ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

Mechanical Characterization and water absorption Behavior of Woven Mat Glass Fiber / Epoxy Composite Materials

A Thesis Submitted to the School of Mechanical and Industrial Engineering in Partial Fulfillment of the Degree of Master of Science in Mechanical Engineering (Mechanical Design)

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Addis Ababa, Ethiopia

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Declaration

This certifies the thesis title "Mechanical Characterization and water absorption Behavior of Woven Mat Glass Fiber / Epoxy Composite Materials" which is prepared by Gulilat Debebe. The thesis is my independent work and has no previous related work been submitted to any other university to obtain a degree, which compiles with the regulations of the university and meets the accepted standards concerning originality and quality.

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Abstract

In this research the Experimental study of glass fiber composite materials reinforced fiber types are presented. Composite materials have boundless engineering applications where the strength to weight ratio, low costs, and ease of fabrication are required. The main goals of this research work were to characterize the mechanical properties and study the water absorption of behaviors of glass fiber reinforced composites materials using Experimental test. Different literature or research uses different fiber/matrix ratio for composite materials preparation, fabricate and test the mechanical properties, using literature as a reference four different types of fiber/matrix ratio of the specimen were prepared. WP 310 universal testing machine were used to test mechanical properties. The tensile, compression and flexural properties of the glass fiber reinforced Epoxy composite materials were carried out According to ASTM standard. The 50/50 fiber matrix ratio was found higher tensile strength,45/55 fiber/matrix ratio (45%) fiberglass fiber-reinforced composite materials was found higher compressive strength and 25/75 fiber matrix ratio of glass fiber reinforced composite materials were found higher flexural strength and also glass fiber reinforced composite materials specimens were poured in the ordinary water for the various time intervals at room temperature to study the water absorption effect at different periods of times. The water absorption of the specimen shows gradual increases. The effect of water gain in the percentages for glass fiber reinforced composite was observed. Furthermore, the results show, using the glass fiber as reinforcement could successfully develop composite materials in terms of good strength and better water absorption properties for the uses of lightweight purpose of different application.

Key Words: glass fiber, water absorption, hand lay-up techniques, Flexural, Tensile, and Compression properties

Table of Contents

Lists of Tables

Lists of Figures

Abbreviation/Nomenclature

ρ_c - density of composite

m_c - mass of composite

m_r -mass of resin

V_m – Volume of matrix

W_f – Weight of the fiber

W_m – Weight of the matrix

V_f – Volume of fiber

ρ_m – Density of the matrix

ρ_f –Density of the fiber

v_r - Volume fraction of resin

V - Epoxy Volume of Epoxy

W- Width of specimen

σ - Normal stress

ε- Strain

L - Specimen Free Length

ReH- upper compressive yield strength

ReL - Lower compressive yield strength

Rmax- ultimate compressive strength

σ_{bf} - calculated fracture stress (flexural strength), MPa

P- Load at a given point on the load- deflection curve, N

Ec - maximum deflection at the center of the specimen

m - Slope of the tangent to the straight-line portion of the load-deflection beam.

L- Support span of specimen

b- Width of the specimen tested

t - Depth of the specimen (Thickness)

r -strain

CHAPTER ONE: INTRODUCTION

1.1 Background on the Study

In recent few decades, the uses of composite materials have surprisingly increased in different application because of their superior specific properties such as high strength and high stiffness to weight ratio, their design flexibility, improve corrosion resistance and environmental resistance, their fatigue life, the potential reduction of the fabrication process, their lifetime and costs, etc. Thus composite materials are being considered to make lighter, stronger, more efficient, and safe life span for automotive body application. The vehicles are to be good and better in terms of stiffness and strength. For example, carbon-fiber composites have been a weight of one-fifth of steel, but they are very good or better in strength and stiffness. Most of the composite material types that are used in automobile industries are synthetic composite materials.

Fiber-reinforced composite materials have been widely used in various vehicle structures because of their high specific strength, modulus, and high damping capability. If composite materials are applied to vehicles, it is expected that not only the weight of the vehicle is decreased but also that noise and vibration are reduced. In addition to that, composites have a very high resistance to fatigue and corrosion. [1]

Traditionally, the materials used in the construction of vehicle bodies are mainly various grades of steel. Although aluminum-intensive body concepts were used starting from executive class cars, and then later on applied to other car classes. Plastics mainly dominate the vehicle interior, their external application being chiefly limited to non-load bearing components even though recently some innovative plastic materials are being implemented on some vehicle parts such as engine sub-frame and frontal bumpers subsystems to reduce the vehicle weight and improve the occupant and pedestrian safety, [22, 23].

However, the composite materials are used in the automobile industries are the synthetic composite materials based on the different literature man-made or synthetic fibers are very attractive materials to use for automotive application, the produced by combining two or more materials in definite proportion under the controlled conditions.

Mechanical properties of composite materials depend on the different factors like the fiber length, shape, size, orientation, and composition and distribution also volume fraction. The mechanical properties of the polymer matrix, manufacturing techniques, and combination between the fiber and the matrix, it is very common that using the reinforcing polymer matrix composite.

1.2 Theoretical back ground

1.2.1 Composite materials

A composite material is a structural material that consists of two or more materials which together produce desirable properties that cannot be achieved with any of constitute alone [2, 3]. Such composite materials have two main phases; the reinforcing and matrix phase. The reinforcing phase material may be in the form of fibers, particles, or flakes and it is continuous or discontinuous. The matrix phase materials are generally continuous and it serves to distribute the fibers and also to transmit the load to the reinforcing phase material. Reinforcing materials are strong and low densities while the matrix material is usually ductile or tough. The environmental policies forced the industries like automotive industries, packaging, and construction industries to search the ecological friendly materials.

Composites are heterogeneous materials having two or more solid phases, which are in intimate contact with each other on a microscopic scale. Surprisingly in the last three or four decades, the composite industry has grown rapidly with the developments of fibrous composites, about 90% of all composite materials produced are comprise of glass fibers (reinforcement) and either polyester or vinyl ester resin (matrix) reinforced plastics. Composite materials are very light materials (lightweight), high strength and rigidity, low weight to strength ratio materials can be designed in addition to structure, design flexibility, and good corrosion resistance. Composite materials can provide long term resistance to severe chemicals, temperatures, and weathering environments and composite materials have good durability (low maintenance rate or long term life. Generally, composite materials classified as shown in figure 1.1 below. [4]

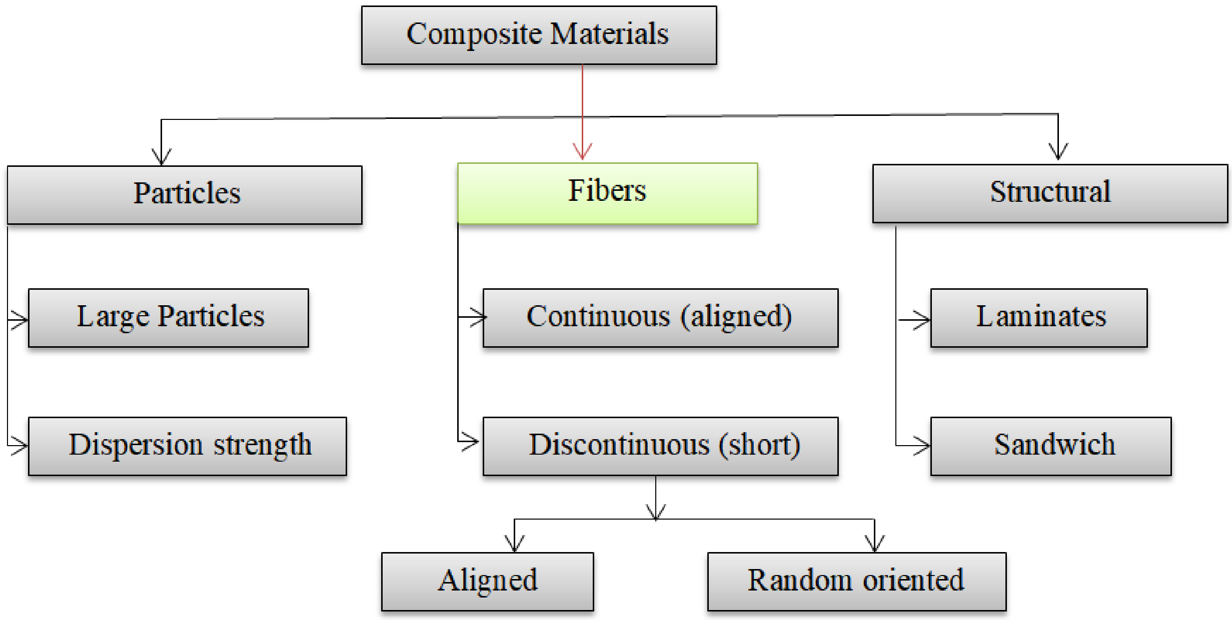


Figure 1. 1 Classification of composite materials [4]

1.2.2 Fibers reinforced composites

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Fiber-reinforced composite materials are mainly consisting of fibers reinforcing and some matrix materials. A fiber has high strength and modulus, and a matrix generally acts as a binder for the fiber. Fibers are a small-short discrete reinforcing material produced from various materials, like steel, plastic, glass, carbon, and natural materials in various shapes and sizes. Generally, fibers are broadly classified into two main groups such as Natural fiber composites and Synthetic fiber composites [2, 4]. Natural fiber composites are composites that the fiber is found naturally (i.e. sisal, bamboo, etc.) and synthetic composites are a man-made composite that produced by combining two or more materials in definite proportions under controlled condition (i.e. carbon, glass, etc.). The fibers depend on the properties of fibers like length, strength, elasticity, maturity, and location with the water alkali; acids, etc. man-made fibers can have fixed with the required properties depend on the research. The synthetic fibers are stronger than natural fibers, they can easily process and comparatively the lifetime is high.

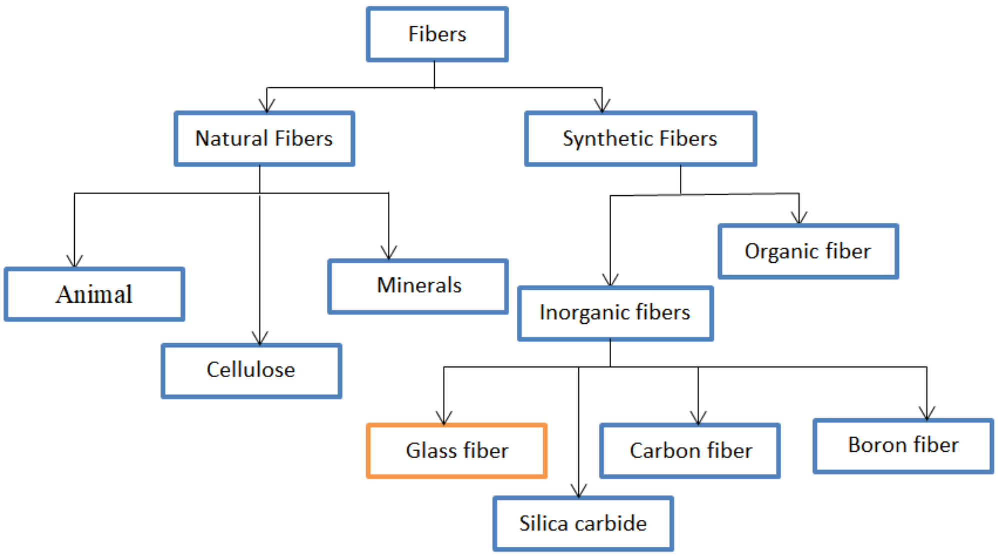


Figure 1. 2 Classifications of fibers[36]

1.2.2.1 Glass fibers

Glass fiber reinforced resins have been using since the 1940s. Glass fiber reinforced resins are strong and very light materials their stiffness is not very high. Composite materials are made from two or more constituents that remain distinct and separate on a macroscopic level while forming a single component. It consists of a matrix and reinforcement; the matrix is a material holding the reinforcement together in position and helps in transferring the loads. Matrix materials support and surround the reinforcement materials by maintaining relative positions. Most composites had been created to improve combinations of mechanical characteristics such as strength, wear resistance, stiffness, toughness, ambient, and high temperature and aesthetic properties [6]. The glass fiber composites' strength/weight ratios are higher than those of most other materials and their impact resistance is phenomenal. Further, they possess good electrical properties, resistance to moisture and outdoor weathering, and resistance to heat and chemicals. Fiberglass, in which glass fibers are mixed with a polymeric resin. If one were to cut the fiberglass and, after suitable preparation of the surface, look at the material, the glass fibers and polymer resin would be easy to distinguish. Composite materials application has been a trend due to its load sustaining capacity in various engineering applications under different atmospheric conditions. Polymer matrix composite is one of the major composite type having wide applications. E-glass/epoxy is one of the versatile types of composite based on its flexible production technique and Now a day in the whole world increasingly concerned with sustainability issues to brought about natural resources and environmental protection so that environmentally friendly became quite very attractive. Environmental friendly materials have been in considerable demand in recent years.

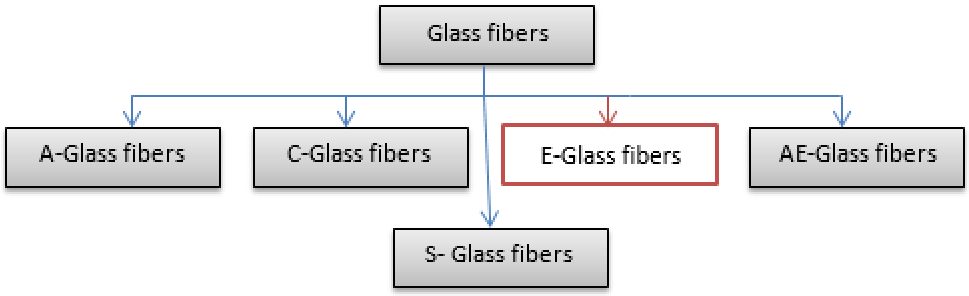


Figure 1. 3 Classification of glass fibers [2]

Fiber-reinforced composite materials have been widely used in various vehicle structures because of their high specific strength, modulus, and high damping capability. If composite materials are applied to vehicles, it is expected that the weight of the vehicle is decreased. In addition to that, composites have a very high resistance to fatigue and corrosion. [3]

Previously, the different types of materials are used in the construction of vehicle bodies especially steels. Although aluminum-intensive body concepts were used starting from executive class cars, and then later on applied to other car classes. Plastics mainly dominate the vehicle interior, their external application being chiefly limited to non-load bearing components even though recently some innovative plastic materials are being implemented on some vehicle parts such as engine sub-frame and frontal bumpers subsystems to reduce the vehicle weight and improve the occupant and pedestrian safety, [5]. The mechanical properties of randomly oriented E-glass fiber reinforced epoxy such as flexural and tensile strength increased with an increase in weight fraction of the fiber [27]. The introduction of better material, design optimization, and better manufacturing processes, to the rising demand of lightweight vehicles and better mechanical performance of materials in automotive applications, different material combinations such as composites, plastic, and lightweight metals are implemented. Applications of composite materials in automotive industries already include some primary and secondary structures like dashboard, roof, floor, front & back bumper. To estimate strength and stiffness, structural materials are subjected to mechanical testing such as tensile, compression, and flexural tests.

