ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

Manufacturing and Investigation on Mechanical Properties of False Banana Fiber and Glass Fiber Composite Material for Vehicles Body Panel

A thesis submitted to Adama Science and Technology University in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering.

by

Adugna Diriba

Mechanical System and Vehicle Engineering Department

June, 2018

Adama, Ethiopia

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Advisor: Mr. N. Ramish Babu (Asst. Prof.)

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APPROVED BY THE EXAMINERS BOARD

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LIST OF ABBREVIATIONS, SYMBOLS AND ACRONYMS

FBF	False Banana Fiber
FG	Fiber glass
ASTM	American Standard for Testing Materials
DAVI	Dejen Aviation Industry
Gp- Resin	General Purpose Resin
UTM	Universal Testing Machine
ECAE	Ethiopia Conformity Assessment Enterprise
ASTU	Adama Science Technology University
Gp-Hardener	General purpose resin
Gp Jell coat	General purpose top coat
FBFGFREC	False banana fiber and glass fiber reinforced epoxy composite
METEC	Metal and Engineering Corporation
FRP	Fiber Reinforced Polymer
NaOH	Sodium hydro oxide
TPO	Thermoplastic Olefins
Eq.	Equation
NF	Natural fiber
ISO	International standard organization
PBI	Polybenzimidazole
BMI	Bismaleimides

ABSTRACT

The need to develop less expensive and durable natural composite body is necessary for both automotive dash board and body panels. The main target of this paper was to prepare the composite material from the hybrid of false banana fiber (FBF) and fiber (FG) glass with epoxy binder for mechanical tests and sample production at the end. The proportion of false banana to fiber glass is 60% of fiber glass and 40% of false banana fiber to look for results on different arrangement, orientations (0^0,$\pm 45^0$,(0^0 ,90^0)) without varying volume of both FBF and GF. This thesis was focusing on the effect of mechanical properties like tensile strength, bending (flexural) performance and water absorption of the false banana fiber and glass fiber as a composite material for further production of vehicle body panel to replace the damaged one. This thesis covered the methodology to the required mechanical and physical properties composite by proper mixing and treating with chemicals NaOH. Two sheet metals were prepared for FBFGFERC fabrication in the shop using AUTOCAD design and also molded different fiber orientation (0^0, 45^0,(0,90^0)) had been prepared. This also showed how to produce vehicle panels locally to replace the damaged panels of the vehicle. The overall tensile strength result showed that from FBFGFERC zero degree fiber orientation had shown 144.67MPa which is higher than forty five degree and zero ninety degree of fiber orientations. In a compressive strength test also 48.54 MPa which was higher result is obtained from the zero ninety fiber arrangements. In the case of both bending strength test and water absorption test, 2713.33N and 4.96% water intake obtained from the zero ninety which is relatively less obtained from zero degree fiber orientations. The results obtained from different mechanical and physical test showed that vehicle body panel is better to be produced from the zero and zero ninety degrees of fiber orientations. It is concluded that it is possible to use locally available false banana fiber for fabrication of vehicle body panels which brings economic benefits to both farmers and local vehicle body maintenance garages. False banana fiber is also recommended to prepare the composite materials for construction of the vehicle body panel due to the facts minimizing the importation of car body panels from abroad and facilities for preparation and testing of composite materials.

Key words*: false banana fiber, glass fiber, lightweight, body panels, fiber reinforced Composites,*

CHAPTER ONE

INTRODUCTION

1.1 Back ground

As we know all the previous vehicles body was manufactured from steel sheet metals which are very heavy to the vehicles resulting in many problems like fuel consumption, production cost of metals, and more exhaust emission, less power. The demand for less fuel consumption and minimum emission saving in the automobile industry has increased significantly over year to year. One of the issues to reduce amount of fuel energy consumption is weight reduction of the vehicle body. A new idea in technology material was introduced with polymeric based composite materials, which is free of rusting (corrosion free), better specific stiffness, longevity less weight, yet capability according to manufacture complex shapes, exceptionally greater specific strength, then high impact energy absorption. Replacement of polymeric based (non-metallic) composite material in automobile body parts was efficiently implemented for the reductions of fuel consumption and vehicle weight [1].

Previously, the materials used in the manufacturing of vehicle bodies are mainly from the various types of steel. Aluminum-metal also implemented for executive class car bodies, and then later on used to other car classes. Plastics materials were mainly dominate the vehicle interior dash panels production, but for external application is limited due to non-load carrying components although recently plastic materials are being introduced on some vehicle body parts like engine sub-frame and frontal and rear bumpers subparts for the reduction of the vehicle toughness body ounce as well namely occupant or pedestrian protection improvement [3, 4].

Different fiber reinforced composite materials have been broadly used in various vehicle body structures due to their high damping capability and specific strength, modulus. When the composite materials are added to vehicles body panels, it is expected that total weight of the vehicle, noise and vibrations are dramatically reduced. Additionally, composite materials in the automotive body have a very high resistance to corrosion and fatigue [2].

Therefore to use natural resources and economize fuel energy consumptions, vehicles weight reduction has been the main goal of automobile factories in the present time. Vehicle weight reduction can be optimized mainly by introducing of better material, design optimization and better manufacturing processes [3].

Because of rising in demand of more mechanical efficiencies of materials and lightweight vehicle in automobile product applications, different material combined and acts as a body parts such as plastic, composites, rubbers and light weight metals are implemented on primary and secondary structural body parts of vehicles. Most automobile industries are applying different types of composite materials in body part paneling like different pillars, roof, dashboard, floor, front and rear bumper [3,5].

In this work, fabrication of composite with different fiber orientations and mechanical property test of the false banana fiber and glass fiber reinforced epoxy composite material is the main goal to replace the damaged metallic materials local garages.

Automotive industry is nowadays direction toward a new path, comprising introduction of composite materials extracted from plant fibers as a substitute of glass fibers as durable and good as reinforcing agent. Their commonly known thickness (around 1.5 towards 2.5 because of glass) durability for glass) associated with their high mechanical properties bring automotive manufacturers new opportunities for a lightweight design approach. For example, the production about flax fibers as like reinforcing aspect brings decrease environmental impacts than production concerning glass fibers. Static features concerning bio-composites such as PLA/Flax/Balsa bio-sandwich shows numerous environmental benefits in contrast after those regarding glass/polyester composites durability and sandwich counterparts [13]. Some vehicle metallic body parts are substituted by polymeric based composite material in automotive components was successfully and smoothly implemented for fuel and weight reduction.

1.2 Statement of the problem

Reduction of weight of the vehicle by employing lightweight materials for reducing fuel consumption there by pollution is a major challenge faced by vehicle producers as well as much the accident and street irregularities. Ethiopia is very much dependent on importation of body panels either for building the body or to replace the damaged panels. So there is an urgent need to develop light weight composite materials with local available natural fiber for fabrication of vehicle body panels. Recently, there is dramatic material and design change all over the world not only for car body but also on other engineering fields. Nowadays automotive assembling industry numbers are increasing in Ethiopia on both governmental and private institutions specially in government hand there are medium sized and long city buses for different cities are rebuild by Bishoftu Automotive and Locomotive Industry under Metal and Engineering Corporation (METEC) in Bishoftu and dire dawa Ethiopia. Like vehicles body panels most of the air force craft bodies are produced in Dejen Aviation Industry using fiber glass except the power unit (engine). The need of this fiber glass composite body for spare part is expensive and not environment friendly when it is needed to replace at the time of vehicle body damage occurring due to different conditions and accidents. Therefore Ethiopia is depending on other countries to bring or importing those synthetic fiber and other row materials for the fabrication of light weight car body parts, Therefore these can lead the company to lose the income, deny the country's resource to be used and also cause pollution on Environment during the Disposal of the used Composite Material.

Therefore this paper tries to minimize the above problems which occurs on the composite manufacturer here in Ethiopia by the use of false banana fiber and fiber glass reinforced Epoxy hybrid composite material for the production of vehicle body parts locally in both small and large vehicle body maintenance garage which contributes directly to the vehicles industry and indirectly to Ethiopia's ability to minimize or save hard currency and provides expanded opportunities from the rural people those planting false banana plant up to the composite production factory (garage)[28].

1.3 Objective

1.3.1 General objective

The general objective of this thesis is to manufacture vehicle body panel from false banana fiber and glass fiber composite materials.

1.3.2 Specific objectives

The specific objectives of this thesis are as follows

- ✓ To extract residual nutrients and treat fiber from false banana plant.
- ✓ To prepare composite material of false banana fiber and glass fiber.
- ✓ To test the mechanical properties of composite material prepared.
- ✓ To fabricate a vehicle body panel (bumper) using best result composite material.
- ✓ To make the finishing work of composite material.

1.4 Significance

Plant fibers are emerging as low cost, lightweight yet apparently environmentally superior options to glass fibers among many composites. Producing reinforced composites locally from false banana fiber and glass fibers are increasing the use and replacement of sheet metals car body using in transportation and automotive applications due to their overall production rate, mechanical performance, lightness, chemical stability, recovered energy, carbon credits and end-of-life recyclability. False banana fibers are biodegradable, easily available, and low cost and provide an opportunity for the utilization agricultural product and helping to develop rural industry. Since natural fibers are non-abrasive, non-corrosive and minimizes deforestation of a country and also resulting in reduced material consumption hence tool wear cost can be reduced.

Beside that it has also extra advantages (benefit) like:-

- ✓ Low density and high specific strength and stiffness
- ✓ False Banana fibers are a renewable resource, for which production requires little energy, involves CO_2 absorption, whilst returning oxygen to the environment
- ✓ False Banana fibers can be produced at lower cost than synthetic fiber
- ✓ Low hazard manufacturing Processes and easy for disposal
- ✓ Low emission of toxic fumes when subjected to heat and during incineration at end of life
- ✓ Less abrasive damage to processing equipment compared with that for synthetic fiber composites
- ✓ Fbf and fg will have a good dielectric effect (good insulation) on modern vehicles to avoid signal and electric wires from short circuiting or unwanted grounding

The targeted beneficiaries are false banana (enset) plant farmers, automobile industries, garages, researchers in this field society and country as a whole.

1.5 Scope

This thesis work is delimited to the preparation of composite material samples with varying orientation of false banana fiber and fiber glass. Testing of the sample specimen with the available testing facilities and body panel modeling using AUTOCAD software also tried. This study experimentally explores the feasibility of using false banana fiber and glass fiber reinforced epoxy composite material in automotive industry. The mechanical properties like tensile strength, compressive strength and bending strength and water absorption of FBFGFREC were tested.

Construction of the prototype of the vehicle body panel with FBFGFERC material is also included.

1.6 Limitations

Many obstacles were faced during the execution of this thesis work. There is no sufficient literature available related false banana fiber and glass fiber reinforced composites material, and fabrication of vehicle body using composite materials. Finding testing machine facilities was another big challenge. Fabrication of vehicle body panel is time consuming process. There is a shortage of time. Most of the literature reviews contents are found from journals and some books searched from internet. It was impossible to get a well organized laboratory that can test all the required tests. For instance tensile Strength was tested in Ethiopia Conformity Assessment Enterprise(ECAE),water absorption was tested in ASTU material Engineering laboratory and the remaining compression and bending test were performed in ASTU mechanical Engineering material test laboratory; There is no highly competitive laboratory setup for the testing of natural fiber and fiber glass composite and no fully established workshop for the fabrication of composite material.

Finally, since only four Mechanical Properties are investigated towards the use of FBFGFREC for automotive body application, it seems not to provide sufficient information or evidence of FBFGFREC to use as one of a vehicle body panel. The material, process and molding time to prepare these samples are also not as perfect as compared to the specialized composite companies because we are using only the materials available in ASTU, MSVE work shop.

Hence, It was very difficult to obtain the materials related to this thesis like fiber glass, epoxy resin, hardener, jell coat and others mixing and hand lay-up brushes.

1.7 Organization of thesis

This thesis report focuses on preparation of false banana fiber and glass fiber reinforced epoxy composite materials, testing the properties of prepared composite material and fabrication of vehicle body panel. All the methods, results, discussions and conclusions and recommendations are briefly stated.

The thesis comprises six chapters.

Chapter 1: Introduction which Introduced the background of natural fiber and glass fiber composite materials and this project objectives. Statements of the problems, general and specific objectives of the study, Significance of the study (Benefits), Scope and limitations.

Chapter 2: Literature review which reviewed mostly relevant and recent research journals, papers regarding natural fiber composite materials, banana fiber composite materials, glass fiber composite materials ranging from polymer types, glass fiber types, and composite's chemical, mechanical properties. Recent researches on false banana fiber reinforcement on polymers are widely reviewed.

Chapter 3: Materials and methods introduced. All non consumable and consumable materials in laboratory work for FBFGFREC preparation and related Experimental testing equipment(power tools)supporting to this paper covered to get mechanical Properties of false banana fiber and glass fiber reinforced epoxy composite. The preparation and production method of test specimen and the whole procedures are discussed here.

Chapter 4: Result and discussion introduced. All the Mechanical Properties are investigated. The experimental plan for investigation of, tensile, compressive, bending properties and water absorption of false banana fiber and glass fiber reinforced epoxy composites are covered and discussed in detail.

Chapter 5: Summary, conclusions and recommendations. This chapter includes the conclusion, Scope for future work recommendations for future works of this thesis report. Conclusions describes the application of the validated FBFGFREC matrix orientations to vehicle body panel application Comparing all the above listed mechanical properties with previous works on banana fiber and glass fiber reinforced epoxy composite material. The recommendation and future research direction in this area of false banana fiber and glass fiber hybrid composite materials will be discussed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Composite Material

Composite materials are becoming more important in the construction of buildings partitions beautify, automobiles body panels like interior and exterior parts, materials for machines and industries and aerospace structures. Now days automobile internal parts like dash panels and binder plate on the internal parts of the panels are made from composite materials, such as front and rear bumper, spoilers, air dams, corner vanes, dash boards, mudguards, aero foils ,cab roof deflector ,cab to trail body gap seals, tractor and trailer skirting for drag reduction ,extended side panels on heavy duty trucks for body edging and flight controls for air planes , were developed during the 1960s for their weight savings over steel and others types of metals . New generation small and big automobiles are designed with partial composite substances systems and the repair of these superior composite materials calls for in-depth abilities over made-up composite systems, materials, and tooling. The number one blessings of composite substances are their high strength, especially low weight, and corrosion resistance. Since the 1990s, natural fiber composites are emerging so sensible alternatives according to glass-reinforced composites into much applications. The idea concerning the usage of cellulose fibers namely reinforcement in compound materials is not a current yet latest some. Peoples had used this idea for a long time, since the beginning of our civilization when grass and straw were used to reinforce mud bricks.

Based on Autar K. Kaw: „Mechanics of Composite Materials‟. Taylor & Francis Group, 2006. [6], A composite materials are as a whole engineered materials made from more than one constituents with different physical or chemical properties, which and distinct within the completed structure, remain unique and wonderful inside the finished structure.. The composite material should additionally have properties which overcome the properties of the individual constituents that make up the composites [6, 7]. Generally the composite materials consist of a matrix reinforced with particles or fibers. Natural fibers had been used for reinforcing purpose till before long in to after the mid 20th century. Plant fibers were used for reinforcing purpose with in to the mid twentieth century. However since 1950 there was an extended demand for stronger and stiffer, but light weight, composites, in fields such as aerospace, transportation and construction. This enhances to produce the incorporation of high performance fibers for reinforcement. Those newer composites have relatively low specific gravity, more strength and modulus of elasticity comparing to the traditionally engineering materials like metals [8].

The interest in natural fiber reinforced polymer composite is rapidly growing both in terms of industrial applications and basic research. The availability, renewability, biodegradability, low density, low cost and satisfactory mechanical properties of the natural fibers make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites [9–11]. High performance thermoplastic/natural fiber composite materials offer significant potential advantages than thermo sets including higher damage tolerance, unlimited shelf life, faster component manufacturing time and greater recyclability. The main attraction of thermoplastic composite materials lies in the possibility of achieving very short remolding times as no chemical reaction is required. Because of the high viscosity of the thermoplastic matrix material, it is generally not easy to properly impregnate a fiber reinforcement lay up during the manufacturing process. Due to these difficulties in resin impregnation, intermediate materials that are partially impregnated have been developed which offer a route to more efficient manufacturing of thermoplastic composites [12, 13].

In general, the processing of thermoplastic composites is classified into two categories: pre impregnation and post impregnation. In the former case, the fibers are wetted and impregnated by the polymer in one step. The pre-impregnated fibers can be prepared by solution mixing or melt mixing. In post-impregnation, the polymers are available in the forms of film, filaments, or powder [14]. The fibers and the polymer are mixed in a desired manner without any adhesion or bonding. Impregnation takes place during part fabrication. The polymeric fibers can also be mixed with reinforcing fibers to form a commingled bundle, which can be used in various applications. With commingling a good blending of matrix and reinforcement fibers is possible [14]. He studied the effect of the commingling process variables, namely air pressure and volume fraction of the matrix forming fibers on the structure and properties of Glass/polypropylene, Glass polyester and Glass nylon commingled yarns [15]. Another researcher reported the visco-elastic behavior of commingled composites of polypropylene reinforced by 22, 35, and 50 % by volume of unidirectional glass fibers, by taking into account qualitative and quantitative morphological analysis [16]. The aim was to separate the mechanical properties of the different phases in order to reveal the presence of either an enter phase or changes in PP chain motions due to the fiber aggregates. They investigated the properties of thermoplastic composites reinforced by flax fabrics [17].

2.2 False banana fiber extraction

There are two ways of false banana fiber extraction adopted. These are stripping and decortications by a decorticator.

2.2.1 Stripping

The most widely used and oldest method of removing fiber from the leaf sheaths consists of two basic operations: first, separating the fibrous outré layer from each leaf sheath, this outer layer being termed "tuxy" and the operation "tuxying"; and second removing pulpy material, thus freeing the fiber strands from the tuxy, the operation being termed stripping or cleaning. Both operations have to be performed as soon as possible after the stalk is felled. The tuxying operation is usually done in the field. The workman inserts a point of knife between the outer and middle layers of the leaf sheath, freeing an end of the outer layer 1 to 3 inch wide. This strip or tuxy is pulled off the entire length of the sheath. Each leaf sheath furnishes 2 to 3 tuxies. When all tuxies are removed from the leaf sheath, it is removed from the stalk and allowed to remain on the field for organic fertilizer. Usually another workman picks up the tuxies and carries them to the place where the stripping or cleaning operation is to be performed [21].

