G

H

[E] Fiber Weight, [F] Gypsum Weight [G] Water Weight [H] Plastic

APPENDIX C

TENSILE TEST

[I] UTM Machine, [J] Tested Sample, [K] Tested Sample, [L] When Readin

APPENDIX D

FLEXURAL TEST


M


N


O

Flexural Test Graphs

APPENDIX E

IMPACT TEST


P


Q


R


S

[Q] Impact Machine, [R] Sample, [S] Tested Sample, [T] Absorbed Energy