Tests aimed at evaluating the mechanical characteristics of fibrous polymeric composites are the very foundation of the technical specification of materials and for design purposes. The mechanical testing of composite structures to obtain parameters such as strength and stiffness is time-consuming. It is, however, an essential process; the data obtained from these tests can then be directly related to varying degrees of simplicity and accuracy to any structural shape. In this study, mechanical characterization and water absorption behavior of woven /Epoxy composite materials with different fiber/ matrix and mechanical property characterization of the E-glass fiber reinforced epoxy composite is the alternative materials for automotive industries in Ethiopia.

1.3 Statement of the Problem

The uses of composite materials for different applications are radically increased in the recent few years due to the advantages of composite materials. Composites materials need in the versatility in their properties in which enables them to apply in various fields like aerospace, automotive, architecture, energy, infrastructure, sports and recreation, transportation, etc., due to their flexibility, low material cost and improved productivity. In a previous automotive application, the weight of the automobile made very high problems and which is the high weight with around 68% of automotive body cover with iron and steel. In the last few decades, a significant change occurred in the automotive industry in Ethiopia which incorporates assembling of different types of automobile cars. Different types of automotive body parts are assembled in a governmental institution. The parts are not manufactured in Ethiopia, but they are imported from other outside countries like China, Dubai, and India. But now some of the fiber composites are started to manufacture in Ethiopia by using different composite materials for different purposes. Thus this thesis investigates the mechanical characterization and water absorption behavior of woven mat fiberglass/ Epoxy composite materials by using laboratory, Experimental test, and Water absorption by glass fiber reinforced epoxy resin because investigating the properties of composite materials can open the opportunities of Ethiopian industry and its influence on the mechanical properties of composite materials under immersion tests, which contribute directly to the automobile industry in Ethiopia. This has indirectly the ability to generate or save the money and provided and a good opportunity to our country Ethiopia.

1.4 Objectives of the study

1.4.1 General Objectives

The general objective of this thesis is to determine the mechanical characterization and water absorption behavior of woven mat fiberglass /Epoxy composite materials.

1.4.2 Specific objectives

- To fabricate the fiberglass-reinforced epoxy composite material.
- To Characterize of mechanical properties such as tensile strength and modulus of elasticity, flexural strength, the compression strength of fabricated composite material.
- To study the water absorption behavior of woven mat glass fiber reinforced epoxy composites by the prepared various length of the fiber using hand lay-up technique.

1.5 Methodology

Mechanical properties of materials are very essentials to construct a mechanically sound like structure. The mechanical properties can conduct by the experimental tests on the specimen of composite materials. The specimen was fabricated using hand lay-up techniques. hand lay-up is the simplest method used for the producing of reinforced composite materials. The following procedure were used from starting to completion.

Step 1. E-glass fiber is used as a fabric it is prepared, Epoxy resin and Hardener both of them are prepared as a matrix material

Steps 2. Mixing the Epoxy resin and hardener were takes place for 60 second until they clearly appeared in the solution.

Step 3. Hand lay-up techniques are the simplest and the oldest method used to produce the reinforced laminated. Mold released were painted the mold then the Mixing Resin is poured in to the mold then the fibers and rollers are used to remove bubbles or air gaps. The reins were impregnated in to the fibers and the air gap removed.

Step 4. After the glass fiber layer were prepared in the mold the hydraulic press was pressed it for 24 hours at room temperature for curing.

Step 5. The prepared composite or sample were cut according to the ASTM standards for the tensile strength test, compressive strength test and flexural strength test

Step 6. The specimen or the composite were tested for the tensile strength, compressive strength and flexural strength using WP 310 universal testing machine of 50KN capacity.

Step 7. The specimen or the composite immersed in the distilled water at room temperature to check water absorption behavior.

1.6 Scope of the study

This thesis study is focused on the experimental study on the mechanical characterization and water absorption behavior of woven mat glass fiber/Epoxy composite materials in the industry of Ethiopia. The mechanical characterization of the study is on mechanical properties of like compressive strength, flexural strength, and tensile strength were characterized also the water absorption behaviors of woven mat glass fiber/Epoxy composite materials were studied.

1.7. Limitation of the study

Among the many problems /obstacles that faced to conduct the thesis work were the following.
First, it is very hard to find out the literatures, the whole literature that reviewed journals are searched from the internet. There is no ready to use and highly competitive laboratory set up for the characterization of E-glass fiber reinforced composite materials. Since the only three mechanical properties and water absorption behavior of the composite materials are investigated the uses of the E-glass reinforced composite materials were not providing enough or full evidence.

1.8 Organization of the thesis

This thesis report focuses on the fabrication and mechanical property characterization such as tensile, compression and flexural property of glass fiber reinforced epoxy composite, and also water absorption behavior of glass fiber reinforced epoxy composite and results from the discussion.

Chapter 1: Introduces the background of synthetic fiber (man-made) composite materials, the project objectives. Statement of the Problem, Scope of the study, limitations of the study, fiber types, and mechanical properties.

Chapter 2: includes the relative kinds of literature about different synthetic fiber (man-made) composite materials based on their different methods, how they analyzed, get the problems and it includes identifying the gap.

Chapter 3: Experimental deals with the mechanical Properties glass fiber reinforced epoxy composite, in this chapter the method materials for the preparation of test specimen discussed here. The Mechanical Properties are investigated Designs the experimental plan for investigation of flexural, tensile, and compressive properties of glass fiber reinforced epoxy composites.

Chapter 4: Characterization of composite material; the flexural, tensile and compression properties are discussed in detail Fabrication and Mechanical Property Characterization of glass fiber Reinforced Epoxy Resin for multi-purpose application.

Chapter 5: Is the conclusion of this thesis report. Conclusions describe the application of the validated fiber/matrix weight fraction to different Application Comparison with previous works on glass fiber reinforced epoxy composite material and the recommendations and future work of this thesis.

CHAPTER TWO: LITERATURE REVIEWS

2. Introduction

The purpose of this literature review is to provide background information on the issues to be considered in this study and to emphasize the relevance of the present study. This section includes reviews of available research reports about previous work related to synthetic fiber composite, critically involving various studies carried out by various researchers related to the field of Mechanical characterization and water absorption behavior of woven mat fiberglass/Epoxy composite materials, on the automotive structures. At the end of the literature survey, the knowledge gap in the earlier investigations/studies are presented

Muthuraj et.al [7] is conducted research on characterization and comparison of natural fibers and synthetic fibers composite laminate. The researchers are used hemp fiber to fabricate the natural fiber composite with suitable processing then examine the mechanical properties with 10%, 20%, and 30% by weight percentages of fibers. Here there is no significant change in the tensile strength observed for treated hemp fiber reinforcement. The paper concludes that hemp/epoxy fabric reinforced composites, among the natural fibers hemp/Epoxy, have been found stronger and better reinforcing materials.

A. Manikandan and R. Raj Kumar [8] the paper investigate the mechanical properties of glass fibers reinforced composites with different weight proportion by using hand layup techniques followed by comparison, molding, different composites were prepared with varying the glass fiber and using ASTM standards. They conduct different mechanical tests and also they evaluate by adopting the mixture design optimization techniques and predict the mechanical properties with the combination but the investigation is conducted for general fiberglass composites.

O.Warbhe et.al [9] in the paper investigation was made about conserve natural resources and economizes energy; weight reduction has been the main focus of automobile manufacturers in the present. Weight reduction can be achieved primarily by the introduction of better material, design optimization, and better manufacturing processes. In the introduction of composite materials, it is possible to reduce the weight of components without any reduction in load carrying capacity and stiffness. The composite materials have more elastic strain energy storage capacity and high strength to weight ratio. The composite material offers opportunities for substantial weight saving but not always are cost-effective over their steel counterparts. A composite material is a material in which two or more distinct materials are combined but remain uniquely identifiable in the mixture. The most common example is, perhaps, fiber-glass, in which glass fibers are mixed with a polymeric resin. If we break the composite, the fibers and resin would be easily distinguished.

Bhanupratap R & H.C Chittappa. [10] In the paper hybrid composites are occupying the place of conventional materials by meeting the requirement of industries, aerospace, mechanical, space, construction, and biomedical application. But the desire of achieving the higher modulus to density ratio always remains starved as it requires the maximum output in minimal consumption with better life expectancy to find the economical means of utilizing the technology for different applications. Here an attempt is made to study, observe, and compare to know the tensile behavior of the hybrid polymer composite material. From the result, the increased layer of Kevlar to the jute fiber shows improvement in the tensile strength and tensile modulus**.**

Suhad D. Salmanet.al [11] the paper is investigated about characterizes and evaluates the physical, mechanical, and morphological properties of plain woven kenaf fabric and its composites with three types of thermoset resin at 0∘/90∘ and 45∘/-45∘ orientation, to assess their suitability as lignocellulose reinforced polymer composites. The woven kenaf composite material is fabricated with three types of thermoset matrix to study the mechanical properties with more emphasis. The matrix types used are epoxy, unsaturated polyester, and vinyl ester. Plain woven kenaf possesses a good mechanical strength; therefore, it is a good possible candidate to be used as the reinforcement material in polymer composites. The stress-strain diagram of woven kenaf fiber reinforced thermoset composite is linear. The tensile, flexural, and impact strengths of the woven kenaf/epoxy composite are superior to those of the others. Fractography studies of the fracture behavior of the epoxy composite show that a better fiber-matrix adhesion exists (kenaf fibers were almost broken in the fracture plane). The variation of the mechanical properties, for the same type of thermoset, due to the variation of the fiber orientation, is significant. The results obtained from this study suggest that woven kenaf has higher properties for use as reinforcement in the thermoset composites sector.

M. Raghavendra et al [12] Investigated studies on woven glass Fiber-reinforced polymer matrix and determined the tensile strength, compressive strength, and in-plane shear strength at room temperatures and high temperatures and high temperatures. The test data is statistically analyzed it was found that the specimens at higher temperatures showed low strength when compared with the specimens at room temperature.

Dr. Muhsin J. Jweeg, Asst. et.al [13] the research investigates on Experimental and Theoretical Studies of Mechanical Properties for Reinforcement Fiber Types of Composite Materials. The experimental work and the theoretical investigation covered the study of modulus of elasticity for long, short, woven, powder, and particle reinforcement of composite materials with a different volume fraction of fiber. There is a comparison between the experimental and theoretical results on the modulus of elasticity of different composite materials. Then on the result, the effects of fiber and resin on the modulus of elasticity were presented, and also the effects of volume fraction of fiber and matrix materials on the modulus of elasticity for composite materials were shown. The result agrees on the experimental and theoretical study on different composite materials that showed modulus of elasticity for reinforcement composites in unidirectional fibers types and woven reinforcement fiber types for transverse direction.

O. Adekomayaand and K. Adama [14] Presented research on investigating water absorption and thickness swelling tendencies of polymeric composite materials for external wall applications in refrigerated vehicles. The author tries to replace the external metallic wall of refrigerated vehicles on the front burner as the weight of the metallic insulated panel continues to pose a challenge to the refrigeration unit and environment. They fabricate five composite materials to replace the metallic external sheet for refrigeration vehicles, the main role on the paper was to investigate the moisture absorption and thickness swelling tendencies of these composite specimens as these properties determine the suitability of these materials for refrigerated wall and their Key findings from this experiment were the absorption behavior of composites at 30o and 60o was consistent until 60 hours duration of immersion before a significant disparity was observed.

Yakubu Dan-mallam et.al [15] presented research conducted on Mechanical Characterization and Water Absorption Behavior of Interwoven Kenaf/PET Fiber Reinforced Epoxy Hybrid Composite. The paperwork on the development of interwoven fabric for composite production to address the challenges of balanced mechanical properties and water absorption behavior of polymer composites. The authors of the select, kenaf, and PET (polyethylene terephthalate) fiber as reinforcing materials to develop the woven fabric and low viscosity epoxy resin was chosen as the matrix. On the paper, a significant increase in tensile strength and elastic modulus of approximately 73% and 53% was recorded with neat epoxy. Similarly, flexural strength, impact strength, and inter-laminar properties were also realized with neat epoxy. This enhancement of mechanical properties may be attributed to the interlocking structure of the interwoven fabric, individual properties of kenaf and PET fibers, strong interfacial bonding, and resistance of the fibers to impact loading. The water absorption of the composites was studied by prolonged exposure in distilled water.

E. Muñoz and J. A. García-Manrique [16] Water Absorption Behavior and Its Effect on the Mechanical Properties of Flax Fiber Reinforced Bio-epoxy Composites. There were considerable interests by the author to use the natural fibers like as reinforcement in polymer composites and the development of resins from renewable resources. Then this paper focuses on eco-friendly and sustainable green composites manufacturing using resin transfer molding (RTM) process. Flax fiber-reinforced bio-epoxy composites at different weight fractions (40 and 55 wt. %) were prepared to study the effect of water absorption on their mechanical properties. The water absorption test was carried out by immersion specimens in a water bath at room temperature for the time duration. Tensile and flexural properties of water immersed specimens were evaluated and compared to dry composite specimens. The results suggest that swelling of flax fibers due to water absorption can have positive effects on the mechanical properties of the composite material. The results of this study showed that the RTM process could be used to manufacture natural fiber-reinforced composites with good mechanical properties even for potential applications in a humid environment.

Lokesh. M et.al [17] the paper investigated the Mechanical Characterization of Epoxy Polymer Composite Reinforced with Ramie and Synthetic Fiber. The paperwork in detail about the Evolution of the Polymer Composites with synthetic fiber and natural fillers as a maintainable alternative for some engineering applications, predominantly in aerospace applications and automobile applications. An experimental study of mechanical characterization of Ramie fiber/glass fiber/ Kevlar fiber Reinforced epoxy composite was done on the research. The study included Fabrication of Ramie fiber/glass fiber/ Kevlar fiber epoxy composite using hand lay-up technique, a Mechanical characterization such as tensile strength, flexural strength, impact strength, and hardness no.

Sudhir S Mathapati et.al [18] the paper conducted on the Testing and Analysis of Mechanical Properties of E- Glass Fiber Reinforced Epoxy Polymer Composites. In this Studies the composites are playing a very important role in material science, metallurgy, chemistry, solid mechanics, and engineering applications. The E-glass fiber-reinforced polymer composite is more widely used in the automotive industry and other industrial applications, due to their advantages, like low cost, noise control, low weight, and ease of processing. The paperwork on the mechanical properties of the chopped strand mat of E-glass fiber-reinforced composites. The percentage variation of the glass fiber contents was 1%, 2%, and 3%. And the final point of view, mechanical results are compared with the FEA results by using analysis software like ANSYS.

Erden S. et.al [19] investigated the mechanical behavior of woven roving E-GF-reinforced unsaturated polyester composites with a matrix modification technique. The oligomeric siloxane was added to the polyester resin at different levels like 1, 2, and 3 Wt% respectively. Incorporation of oligomeric siloxane into the polyester resin increased the mechanical properties such as interlaminar shear, flexural and tensile strength, modulus of elasticity, and vibration values. Glass/polyester with 3 wt% of oligomeric siloxane composite was found to be better mechanical properties compared to other combinations.