2.2.2 Decortications

False banana fiber is also cleaned by means of a decorticator. Small spreaders machine used to separate fibers form the stem of the plant.

Initially the Pseudo stem is abstracted form the fully grown trunk. The stem is kept under the sunlight for 15 – 20 days. Then the dried fibers were soaked in water for at least 20days. Again it is dried under the sunlight until all the moisture is taken out. And finally the stem is cut horizontally and then the fibers are extracted.

Mature banana pseudo-stem was obtained from farm and was cut into length of 500 mm shied longitudinally into four pieces and each was totally submerged in water for 15 days The stems from banana plants (Musa paradisiaca) were selected from an 11-month-old plantation. The plantation is located 1,050 meters above sea level, has 22.5ºC average temperature, 76% relative humidity, 2.100 mm annual rainfall, 6.1 soil PH and 2,010 hours annual sunshine .The two figure 2.1 and figure 2.2 are showing false banana plantation and extraction process for separation of food and fibers.

Figure 2.1 False banana plantations

Figure 2.2 Extraction of food and fiber from false banana

The dried and treated fiber were dried in an oven or subjected to sun light for 5 to 7 days in order to remove free water, and then cut to required dimension.

In the world of materials the development of composites material the most common advanced materials in the later part of 20th century has given a boost to the engineering field. Composites were developed mainly with the considerations high strength and light weight. The aerospace and defense sectors are responsible for this growth, which always gave thrust for light weight but high strength material. However, nowadays, all the fields of life like Civil, transportation, medical and general construction industries are also extensively using composite materials. The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses In the world of materials the development of composites material the most common advanced materials in the later part of 20^{th} century has given a boost to the engineering field. Composites were developed mainly with the considerations high strength and light weight. The aerospace and defense sectors are responsible for this growth, which always gave thrust for light weight but high strength material. However, nowadays, all the fields of life like Civil, transportation, medical and general construction industries are also extensively using composite materials. The word composite in the term composite material Signifies that two or more materials are combined on a macroscopic scale to form a useful third material. Naturally, not all of the properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another, e.g., thermal insulation versus thermal conductivity. The objective is merely to create a material that has only the characteristics needed to perform the design task.

The interest in natural fiber-reinforced composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocelluloses fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products etc. Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. 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. There are several methods of random fiber orientations, which in a two-dimensional one, yield composites with one-third the strength of a unidirectional fiber-stressed composite, in the direction of fibers. In a 3- dimension, it would result in a composite with a comparable ratio, about less than one-fifth. In very strong matrices, moduli and strengths have not been observed. Application of the strength of the composites with such matrices and several orientations is also possible. The longitudinal strength can be calculated on the basis of the assumption that fibers have been reduced to their effective strength on approximation value in composites with strong matrices and no longitudinally orientated fibbers. It goes without saying that fiber composites may be constructed with either continuous or short fibers. Experience has shown that continuous fibers (or filaments) exhibit better orientation, although it does not reflect in their performance. Fibers have a high aspect ratio, i.e., their lengths being several times greater than their effective diameters. This is the reason why filaments are manufactured using continuous process. This finished filaments. Mass production of filaments is well known and they match with several matrices in different ways like winding, twisting, weaving and knitting, which exhibit the characteristics of fabric. Since they have low densities and high strengths, the fiber lengths in filaments or other fibers yield considerable influence on the mechanical properties as well as the response of composites to processing and procedures. Generally, not much of the papers have published on the banana fiber reinforced Epoxy composites.

He conducted the experiments of tensile and bending strength tests were carried out using natural fiber with composite materials (woven banana fiber/epoxy).

They found its material characteristics(bending modulus, flexural rigidity, hardness number,% gain of water) by conducting tests like flexural test, hardness test, water absorption test, impact test, density test, and their results are measured on sections of the material and make use of the natural fiber reinforced polymer composite material for automotive seat shell manufacturing. It is found that polymer banana reinforced natural composites is the best natural composites among the various combination. It can be used for manufacturing of automotive seat shells among the other natural fiber combinations [17]. Another researcher studied the Influence of polarity parameters on the mechanical properties of composites from polypropylene fiber and short banana fibre.BF surfaces were modified chemically to bring about improved interfacial interaction. The polarity parameters of the chemically modified BF were investigated using the solvatochromic technique. It was found that the polarity of the BF was decreased after the chemical treatment. The fiber/matrix interactions were found to depend on the polarity of the BF. The improved fiber/matrix interaction was evident from the enhanced tensile and flexural properties. The diameter of the chemically modified BF was measured using an optical microscope.

The incorporation of fiber into rubber matrix increases the hardness of the composite, which is related to strength and toughness. The close packing of fibers in the compounds increases the density while resilience decreases. The composites made from 15mm length banana fibers shows the maximum tensile strength and good tear strength [18].

He did the experiment on the synthesis of bio –degradable banana fibers. Reinforcement provides strength and rigidity to help and support the structural load. Polymer matrix composites are widely used but the mechanical properties of polymers are inadequate for many structural purposes [19].

In practical their strength and stiffness are low compared to ceramics and metals. These difficulties are overcome by reinforcing other materials with polymers. Applying natural fibers as reinforcing material in polymer composites is underway in various researches. In India, banana is abundantly cultivated. Banana fiber can be easily obtained from the pseudo stem after the fruits and leafs are utilized. These researchers have been involved number of investigations on several types of natural fibers such as bamboo, kenaf, hemp, flax, and jute to study the effect of these fibers on the mechanical properties of composite materials[20]. Other researchers are studied the mechanical properties of tensile, flexural, impact and water absorption tests were carried out using banana/epoxy composite material[21]. They studied the effect of alkali and SLS (Sodium LaurylSulphate) treatment on Banana/Kenaf Hybrid composites and woven hybrid composites. Thermosetting resins are costly and the thermosetting resins commonly used in engineering application are epoxy which has better mechanical properties. The thermoplastics of recycling possibilities whereas the thermo sets achieve improved mechanical properties. Polyester resins are low cost materials. Vinyl ester resins make a compromise between the above two limits. They have low properties comparing with epoxy, but are available at low cost. He conclude that Banana fiber have a good specific strength properties comparing to those of conventional materials like glass fibers. He also studied that banana Material has lower density than glass fiber specially a banana fiber those were treated with Alkali treatments (Na OH) have been proven effective in removing impurities from the fiber, decreasing moisture absorption and enabling mechanical bonding and thereby improving matrix reinforcement interaction.

The important part of this study consisted of uniaxial compressive tests done with natural fiber mixtures. Thus, the results obtained from mechanical tests were presented in the form of stress–strain graphs. In addition, mechanical properties were related to the water content for workability, unit weight and fiber contents and discussions were given. The results show that as fiber content increases, compressive and tensile strengths decrease, and shrinkage rates decrease [22].

Mishra et al. (2003) the impact and tensile behavior of epoxy resin reinforced by oil palm/glass fiber was investigated. He investigated the effect of the hybridization of sisal/glass and pineapple/glass-polyester composites on the moisture uptake characteristics of composites. The authors observed that water absorption of the hybrid composites were less than that of un hybridized composites [23].

2.3 Bio-composites

Bio composites are composite materials made from natural/bio fiber and petroleum based plastic renewable resource based plastic. Composites produced from synthetic fibers and biopolymers could also be called bio composites. The bio composites derived by combining plant derived fiber with bio-derived plastic are likely to be more eco-friendly [24, 25], thus, reducing the environmental challenges. Being environmentally-friendly and sustainable are the major attractions for 100%biocomposites. These bio composites are suited for simply disposing or composting at the end of their life without damaging the environment or can be recycled by energy recovery. These composites are defined as composites that are designed with the lowest possible environmental foot print. Some of the biodegradable matrices (natural and synthetic) that can be applied for making bio composites [24, 25].

Advantages of bio-composites

The composites reinforced with natural fibers like banana are abundant, cheaper and of low density, biodegradable and carbon dioxide-neutral. Banana fiber has the potential to compete with glass fiber, as reinforcing agents in plastics. Jute composites are true substitute of wood. A range of products that are presently being produced from jute composites are sheet/board, door, window, furniture, corrugated sheet, etc

• Unbreakable, maintenance free, durable

- Fire retardant and water resistant
- UV, acid and alkali resistant
- Less abrasive
- Less costly
- Low thermal conductivity (good dielectric effect)
- Biodegradable
- Renewable
- Eco-friendly

2.4 Hybrid composites

One way of deliberately regulating the properties and performance of composite materials is to use hybrid fibrous fillers (synthetic or natural fiber) into a single matrix. It will give these composite materials specific properties, and allow for the expansion of the area of their application. Its functionality depends on the balance between the properties of each individual component. The properties of a hybrid composite depend directly on the fiber content, length of fibers, arrangement and orientation of both the fibers and also fiber-matrix bonding [21].

2.5 Previous Works

Rahman et al. One way of deliberately regulating the properties and performance of composite materials is to use hybrid fibrous fillers (synthetic or natural fiber) into a single matrix. It will give these composite materials specific properties, and allow for the expansion of the area of their application. Its functionality depends on the balance between the properties of each individual component. The properties of a hybrid composite depend directly on the fiber content, length of fibers, arrangement and orientation of both the fibers and also fiber-matrix bonding [26].

Satish Pujari et al. They considered that One of the major problems of natural fibers in composites was their high moisture sensitivity and causing reduction of mechanical properties and delaminating. This may be due to poor interfacial bonding between resin matrices and fibers. They tried to modify the fiber using graft copolymerization. The resulting co-polymer displays the characteristic properties of both fibrous cellulose and grafted polymer. One of the most explored chemical modifications is the acetylating-esterification of cellulose-OH, by reaction with acetic anhydride. This was reduced hydrophilicity and Swelling of lignocelluloses and their composites.

From the experiments he observed that Tensile Strength of banana fiber has 529-914 (Mpa) which is better than 200-450MPa of jute fiber and around 27-32 Young's Modulus (Gpa) better than 20-55 (Gpa) of jute fiber [27].

Mehamud et al. studied on Mechanical Property Evaluation of Ethiopia Banana Fiber Reinforced Polymer Composites. He prepared four sets of samples, the first one set was 5% banana fiber with 95% epoxy resin, the second set was 10% banana fiber with 90% epoxy resin, third set was 15% Banana fiber with 85% of epoxy resin and fourth set is 20% Banana fiber with 80% of epoxy resin, For all of the specimens the arrangement was 0/90 degree (straight unidirectional) orientation

He observed that tensile strength that 20% banana fiber and 80% epoxy resin scored 56.5 MPa, 15% banana has 47.4 MPa. , 10% banana has 42.6 MPa and 5% banana fiber which have only 37.8 MPa. When fiber concentration increases the tensile strength also increases. In his Impact tests showing that 20% and 15% banana unidirectional scored higher impact strength than other fiber samples. For bending strength result also shows that 20% banana fiber/ epoxy unidirectional exhibits 340.625 MPa which was better than other banana fiber percentages [28].

Ashwani Kumar et al. Studied on the development of glass/banana Fibers Reinforced Epoxy Composites. He prepared 30%, 20% and 10% weight fraction of fiber reinforcement for both GFREC and BFREC. On the experiment he observed that 30% weight fraction of fiber scored more mechanical properties than those of 20%, and 10% weight fraction of both Glass Fiber as well as Banana Fiber reinforcement. The experimental results show that GFREC had more Tensile Strength and bending Strength than BFREC. Again he hybridized GFREC with BFREC varying wt. Finally he showed that hybrid matrix had greater tensile Strength and bending Strength than both GFREC and BFREC. Finally he has been noticed that by adding a small wt. percentage of Banana Fiber in GFREC it is possible to enhance its properties to a great extent. The Hybridization of Banana Fiber and Glass Fiber not only improve the mechanical properties of FRP composite but also reduce its cost and make it Eco Friendly composite[29].

Shashank T.A et al. Studied on the fracture toughness of hybridized glass fiber and banana fiber with the ratios of banana fiber with 15, 20, 25 and 30% were hybridized with 20, 15, 10 and 5% of glass fiber to form composite materials. He compared the above materials with 35%glass fiber and banana fiber. Using ASTM D5045 he observed that the fracture toughness of non-hybridized 35% banana fiber showed highest fracture toughness value and 35% glass fiber showed the least one [30].

G Gupta et al. he studied on the hybrid composite material composed of glass fiber (20 wt %) and banana chopped filler (5 wt%, 10 wt%, 15 wt %) plus polyesters. He tried to look the results of tensile strength, bending strength, hardness and impact strength of all the specimens. The results he obtained indicating that the maximum tensile and bending strength obtained at 15wt% chopped banana filler loading. But could get the good hardness results between (5wt% to 10wt %) of chopped banana fiber range only [31].

M. Ramesh et al. worked on "Processing and Mechanical Property Evaluation of Banana fiber reinforced polymer pomposities "using40% banana fiber + 60% Epoxy resin, 50% banana fiber + 50% Epoxy resin and 60% banana fiber + 40% Epoxy resin. He observed that the tensile strength of 50% banana fiber + 50% Epoxy resin are better than others two composites and for bending strength and impact tests the 60% banana fiber + 40% Epoxy resin was best than others [32].

Many interesting studies have been conducted to explore different hybrid composites with different applications. The impact and tensile behavior of epoxy resin reinforced by oil palm/glass fiber was investigated by [33].Investigated the effect of the hybridization of sisal/glass and pineapple/glass-polyester composites on the moisture uptake characteristics of composites. The authors observed that water absorption of the hybrid composites were less than that of hybridized composites. In an interesting research, the hybrid bio composites were made by pineapple and sisal fiber reinforced thermo sets and thermoplastics resins. The authors dealt with the structure, composition and properties of hybrid bio composites. The mechanical performance of short, randomly-oriented, sisal-banana hybrid fiber reinforced polyester composites was investigated. A positive hybrid effect was observed in the flexural and tensile strength and modulus of the hybrid composites. The tensile properties of knead fiber/wood flour-polypropylene hybrid composites were investigated. The possibility of improving the outdoor properties of NFCs needs to be investigated. Therefore, studies on improving the mechanical properties and specifically reducing the water absorption in NFCs need to be done. Making a composite system consisting of two different fibers with different morphologies may be a good solution. The poor mechanical properties of baste fiber reinforced composites can be improved by admixing cellulose fibers to baste fibers. The effects of the admixture of

Lyocell fibbers with flax fiber reinforced polypropylene composites on the mechanical properties. Further investigation was carried out by. Composites of the fiber mixtures of hemp/Lyocell were investigated [33].

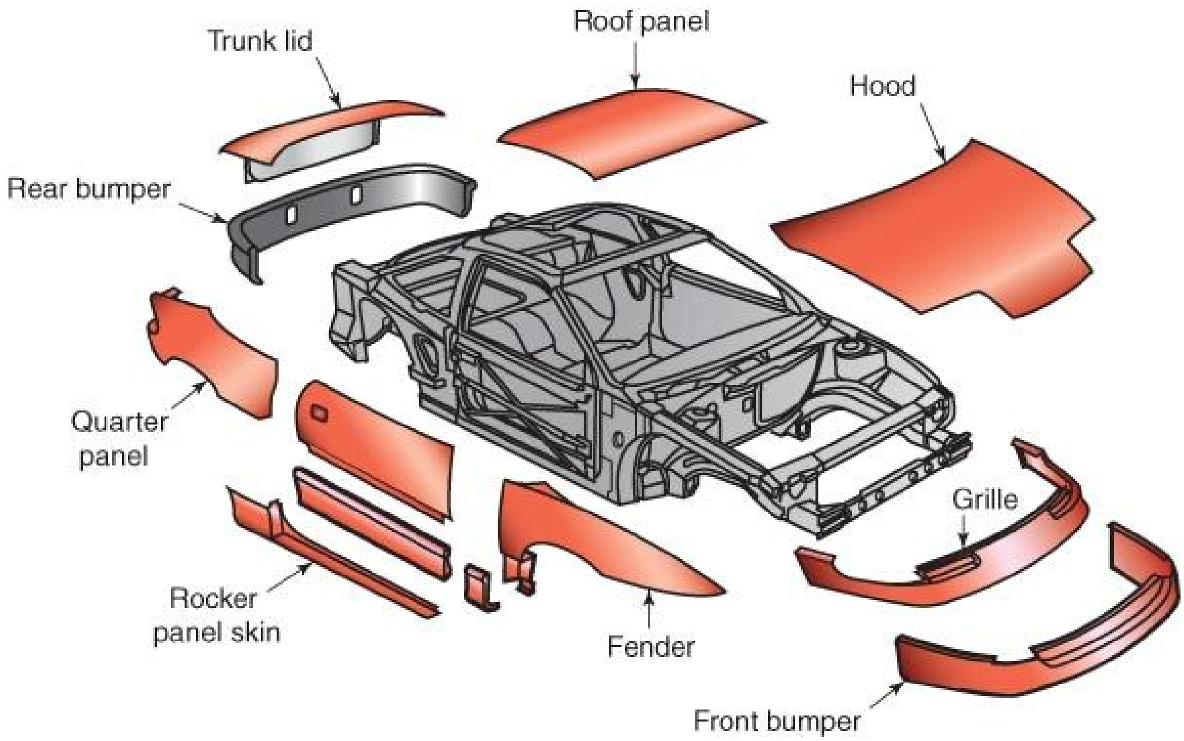


Figure 2.3: Car body panels [internet]

2.6 Fiber Orientation

The strength and stiffness of a composite buildup depends on the orientation sequence of the plies. The practical range of strength and stiffness of carbon fiber extends from values as low as those provided by fiberglass to as high as those provided by titanium. This range of values is determined by the orientation of the plies to the applied load. Proper selection of ply orientation in advanced composite materials is necessary to provide a structurally efficient design. The part might require 0° plies to react to axial loads, ±45° plies to react to shear loads, and 90° plies to react to side loads.

Because the strength design requirements are a function of the applied load direction, ply orientation and ply sequence have to be correct. It is critical during a repair to replace each damaged ply with a ply of the same material and ply orientation.

The fibers in a unidirectional material run in one direction and the strength and stiffness is only in the direction of the fiber. Pre-impregnated (prepreg) tape is an example of a unidirectional ply orientation.

The fibers in a bidirectional material run in two directions, typically 90° apart. A plain weave fabric is an example of a bidirectional ply orientation. These ply orientations have strength in both directions but not necessarily the same strength. The plies of a quasi-isotropic layup are stacked in a 0°, –45°, 45°, and 90° sequence or in a 0°, –60°, and 60° sequence. These types of ply orientation simulate the properties of an isotropic material. Many aerospace composite structures are made of quasi-isotropic materials [34].