Suresha B. et.al. [20] Prepared woven mat GF-reinforced epoxy composite using hand lay-up method. The epoxy resin was mixed with the hardener in the weight ratio of 100:12. The resin and fibers were mixed to make a 3 mm thickness of the sample with the application of a hydraulic press of 0.5 MPa. The specimen was allowed to cure for a day at room temperature. After de-molding, the post-curing was done at 1200C for 2 h using an electrical oven. The prepared laminate size was 250 mm * 250 mm* 3 mm.

Husic S. et.al. [21] Investigated the mechanical properties of untreated E-glass-reinforced polyurethane composites with two polyurethanes like soy polyol and petrochemical polyol Jeffol resin. The result showed that the soy polyol based composite was lower flexural, tensile, and interlaminar shear strength compares to petrochemical polyol Jeffol-based composite. This was due to lower cross-linking density and the presence of the side dangling chains in the matrix. The interlaminar shear strength was similar for both for two resin composites.

Mr. Chavan. et.al [33] the paper tried to investigate the review on the development of glass fiber/Epoxy composites materials and its characterization. As the paper tries to observe in various aspects related to manufacturing and mechanical characterization some limitations work carried out to analyze tensile strength, shear, and flexural strength by varying the volume fraction of the glass fibers and Epoxy resin materials. As the paper gave information about the manufacturing process of laminated glass fiber /Epoxy composites are the main areas of interest of the research by taking different orientation.

2.1 Research gap in previous investigation

- Many researchers have been done on the different types of synthetic fibers for fabricating the composite materials, however, very little has been reported on the reinforcing potential of glass fiber despite its several advantages over others.
- On the fabricated composite material, many research has been done using the synthetic or man-made composites as a reinforcement. However it is hard to get using glass fiber especially using E-glass fiber.

  All the above literate's are deals all about the mechanical characterization and material properties of composite materials (natural and synthetic fiber composites). the mechanical characterization properties of composites materials on the Tensile strength, flexural strength and compressive strength and water absorption of woven mat/glass fiber composite materials, of course, many types of research have been done using the synthetic or man-made fibers composites as reinforcement. From the above literatures review and research gap it is possible to conclude that the composite materials for different application are still the demanding research areas and there is still a lack of experimental analysis of the composite materials and Also there is a lack of research on the manufacturing and mechanical property characterization of the woven mat E-glass fiber /epoxy laminate composite materials.

CHAPTER THREE: EXPERIMENTAL DETERMINATION OF COMPOSITE MATERIALS

3.1 Introduction

In this thesis, the manufacturing process of the E-glass fiber reinforced Epoxy composite materials has been presented. The mechanical properties of the E-glass fiber reinforced Epoxy composite properties were fully characterized experimentally. Experimental procedure for measuring the strength and stiffness of the laminated specimen under the tensile, compression, and flexural properties and water absorption behavior under the different conditions and its results with the discussion are presented.

3.2 Materials and methods

3.2.1 Materials

For this study, important materials are selected according to their properties which are known as glass fiber, Epoxy resin, and hardener. The most suitable curing agent must be selected according to the uses condition, application, workability, and other factors. Epoxy resin with the standard brand name of system# 2000. Catalysts are used to cure the Epoxy resin by adding, which causes the chemical reaction without changing the resin, causes the chemical reaction without changing the chemical composition. Catalysts are used to initiate the chemical reaction of the Epoxy resin from the liquid state into a solid-state. The hardener is purchased from the local market with the brand name of SYSTEM #2060. The most commonly used fiberglass used in the fiber-reinforced plastic industry E-glass is selected and for the according to the availability E-Glass fiber is used in this present work. Glass fiber is a material made up of several fine fibers of glass [23]. The material types and composition of the materials are shown in table 3.1 and 3.2 respectively. All materials are purchased from the local market in Ethiopia around guard shola. Epoxy of SYSTEM #2000 EPOXY RESIN, mixed with hardener SYSTEM #2060 HARDENER is used to prepare the composite plate. The weight ratio for mixing epoxy and hardener is 100:5 (20:1) which 100grams of Epoxy resin is and 5 grams of hardener [24].

Reinforcing fiber	E-glass Fiber
Matrix system	Epoxy resin(2000 EPOXYRESIN) and #2060 HARDNER
Molding process	Hand layup followed by room temperature
Reinforcement matrix ratio	100:5

Table 3. 1materials details

Sample type	Composition
Sample 1	Epoxy (75% of weight) , E-glass fiber (25% of weight) and hardener (5% weight of Epoxy)
Sample 2	Epoxy (65% of weight) , E-glass fiber (35% of weight) and hardener (5% weight of Epoxy)
Sample 3	Epoxy (55% of weight) , E-glass fiber (45% of weight) and hardener (5% weight of Epoxy)
Sample 4	Epoxy (50% of weight) , E-glass fiber (50% of weight) and hardener (5% weight of Epoxy)

Table 3. 2 Composition of E-glass fiber composite

3.2.2 Calculation of Weight of the Fiber Fraction and the Matrix content of the composite

The volume of the composite was calculated by multiplying the length, width, and breadth of the mold prepared for molding the composite material equation (1) below and the density of the composite was calculated by a method which enables the rule of law of mixture to be applied and was obtained first by adding the volume fraction of the epoxy resin and glass fiber for each fiber/matrix ratio the density of the composite obtained as shown equation (2) below. After getting the density of the composite multiplied by the volume of the composite equation (2) then the mass of the composite obtained then the mass of the composite multiplied by each fiber/matrix ratio then the mass of each E-glass fiber and epoxy resin obtained [32]. The density of the E-glass fiber and epoxy resin was taken as 2.54 g/ cm3 and 1.27 g/cm^3 respectively [23].

3.2.2.1 Find the Mass of the Fiber for Specimens

The volume of composite was calculated by using the volume formula

Volume of die = (length)* (width)*(breadth) ------------------- (1)

Volume of die (mold) = 225mm*225mm*4.mm =202500mm^3 = 202.5cm^3

The density of the Epoxy resin is 1.27gm/cm^3 and the density of the hardener is 0.94gm/$cm^3$and the mixed ratio 100:5 depend on the mass.

We already know that density is calculated by the formula Density = Mass / Volume the form this relation density of E-glass fiber is Density=Mass /Volume**,** and also density of Epoxy resin.

Then the mass of the Epoxy= (density)*(volume).

Volume of composite=Volume of Epoxy resin +volume of E-glass fiber

$$V_{\text{composite}} = V_{\text{Epoxy resin}} + V_{\text{E-glass fiber}} \ldots\ldots\ldots\ldots (2)$$

$$\frac{Mass\ of\ composite}{\rho \text{ of composite}} = \frac{Mass\ of\ Epoxy}{\rho \text{ of Epoxy}} + \frac{Mass\ of\ \text{E} - \text{glass fiber}}{\rho \text{ of E} - \text{glass fiber}}$$

$$M\left(\frac{1}{\rho_{\ composite}}\right) = Mass\ Epoxy\left(\frac{1}{\rho_{\ Epoxy}}\right) + Mass\ of\ \text{E} - \text{glass fiber}\left(\frac{1}{\rho_{\ \text{E}-\text{glass fiber}}}\right)$$

The total mass of the of composite is the sum of the Epoxy and the glass fiber ratio mass according to the ratio then

$$\frac{1}{\rho_{\ composite}} = 0.75\left(\frac{1}{1.27}\right) + 0.25\left(\frac{1}{2.54}\right)$$

$$\frac{1}{\rho_{\ composite}} = 0.59055 + 0.0984$$

$$\frac{1}{\rho_{\ composite}} = 0.688975$$

ρ_c =1. 451 gm. /cm^3 (this is for *25*% of E-glass fiber reinforced Epoxy Composite material.) In the similar manner it calculated for 35%, 45% and 50% of E-glass fiber reinforced Epoxy Composite material.

$$M_c = \rho_c \text{ x } V_c \text{ ------------------- (3)}$$

$$M_c = \rho_c \text{ x } V_c$$

$$= 1.451 \text{ gm/cm}^3 * 202.5\text{cm}^3 = 293.83 \text{ gms}$$

Designation	Composition		Mass (gms)		Calculated Total mass (gms)
	Epoxy resin %	E-glass fiber %	Epoxy resin	E-glass fiber	
Sample 1	75	25	220.37	73.46	293.83
Sample 2	65	35	202.70	109.15	311.85
Sample 3	55	45	182.66	149.45	332.11
Sample 4	50	50	171.12	171.12	342.24

Table 3. 3 *calculated specimen compositions used in this study*

Designation	Composition		Mass (gms)		Total mass (gms) after
	Epoxy resin %	E-glass fiber %	Epoxy resin	E-glass fiber	
Sample 1	75	25	215.99	71.995	287.98
Sample 2	65	35	199.77	107.57	307.34
Sample 3	55	45	179.58	146.93	326.51
Sample 4	50	50	167.86	167.86	335.72

Table 3. 4 *measured specimen compositions used in this study after the preparation*

3.3 Calculation of the volume fraction of the fiber and the matrix contents of the composite

The volume ratio of fiber is an important mathematical element in composite engineering. fiber volume ratio or fiber volume fraction is the percentage of fiber volume in the entire fiber-reinforced composite materials. When the manufacturing of the polymer composite fibers is impregnated with the resin. The amount of resin to fiber ratio can be calculated by the geometric organization of the fibers, which affects the amounts of resin that can be entering into the composites [25]. The amounts of fiber in the fiber-reinforced composite directly corresponding with the mechanical properties of the composites.

The fiber and the matrix volume fraction (VF, VM), here the volume of the fiber, the volume of matrix and the volume of composite given by

For sample 1. $V_f = \frac{W_f}{\rho_f} = \frac{73.46\ gm}{2.54gm/cm3} = 28.9$, $V_m = \frac{W_m}{\rho_m} = \frac{220.7}{1.27} = 173.78$, $V_C = 202.68$

For sample 2. $V_f = \frac{W_f}{\rho_f} = \frac{109.15\ gm}{2.54gm/cm3} = 42.97$, $V_m = \frac{W_m}{\rho_m} = \frac{202.7}{1.27} = 159.61$, $V_C = 202.58$

For sample 3. $V_f = \frac{W_f}{\rho_f} = \frac{149.45gm}{2.54gm/cm3} = 58.84$, $V_m = \frac{W_m}{\rho_m} = \frac{182.66}{1.27} = 143.83$, $V_C = 202.67$

For sample 4. $V_f = \frac{W_f}{\rho_f} = \frac{171.12\ gm}{2.54gm/cm3} = 67.37$, $V_m = \frac{W_m}{\rho_m} = \frac{171.12}{1.27} = 134.74$, $V_C = 202.11$

$$V_C = V_F + V_M$$

The fiber volume fraction= $\frac{\text{volume of fiber}}{\text{total volume}}$, $V_f = \frac{V_f}{V_f + V_m} = \frac{V_f}{V_c}$ and

The matrix volume fraction =$\frac{\text{volume of the matrix}}{\text{total volume}}$, $V_m = \frac{V_m}{V_f + V_m} = \frac{V_m}{V_c}$

For sample 1. $V_f = \frac{V_f}{Vc} = \frac{28.9}{202.68} = 0.143$, $V_m = \frac{V_m}{V_c} = \frac{173.78}{202.68} = 0.857$

For sample 2. $V_f = \frac{V_f}{Vc} = \frac{42.97}{202.58} = 0.212$, $V_m = \frac{V_m}{V_c} = \frac{159.61}{202.58} = 0.788$

For sample 3. $V_f = \frac{V_f}{Vc} = \frac{58.84}{202.67} = 0.29$, $V_m = \frac{V_m}{V_c} = \frac{143.83}{202.67} = 0.71$

For sample 4. $V_f = \frac{V_f}{Vc} = \frac{67.37}{202.11} = 0.333$, $V_m = \frac{V_m}{V_c} = \frac{134.74}{202.11} = 0.667$

Where

$\boldsymbol{V_m}$ − *Volume of matrix* (cm^3)

$\boldsymbol{W_f}$ − *Weight of the fiber (grams)*

W_m – *Weight of the matrix (grams)*

V_f – *Volume of fiber (cm³)*

ρ_m – *Density of the matrix (g/cc)*

ρ_f –*Density of the fiber (g/cc)*

3.4 Fabrication of fiber glass reinforced epoxy composite material process

According to the composite material theory, the sample guide line composite material fabrication processes shown in figure 3.3 below.

Figure 3. 1 fabrication approaches of composite materials

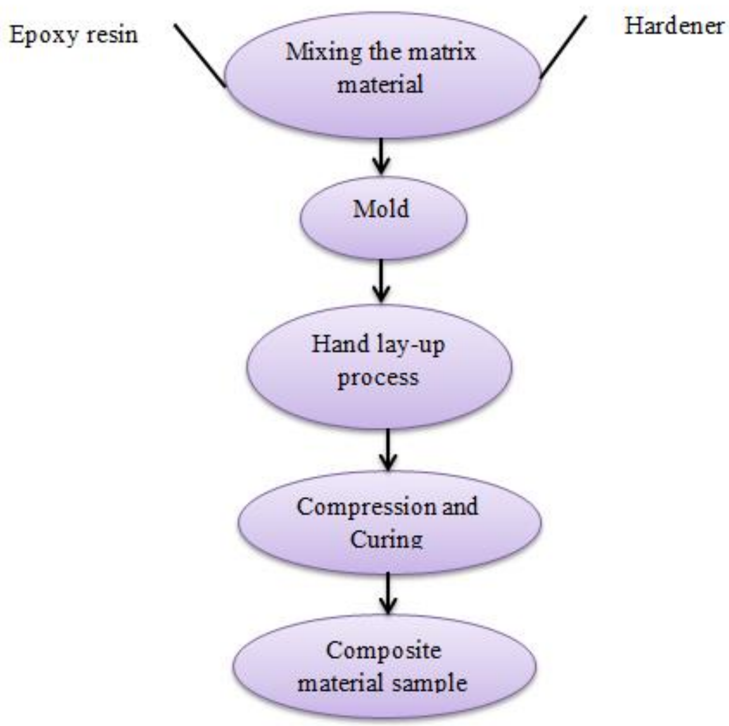


Figure 3. 2 Schematic flow diagram for E-glass fiber reinforced epoxy resin composites fabrication

As it is shown in the schematic diagram of figure 3.1 above. For the preparation of E-glass fiber reinforced Epoxy resins composites. This composite specimen in the mold cold compression methods. Epoxy resin and Hardener were taken into the mixed tanker like nickel or in the high land plastic to mix it very well. Then to the lay-up reinforced E-glass fiber on the mold. The Epoxy Composite sample was fabricated by using the hand lay-up process (Techniques).

The composites fabrication process involved some forms of molding the shape the resin and reinforcement. A mold tool is required to give the unformed resin/fiber combination its shape and during the cure. The most basic fabrication methods for thermoset composite are hand lay-up which typically consists of laying dry fabrics layers [26]. The following materials are used for the fabrication of E-glass fiber reinforced epoxy composite. Epoxy resin, hardener, and E-glass fiber and Hand lay-up technique is the simplest method of composite processing. The processing steps are quite simple. The first process (Techniques) a releasing agent sprayed on the surface of the prepared mold to avoid unnecessary sticking materials from the surfaces. The important doing this is to get good surfaces to finish off the prepared product. The mixture of Epoxy resin and the suitable hardener is poured on the surfaces of the mold after the Vaseline then Fibers are reinforcement in the forms of the woven mat at upper surfaces of the mold, and then the mixture of Epoxy resin and the suitable hardener is poured on the surfaces of the woven mat already placed in the mold by the help of the brush. Second, the layer of reinforcement is then placed on the polymer surfaces, and thus time the roller is used to remove the air gaps or bubbles as well as excessive matrix present. This process is repeated step by step for each layer of reinforcement and matrix until the required thickness is achieved. After a while the releasing agent is sprayed on the inner surfaces of the top mold which is kept on the achieved thickness and pressure is applied by a hydraulic machine. after curing at room temperature mold is open and developed composite parts are taken out. There are some Advantages like the process is simple to use, the process results in low-cost tooling with the use of room-temperature cure resins, any combination of fibers and matrix materials are used and Higher fiber contents and longer fibers as compared to other processes.

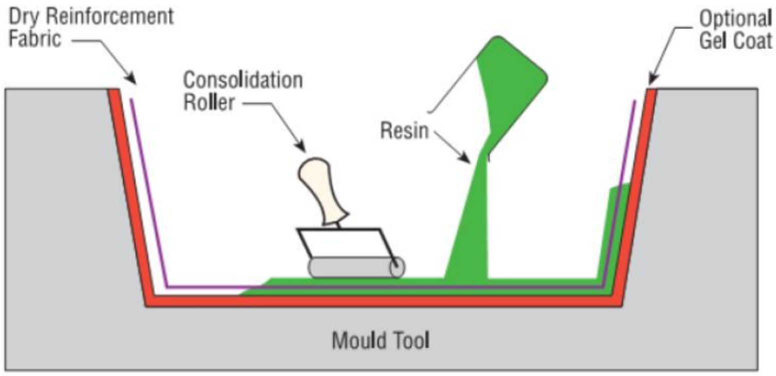


Figure 3. 3 Hand layup Techniques

3.4. 1 Materials Requirements of Hand-lay-up method

3.4.1.1 Mould Preparation

The square plate mold with dimensions: 225mm × 225mm x 15 mm was specifically fabricated for the development of the specimen test in line with other published works, assembled with base and top plates, for the easy removal of the specimen, without sticking. The mold cavity was thoroughly cleaned to avoid particles interaction with the epoxy resin and were coated the inner layers of the mold with normal Vaseline for easy removal of the composite specimens.

Figure 3. 4 mold

3.4. 1.2Mold Release

Mold release is essential for preventing the epoxy from sticking to the mold when the composite are apart. Even though, there are several types of mold release used depending on the mold material and desired characteristics of the finished part, the most common type and used for this work is normal Vaseline for better surface finish of the composite as shown figure 3.4above.

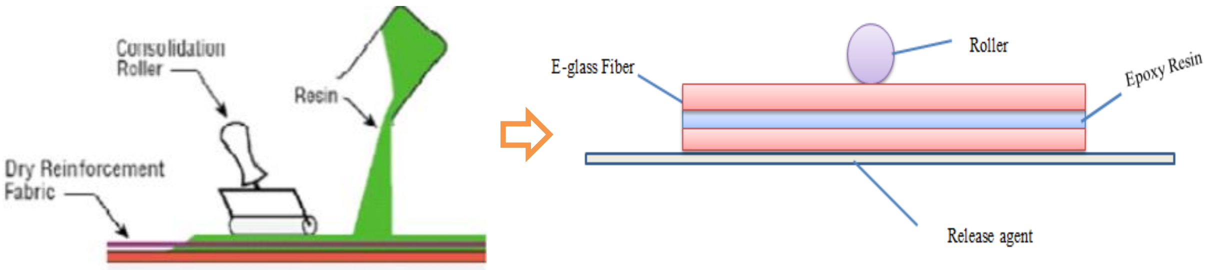


Figure 3. 5 E-glass fiber reinforced epoxy composite molding sketch

Figure 3. 6 prepare measuring and cutting of the glass fiber to prepare the sample

3.4.1.3 Compression and curing

In this work the reinforced composite was prepared woven mat glass fiber reinforced Epoxy composite using hand layup method. The Epoxy resin was mixed with the hardener in the weight ratio of 100:5. The resin and fiber were mixed to make 4mm thickness. The 5MPa of pressure hydraulic press machine was maintained and it holds for 24 hours for curing at room temperature. After 24 hours the glass fiber reinforced /Epoxy composite were removed from the molds. The hydraulic press machine used is shown in figure 3.7

Figure 3. 7 Standard Hydraulic Press for curing

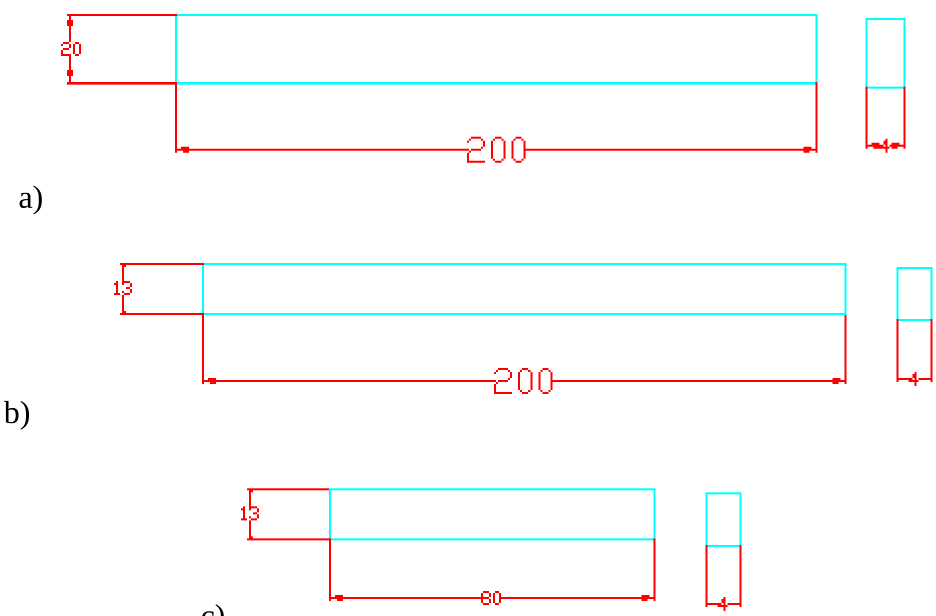
Figure 3. 8 E-glass fiber reinforced epoxy composite material

3.5 Procedure for preparing the experimental specimen sample

3.5. 1 preparing the test pieces with required dimension

Test Specimens	ASTM	Size
Tensile test Specimens	ASTM D-3039/D-3039M	200mm*20mm*4mm
Flexural test specimens	ASTM D-3410M	200mm*13mm*4mm
Compression test specimens	ASTM D-3410M	80mm*13mm*4mm

Table 3. 5 Test specimen detail



all dimension in mm

Figure 3. 9 Test Specimen with Dimensions- (a) Tensile Test Specimen

(b) Flexural Test Specimen

(c) Compression Test Specimen

After the E-glass fiber reinforced epoxy composite Specimen cut in to the desired dimension based on the respective standards for each weight ratio of 25/75%,35/65%,45/55% and 50/50% were tested using the three different strength testing procedures: The flexural test, compression test and tensile test for each set of specimen. The mechanical properties of randomly oriented E-glass fiber reinforced epoxy such as flexural and tensile strength increased with increase in weight fraction of the fiber The test in this research requires the specimen of E-glass fiber. It is dictated that the appropriate standard was followed while preparing the specimen for E- glass fiber reinforced Epoxy composite materials test.

The American standard society of testing materials was used to prepare the sample specimen. Tests were done of laminate the composite materials like Mechanical testing of fiber, Mechanical properties of testing matrix and Mechanical testing of lamina. The composite was characterized for different properties using the testing method ASTM D-3039/D-3039M for Tensile strength test, ASTM D-3410M for compression strength test and ASTM D-3410M flexural strength test.

After the E-glass fiber glass reinforced Epoxy composite specimen prepared and cut in the specimen in to the desired dimension based in the standard for each weight ratio of 25/75, 35/65, 45/55 and 50/50 were testing using three types of mechanical properties strength testing procedure. The tensile strength test, compression strength test and flexural strength for each of three set of specimen.

Figure 3. 10 sample preparation for the test

3.5.2 Introduction to the test apparatus

Universal Testing Machine (UTM) Testing System used to test the tensile strength, compressive strength, flexural strength and strength of different materials. In this study all the materials tests were done in defense university college of engineering, mechanical engineering work shop by using computer control electro hydraulic servo universal testing machine with the model WP 310, which has a capacity of up to 50 KN with 2 mm/min testing speed. Also the computer is connected to the testing machine for data, acquisition and displacement (mm) and load (N) are monitored for the static Experiment.

Figure 3. 11 Universal testing machine testing machine model WP 310

Generally, the required E-glass fiber reinforced composite materials properties are characterized under the three primary loading models such as tension, compression and flexural.

3.5.3 Mechanical properties testing for composite materials characterization

Mechanical properties of composite materials were evaluated by tensile strength, compressive strength, impact strength and flexural strength measurements testing. In this thesis tensile strength, compressive strength and flexural strength tests were carried out using universal testing machine. Here two identical samples were tested for tensile strength, two identical samples were tested for compressive strength, and two identical samples were tested for flexural strength. Mechanical testing often involves the deformation or breakages of samples material (tests specimen). some common forms of test specimen used for this study test specimen and loading situation are shown in the figure 3.12 below. Specimens are nothing more than specialized engineering components in which known stress or strain state in applied and the material properties of woven fiber glass /Epoxy reinforced composite material are inferred from the resulting of mechanical response.

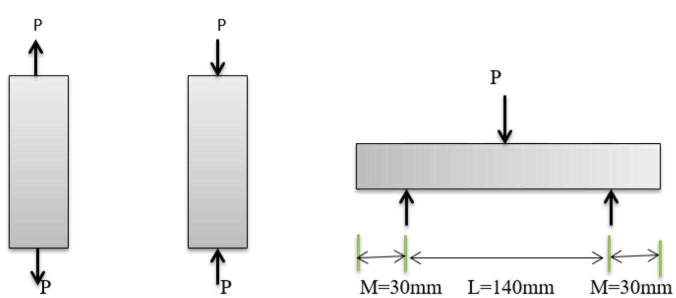


Figure 3. 12 Geometry and loading in mechanical testing of reinforced composite materials.

3.5.3.1 Tensile strength test (ASTM D3039 /D-3039M)

The primary objective of this test was to evaluate the in-plane tensile properties of glass fiber composites. For each sample, every specimen was tested in each machine and cross-machine direction Each specimen was 200mm by 20 mm by During the test the specimens were placed in the grips of UTM (universal testing machine) and axial load is applied through both the ends of the specimen. Tensile strength often the capacity of materials or structure to withstand loads tending to elongate, tensile strength resists tension or being pulled apart where the tensile strength is measured by the maximum stress that the E-glass fiber reinforced epoxy composite material withstand before breaking. Tensile test was examined according to ASTM D3039 /D-3039M using universal testing machine at room temperature. The universal testing machine consists of three main units, namely control units, recording units and hydraulic and straining units'. the universal tensile strength machine is usually found by performing a tensile test and recording the engineering stress vs. strain. Specimen are placed in the grips of a universal testing machine at a specified grip separation and pulled until the failure take space. For ASTM D3039 /D-3039M the test speed can be determined by material specification or time to failure. A typical speed for standard test specimens in 2mm/min.

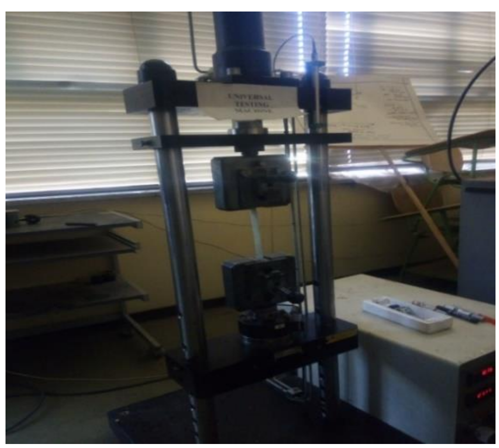


Figure 3. 13 Specimen under tensile testing

3.5.3.2 Compression strength test (ASTM D-3410M)

This section involved in subjecting of specimen with the axial Compression loading using the universal testing machine for the composites specimen. The specimen was prepared according to the ASTM standard (ASTM D-3410M). The sample was placed between the anvils to commence the compression testing. In this time the maximum load was recorded on the specimen with the dimension of the specimen (80mm*13mm*4mm). Compressive load is applied fiber glass/epoxy composite specimens and maximum failure load are recorded to compression strengths.

Figure 3. 14 Specimen under compression testing

3.5.3.3 Flexural strength test (ASTM D-3410M)

Flexural strength of the fiber reinforced composites was determined by conducting three-point bend tests on the specimen in UTM (ASTM D-3410M). The specimen is prepared according to the ASTM standard. Three-point bending method is followed in this testing of composites. This test is the bending test, were conducted using machine with the sample dimension (200mm*13mm*4mm) because the strength is a material ability to resist deformation under the load that applied, so that the short beam shear tests are performed on the composite materials. The three points bending test is conducted using the machine, which generally promote the failure inter-laminar shear. The test conducted as ASTM standard using the universal testing machine.