2.6.1 Warp Clock

Warp indicates the longitudinal fibers of a fabric. The warp is the high strength direction due to the straightness of the fibers. A warp clock is used to describe direction of fibers on a diagram, spec sheet, or manufacturer's sheets. If the warp clock is not available on the fabric, the orientation is defaulted to zero as the fabric comes off the roll. Therefore, 90° to zero is the width of the fabric across.

2.6.2 Roving

A roving is a single grouping of filament or fiber ends, such as 20-end or 60-end glass roving's. All filaments are in the same direction and they are not twisted. Carbon roving's usually identified as 3K, 6K, or 12K roving's, K meaning 1,000 filaments. Most applications for roving products utilize mandrels for filament winding and then resin cure to final configuration.

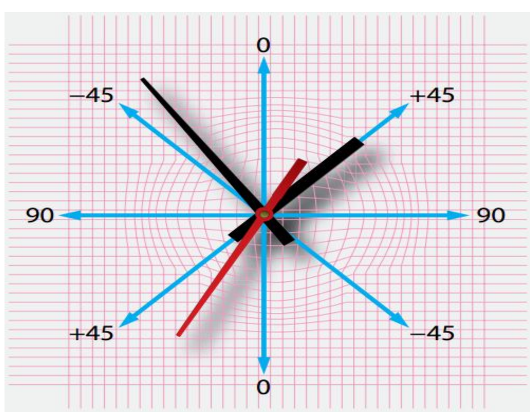


Figure 2.4:Roving (clock) direction fiber arrangements

2.6.3 Unidirectional (Tape)

Unidirectional prepreg tapes have been the standard within the aerospace industry for many years, and the fiber is typically impregnated with thermosetting resins. The most common method of manufacture is to draw collimated raw (dry) strands into the impregnation machine where hot melted resins are combined with the strands using heat and pressure. Tape products have high strength in the fiber direction and virtually no strength across the fibers. The fibers are held in place by the resin. Tapes have a higher strength than woven fabrics [36].

2.6.4 Bidirectional (Fabric)

Most fabric constructions offer more flexibility for layup of complex shapes than straight unidirectional tapes offer. Fabrics offer the option for resin impregnation either by solution or the hot melt process. Generally, fabrics used for structural applications use like fibers or strands of the same weight or yield in both the warp (longitudinal) and fill (transverse) directions. For aerospace structures, tightly woven fabrics are usually the choice to save weight, minimizing resin void size, and maintaining fiber orientation during the fabrication process [34]. The bellow figure 2.5 showing bidirectional and unidirectional fiber arrangement of composite material.

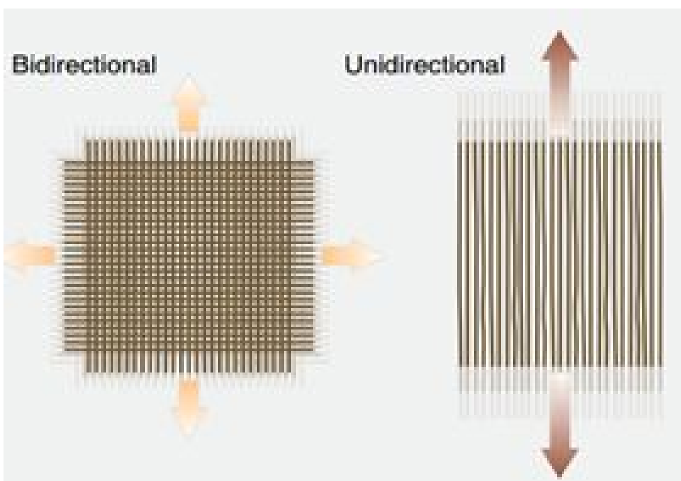


Figure 2.5: Bidirectional and unidirectional [34, 36]

2.7 Fiber glass

Fiberglass is often used for secondary structure on aircraft, such as fairings, radomes, and wing tips. Fiberglass is also used for helicopter rotor blades. There are several types of fiberglass used in the aviation industry. Electrical glass, or E-glass, is identified as such for electrical applications. It has high resistance to current flow. E-glass is made from borosilicate glass. S-glass and S2-glass identify structural fiberglass that have a higher strength than E-glass. S-glass is produced from magnesia-alumina-silicate. Advantages of fiberglass are lower cost than other composite materials, chemical or galvanic corrosion resistance, and electrical properties (fiberglass does not conduct electricity). Fiberglass has a white color and is available as a dry fiber fabric or prepreg material.

2.8 Type of resins

2.8.1 Thermosetting Resins

Resin is a generic term used to designate the polymer. The resin, its chemical composition, and physical properties fundamentally affect the processing, fabrication, and ultimate properties of a composite material. Thermosetting resins are the most diverse and widely used of all man-made materials. They are easily poured or formed into any shape, are compatible with most other materials, and cure readily (by heat or catalyst) into an insoluble solid. Thermosetting resins are also excellent adhesives and bonding agents [34].

2.8.2 Polyester Resins

Polyester resins are relatively inexpensive, fast processing resins used generally for low cost applications. Low smoke producing polyester resins are used for interior parts of the aircraft. Fiber-reinforced polyesters can be processed by many methods. Common processing methods include matched metal molding, wet layup, press (vacuum bag) molding, injection molding, filament winding, pultrusion, and autoclaving [34].

2.8.3 Vinyl Ester Resin

The appearance, handling properties, and curing characteristics of vinyl ester resins are the same as those of conventional polyester resins. However, the corrosion resistance and mechanical properties of vinyl ester composites are much improved over standard polyester resin composites [34].

2.8.4 Phenol Resin

Phenol-formaldehyde resins were first produced commercially in the early 1900s for use in the commercial market. Urea-formaldehyde and melamine-formaldehyde appeared in the 1920–1930s as a less expensive alternative for lower epoxies are polymerizable thermosetting resins and are available in a variety of viscosities from liquid to solid. There are many different types of epoxy, and the technician should use the maintenance manual to select the correct type for a specific repair. Epoxies are used widely in resins for prepreg materials and structural adhesives. The advantages of epoxies are high strength and modulus, low levels of volatiles, excellent adhesion, low shrinkage, good chemical resistance, and ease of processing. Their major disadvantages are brittleness and the reduction of properties in the presence of moisture. The processing or curing of epoxies is slower than polyester resins. Processing techniques include autoclave molding, filament winding, press molding, vacuum bag molding, resin transfer molding, and pultrusion. Curing temperatures vary from room temperature to approximately 350 °F (180 °C). The most common cure temperatures range [34].

2.8.5 Polyimide's

Polyimide resins excel in high-temperature environments where their thermal resistance, oxidative stability, low coefficient of thermal expansion, and solvent resistance benefit the design. Their primary uses are circuit boards and hot engine and airframe structures. A polyimide may be either a thermo set resin or a thermoplastic. Polyimides require high cure temperatures, usually in excess of 550 °F (290 °C). Consequently, normal epoxy composite bagging materials are not usable, and steel tooling becomes a necessity. Polyimide bagging and release films, such as Kapton are used. It is extremely important that Upilex replace the lower cost nylon bagging and polytetrafluoroethylene (PTFE) release films common to epoxy composite processing. Fiberglass fabrics must be used for bleeder and breather materials instead of polyester mat materials due to the low melting point of polyester.

2.8.6 Polybenzimidazole (PBI)

Polybenzimidazole resin is extremely high temperature resistant and is used for high temperature materials. These resins are available as adhesive and fiber.

2.8.7 Bismaleimides (BMI)

Bismaleimide resins have a higher temperature capability and higher toughness than epoxy resins, and they provide excellent performance at ambient and elevated temperatures. The processing of bismaleimide resins is similar to that for epoxy resins. BMIs are used for aero engines and high temperature components. BMIs are suitable for standard autoclave processing, injection molding, resin transfer molding, and sheet molded compound (SMC) among others.

2.8.8 Thermoplastic Resins

Thermoplastic materials can be softened repeatedly by an increase of temperature and hardened by a decrease in temperature. Processing speed is the primary advantage of thermoplastic materials. Chemical curing of the material does not take place during processing, and the material can be shaped by molding or extrusion when it is soft. Semi-crystalline Thermoplastics Semi-crystalline thermoplastics possess properties of inherent flame resistance, superior toughness, and good mechanical Properties at elevated temperatures and after impact, and low moisture absorption. They are used in secondary and primary aircraft structures. Combined with reinforcing fibers, they are available in injection molding compounds, compression-moldable random sheets, unidirectional tapes, prepregs fabricated from tow (towpreg), and woven prepregs. Fibers impregnated in semi-crystalline thermoplastics include carbon, nickel-coated carbon, aramid, glass, quartz, and others [35].

2.8.9 Amorphous Thermoplastics

Amorphous thermoplastics are available in several physical forms, including films, filaments, and powders. Combined with reinforcing fibers, they are also available in injection molding compounds, compressive moldable random sheets, unidirectional tapes, woven prepreg, etc. The fibers used are primarily carbon, aramid, and glass. The specific advantages of amorphous thermoplastics depend upon the polymer. Typically, the resins are noted for their processing ease and speed, high temperature capability, good mechanical properties, excellent toughness and impact strength, and chemical stability. The stability results in unlimited shelf life, eliminating the cold storage requirements of thermo set prepreg [37].

2.9 Curing Stages of Resins

Thermosetting resins use a chemical reaction to cure. There are three curing stages, which are called A, B, and C.

• A stage: The components of the resin (base material and hardener) have been mixed but the chemical reaction has not started. The resin is in the A stage during a wet layup procedure.

• B stage: The components of the resin have been mixed and the chemical reaction has started. The material has thickened and is tacky. The resins of prepreg materials are in the B stage. To prevent further curing the resin is placed in a freezer at 0 °F. In the frozen state, the resin of the prepreg material stays in the B stage. The curing starts when the material is removed from the freezer and warmed again.

• C stage: The resin is fully cured. Some resins cure at room temperature and others need an elevated temperature cure cycle to fully cure.

2.10 Introduction of testing equipments

2.10.1 Micrometer/Varner caliper

The main use of the Varner caliper and micrometer is to measure the internal and the external diameters of an object and it has up to 0.01mm thickness. Those measuring devices are important to measure the overall dimensions of the specimens.

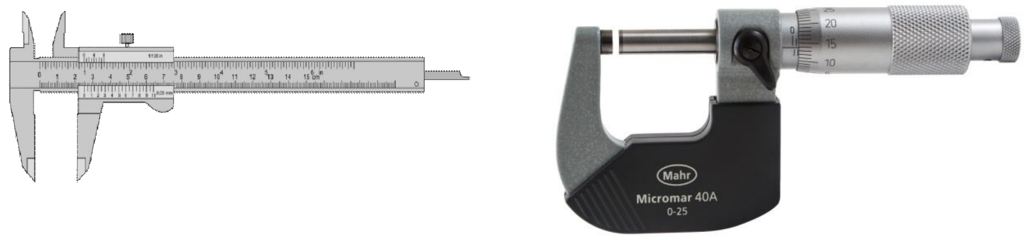


Figure 2.6: Varner caliper and micrometer

2.10.2 Analytical (digital) balance

The digital mass balances in the general chemistry labs are very sensitive instruments used for weighing substances to the milligram (0.001 g) level. This balance equipment also important to measure while mixing the composites.

Figure 2.7: Digital balance

2.10.3 Electrical (micro wave) oven

An oven is a thermally insulated chamber used for the heating, baking, or drying of a substance, and most commonly used for cooking. In this work it will helps to remove water (moisture) from the composite specimens within a short period of time by adjusting the heating ranges [33].

Figure 2.8: Digital electrical stove

2.10.4 Band saw

The band saw is a machine used for cutting irregular shapes. The second most common use is in re sawing or ripping lumber into thinner slabs. A band saw also makes the smoothest cuts and, with the appropriate blade, can be used to cut materials other than wood, including metal [34].

Figure 2.9: Band saw:

2.10.5 Universal testing machines (UTM)

The universal testing machines are a computer equipped machines used to measure the materials mechanical properties under different load conditions. This can measure tensile, compressive, and bending strength of the materials by simply by changing the jaws and modes of operations [35].

The main components of the universal testing machine are: actuator, attachment kit and, measuring and safety devices frame, engine, gear, screws, and crosshead grips (gripping jaws) extensometer, specimen, and hardware and software control.

Tensile test purpose

Tensile test determines the strength of the material subjected to a simple stretching operation. Typically, standard dimension test samples are pulled slowly (static loading) and at uniform rate in a testing machine.

Compression Test purpose

To conduct compression test on a specimen using a universal testing machine (UTM) to determine ultimate compressive strength of the material [33].

$$\text{Ultimate compressive strength (MPa)} = \frac{\text{Ultimate load}}{\text{Cross-sectional area}}$$

The figure 2.10 bellow is a universal testing machine which is used to test different mechanical properties of the materials

Figure 2.10 Universal testing machines [33].

CHAPTER THREE

MATERIALS AND METHOD

3.1 Materials

For sample preparation many kinds of materials are included to produce a composits. The details of the materials are explained as below.

3.1.1 General purpose unsaturated polyester Resin

Epoxies resins are polymerize able thermosetting resins and are available in a variety of viscosities from liquid up to solid. Most of the time, Epoxies are used widely in resins for prepreg materials and structural adhesives. Epoxies have different advantages like, low shrinkage, high strength and modulus, excellent adhesion, good chemical resistance, low levels of volatiles and ease of processing. Epoxy resins are often acts as a matrix because they have a very good mechanical properties and good handling properties, including production. The Gp resin is a product and imported from Saudi Arabia mostly and used for this study named is by TOPAZ-1110 Resin which is available and purchased from the local market in some places of Addis Ababa gurd shoal area , Ethiopia. There are different kinds of Epoxy resins for different kinds of composite material production and are the prevalent polymer used with advanced composites. Their extensive use is primarily due to their superior mechanical properties, excellent adhesion, good possibility utilizing addition-type reactions, low cure shrinkage and low cost. The mechanical properties of Gp resin data is given in the table 3.1given below extracted from the property sheet given in the appendix.

Table 3.1 TOPAZ-1110TP resin Physical Properties (at 25^0C)

Properties	Values	Units	Test Methods
Appearance	Pinkish Viscous Liquid	-	-
Viscosity	575-675	Cgs	ISO 2555-1974
Specific gravity	1.13	kg/m^3	ISO 2811-1974
Acid Value	23-28	KOH	ISO 2114-1974
Styrene Content	38 ± 3	%weight	ISO 2114-1974
Flash Point	34^0	Centigrade	ASTM D 327B-73
Storage Stability	4	Months	-
Gel time (1.5% MEKP)	15-20	Minutes	-
Peak Exotherm	150-165	C^o	-

Table 3.2 Mechanical and Physical data of TOPAZ-1110TP in cured states

Properties	Pure Resin	Reinforced	Unit
Glass content	-	33%	% Weight
Specific gravity	1.2	1.45	g/CC
Tensile strength	50	80	N/mm^2
Tensile Modules	3000	6000	N/mm^2
Elongation (Min)	2.5	2.0	%
Flexural Strength	80	120	N/mm^2
Flexural Modulus	3000	6000	N/mm^2
Volume Shrinkage	7		%
Heat Distortion	$75\pm5C^0$		Centigrade
Barcol Hardness	40	45	

Polyester resins used in the composites industry are made up of three main components, the base resin, styrene monomer and additives. There are many types of base resin:

- Orthophthalic resins (ortho or general purpose)
- Isophthalic resins (iso)
- Terephthalic resins
- Dicyclopentadiene resins (DCPD)
- Neopentyl glycol resins (NPG or iso-NPG or ortho-NPG)

3.1.2 Hardener (catalyst)

Hardener have another name called #2060 HARDNER ,Epoxy resin and any composite materials are hardened and cured by adding a catalyst, which causing a chemical reaction without changing resin its own composition. The catalyst (hardener) initiates the chemical reaction of the epoxy resin and monomer ingredient from semi liquid to a solid state. Hardener can be purchased from any local market and the curing agent is applied in the ratio of one to twenty of hardener and gp resin during mixing time.

3.1.3 Fiber glass (50%)

The glass fibers that are a reinforced material contain silica or silicate, with varying amounts of oxides of calcium, magnesium, and sometimes boron. They adjust the glass fiber then reinforced it to be the shape they want, with additive filling they want. There are different types of glass fibers:

A-glass - Used where electrical resistivity of E-glass is not needed.

AR-glass – Used in Portland cement substrates.

C-glass – Used in acid corrosive environments.

D-glass – Used in electrical applications.

E-glass – E-glass is known in the industry as a general-purpose fiber for its strength and electrical resistance.

ECR-glass – Used where strength, electrical conductivity and acid corrosion resistance is needed.

R-glass – used where higher strength and acid corrosion resistance is needed.

S-glass – Used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed.

S-2 glass – And they are dangerous to breathe (glass fiber). When you inhale them into your lungs, they are not easily broken down by your body if at all. If you don't like the idea of getting wood or metal particles in your lungs, then you shouldn't inhale glass fibers either. For small amounts, you will be fine. You can wear a cheap dust mask to avoid this.

Fiberglass is lightweight, corrosion resistant, and economical, easily processed, and has good mechanical properties [23].

Figure 3.1 Chopped Strand Mat fiber glass

For this work the Chopped Strand Mat fiber glass material is selected due to its availability and low price, in fact there is stronger fiber glasses mentioned on the above listed.

3.1.4 Preparation of raw false banana (enset) Fiber

False banana (Enset) is a member of the same botanical family as the banana, but which is not producing its fruit like banana. The main edible parts of the enset plant are the starchy rhizome and pseudo stem. It is also a staple food guaranty for more than 15 million people in the southwestern part of Ethiopia. The fiber, having a hair like structure, locally called “kancha” is collected after scarping of the leaf sheath and leaf bases around the pseudo stem. The inner part of the pseudo stem is simply discarded as waste. These residues are abundant natural resources and can be potential source of cellulosic fiber. The extraction process is manually by a hand and its primary target is to get food ‘kocho’ and the byproduct of this process is banana fiber material .this can be collected from the the southern parts of a country and from markets sell for different purpose in markets.

3.1.5 Sodium Hydroxide (Na OH)

Sodium hydroxide is a whitish solid, which is available in pellets, flakes, granules, and as a 50% saturated solution [34]. Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air. It also known as lye or caustic soda has the molecular formula Na OH and is a highly caustic metallic base and alkali salt. It is applicable in many industries a strong base chemical (ph9-13) in the manufacture of, sugar, paper, textiles, pulp drinking water, soaps and detergents [44].

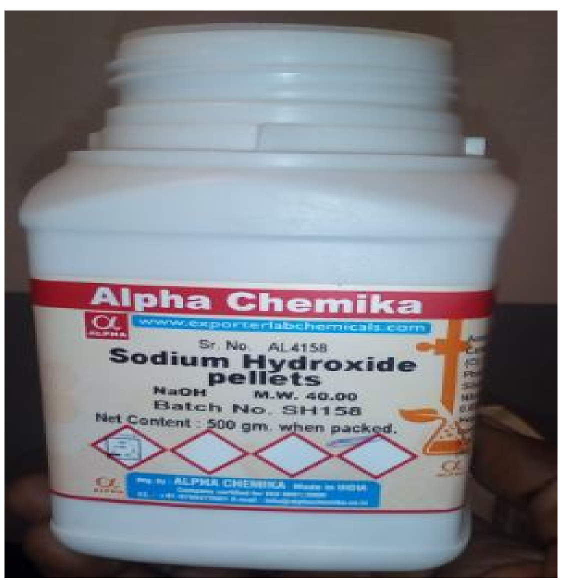


Figure 3.2: Sodium hydroxide

For this work it is used NaOH in pellets form, purchased from local chemical suppliers with the brand name and code of RANKEM, S0290 respectively and performed chemical treatment of false banana fiber.

$$\text{Fiber} - \text{OH} + \text{Na OH} \rightarrow \text{Fiber} - \text{O} - \text{Na} + H_2O \text{-----------------------------------} \quad (3.1)$$

Assuming $P^H = 12$

$$P^H + P^{OH} = 14 \quad \text{---------------------------} \quad (3.2)$$

$$P^{OH} = 14\text{-}12 = 2$$

$$P^{0H} = -\text{Log}\,[OH]$$

$$[OH] = 2 \times 10^{-2}\ M$$

Morality = Number of mole/Volume (M= N/V)

$$N = M \times V$$

$$N = 2 \times 10^{-2}\ M \times 10\ \text{liter}$$

$$N = 0.02 \times 10 = 0.2\ \text{mole}$$

Mw of Na OH= 40

N= mass/molecular weight= M/Mw

$$0.2\ \text{mole} = m/40$$

$$\text{Mass} = 0.2 \times 40 = 8\ \text{gram}$$

Therefore 8 gram of sodium hydro oxide is sufficient to mix 10 liter of water to bring ph-12.15 which is approaches to strong base.

3.1.6 General purpose jell coat

Gel coat (top coat) is a semi liquid paint or material used to provide a high-quality finish on the visible surface of a fiber-reinforced composite. The most common gel coats are thermosetting polymers based on epoxy or unsaturated polyester resin chemistry. Gel coats are modified resins which are applied to moulds in the liquid state. An outer layer of gel coat is typically 0.5 mm to 0.8 mm (0.02 in to 0.03 in) thick. Gel coat is usually the first layer applied to the mould and its purpose is to:

- provide an attractive finish to the surface of the product
- act as a barrier against absorption of water or chemicals
- act as a barrier against UV radiation from sunlight which can degrade the part
- provide an abrasion resistant surface(hydrolysis)
- act as a screen against protruding surface reinforcing fibers

Figure 3.3 Gp gel coat

Table 3.3 Mechanical/Physical Data for the Gel coat Base cured state

Properties	Value	Unit test
Tensile strength	45MPa	N/sq mm
Tensile Modulus	2800MPa	N/sq mm
Tensile Elongation	3	%
Heat Distortion Temperature	70-75	^{0}C
Barcol Hardness	40-42	934 -1
Water absorption	70-85	Mg/test piece

The Mechanical/Physical data for the gel coat are obtained from the world fiber glass selling company in addis ababa which is attached on the appendix.

3.2 Mold Release wax (Cream)

Mold Release wax is a cream or semi- fluid smoothes the paint surface or bare metal surface and will reduce the friction between debris and makes meaning that tiny debris is more likely to slide off composite rather than damage it. In this work waxing mold release wax will helps to protect the epoxy resin and clear coat from being binding and easy detaching from the mold panel.

Figure 3.4 Mold Release wax (cream)

In general all the materials used for preparing the FBFGFERC composite are tabulated below in table 3.4.

Table 3.4 Main materials purchased for composite work [34].

Materials	quantity
Fiberglass Chopped Strand/Random Weave Mat	4 kg
False banana fiber(Enset)	20 kg
GP Bonding Resin for binding both banana fiber and fiber glass	10 liter
GP Resin Catalyst(hardener)	2 liter
GP gel coat(a high-quality finish)	2 liter
NaOH(improve the thermal resistance ,increases roughness from the false banana fiber surface.	300 mg
Wax (to add a layer of shine and film of layer).	1kg
Anti silicone or Anti oxides(M-600) reentrant lubricant (for cleaning oil, dirt, derbies…from molding plate)	2 liter

Note that: Working with Fiberglass is very hard and needs special safety. It is nasty stuff, and can get into your skin, your lungs, and your eyes. When working with these materials it is important to wear a respirator, gloves, and safety glasses. It is advised that you wear a paint suit to cover all skin that could be exposed to fiberglass particulate.

The consumable materials are listed in the table 3.5 given below.

Table 3.5 Lists of consumable material

Consumable Materials:	unit	Quantity
Small Disposable Paint brushes	pcs	10
Angle Grinder with Grinding Disc	pcs	02
Orbital Sander with 80 Grit Disc	pcs	03
Stir Sticks	pcs	01
Respiratory	pcs	02
Gloves	pcs	50
Safety Glasses	pcs	01
Permanent Marker	pcs	01
Scotch Tape	pcs	01
Rags	kg	2

3.3 Sample Preparation Methods

3.3.1 Preparation of false banana fibers

False banana fiber was prepared in different length for chopped and others orientations. For instance for chopped specimen the length of fbf is cut in to 20 mm length and 400 mm length for the rest of all orientations. This sample preparation has more similarities with the preparations of other natural and artificial composite materials that are applicable for different engineering aspects.

The flow chart given in figure3.5 shows the various steps followed in the preparation of the composite materials.

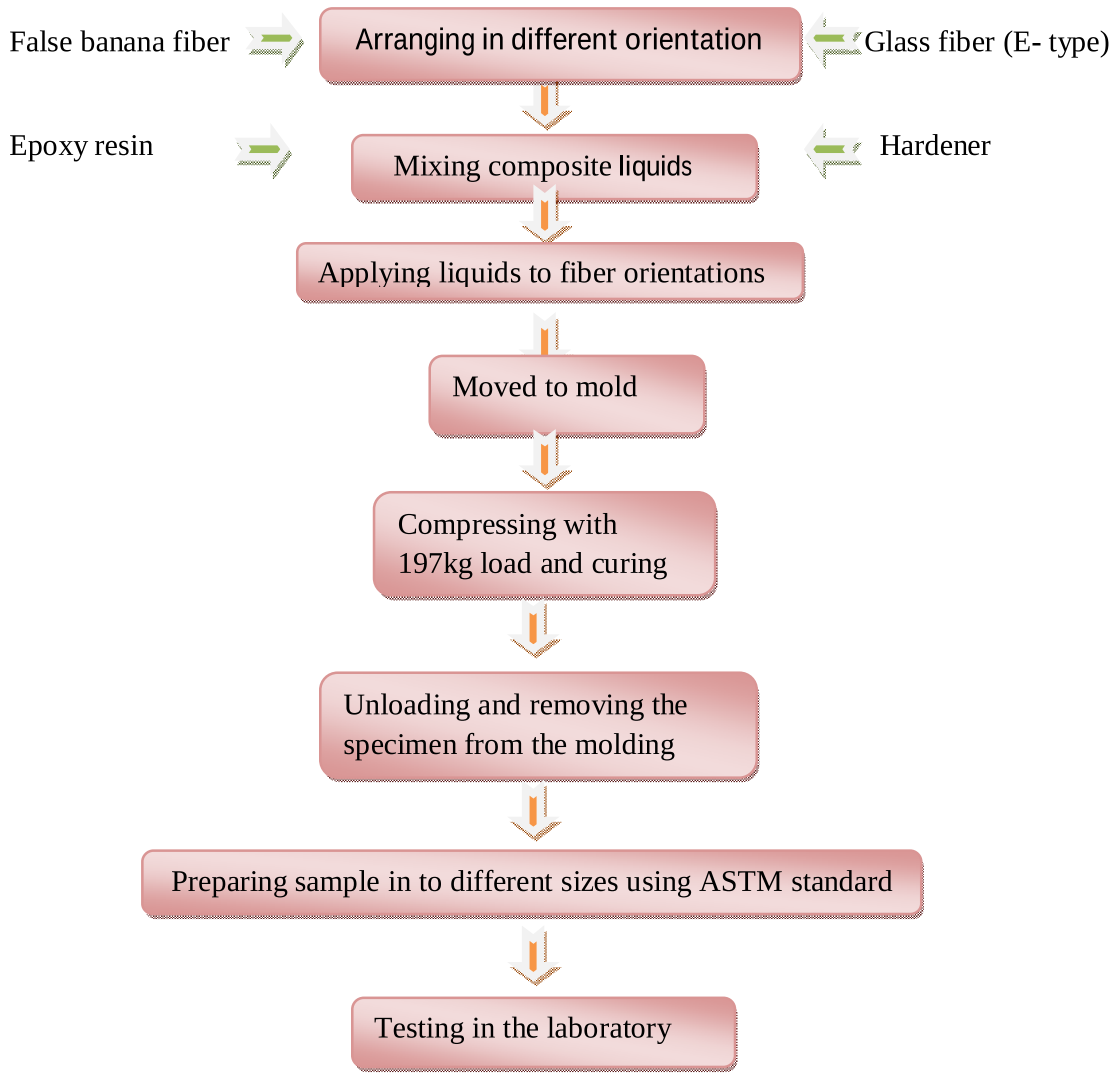


Figure 3. 5 Schematic flow diagram for fabrication of FBFGFERC specimen

3.3.2 Preparation of false banana fiber and fiber glass

Composite materials are prepared following certain procedure using the materials listed above in the tables. Chopped Strand Mat fiber glass is purchased from fiber glass market in Addis Ababa and cut in to the size of 400 mm by 300 mm to lay up in to the specimen molding prepared bare metal. The steps to mold the fbf and fiber glass are as follows [28].

- Collecting the false banana fiber from the southern part of Ethiopia where it grows mostly.Figure3.6 shows the collected false banana fiber.

Figure 3.6 Extracted false banana fiber

- Preparing the solution by mixing 8-gram of NaOH in 10 litter of distilled water (H_2O) in the plastic container. The ph value of the solution is 12.1 which is a good base solution.

Figure 3.7 Mixing distilled water with Na OH and testing with ph meter

- The false banana fiber is soaked in the solution for 24 hours to resolve dirt, impurities and increase thermal resistance roughness and mechanical properties.
- Socking a fbf in to this distilled solution container more than this hour, it tends to damage and decrease the the overall advantages listed before [20].

Figure 3.8 Soaking a fbf in base solution container for 24 hour.

- After soaking for 24 hours, the false banana fiber was washed thoroughly to with more amount of water to remove the base solution from the fiber and completely.

Figure 3.9 washing the soaked false banana fiber using tap water repeatedly.

- The fbf was dried for one day in sun light [20].

Figure 3.10 Exposing the false banana fiber to the sun light to dry.

- Preparing local weaving(loom) equipments using $1m^2$ wood plate and nail to produce different fiber orientations like chopped, 0^0, $\pm45^0$, 90^0.

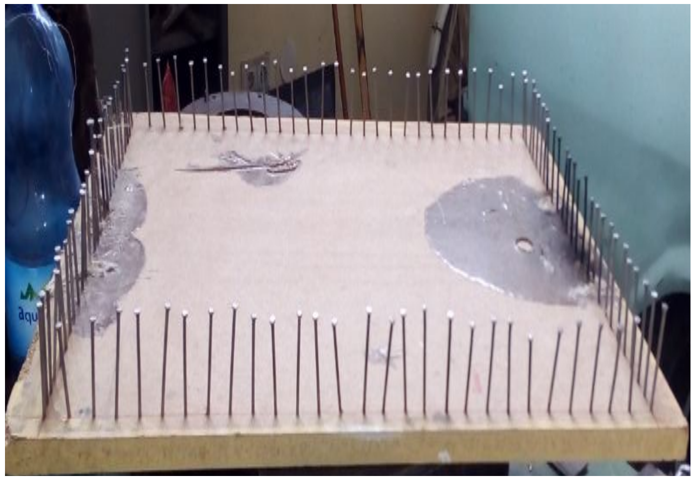


Figure 3.11 Locally prepared weaving (loom) equipments.

Figure 3.12 Arranging the fbf using local weaving (loom) equipment.

- Arranging the false banana fiber in different orientations to mold different specimens.
- Preparing Bonding and shaping the sheet metals for bumper mold.
- Waxing the specimen on both upper and lower parts to create a thin film and preventing the specimen being bonded with molding plates.
- Measuring and Cutting the E-type fiber glass to the specified plate size.
- Sandwiching the fbf between bottom and upper fiber glass and keeping it flat using flattening plates.
- Mixing the gp-resin with gp-hardener in the plastic container in the ratio of 1:20.

- Applying the mixed resin on to the FBFGFERC mat using hand layup method fully.
- Applying 197 kg load on the composite for 24 hour; this makes the epoxy to be filled with resin in all the small vacuum holes of the specimen and makes the spacemen flat and smooth. Additionally it will remove excess resin out of the specimen across all sides.
- Unloading the composite materials from the mold checking its conditions.

3.3.3 Preparation of epoxy and hardener

The proportion of Epoxy and hardener must be in a good ratio to prepare the composite plate. The weight ratio for mixing epoxy and hardener is 20:1. Hardeners include anhydrides (acids), amines, polyamides, dicyandiamide etc. The glass mixer is strewed with stirrer for about one and half minutes continuously. The mixing is performed in the mixing containers(bowl).The bowl is locally made from one litre water container. To prevent melting of the bowl during the exothermic reaction, it is mixed slowly with the tongue depressor and continuously to ensure no air bubbles trapped.

3.3.4 Hand layup and molding

Hand-lay-up method is very important to fill up every vacuumed gap of the prepared hybrid mould with an appropriate amount of epoxy resin mixture and layers of random FBFGFERC, such that starting and ending with layers of resin. Fiber deformation and movement should be eliminated to get good quality, smooth fiber composites. Therefore, during curing, a compression load of 197kg was applied on the mould and the air gaps formed b/n the fibers during the processing were gently squeezed. The air present in between the fiber and resin was release due to the application of the load. It was kept for one day to get perfect sample. The wet sample was pressed hard to remove excess resin and then it was dried [29].

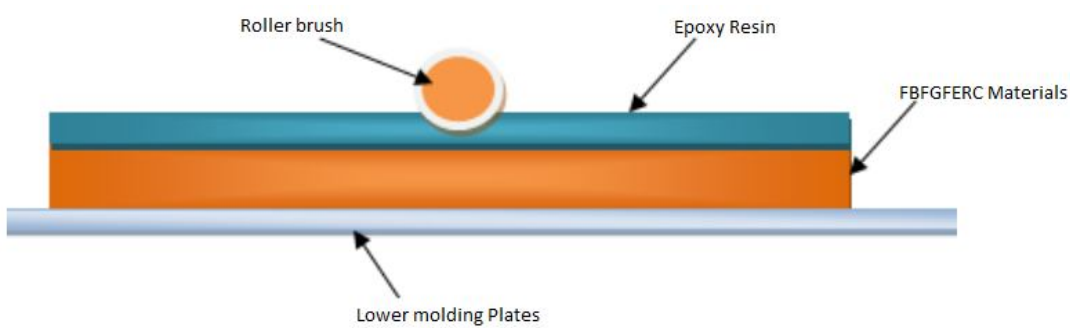


Figure 3.13: Laying the FBFGFERC on molding plate.

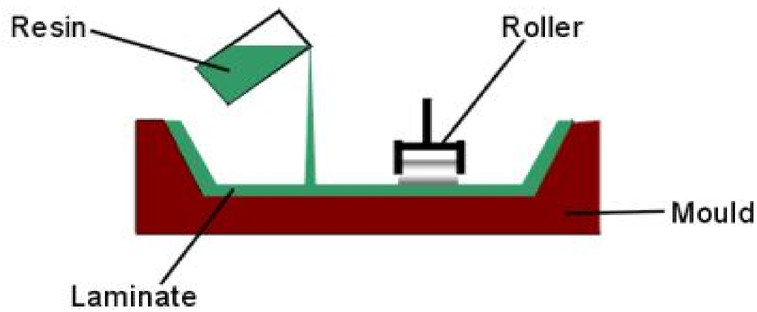


Figure 3.14: Hand layup of the prepared materials with resin.

Figure 3.15: Molding plate and molded composite.

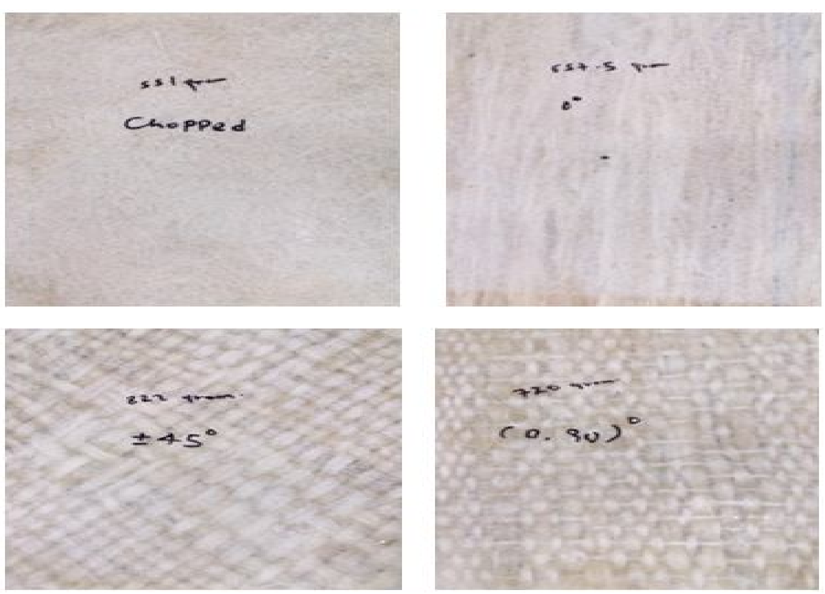


Figure 3.16: Cured sample with different orientation of FBFGFERC.