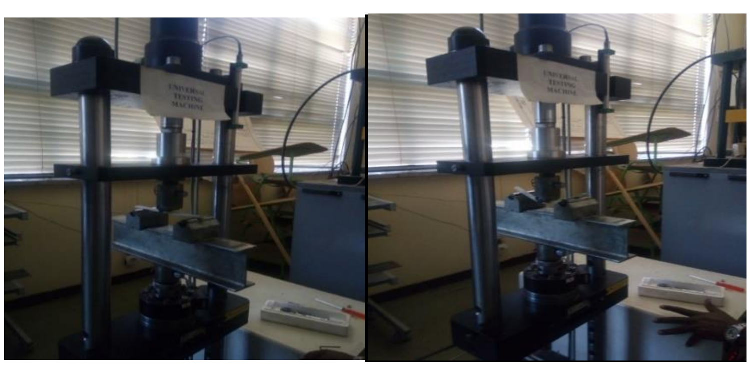


Figure 3. 15 Flexural Test Setup Universal Testing Machine

3.6 water absorption of E-glass fiber reinforced Epoxy composite materials

The water absorption test of E-glass fiber reinforced composite were done as per ASTM 570 by the immersion in distilled water at room temperature. The samples were taken out from the surface of sample weighted immediately using the precise balance machine to find out the content of water absorbed. The specimen was weighed regularly for first test for water absorption take 5 days (120 hours) and the second test 13 days (312hours). then the water absorption was calculated by weight gain of the sample is measured at a different time interval by using the formula. The main reason distilled water offers the best choice for use in science projects is that it is inert, which means little to nothing remains in the water after distilling. The use of distilled water in this composite Experiment is to assure that the outcome of the test is fair. Because distilled water basically contains nothing in it, since it is inert, it won't affect the outcome of tests completed for science projects. In the science project experimental test using the water as a control element in the experiment, water Distillation kills most organic matter and removes minerals from the water, making it an ideal control element for science projects and laboratory tests.

$$\text{Water absorption }\% = \frac{W_2 - W_1}{W_1} * 100 \text{ ----------------------------- } (4)$$

Where

W_1- Weight of the dry sample

W_2- Weight of the wet sample

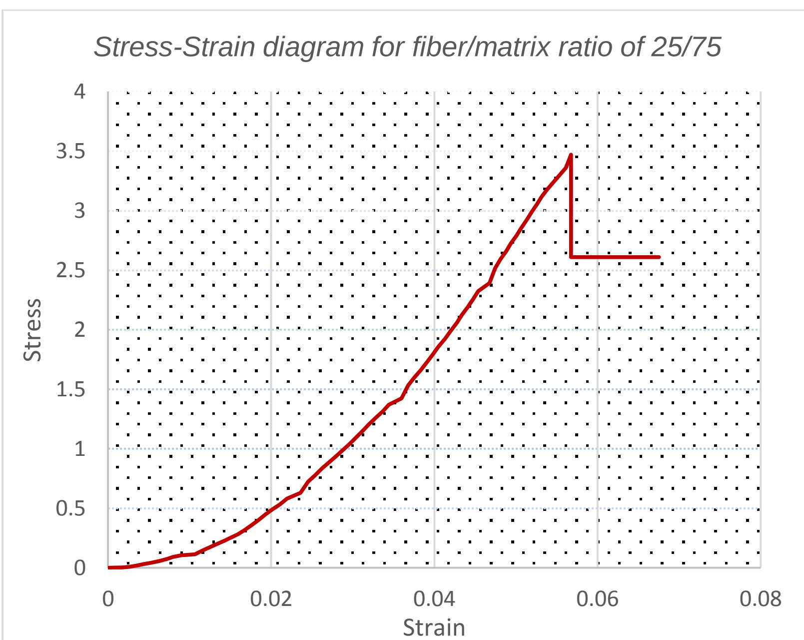
CHAPTER FOUR: RESULTS AND DISCUSSION

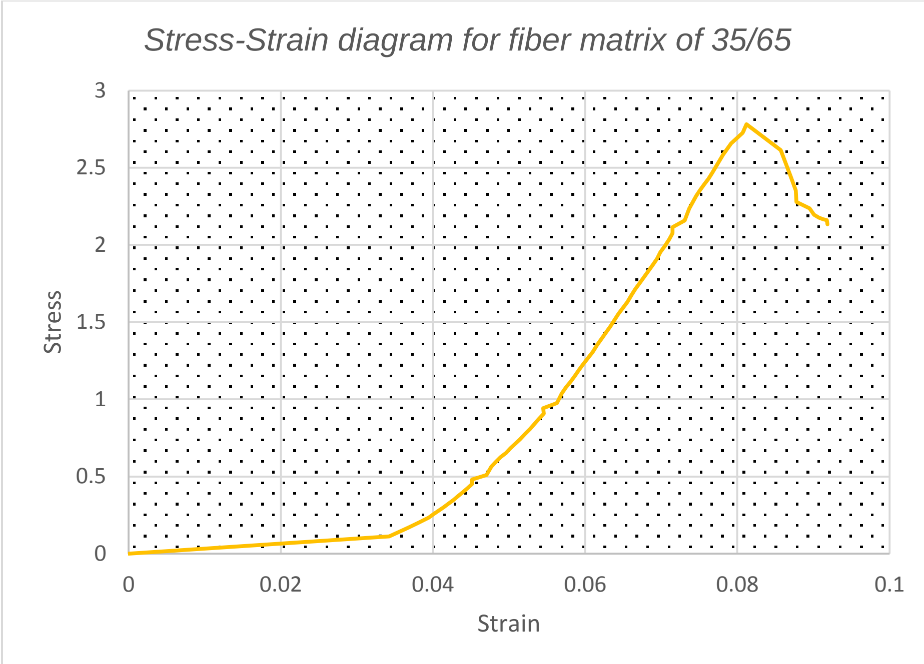
4.1 Results

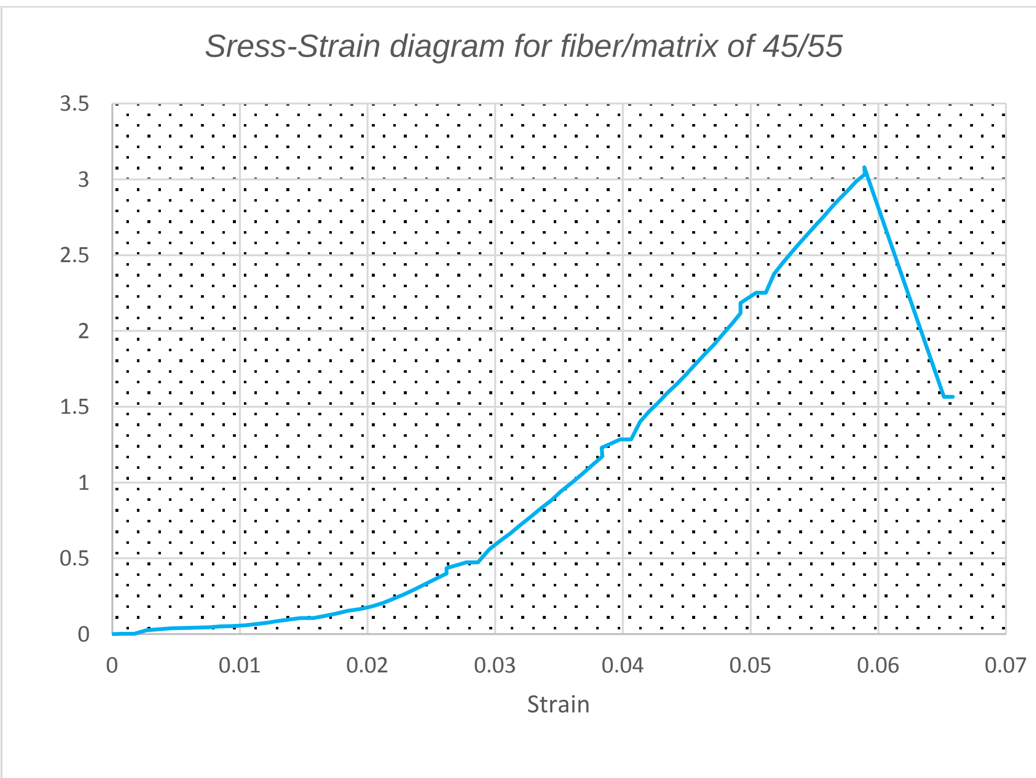
Fiber reinforced composite specimen prepared were subjected to the tensile, flexural(bending) and compression strength tests and also water absorption behavior of E-glass fiber reinforced composites. The obtained results were analyzed, compare and conclusion justification were derived from the experimental tests. E-glass fiber reinforced composite materials showed the better mechanical properties in all the results.

4.1.1 Tensile test

The data that recorded from the WP 310 Universal testing machine, stress- strain curve, force-displacement curve were displayed below in the figure. The composite materials were characterized for the tensile properties methods of ASTM D-3039/D-3039M. The tensile elongation evaluation, the test was performed on universal testing machine which found in defense Engineering University college. The sample where placed between the grippers and pulled apart until the failures takes place. Two samples were tested for each sample ratio of fiber/matrix.




Stress-Strain diagram for fiber matrix of 35/65
Stress
3
2.5
2
1.5
1
0.5
0
0
0.02
0.04
0.06
0.08
0.1
Strain


Sress-Strain diagram for fiber/matrix of 45/55
3.5
3
2.5
2
1.5
1
0.5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Strain

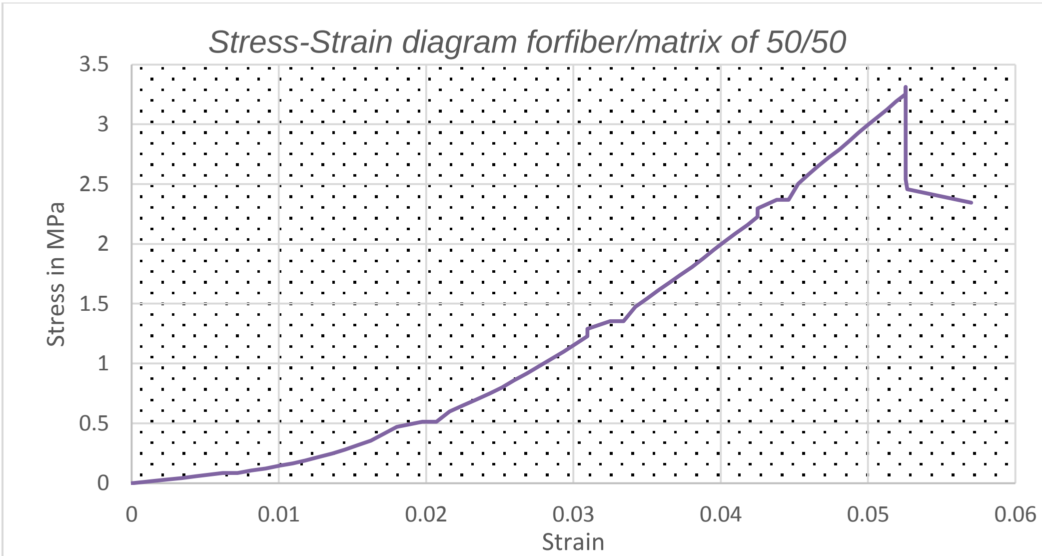


Figure 4. 1 Stress - Strain for all four specimens under tensile test separately

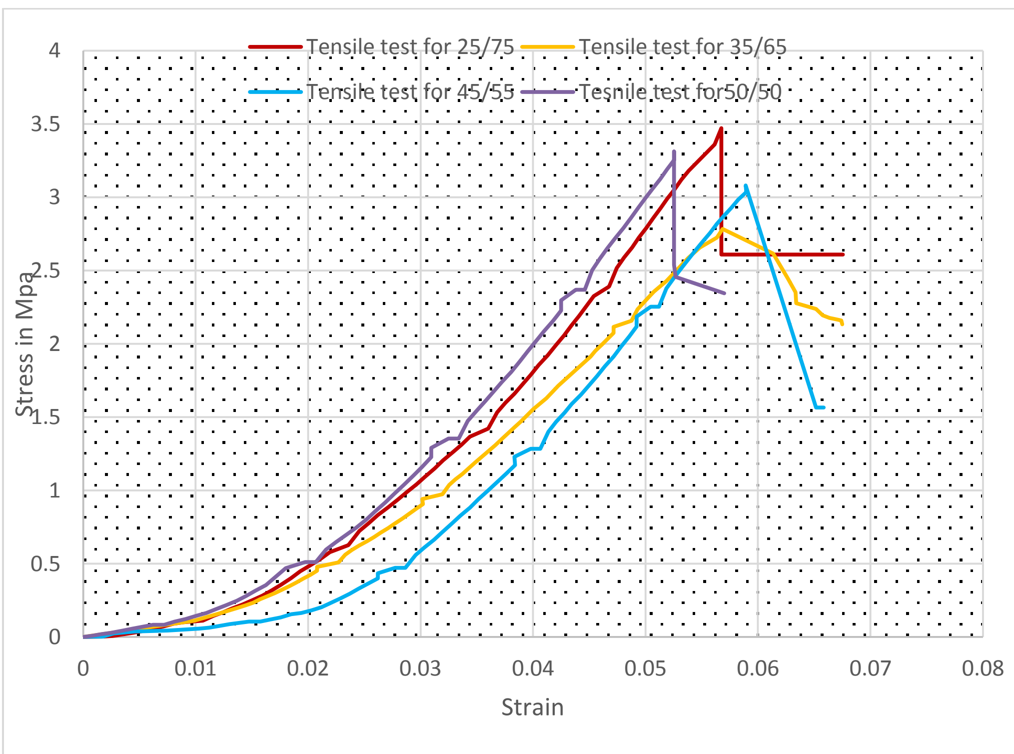
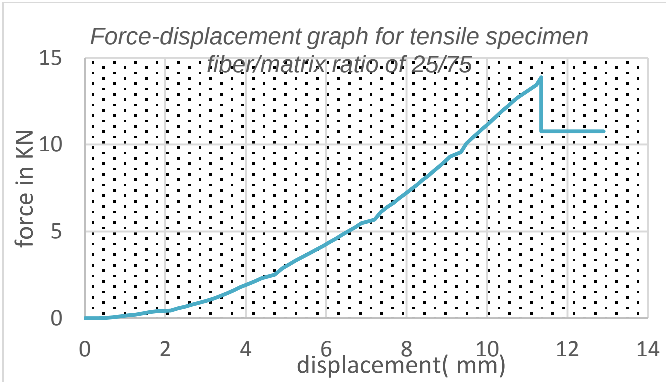
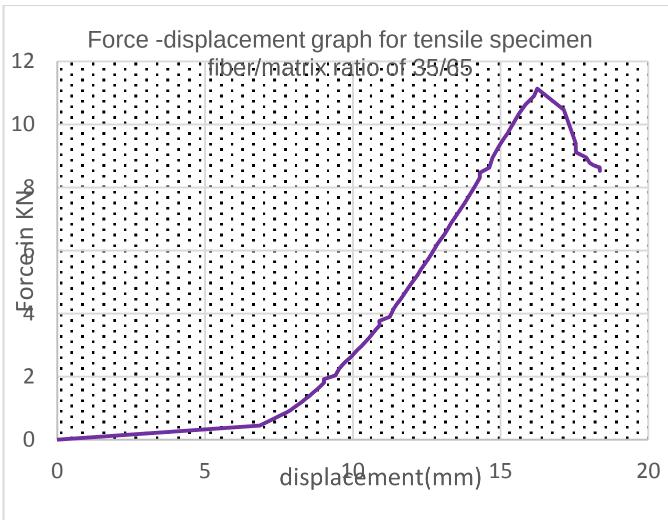
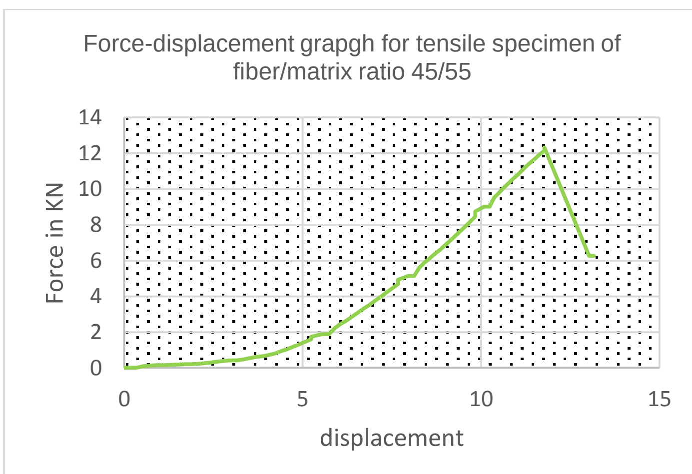


Figure 4. 2 Stress- Strain graphs for all samples together under tensile test

The stress-strain is obtaining from the load and elongation of a given primary output from the Experiment that defined the curve of stress-strain in the above graphs.


Force-displacement graph for tensile specimen fiber/matrix ratio of 25/75
force in KN
displacement(mm)
0
5
10
15
0
2
4
6
8
10
12
14


Force -displacement graph for tensile specimen fiber/matrix ratio of 35/65
Force in KN
displacement(mm)
0
2
4
6
8
10
12
0
5
10
15
20


Force-displacement grapgh for tensile specimen of fiber/matrix ratio 45/55
Force in KN
displacement
0
2
4
6
8
10
12
14
0
5
10
15

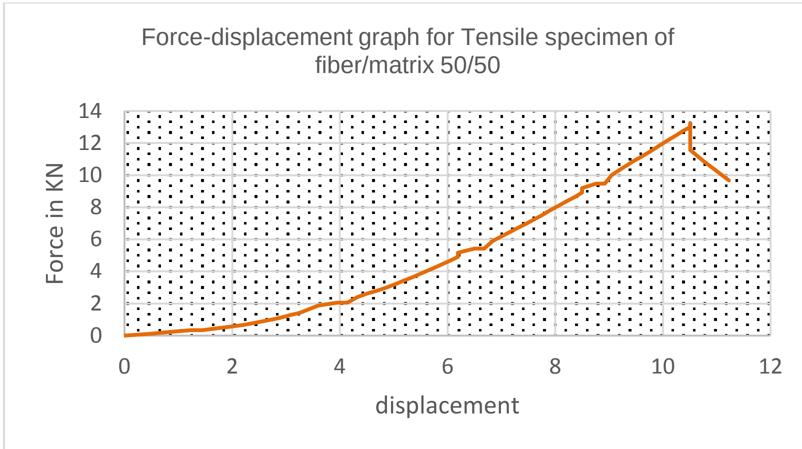
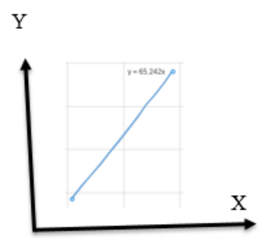


Figure 4. 3 Force –displacement graph for tensile specimens

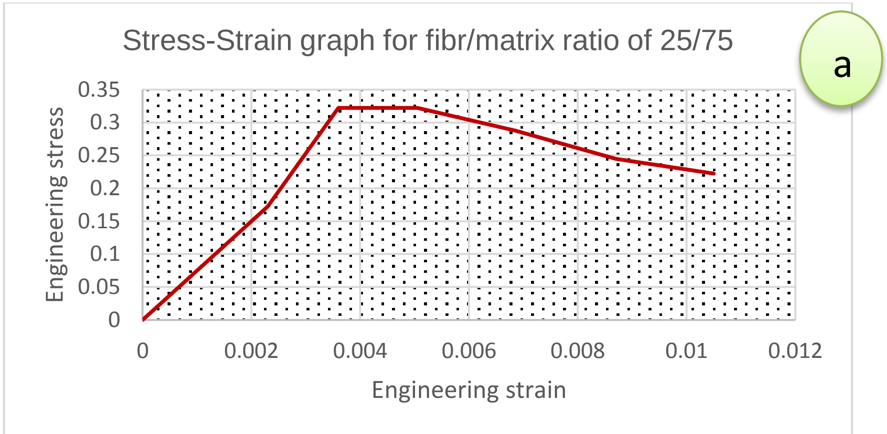
The modulus of the elasticity (young's modulus) is the ratio of stress to strain by computed from the modulus line taken. Here take the two points is necessary to find the values of the modulus (using the slope theory). The results of this division are the modulus of the materials tested. In order to find the modulus

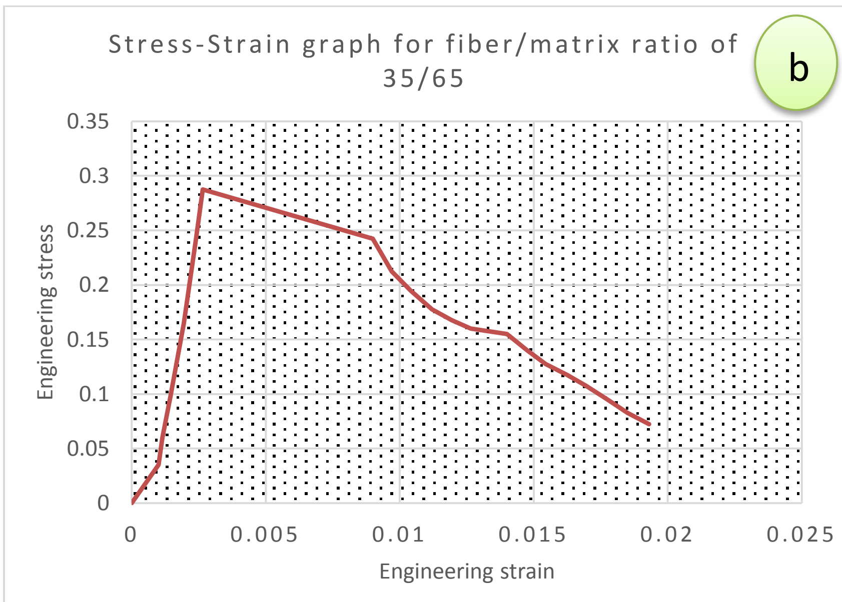


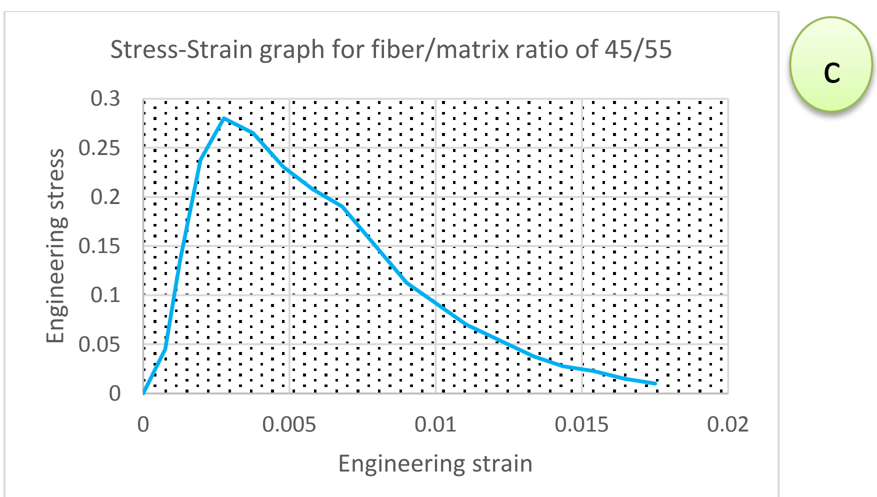
$$\text{Modulus in MPa} = \frac{\Delta stress\ in\ MPa}{\Delta Strain\ in \frac{mm}{mm}} = \frac{\Delta\sigma}{\Delta\varepsilon} \text{ ……………………….. (5)}$$

4.1.2 Compression Test

The compressive test specimen was prepared as four different fiber/ matrix orientation with the fiber matrix ratio of 25/75, 35/65/45/55/ and 50/50 were used. For each ratio two specimens were prepared and the results of the test showed in the figure 4.4 - figure 4.6 below. As shown in the figures below the force- displacement and stress-strain curve of the composite tests of the fiber reinforced composite materials. Compressive properties explain the performance of a material under compressive loads. Compressive strength and modulus are the most important values to be noted from the compression tests.


Stress-Strain graph for fibr/matrix ratio of 25/75
a
Engineering stress
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.002
0.004
0.006
0.008
0.01
0.012
Engineering strain


Stress-Strain graph for fiber/matrix ratio of 35/65
b
Engineering stress
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.005
0.01
0.015
0.02
0.025
Engineering strain


Stress-Strain graph for fiber/matrix ratio of 45/55
c
Engineering stress
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.005
0.01
0.015
0.02
Engineering strain

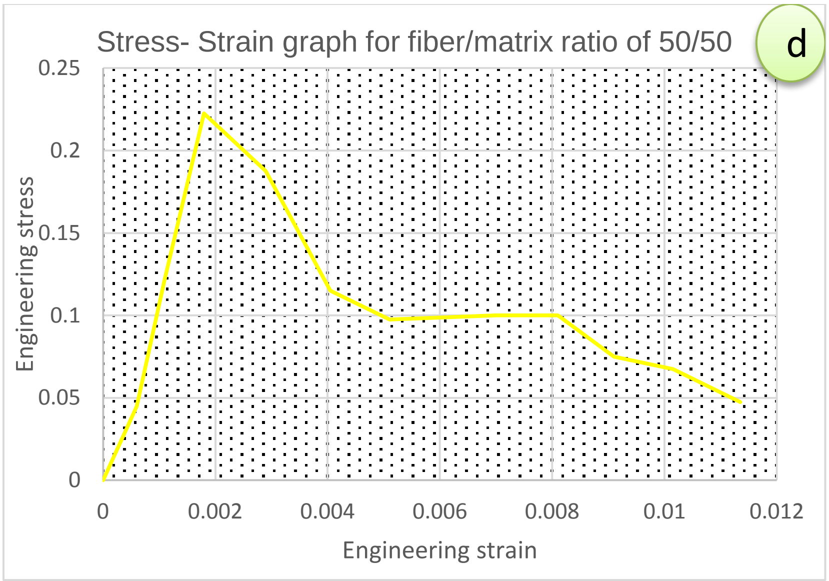


Figure 4. 4 Engineering stress - Strain curve for compression test

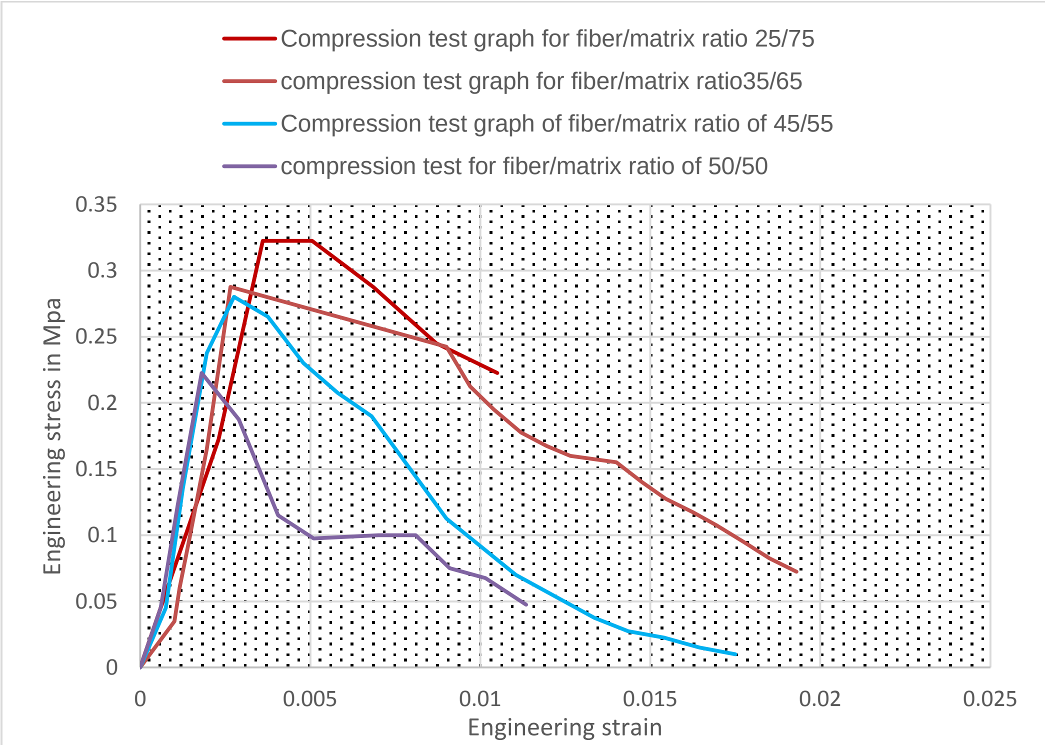


Figure 4. 5 Engineering stress-strain graph for compression specimens.

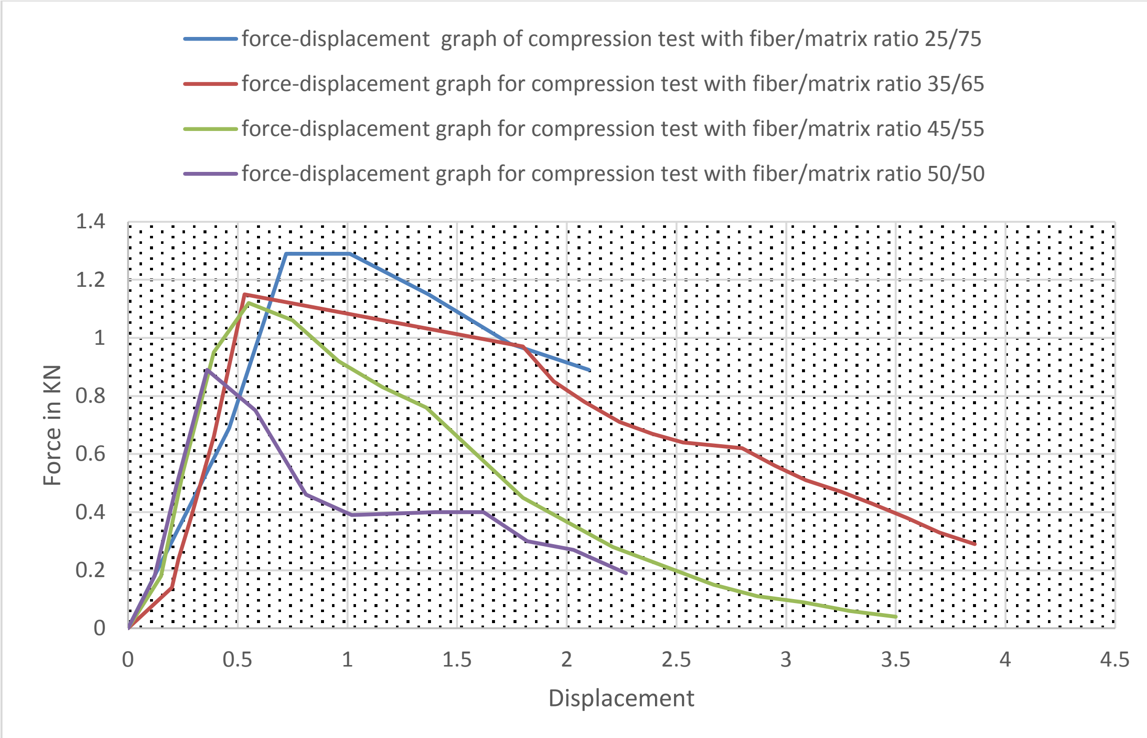


Figure 4. 6 Force-displacement graph for compression specimens.