3.3.5 Measuring the composite specimen using digital balance

After curing the specimen was weighed using digital balance. The digital balance used for weighing is shown in the figure 3.17given bellow.

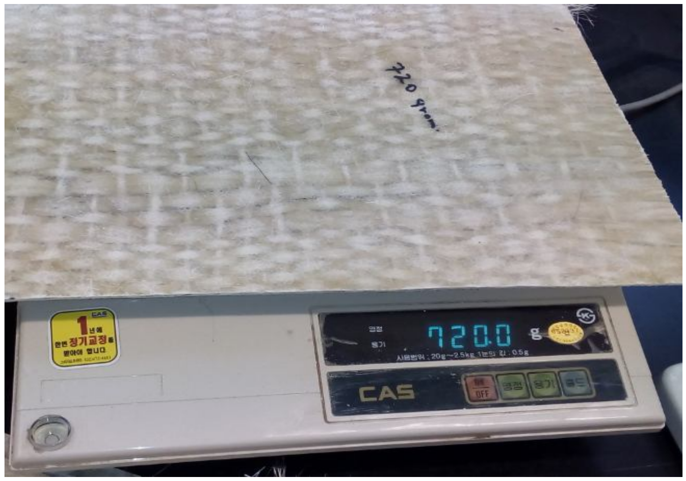


Figure 3.17: Measurement of specimen using digital balance.

Table 3.6: Mass of constituents of the composite.

FBFGFERC orientation	Mass of Materials in gram			
	False banana fiber	Glass fiber	Gp epoxy resin	Composite mass
0^0	122	120	415.5	657.5
$\pm45^0$	159	156	508	822
$0,90^0$	149.5	148.5	422	720

3.4 Specimen preparation

The prepared specimen was cut using band saw according to the ASTM standards in to different sizes.

The figure 3.18 given below shows the cutting process of the specimen using a band saw.

Figure 3.18: Band saw for cutting a specimen.

3.4.1 Specimen preparation for tensile test

After the FBFGFREC reinforced epoxy composite Specimen cut in to the required dimension based on the ASTM standards for each sizes of 0^0 ,45^0 ,0 and 90^0 were prepared using the three different strength testing procedures: The tensile test, compression test ,bending test and water absorption for each set of specimen.

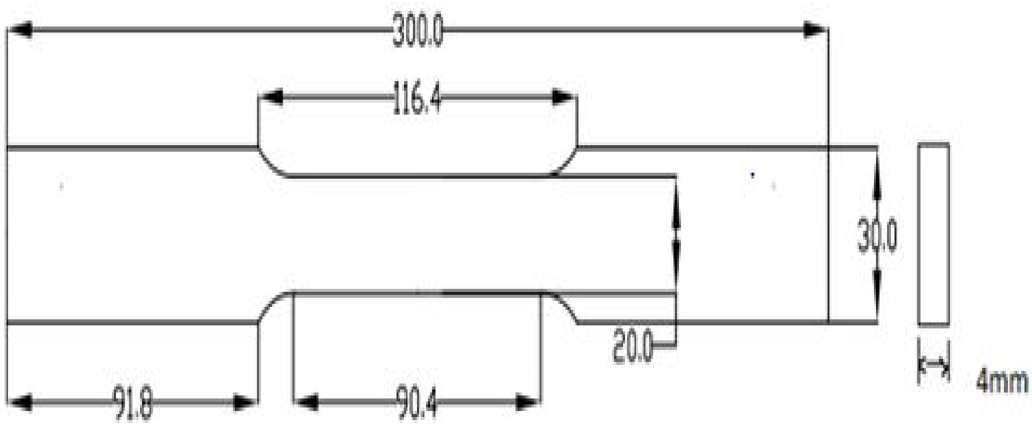


Figure 3.19 Dimensions of specimen for tensile tests.

Figure 3.19: 20 prepared specimens for tensile test.

Figure 3.20: Specimen with 0, ±45, 0 and 90 degree orientations of fibers.

3.4.2 Specimen preparation for compression test

For Compressive test 9- samples of specimens (three for each orientation) cut and prepared for repeatability according to the ASTM D3039/D3039M standard.

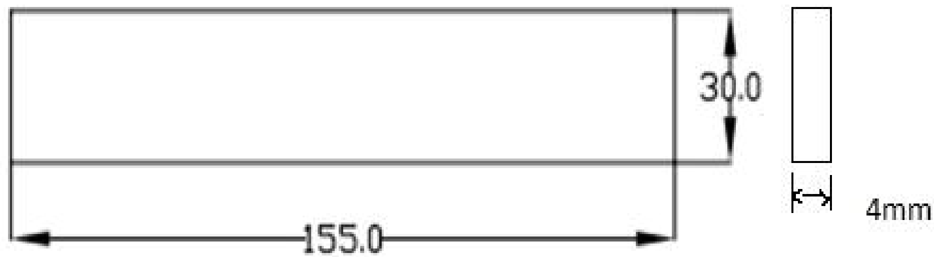


Figure 3.21: Dimensions of specimen for compression tests

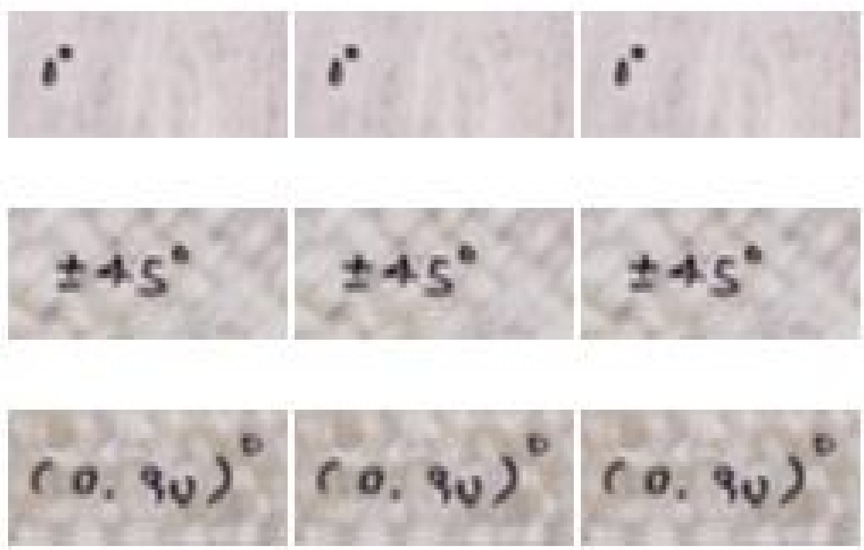


Figure 3.22: 3 Sample ready for compression test.

3.4.3 Specimen preparation for bending test

The Bending test measures the force required to bend the specimen under three point loading situations. This test is often used to select specimen for vehicle body parts that will support loads without braking. This test is also performed using UTM machine in accordance with ASTM D3039/D3039M standard to measure the bending strength of the composites .Nine specimens were prepared from each orientation for bending test with 127mm length, 30mm width and 4mm width.

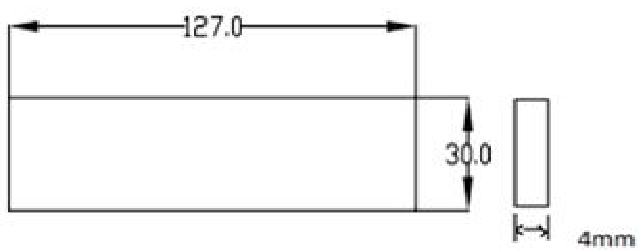


Figure 3.23: Dimensions of specimen for bending tests

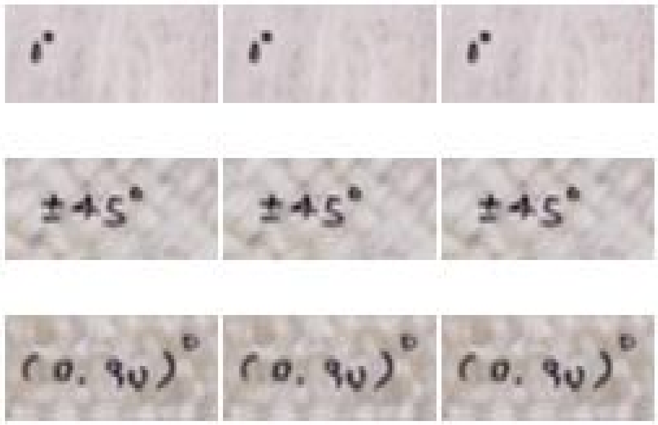


Figure 3.24: Specimen prepared for bending.

3.4.4 Water absorption tests

Water absorption test is needed to know how much water the specimen can absorb from the surroundings. This helps to identify which orientation and finishing does can minimize water absorption distortion. The size of the spacemen for water absorption was obtained in accordance with ASTM C220 standard of 20mm by 30mm with 4mm thickness. The samples were dried in oven at 105 °C for a period of 24 hours. After cooling down in desiccators to room temperature, the dry weight of each was determined and recorded. Samples were then immersed in distilled water at room temperature for a period of 24 hours. Surface water was removed from each sample and the wet weight sample was recorded. All samples were weighed. The amount of water was then determined relative to the dry weight of the sample using water absorption equation in chapter four result and discussion:

Figure 3.25: Sample specimen for water absorption.

3.5 Universal Testing Machine (UTM)

UTM Testing machine is a machine suitable for conducting tests like the tensile, compression, bending and shear test for all kinds of metal and nonmetals. The oil cylinder is set on the bottom in the machine, and with double space frames, the test space can be adjusted automatically. The control unit is composed of computer and control system, it process stress, strain and displacement control modes, the test data can be stored at will, and the data and curves can be reanalyzed, part amplified and data re-edition, test conditions (specimen, measurement) are programmable, all the mechanical properties can be obtained automatically, and print whole test report and curve.

These frames feature are dual spaces, so users can quickly change between tension and compression testing without having to remove heavy fixtures. Control console with integrated hydraulic power pack, precise loading regulator and unloading valves, Extra-length screws and columns, with an adjustable upper crosshead, to increase the available test space for longer test samples. Semi-open front hydraulic wedge clamps for easier loading and rapid loading and unloading of specimens. Accessories for suitable tests are Main frame; Control console; Controller and sensor; Computer and software; Hydraulic oil pipe and control button box; Sample jaw three sets; Bend support saddle; Bend pressure energy; Spherical compression plate; Lower compression plate; Top board; Ground screw and nut; Inner hexagon spanner; Double offset ring spanner; Other accessories full sets [33].

Figure 3.26: Universal testing machines [33].

Some parameters must be adjusted when we need to work on UTM machine for ultimate tensile strength (UTS) or peak stress; The cross-head speed adjusted to 2 mm/min, and gauge length was 200 mm. Load-elongation curve, breaking load, peak stress and % strain at peak stress were acquired in real time by machine and provided at the end of each test.

Figure 3.27: UTM holding and fracturing the specimen.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Laboratory Test Results

4.1.1 Tensile Test results

The goal of tensile test was to evaluate the in-plane tensile properties of FBFGFERC composites. For tensile strength test, 9 specimens were prepared for three different orientations zero degree, forty-five degree and ninety degree fiber/matrix using ASTM D3039/D3039M standard. The ratio of false banana fiber and fiber glass materials for this work was (50%/50%) by mass. For each sample, 3 specimens were tested in the machine. Each specimen was 30 mm width by 300 mm length with 4mm thickness. During the test the specimens were placed in the grips (jaws) of UTM and load is axially applied through both the ends of the specimen.

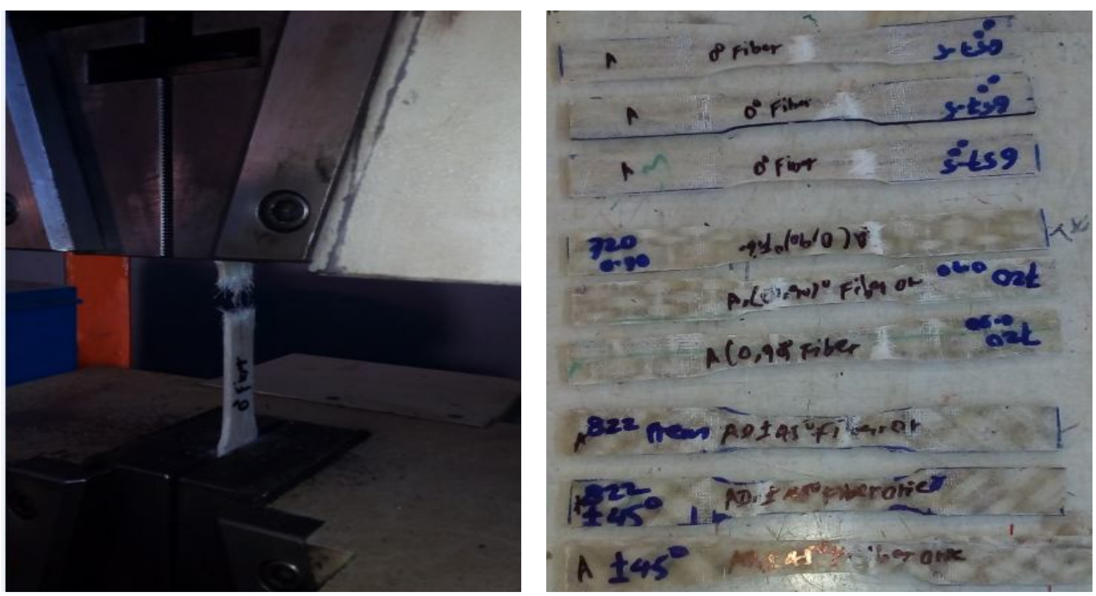
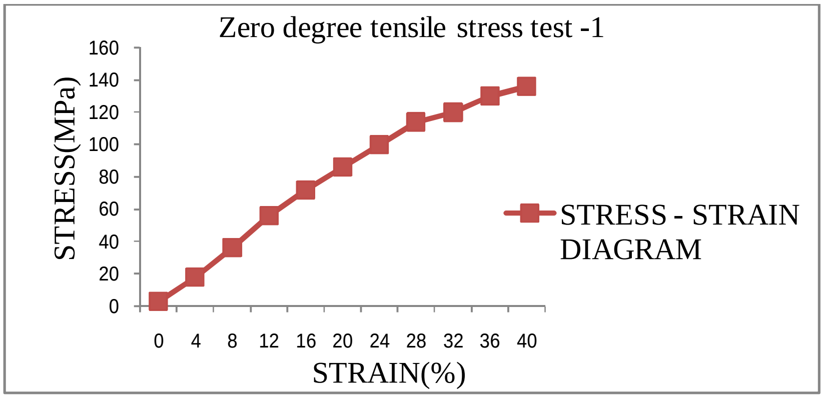
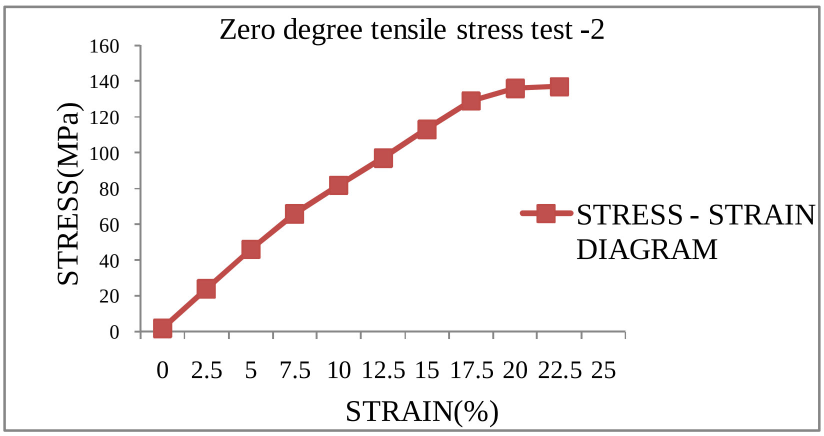


Figure 4.1: Specimen fractured by UTM tensile force.



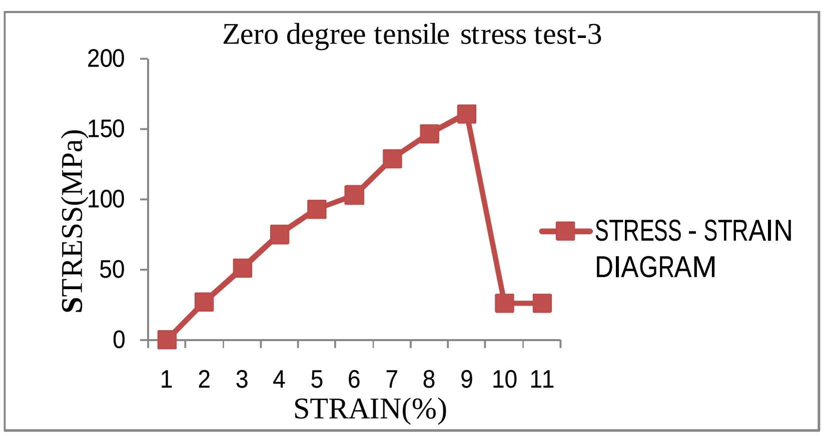
a, Zero degree tensile strength tests -1

From the above graph it is observing that zero degree tensile test on exhibits 136MPa.



b, Zero degree tensile strength tests -2

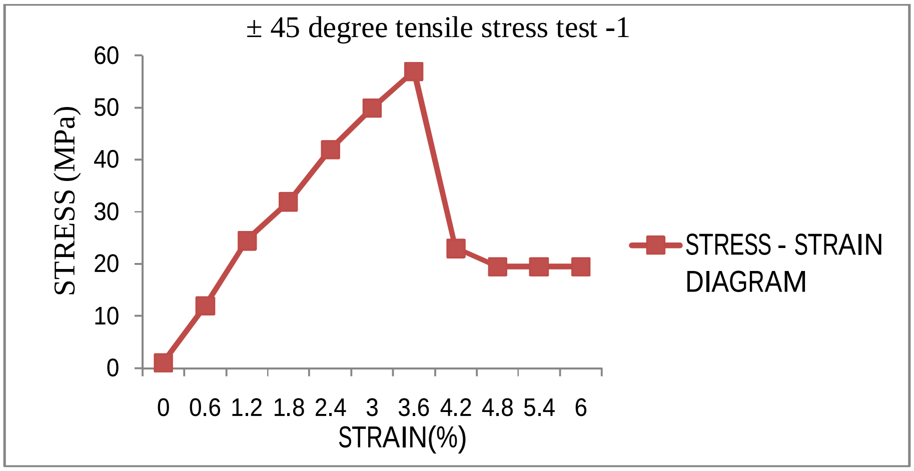
From the above graph observing that maximum tensile strength of tests -2 is 137MPa.



c, Zero degree tensile strength tests -3

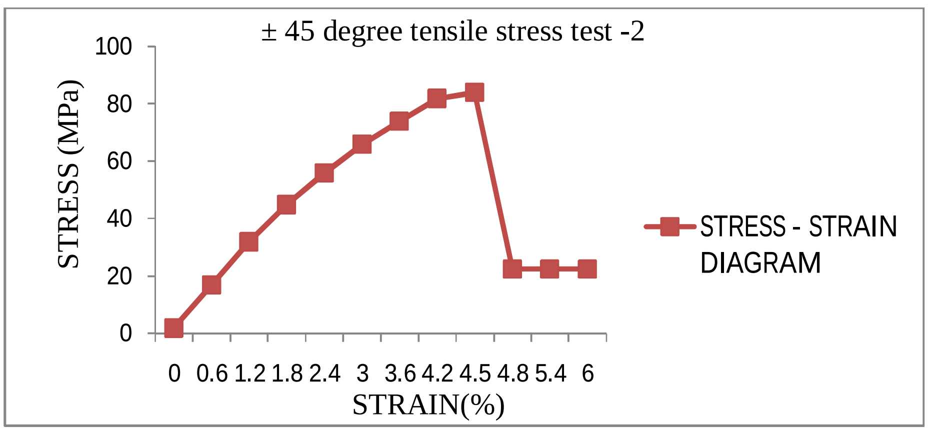
The above graph showing that the maximum tensile strength of test-3 is 161MPa.