4.1.3 Flexural (bending) Test

The flexural tests of the glass fiber reinforced composite panels were conducted according to ASTM D-3410M using a universal testing machine, with the model WP 310 and load of 140N, 130N, 120N and 100N respectively. The three-point bending test was carried out in UTM machine according to the ASTM standard to measure. The flexural Strength of the Epoxy reinforced composites. The load deflection curve obtained from the three point flexural tests of conventional.

$$\text{Flexural strength} = \frac{3.P.L}{2.b.t^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where

-L is the span length of the sample (mm)

P- The maximum load applies on the specimen center (N)

b- The width of the specimen (mm)

t - The thickness of the specimen

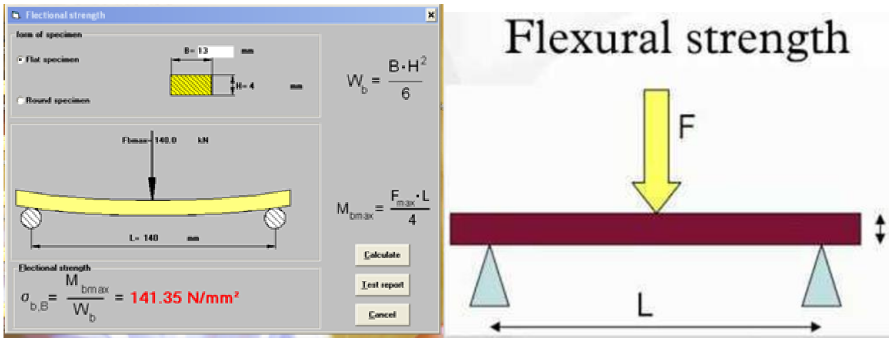


Figure 4. 7 Flexural strength test sample in UTM (screen shoot figure during the test left side one)

The load was applied on the middle points of the specimen at the speed of 2 mm/min. the span length was 200mm, it observed that the curves is increased linearly with respect to the displacement until the maximum force exist.

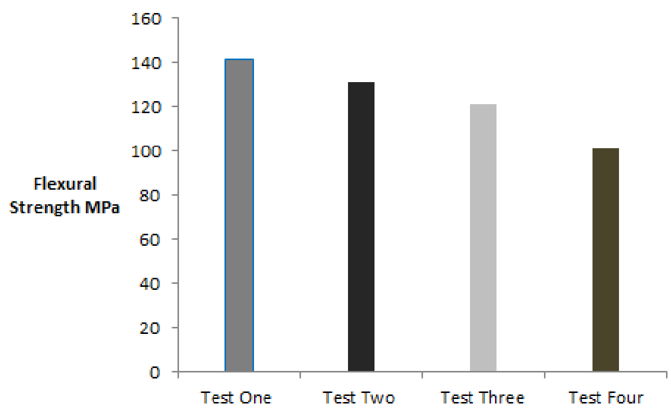


Figure 4. 8 Flexural strength comparisons for all specimens

4.1.4 Water absorption behavior

In this thesis the water absorption behaviors of all the composite specimens, measured at room temperature for a different immersion period of the specimen in the water which is the first for five days and second for 13 days which is 120 hours and 312 hours are shown in Figures 4.9 the specimens were poured in to the water respectively. The percentage moisture absorption of all the specimens showed considerable rise as the exposure time increases, in the observation the water absorption of fiber glass reinforced /Epoxy composite capacity seen as according to the equation 4 above. The composite samples were immersed in water during a time until the saturation period was reached. Four specimens were immersed in the water at room temperature. The specimens immersed in the water for five consecutive days and 13 consecutive days. For all four specimens' together weighs, 0.158grams before the immersion and after five days' immersion of samples in the water it weighs 0.168grams then

$$\text{Water absorption } \% = \frac{W2-W1}{W1} = \frac{0.168-0.158}{0.158} * 100 = 6.33\%$$

Then the next steps were waiting the sample immersed sample in the water for 13 consecutive days then the following results were recorded for every samples tests. For Tensile ASTM standard test sample water absorption behavior calculation shown in the equation 3.

Figure 4. 9 measuring of specimen before and after water immersion

The water absorption of the glass fiber reinforced composite sample was calculated with the equation 4.the weight gain (%) as a function of times for the mechanical properties tests. For every four samples with 312 hours of water immersion, the maximum percentage of the weight gains is 6.35% for the tensile, 6.65% for the flexural test and 6.5% for the compression test. As we can have observed from the process of the water absorption at the beginning and after its slow and finally after the time of immersion the same approaches to the saturated stages, for all water absorption behaviors of the sample the fiber volume fraction increased for all tested samples the initial rate of the process and the maximum water absorption increases.

Figure 4. 10 Specimens Immersed in Distilled Water

4.2 Discussion

4.2.1 Tensile test

The results of tensile strength and elastic modulus of the woven mat glass fiber /Epoxy composites are presented in table 4.1 below. The tensile strength of the woven mat glass fiber composite has significantly increased by increasing the fiber content and decreasing the matrix content in the mixture of fiber glass/matrix. As it is shown in the mixture of fiber glass ratio in previous chapter fiber/matrix ratio (25/75, 35/65, 45/55 and 50/50). During the tensile test, failure of the composite was characterized through progressive breakage of the fibers parallel to the loading axis. It was observed that the failure of glass fiber /Epoxy reinforced composite materials, originally the breakages propagates along the loading of two side gripper direction. The tensile modulus of elasticity varies from 65.6MPa to 90.4MPa and the maximum is obtained for specimen with the glass fiber/matrix ratio of 45/55.

Figure 4. 11 Tensile test after breaking

Table 4. 1 Tensile properties

Composites sample number	Tensile strength [MPa]	Tensile modulus [MPa]
Sample one (25/75)	167.25	65.6
Sample two (35/65)	173.50	70.97
Sample three(45/55)	177.07	90.4
Sample four(50/50)	180.63	89.8

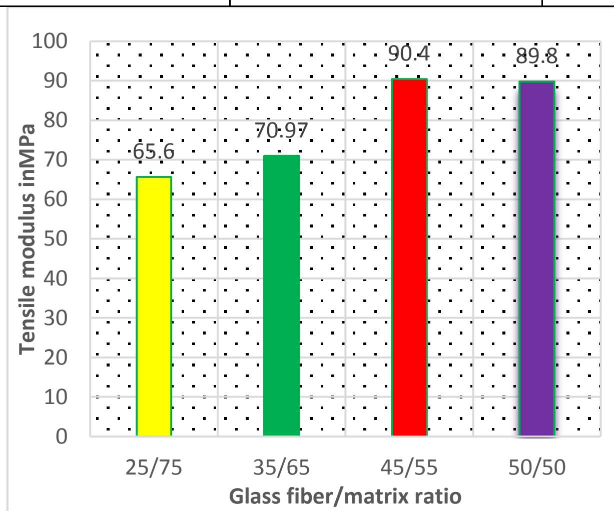


Figure 4. 12 Tensile modulus of elasticity of composites

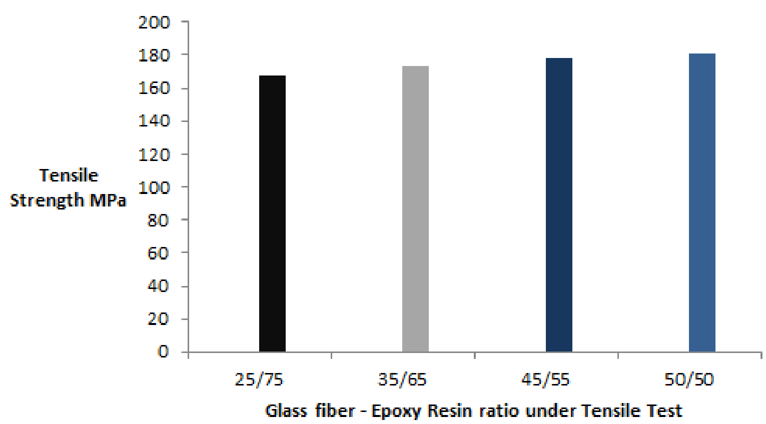


Figure 4. 13 Tensile Strength comparisons for each fiber/matrix ratio

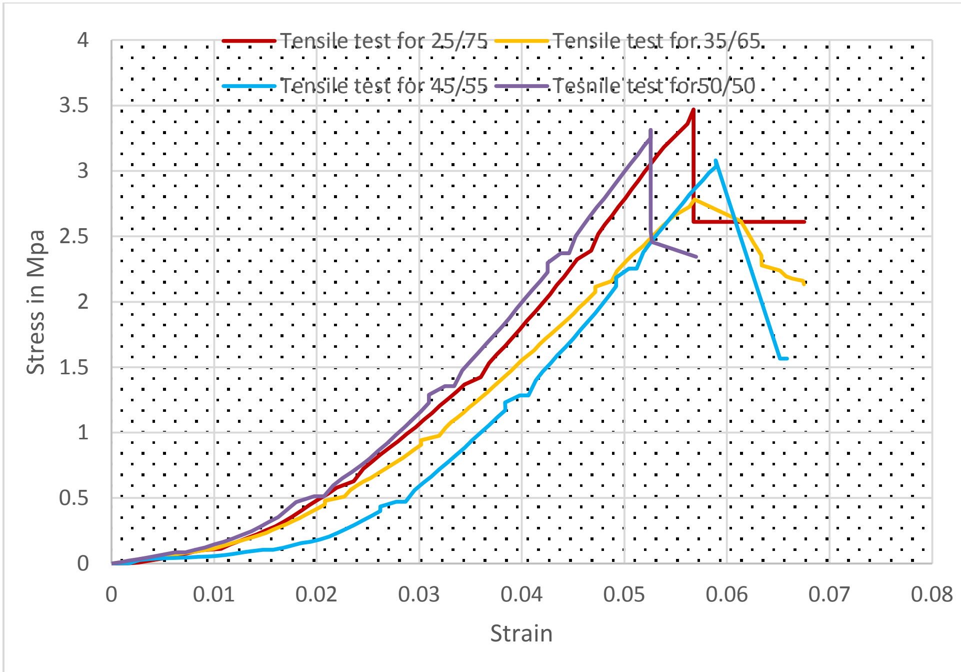


Figure 4. 14 Stress - Strain for all samples together

From the tensile test graph, above the maximum stress found from the universal tensile testing for the sample one (25/75) fiber matrix ratio is 42.59N/mm^2, the maximum stress found from the universal tensile testing for the sample two (35/65) fiber matrix ratio is 44.18 N/mm^2, the maximum stress found from the universal tensile testing for the sample one (45/55) fiber matrix ratio is 45.01 N/mm^2 and the maximum stress found from the universal tensile testing for the sample one (50/50) fiber matrix ratio is 46.02 N/mm^2.

Figure 4. 15 *Tensile specimens after the test*

The typical stress-strain behavior of the glass fiber subjecting to the loading on the specimen both edge by gripper with the loading rate of 2 mm/min. The test exhibits stress-strain behavior as shown in the figure until the failure takes place. It was experimentally investigated that every specimen had maximum stress of 42.59N/mm^2,44.18 N/mm^2, 45.01N/mm^2, and 46.02 N/mm^2 for all specimens respectively. And the maximum strain to failure of 5.3%, 5.68%, 8.52%, and 9.42% for every four specimens respectively.

Observation from the experimental tensile test

- ❖ The fiber/matrix ratio did affect the tensile strength of woven mat fiberglass reinforced composite. Comparing the four specimen results by varying the fiber/matrix ratio can increase or decrease the tensile strength.
- ❖ As shown in figure 4.14 the specimen was break near to the side gripper, this needs further study to decide why the specimen not break at the center.
- ❖ The effects of fiber content on the tensile strength is shown in table.4.1 or the results found from the test increase the value of tensile strength by increase the fiber content in the fiber/matrix ratio, which is

- For 25/75 fiber/ matrix ratio is 42.59N/mm2 with the strain percentages of 5.3%.
- For 45/55 fiber/ matrix ratio is 44.18N/mm2 with the strain percentages of 5.68%.
- For 25/75 fiber/ matrix ratio is 45.01N/mm2 with the strain percentages of 8.52%.
- For 50/50 fiber/ matrix ratio is 46.02N/mm2 with the strain percentages of 9.42%.

Though the tensile strength increase in the composite as the fiber content increase in the fiber matrix ratio.

4.2.2 Compression Test

Compressive strength is the capacity of a material to withstand loads tending to reduce the size, as opposed to tensile strength, which withstands loads tending to elongate. Compressive strength resists compression whereas tensile strength resists tension. Compressive strength is so important in deriving the compressive load limit since at times there might be a fracture in the structure at this limit. The compression test results of the four different specimen’s strength values are given below.

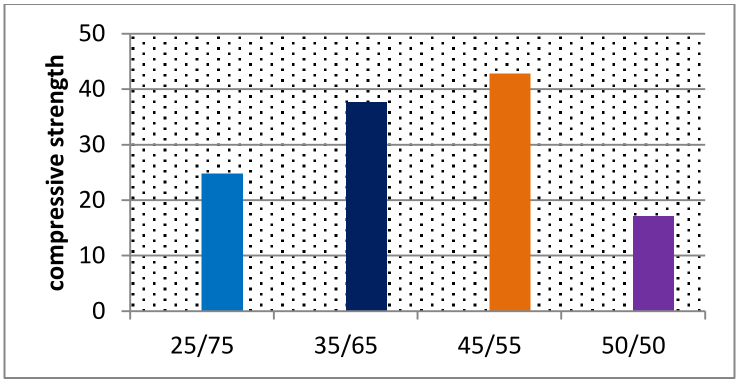


Figure 4. 16 Compressive strength comparison for each fiber/matrix ratio

Figure 4. 17 samples for compression after compression test

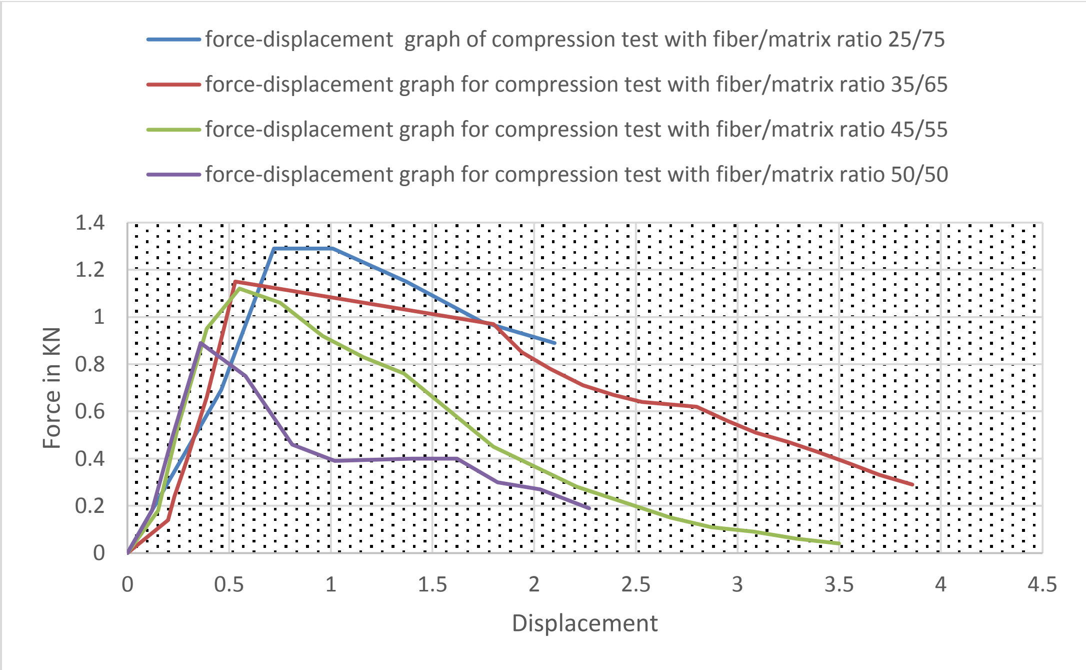


Figure 4. 18 Force-displacement graph for compression specimens.