Figure 4.2: a, b, c are 0(zero) degree tensile strength test.



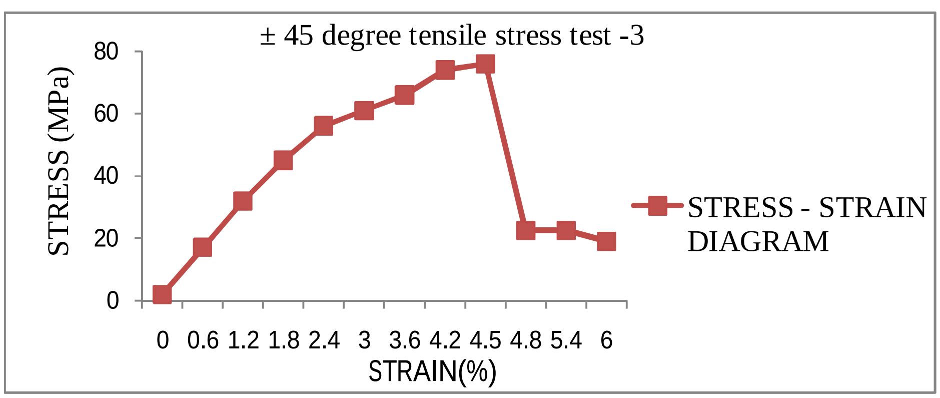
a,± 45 degree tensile test -1

The graph on the above± 45 degree tensile test -1 shows 57MPa of tensile stress.



b,± 45 degree tensile test -2.

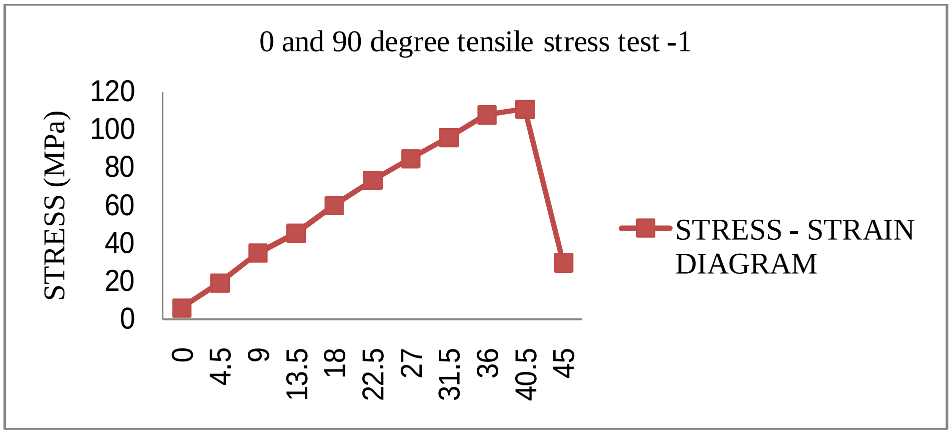
From the above figure observed that, ± 45 degree tensile test -2 exhibits 84 MPa of tensile stress.



c, ± 45 degree tensile test -3.

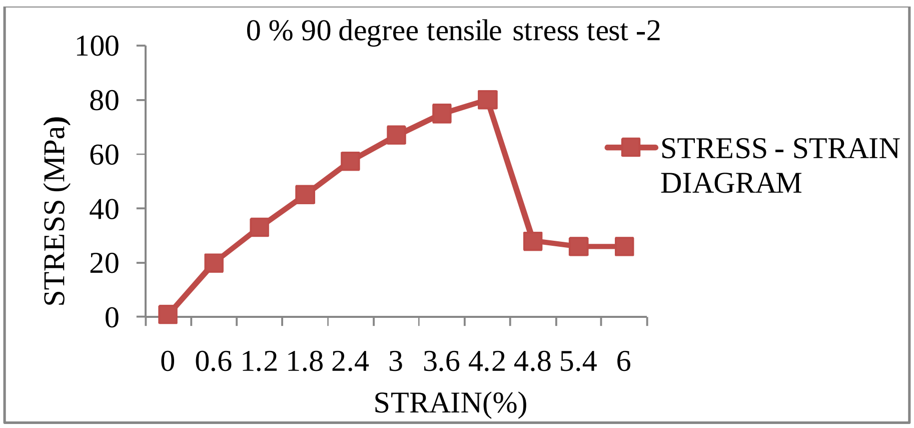
The above figure ± 45 degree tensile test -3 shows 76 MPa of tensile stress.

Figure 4.3: a, b, c are ±45 degree tensile strength test.



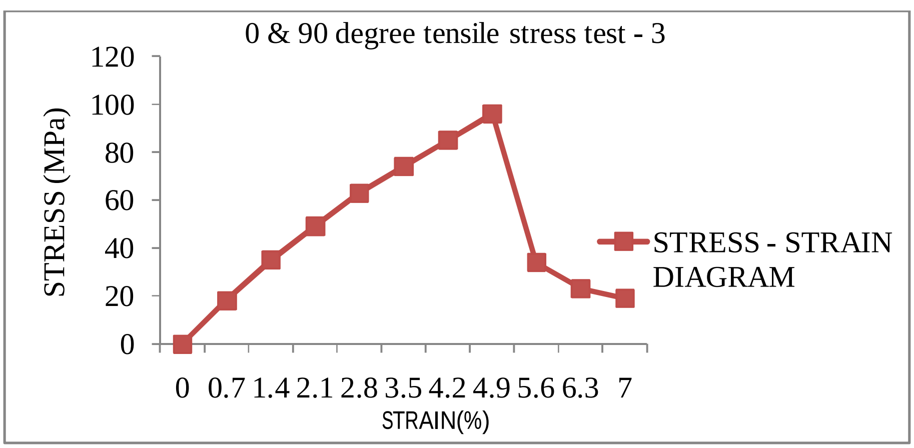
a, 0 and 90 degree tensile strength test - 1

The above figure implies that the maximum tensile strength of this test result is 111MPa.



b, 0 and90 degree tensile strength test - 2

The figure above showing that the tensile strength of this second test is exhibits 80 MPa.



b, 0 and 90 degree tensile strength test - 3

Figure on the above 0 and 90 degree tensile strength test – 3 is showing 96 MPa.

Figure 4.4: a, b, c are (0, 90) degree tensile strength test.

The results obtained from the ECAE laboratory test are listed in the table below.

Table 4.1: Tensile test of the specimen with different orientations

Fiber orientation	Maximum Tensile strength (MPa)			Average(MPa)
	T-1	T-2	T-3	
0^0	136	137	161	144.67
±45	57	84	76	72.33
$(0,90^0)$	111	80	96	95.67

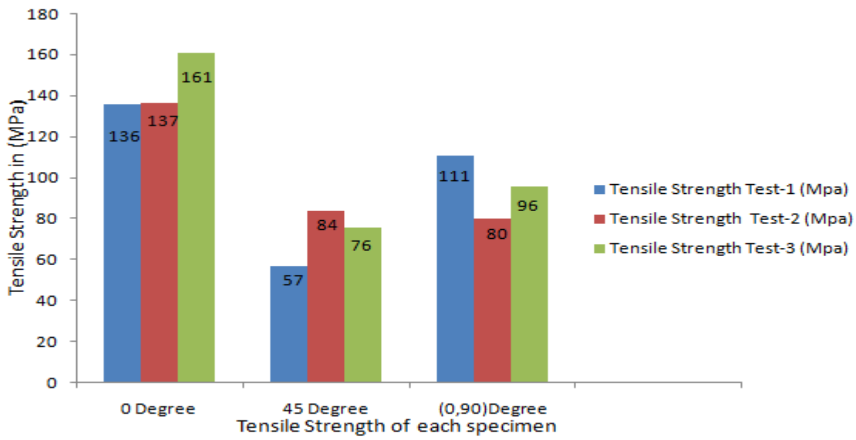


Figure 4.5: Showing tensile strength of specimens.

Figure 4.5 shows individual tensile strength test specimens from different fiber arrangement.

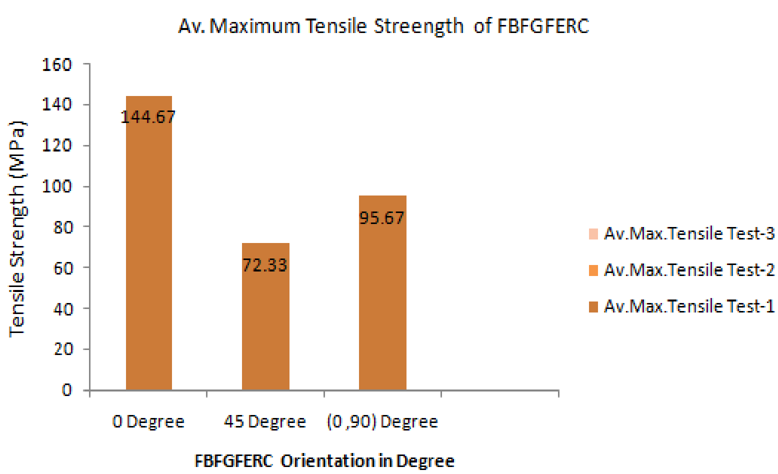


Figure 4.6: Average Tensile strength of FBFGFERC.

Figure 4.6 showing average tensile strength results of each composite specimen.

It is observed from tensile test that the zero (0) degree FBFGFERC has a greater tensile strength value. Therefore it is better to select this orientation for the vehicle body especially for panels those are subjected to either static or dynamic tensile stresses

Table 4. 2: Comparison of tensile stress, elongations and Young's modulus

. Orientations	Samples	Thickness (mm)	Max.Tensile force(kN)	Tensile stress (MPa)	Tensile strength (MPa)	Uniform Elongation **(%)**	Young's modulus (MPa)
0^0 degree	T1	4	14.31	145.5	136	5.9	2466.1
	T2	4	12.45	146.2	137	4.3	3400
	T3	4	12.81	150.3	161	5.8	2591.3
$\pm45^0$ degree	T1	4	6.67	66.2	57	4.5	1471.
	T2	4	9.30	92.3	84	5.9	1564.4
	T3	4	8.47	84	76	4.8	1750
$(0,90^0)$ degree	T1	4	10.06	121	111	5.1	2372.5
	T2	4	7.16	86.1	80	4.9	1757.1
	T3	4	8.77	105.4	96	5.6	1882.1

From the above table observing that, the young's modulus of zero degree fiber is higher than others forty five and zeros ninety fiber orientations.

4.1.2 Compression test results

For Compression test nine samples of specimens (three for each orientation) were prepared according to the ASTM D3039/D3039M standards.

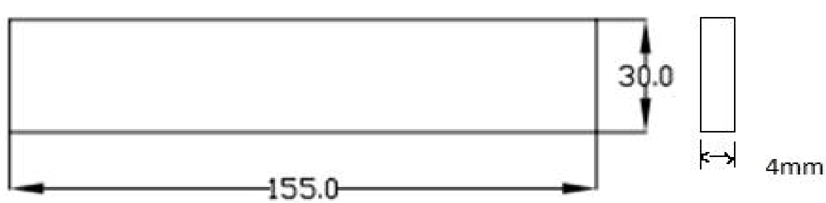
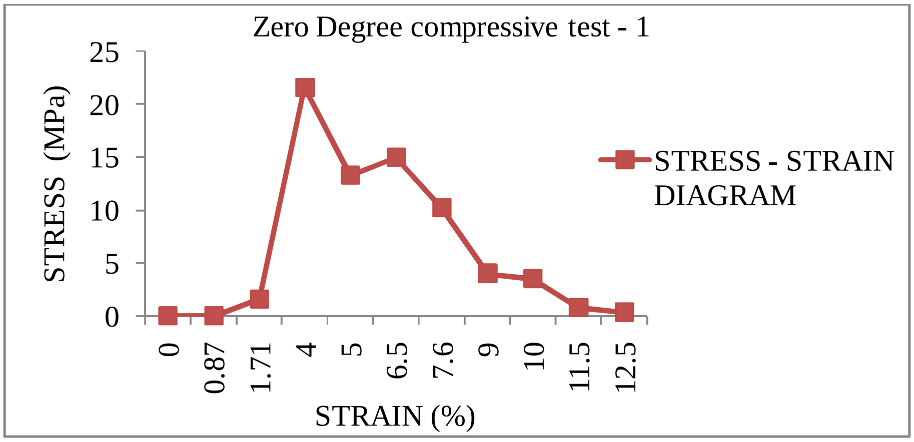


Figure 4.7: Dimensions of specimen for compression tests.

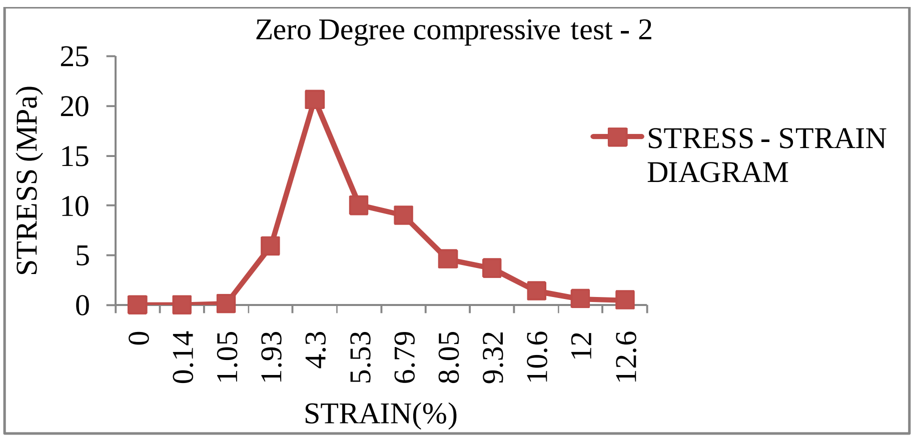
Figure 4.8: Compression strength using UTM.

Three types of 0^0, $\pm 45^0$, $0\&90^0$ of false banana/fiber glass/epoxy having 50/50 mass were used for the specimen. For each test, nine specimens were prepared with different orientations. Compressive forces vs. strain value are given in the table indicated below. The result may vary due to improper preparation and cutting time and during fracture compressive stress of FBFGFERC rapidly decreased with buckling of the specimen.



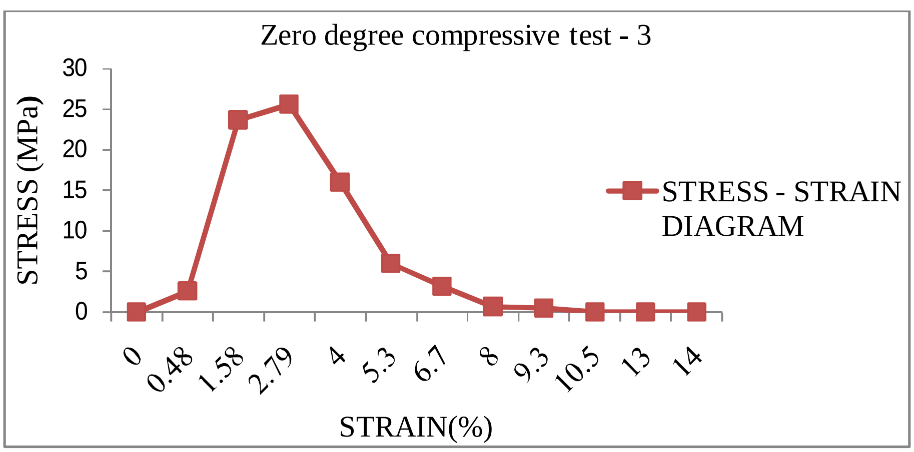
a, Zero degree compressive strength test-1.

The graph on the above is showing maximum compressive strength of 21.57 MPa.



b, Zero degree compressive strength test-2.

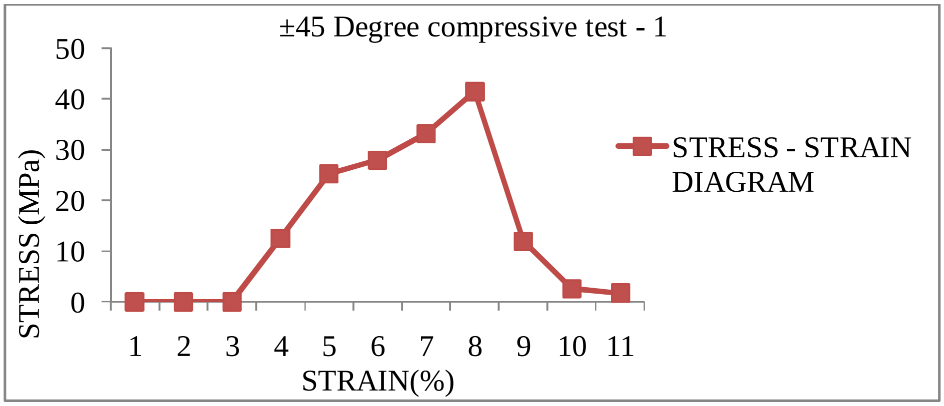
The graph on compressive strength test is showing maximum of 20.57 MPa.



c, Zero degree compressive strength test-3.

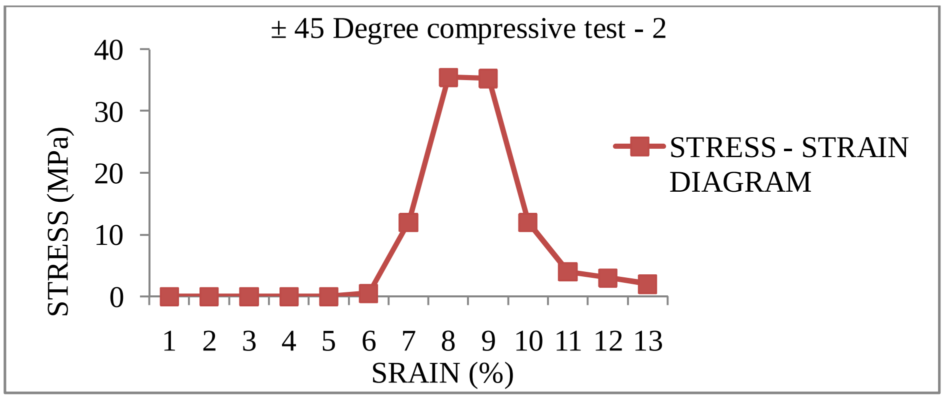
The maximum compressive strength test result from the graph is showing 25.64MPa.

Figure 4.9: a, b, c are compressive strength test graphs.



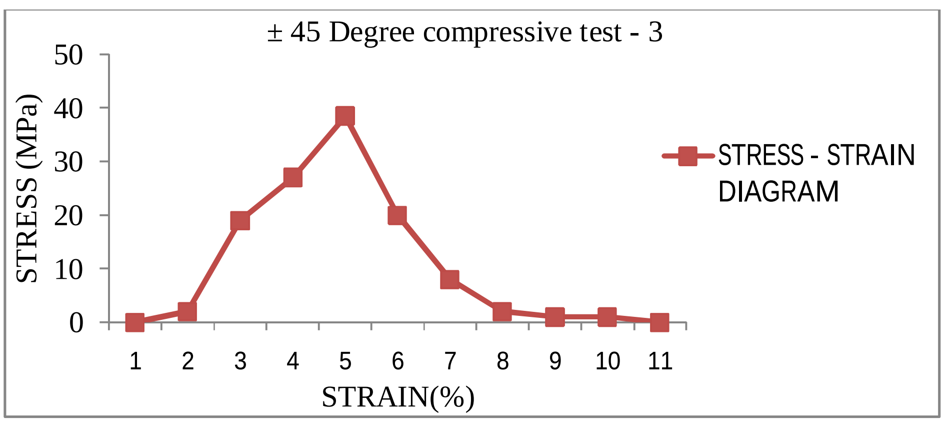
a, ±45 degree compressive strength test-1

The graph shows 41.43MPa of compressive strength test result.



b, ±45 degree compressive strength test – 2.

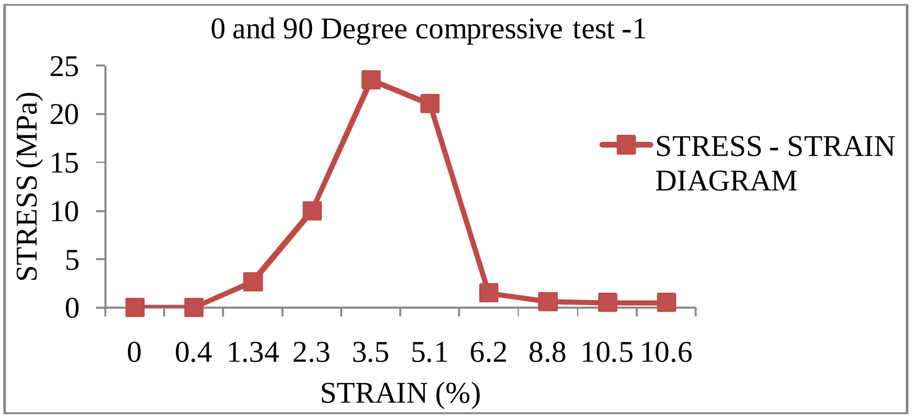
From the graph it is observed that the maximum compressive strength result exhibits 35.43MPa.



c, ±45 degree compressive strength test – 3.

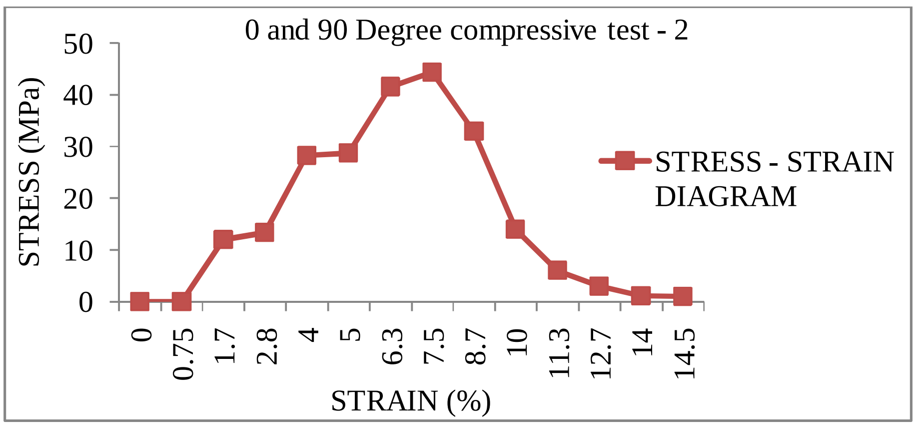
The graph it shows that the maximum compressive strength result exhibits 38.5MPa.

Figure 4.10: a, b, c are (±450) compressive strength test graphs.



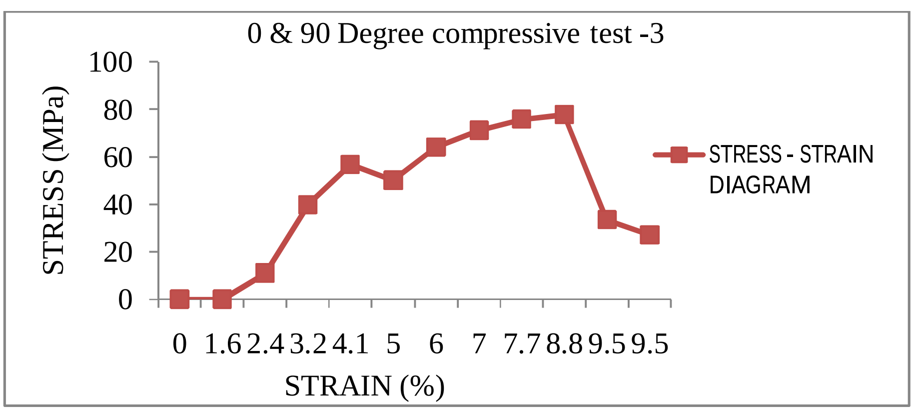
a, 0 and 90 Degree compressive strength test – 1.

The compressive strength test result obtained from the graph is 23.5 MPa.



b, 0 and 90 Degree compressive strength test – 2.

The above figure is indicating 44.36MPa of the maximum compressive strength.



c, 0 and 90 Degree compressive strength test – 3

From the above graph the exhibited maximum compressive strength is 77.75 MPa.

Figure 4.11 a, b, c: are 0 & 90 maximum compressive strength test graphs.

Table 4.3: Maximum Compressive strength and elongations.

Orientations	**Samples**	**Thickness (mm)**	**Max.Load (in k N)**	**Max.comp. Strength (MPa)**	**Elongation (%)**
0^0 degree	C1	4	3.02	21.57	3.97
	C2	4	2.88	20.57	4.3
	C3	4	3.59	25.64	2.79
$\pm 45^0$ degree	C1	4	5.39	41.43	6.74
	C2	4	4.96	35.43	6.5
	C3	4	3.55	38.5	5.52
$(0,90^0)$ degree	C1	4	32.54	23.5	8.95
	C2	4	9.33	77.75	8.89
	C3	4	6.21	44.36	7.46

The results of maximum compressive load, strength and elongation are obtained from the universal testing machine at the time of measurement of all fiber orientation of the specimens. It is obvious that a 0 & 90 degree orientation of FBFGFERC has higher bending strength than others.

Table 4.4: Compressive strength of specimens.

Fiber orientation	Maximum Compression strength (MPa)			Average (MPa)
	C-1	C-2	C-3	
0^0	21.57	20.57	25.64	22.59
$\pm 45^0$	41.43	35.4	38.5	38.44
$0,90^0$	23.5	77.75	44.36	48.54

From the table 4.3, one can observe that (0, 90) orientation specimen has the highest compressive strength compared to others.

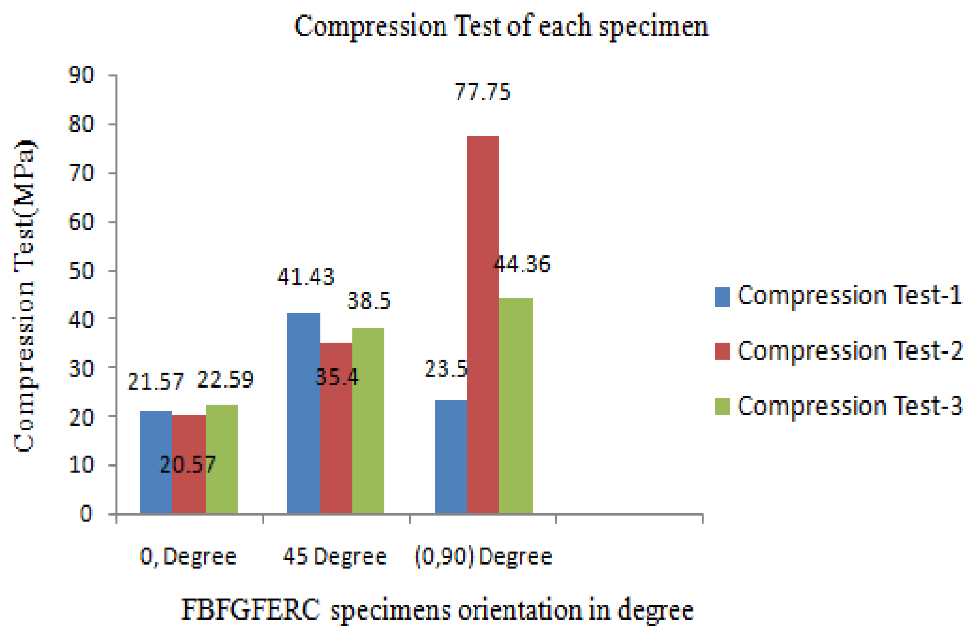


Figure 4.11: Showing compression strength test of each FBFGFERC specimen.

The above figure 4.12 are showing each compressive test results of the specimen with different fiber arrangements having zero & ninety fiber orientations.

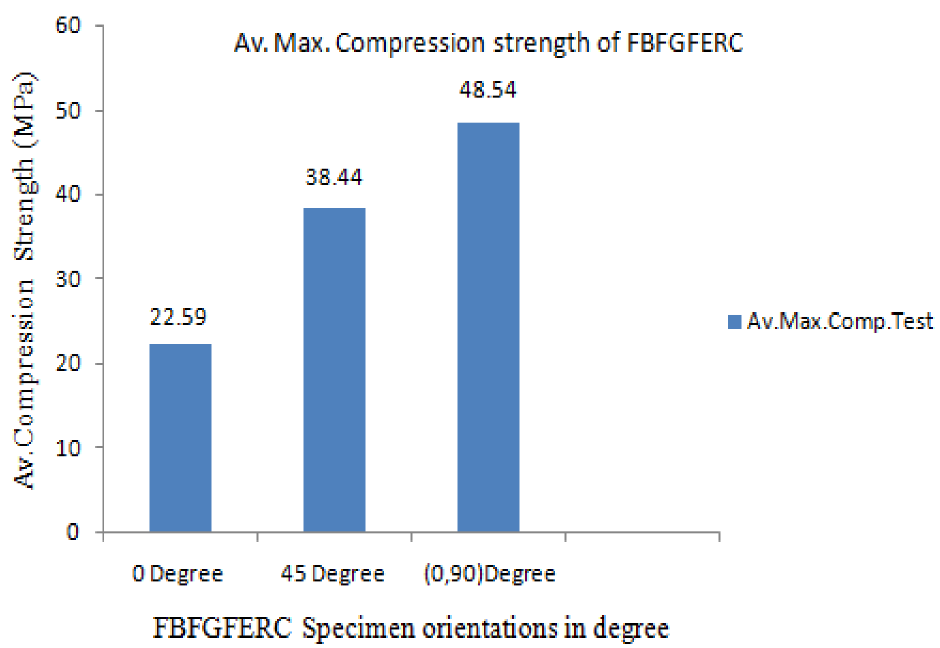


Figure 4.13: Av.max compression strength test of FBFGFERC.

The compression results obtained from the UTM machine shows that the (0, 90) degree orientation specimen have 48.54 MPa which is greater than from both 0(zero) degree and 45degree arrangements of the specimens. Therefore hybrid of false banana fiber with glass fiber in (0, 90) degree arrangement have more compressive stress resistance than those arrangements listed on the above.

4.1.3 Bending test results

The Bending test measures the force required to bend the specimen under three point loading situations. This test is often used to select specimen for vehicle body parts that will support loads without inflection(braking). This test is also performed using UTM machine in accordance with ASTM D3039/D3039M standard to measure the bending strength of the composites. Bending test was performed keeping the bending table on the lower table in such a way that the central position of the bending table is fixed in the central location value of the lower table. The bending supports are adjusted to required distance. Stuffers at the back of the bending table at different positions. Then place the specimen on bending table and apply the load by bending attachment at the upper stationary head.

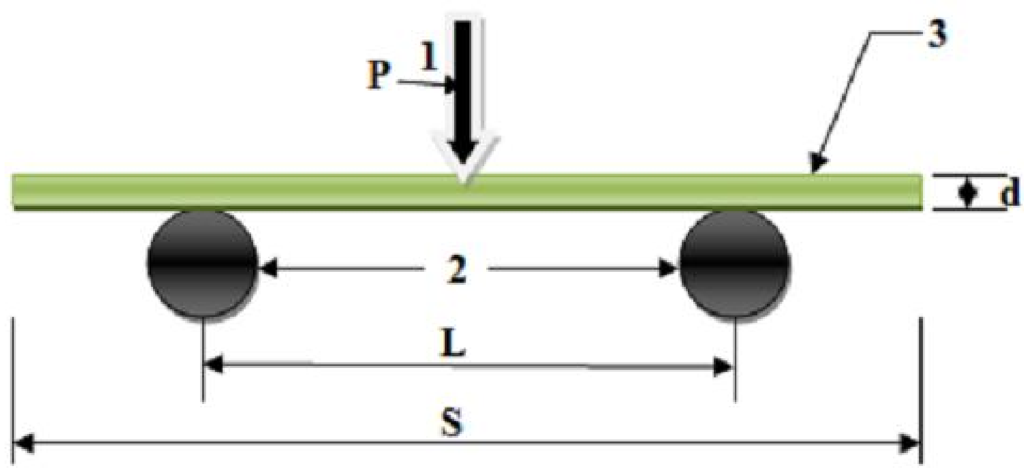


Figure 4.14: Bending strength testing point view.

Where:-

1: UTM power piston, 2: Cylindrical support, 3: specimen, d: thickness of specimen,

L: support distance and S: overall length of specimen

Bending modulus is used as an indication of a material's stiffness when inflection.

The figure 4.14 is explaining the dimensions and positions how to measure a bending test on the universal testing machines.

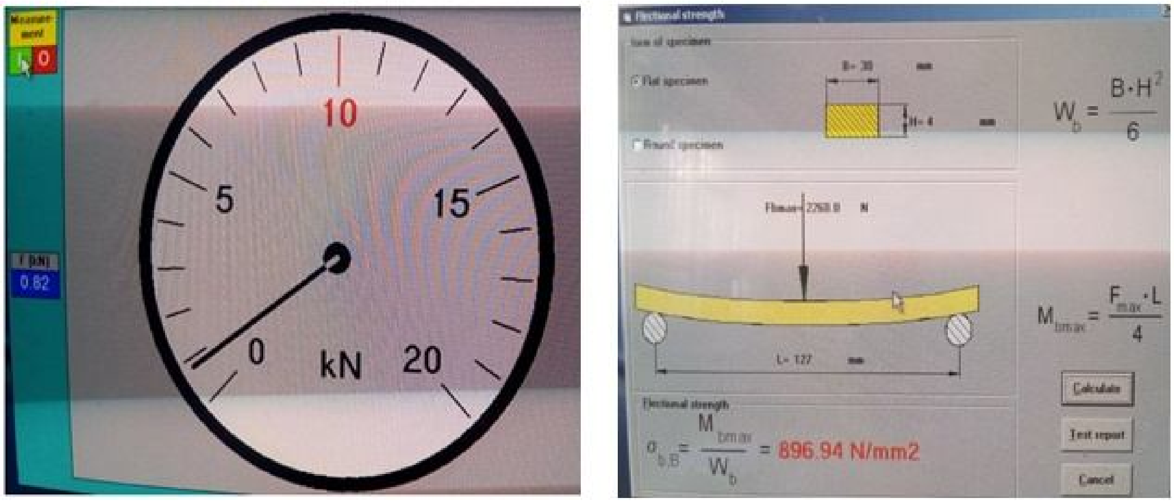


Figure 4.15: The gauges in loading on control system.