The maximum responsible stress for the deformation of the reinforced composite materials experienced to reduce the volume due to tension, thus the high compressive stress that leads to failure which recorded from the experiment results is shown in figure 4.16 above.

Observation from the experimental* compressive *test

- ❖ It is possible to observe from the figure 4.16; the compressive properties are analyzed by using compression test. From this test, we conclude that compressive strength for 25% is less than 35% and 45% of glass fiber content but the recorder results at fiber/ matrix ratio 50/50 it is not satisfactory the consequence for lowering of the compressive strength result obtained would be some errors. The result getting from this test is not satisfactory as compared to other results from the literature.
- ❖ The test was conducted on each sample of 4mm thickness for each. The data obtained from the mechanical testing was used to calculate the elastic properties and compressive strength. Compression strength, breaking load were determined at the higher value recorded from the test. Figure 4.16 shows the high compressive strength values recorded at the fiber/matrix ratio of 45/55.
- ❖ The compression force is acting normal to the section of the specimen hence the load distributed thus reinforcement of materials carries the load from the edges of the specimens, with the same thickness of all four samples, when the fiber content increases the compression strength also increase as we can see in the figure 4.16 which is 25%, 35%, 45% of fiber but at 50% of fiber content compressive strength is much less than those three specimens.

4.2.3 Flexural Test

In the flexure test the specimen is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the specimen through one points of contact (upper loading span) until the sample failure take place. The effect of the fiber on the flexural strength of the composite decreased the reason for the decreasing of the flexural strength or the lower strength properties due to the weak fiber to fiber interaction and poor dispersion of fiber with the matrix.

Figure 4. 19 Specimen after flexural test

The maximum recorded force is the flexural strength of that particular sample. Under this part the three-point bending was considered, when the load is applied at the center of the span length (L) between the supports the highest flexural strength can be determined though the formula.

$$\sigma_{f,b} = \frac{3*P*L}{2(b*t^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Since the applied load is on the center of the span length L of the specimen as shown below the deflection of the specimen can be calculated by considering the specimen as a beam, then

$$E_c = \frac{r*L^2}{6t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Then the maximum flexural strain ε_f also calculated from the formula of

$$\varepsilon_f = \frac{6*E_c*t}{L^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The elastic modulus for bending can be determined through the slope of load deflection curve in a linear region and it can be expresses mathematically as.

$$E = \frac{M*L^3}{4(b*t^3)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where

E – Calculated fracture stress (flexural strength), Mpa.

P-Applied load at a given point on the load deflection curve, N.

E_c *– The maximum deflection at the center of the specimen, mm.*

M- The slope of the tangent to the straight line portion of the load deflection beam.

L- The span length between the support, mm.

b- Width of the specimen, mm.

t- Thickness (depth) of the specimen, mm.

r- Strain, mm/min.

S_{max}- The maximum flexural strength of the material.

Table 4. 2 Flexural test results

Specimen designation	S_{max} [N/mm2]	Ec[mm]	E[N/mm^2]
Sample one(25/75)	141.35	5.47	5.89
Sample two(35/65)	131.25	5.47	5.89
Sample three(45/55)	121.15	5.47	5.89
Sample four(50/50)	111.1	5.47	5.89

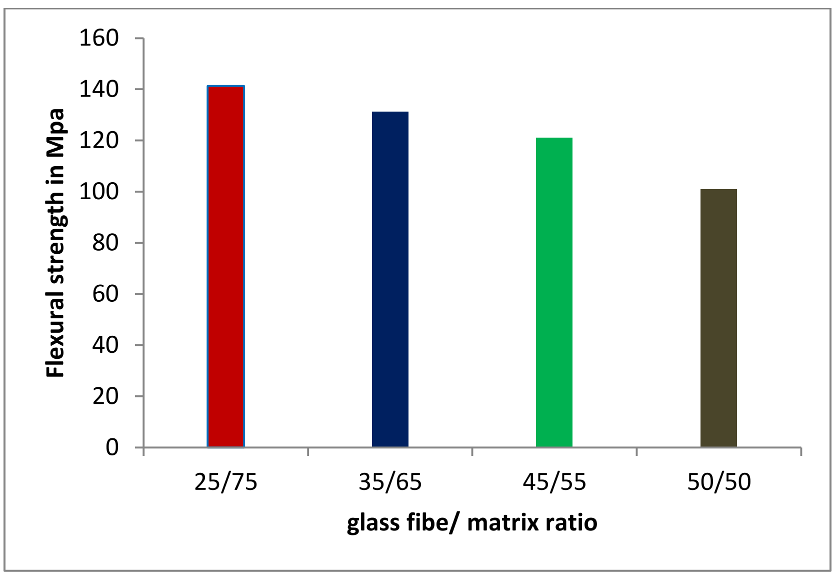


Figure 4. 20 Flexural strength comparisons for each fiber/matrix ratio

Observation from the experimental Flexural test

- As we can see in the figure 4.19 compared the flexural strength for those four fiber/matrix ratio, it is clear that the phenomenon that the higher fiber/matrix ratio of the specimen the flexural strength is decreased (141.35 N/mm2,131.25N/mm2,121.15N/mm2 and 111.1 N/mm2) for the fiber/matrix ratio of 25/75, 35/65, 45/55 and 50/50 respectively. The reason for this reduction might be two reasons, the first reason the Epoxy resin percentage reduction during the preparation of specimen which means the

Epoxy resin covers 75% for sample one, 65% for sample two, 55 % for the sample three and 50% for sample four this might be the first reason. The second reasons might affect the results of the test is the performance of the universal testing machine.

- ❖ The flexural (bending) properties of composites are analyzed under the three-point bending test. From this bending test, the results show that as the % of glass fiber increased the strength of material decreases.
- ❖ Flexural modulus illustrated in figure 4.18since there is no thickness variation which is 4mm for all four specimens and there is no width variation which is 13mm for those all four specimens, the flexural modulus for the test is the same for all of them. Of course, those specimens were prepared with different fiber/ matrix ratio with the same width and the same thickness according to the ASTM standard for flexural strength test of the woven mat glass fiber reinforced composite. When the fiber content increase the matrix content was decreased in the ratio, due to this there might be some error in the flexural testing but it is a great improved flexural strength and flexural modulus which able to use for much automotive body part application in our country, Ethiopia.
- ❖ The result getting from this test is not satisfactory as compared to other results from literature is not satisfactory the consequence for lowering of the flexural strength result obtained.

4.2.4 Water Absorption behavior

The effects of water absorption behavior on mechanical properties of the glass fiber /Epoxy composite can be understood the effect on their constituents. The effect of water absorption on the mechanical properties of glass fiber reinforced composites has been studied slightly by the immersion of the samples in water at room temperature. In those all 13 days the specimen was not reached in its saturation date. In the observation of the water absorption behavior of fiberglass reinforced composite was very slow to reach its maturation period of the specimen. Experimental observation confirmed that the water absorption /moisture absorption might affect the mechanical properties like strength and stiffness to make sure of this, it is very sure that it needs further study on this.

General observation of the study, the study where deals with the E-glass fiber and Epoxy resin were bonded strongly. Which is recorded with the tensile, compression, and bending test due to this test there was the effect that causes the difficulties in the beginning and during the interpretation of the results. Mechanical behaviors of the composites materials are dependent on the arrangements of fiber/ matrix ratio but sometimes due to the internal structure changes might cause deformation that causes changes in mechanical behavior.

4.3 Comparisons present work verses previous work

4.3.1 Tensile test

Different researchers working regarding the tensile strength of the synthetic fiber composite is compared with the current thesis work. From the table 4.3, the tensile strength found in this work is more nearly similar found in between the results of Sudipto sheckhor mondol and kola hari Krishna which is 40/60 with the fiber/matrix ratio and 267N/mm2 results scored and with 50/50 fiber/matrix ratio and the Max results of 80 N/mm2 scored from the Kola Hari Krishna. With the similar fabrication techniques of the glass fiber orientation that can be concluded with the results getting from the present work, fiber orientation is very important for the performance of composites materials. If the performance of the woven mat glass fiber has higher tensile properties for the composite compare with random short glass fiber. Glass fiber has relatively low cost, good strength comparing with other synthetic fibers and it can perform for the automotive body application in the fiber-reinforced composites.

Matrix of the material	Fiber	Fiber orientation	Fiber/matrix ratio	Methods for fabrication	Tensile strength	Reference
Epoxy	E-glass fiber	Woven mat glass fiber	25/75,35/65,45/55, 50/50	Hand lay up	180.63 N/mm^2 (sample. 4)	Present work
Epoxy	E-glass fiber	Woven roving mat	40/60	Hand lay up	267 N/mm^2	Sudipto shakhor mondol [28]
Epoxy	E-glass fiber/ sisal fiber	Chopped sisal and chopped glass fiber	50/50	Hand lay up	70-80 N/mm^2	Kola Hari Krishna [29]
Epoxy	E-glass fiber	Round fiber or Discontinuous	1/1.5	Hand lay up	250N/mm^2	Mr. chavan V.B [30]
Epoxy	Hybrid of E-glass fiber and coconut	Short random fibers	18/82	Hand lay up	40.53 N/mm^2	R.D hemantha et.al [31]

Table 4. 3 Comparison tensile properties of glass fiber composites with previous works

4.3.2 Compression test

The compressive test results carried out in the universal testing machine of four laminates as per ASTM standards the specimen sizes for compression tests were 80mm*13nn*4mm. the compressive test was conducted on the prepared four specimens with the same thickness but different fiber/matrix content. The data used obtained from the mechanical test used to give the final conclusion at the present work and previously worked different researches. The compressive strength of the synthetic fiber is compared with the present thesis work. The compressive strength found in the present study work is recorded between V. Naga Prasad Naidu et.al [38] and Sandhya Rani Borukati et.al [39] compare on the researches on the synthetic fibers. the compressive strength can significantly affect the compression has needs more study on this current work because the length of the fibers has the factor that affect the compression properties of the materials of the compressive strength properties for the long fibers in compression with shorter fibers.

Matrix of the material	Fiber	Fiber orientation	Fiber/matrix ratio	Methods for fabrication	Compressive strength	Reference
Epoxy	E-glass fiber	Woven mat glass fiber	25/75,35/65, 45/55, 50/50	Hand lay up	42.8 N/mm^2 (sample. 3)	Present work
polyester	Sisal / glass fiber	Hybrid composite	With different ratio	Hand lay up	151.497 N/mm^2	V. Naga Prasad Naidu et.al [38]
Epoxy	E-glass fiber/ sisal fiber	Hybrid composite	50/50	Hand lay up	30 N/mm^2	Sandhya Rani Borukati et.al[39]

Table 4. 4 Comparison compressive properties of glass fiber composites with previous works

4.3.3 Flexural test

The experimental investigations on the flexural behavior of glass fiber reinforced epoxy composites with different weight percent of glass fibers have been carried out. The flexural strength is determined on the universal testing machine from the three points bending test. The flexural strength of the glass fiber reinforced composites varies from 100.96N/mm2 to 141.35 N/mm2 and the maximum flexural strength obtained from the glass fiber reinforced composite was 141.35N/mm2. The flexural properties of the present work compared with some of the previous work shows in table 4.4 below. Flexural testing the load applied is perpendicular to the cross-section of the specimen. Hence, the load resisted by the specimen is always higher than the tensile testing. E-glass epoxy composite was found to show superior flexural strength over the tensile strength [31]. The flexural strength which is found in the current work is between S.Pichi Reddy et.al [34] (110.497MPa) and R.D hemantha et.al [31] (177.37 MPa) which is higher than S.Pichi Reddy et.al study results and lower than R.D hemantha et.al study results or researchers work the reason for the variation of results some significant reason will be discussed in the following study and further study will need to figure out why this happening but in general it can be concluded from this work that the glass fiber reinforced composite materials is more suitable to be used in structural parts which need.

Matrix of the material	Fiber	Fiber orientation	Fiber/matrix ratio	Methods for fabrication	Flexural strength	Reference
Epoxy	E-glass fiber	Woven mat glass fiber	25/75,35/65, 45/55, 50/50	Hand lay up	141.35N/mm^2 (sample. 25/75)	Present work
Epoxy	E-glass fiber	Woven roving mat	5/46	Hand lay up	110.497MPa	S.Pichi Reddy et.al [34]
Epoxy	E-glass fiber	Woven roving mat	26/74	Hand lay up	232.84 MPa	Shaik Javeed et.al [35]
Epoxy	E-glass fiber	Woven roving mat	15/85	Hand lay up	228MPa	G. Devendhar Rao et.al [37]
Epoxy	Hybrid of E-glass fiber and coconut	Short random fibers	18/82	Hand lay up	177.37 MPa	R.D hemantha et.al [31]

Table 4. 5 Comparison flexural properties of glass fiber composites with previous works

CHAPTER FIVE: CONCLUSION, RECOMMENDATION AND FUTURE WORK

5.1 Conclusion

Glass fiber reinforced epoxy composite was manufactured and its mechanical performance such as the tensile, compression and flexural properties is determined using laboratory experiment. All the experimental test results gathered an important information about glass fiber reinforced epoxy composite Based on the tensile, compression and flexural properties experiment data studies in this work, few points can be concluded as follows:

- Different mechanical properties of glass fiber reinforced composite materials were determined from different glass fiber to resin percentage ratio.
- The tensile strength of glass fiber woven mat/Epoxy composite material is higher in 50/50 fiber/ matrix ratio as compared with others.
- The Experimental results shows that glass fiber reinforced composite materials exhibits maximum compressive strength of 42.8MPa at 45/55 fiber matrix ratio as compared with other glass fiber reinforced composite materials.
- The experimental results indicate that the glass fiber woven mat/Epoxy composite material has higher flexural strength at fiber matrix ratio 25/75 as compared with others glass fiber woven mat/Epoxy composite material.
- The study shows the effects of water absorption on the mechanical properties of glass fiber reinforced composite materials by immersion of the sample with water at room temperature. It shows that water absorption increases with respect to increase the immersion times increase. It can conclude that the results suggest the glass fiber reinforced composites the water absorption can have a positive effect on the mechanical properties.
- As a conclusion glass fiber/matrix Epoxy composite system has very high mechanical performance, because of that this research gives the confidence to offer it’s for the industrial application such as multi-purpose materials as substitute materials.
- For general suggestion, the glass fiber woven mat/Epoxy composite materials test results were not satisfactory because some uncomfortable fiber/ matrix needs further study on the composite's specimen especially Compressive and flexural properties Tests), also

water absorption behavior of glass fiber were not satisfactory it needs telescopic graphics analysis.

5.2 Future Work

In this thesis mechanical characterization of glass fiber reinforced composites and water absorption behavior was studied. The study is restricted to specified cases. The study can throw more light into the application of glass fiber composite for automotive application; to increase the possibility of finding the appropriate glass fiber for Automotive body application depends on the accurate knowledge of the fabrication and proportion of glass fiber and the matrix material. However; this paper can be extended to another situation listed below.

- Characterization can be done by using different type's synthetic fibers to improve the strength.
- Characterization of the fibers can be done by using different fabrication techniques on glass fiber reinforced composite.
- Mechanical Characterization of the glass fibers with different glass fibers types by using short fiber Mat type.
- Mechanical characterization of glass fiber reinforced composites if the fiber content in the ratio with the matrix is greater than the weight of the Epoxy resin.

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