From the strength of materials equations

Section modulus (W_b)is calculated by the formula: - $W_b = (W \times H^2)/6$ ------------- (4.1)

Maximum bending moment…………………......... $M_{bmax} = (F_{max} \times L)/4$----------- (4.2)

Maximum bending stress……………………….... . $\delta_{b\,max} = M_{bmax}/W_b$------------- (4.3)

Three point bend test was carried out in an UTM in the table indicated bellow

Table 4.5: Bending strength of the specimens

Fiber orientation	Maximum bending load (in N)			Average (in N)
	B-1	B-2	B-3	
0^0	1160	990	1160	1103.33
$\pm 45^0$	1760	2260	1260	1760
$0,90^0$	2130	3960	2050	2713.33

Table4.5: on the above is explaining the each and average bending strength of the specimens with different fiber orientations.

From the above table it is observed that the zero ninety FBFGFERC orientations have 2713.33 N hence better bending force than the other two arrangements.

Table 4.6: Showing deflection, bending moment and bending stresses.

FBFGFERC Orientation	Specimen	Height (mm)	Width (mm)	Length (mm)	F_{max} (kN)	W_b (mm^3)	$M_{b\ max}$ (N.mm)	δ_{bmax} (N/mm^2)
Zero Degree	B-1	4	30	127	1.16	80	36,830	460.38
	B-2	4	30	127	0.99	80	31,432.5	392.91
	B-3	4	30	127	1.16	80	36,830	460.38
45 Degree	B-1	4	30	127	1.76	80	55,800	698.50
	B-2	4	30	127	2.26	80	71,755	896.94
	B-3	4	30	127	1.26	80	40,005	500.06
(0,90)Degre	B-1	4	30	127	2.13	80	67,627.5	845.34
	B-2	4	30	127	3.96	80	125,730	1,571.63
	B-3	4	30	127	2.05	80	65,087.5	813.73

Table 4.6 is introducing the maximum force exerted on the specimen, Section modulus, Maximum bending moment and Maximum bending stress of the specimens with different fiber arrangement.

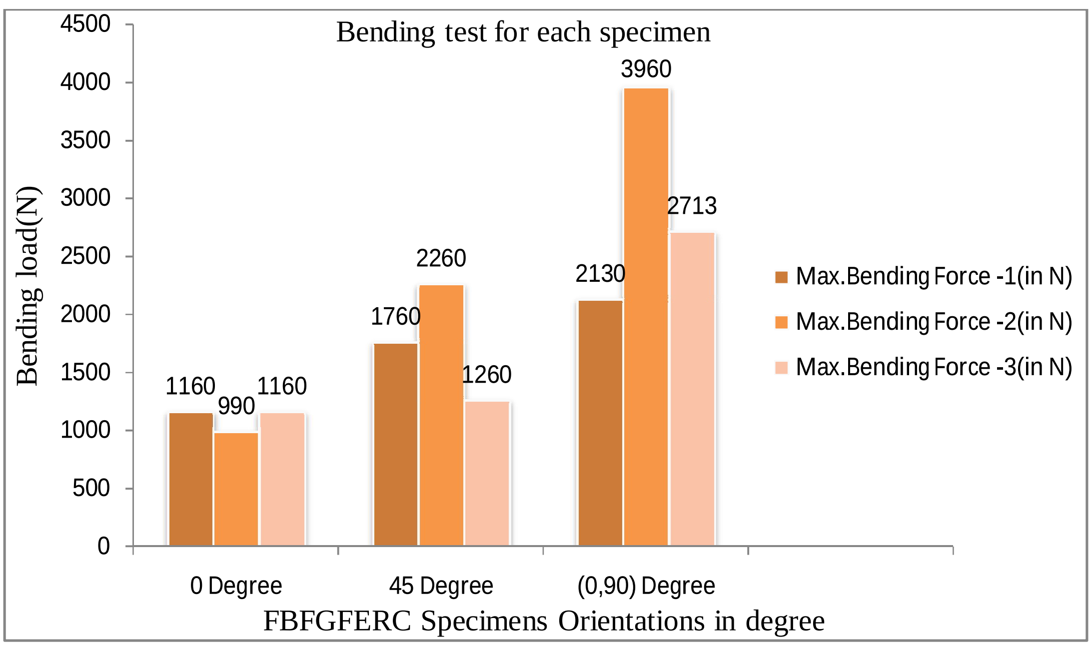


Figure 4.16: Bending load of each specimens

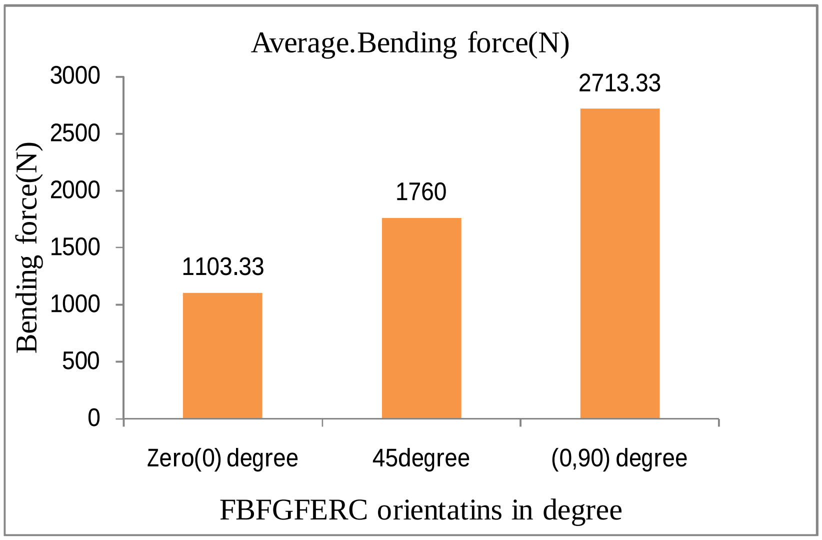


Figure 4.17: Average bending loads

The specimens were tested for bending strength using Universal testing machine with appropriated jaws and the result were obtained for all specimen orientations. From the results registered observed that the zero ninety (0, 90) degree arranged specimen have more bending strength than those of zero degree and 45 degree orientation specimen. Therefore the (0, 90) degree arranged specimen is with better bending strength for auto body where more bending loads are expected.

4.1.4 Water absorption tests results

Water absorption test was performed to know how much water the specimen can absorb through in twenty four hours of time (one day). First all the dry specimens weight were tested and then immersing in to distilled water and putting in to the container (plastic) and putting them to the oven with adjusted 50 ^{0}C temp. After one day again removing the specimen from the distilled water and measuring the weight of the wet specimens. The water absorption values were obtained in accordance with ASTM C220. The samples were dried in an oven at 100 ± 5 °C for a period of 24 hours. After cooling down in desiccators to room temperature, the dry weight of each was determined and recorded. Finally the water absorption was calculated as given bellow.

Water absorption equation:

$$W_m = \frac{W_w - W_d}{W_d} * 100\% \text{-- --- } (4.4)$$

Where: W_m - Water absorption

W_w - Wet weight,

W_d - Dry weight

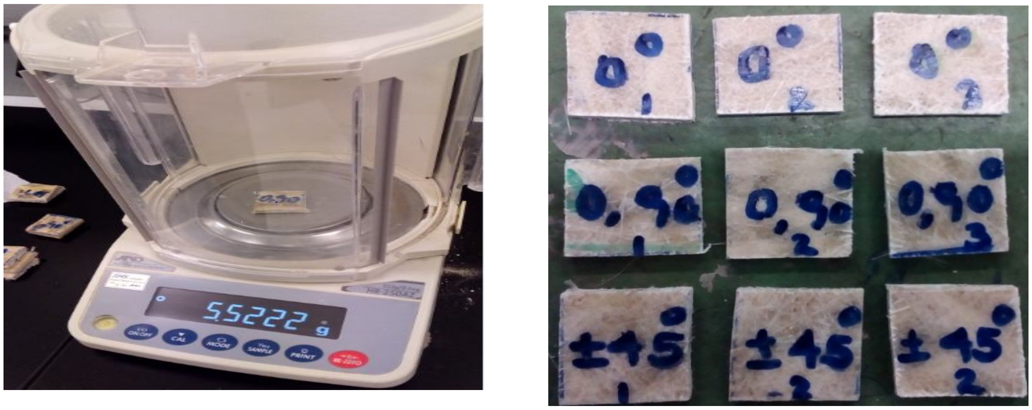


Figure 4.18: FBFGFERC specimens mass prepared from different orientations.

Figure 4.19: FBFGFERC sample in the distilled water for one day.

Table 4.7: Each FBFGFERC samples dry weight and wet weight.

Fiber orientation	Water absorption test(Dry mass)						Average (dry)	Average (wet)
	Sample-1		Sample-2		Sample-3			
	Dry	Wet	Dry	Wet	Dry	Wet		
0^0	4.59	4.77	5.16	5.29	4.71	4.84	4.82	4.96
$\pm45^0$	6.44	6.66	6.39	6.65	6.14	6.40	6.32	6.65
$0,90^0$	4.59	4.73	4.30	4.46	4.17	4.30	4.35	4.49

Water absorption can be calculated using the difference in wet mass and dry mass and multiplying with 100%.

Where: - w_1: First wet mass for all $0^{0,}$ $\pm45^0$,90^0 orientations

w_2: Second wet mass for all $0^{0,}$ $\pm45^0$,90^0 orientations

w_3: Third wet mass for all 0^0, $\pm45^0$,90^0 orientations

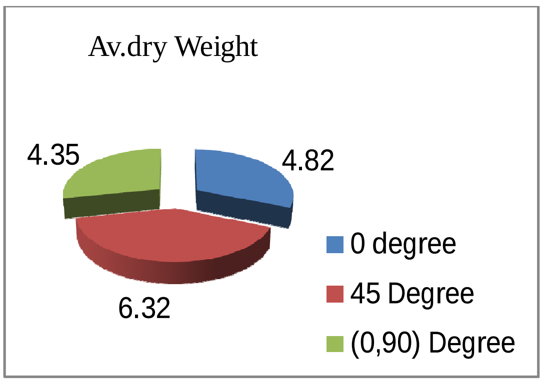
d_1: First dry mass for all 0^0, $\pm45^0$,90^0 orientations

d_2: second dry mass for all 0^0, $\pm45^0$,90^0 orientations

d_3: third dry mass for all 0^0, $\pm45^0$,90^0 orientations

Table 4. 8: Water absorption of FBFGFERC composites (24 hours at room temp).

samples	$(\boldsymbol{w_1}$-$\boldsymbol{d_1})/\boldsymbol{d_1}$*100 In (%)	$(\boldsymbol{w_2}$-$\boldsymbol{d_2})/\boldsymbol{d_2}$*100 In (%)	$(\boldsymbol{w_3}$-$\boldsymbol{d_3})/\boldsymbol{d_3}$*100 In (%)	Av. Water absorption (%)
0^0	3.92	2.52	2.76	3.07
45^0	3.42	4.06	4.23	3.90
$0,90^0$	3.05	3.72	3.11	3.29



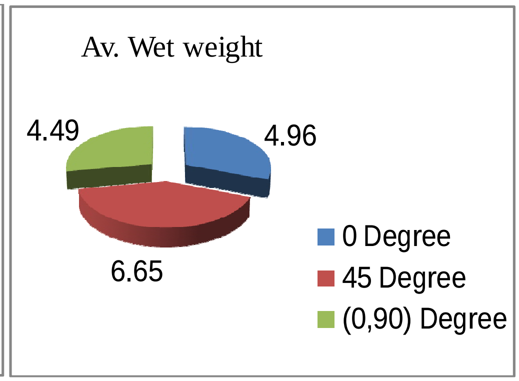


Figure 4.20: Dry and Wet weight of FBFGFERC samples.

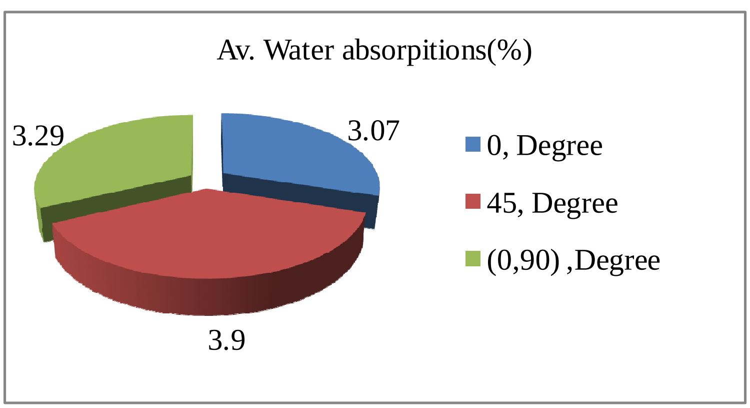


Figure 4.21: Av. Water absorptions of the specimens.

4.2 Discussion

4.2.1 Tensile tests

Table 4.9: Average tensile stress of FBFFGERC.

Fiber orientation	Average tensile test (MPa)
0^0	144.67
±450	72.33
90^0	95.67

Observation

1. The orientation affects the tensile strength of the false banana fiber and glass fiber hybrid reinforced epoxy composite. comparing the maximum tensile strength results for the zero degree (0^0) forty-five(45^0) degree and zero ninety degree(0 ,90^0) FBFGFERC composite, for example the tensile strength result of FBFGFERC composite shows 144.67MPa from zero degree (0^0) , 72.33 MPa from forty-five(45^0) degree and 95.67 MPa from zero ninety degree(0 ,90^0)respectively. Therefore the tensile strength of zero degree (0^0) fiber orientation has more tensile strength than other two matrixes and this hybrid orientation significantly affect tensile strength in relation to others. Vehicles body panel subjecting to more tensile stress shall be constructed with zero degree (0^0) fiber orientation of FBFGFERC.
2. From the tensile result, it is concluded that as the degree of orientation increased the tensile strength will be decreased.
3. Some result variation from the same orientation is also due to some errors at the time of preparation of the specimen.

4.2.2 Compression tests

Table 4.10: Average compressive stress of FBFGFERC.

Fiber orientation	Average compressive stress(MPa)
0^0	22.59
$\pm 45^0$	38.44
$0,90^0$	48.54

Observation

1. Comparing the three average compressive strength of the zero degree (0^0) forty-five (45^0) degree and zero- ninety degree (0, 90^0) FBFGFERC composites specimen, it is found that the zero ninety degree (0, 90^0) have high and significant value which is 48.54 MPa. Some variations in the values observed even between the three samples of (0,90^0) specimen may be due to error molding and cutting process of the FBFGFERC specimen for this test.
2. From the above observation it can be concluded that for automotive body panels specially those are subjected to more compressive stress it is better to use the(0,90^0) degree orientation FBFGFERC.

4.2.3 Bending test

The average bending strength test results of FBFGFERC are tabulated and presented in table 4.11 given below.

Table 4.11: Average bending stress of FBFGFERC.

Fiber orientation	Average bending (in N)
0^0	1103.33
$\pm 45^0$	1760
$0,90^0$	2713.33

From the average compressive test result we conclude that during three points bending test, when the load P is applied at mid span of a flat and rectangular specimen of span L between two rollers, the highest bending strength is determined by:-

Bending stress $\sigma_b = 3PL/2Wt^2$--- (4.5)

Observations

1. Comparing the three FBFGFERC orientations systems (0^0,45^0, (0,90^0)) hybrid fiber for flexural strength. It is a clear that the zero degree specimens scored lower average result.
2. The zero ninety orientations have a better result (2713.33N) comparing to others two composites.
3. On the vehicle bodies especially for those are subjected to more bending stress it is better to use FBFGFERC material made from zero ninety orientations.

4.2.4 Water absorption

1. From the water absorption tests of all FBFGFERC specimens it is found that zero (0^0) degree, 45^0degree and ($0,90^0$) degree absorbs around 3.07%, 3.90% and 3.29% respectively.
2. Relatively more amounts of water was absorbed by the 45^0 FBFGFERC specimens.
3. Minimum amount of water absorption observed by the zero (0^0) degree fiber orientation.
4. For better or minimum water absorption it is better to manufacture vehicle body from the FBFGFERC having zero (0^0) degree orientations.

4.3 Fabrication of Composite Bumper

Based on the results obtained from the mechanical and physical laboratory tests of tensile, compressive, bending and water absorption concluding that it is best to manufacture vehicle body panel that have relatively less stresses specially bumper body panel locally using zero ninety(90^0) degrees even though the result is not as such equal as the E-glass fiber composite materials. The selected fiber orientation exhibited good strength in all mechanical properties.

4.3.1 Bumper

Bumpers are an automobile body part which is designed to reduce or prevent physical damage to the front and rear of vehicles in low-speed crashes. The bumpers are also designed to protect the hood, trunk, grill, fuel, exhaust and cooling system. It is a shield that can be usually made of steel, aluminum, rubber, plastic or other materials.

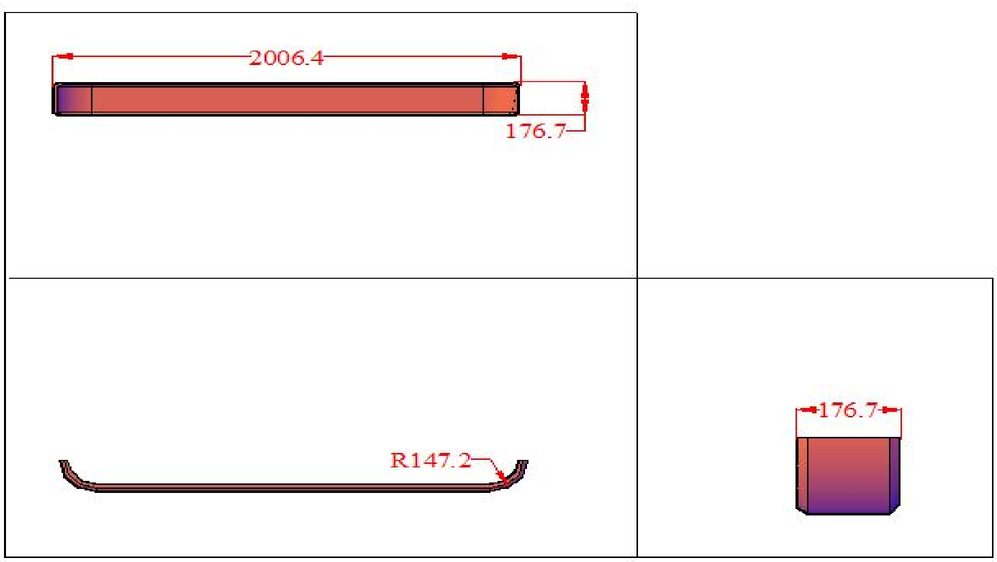


Figure 4.22: Bumper multi view with dimension.

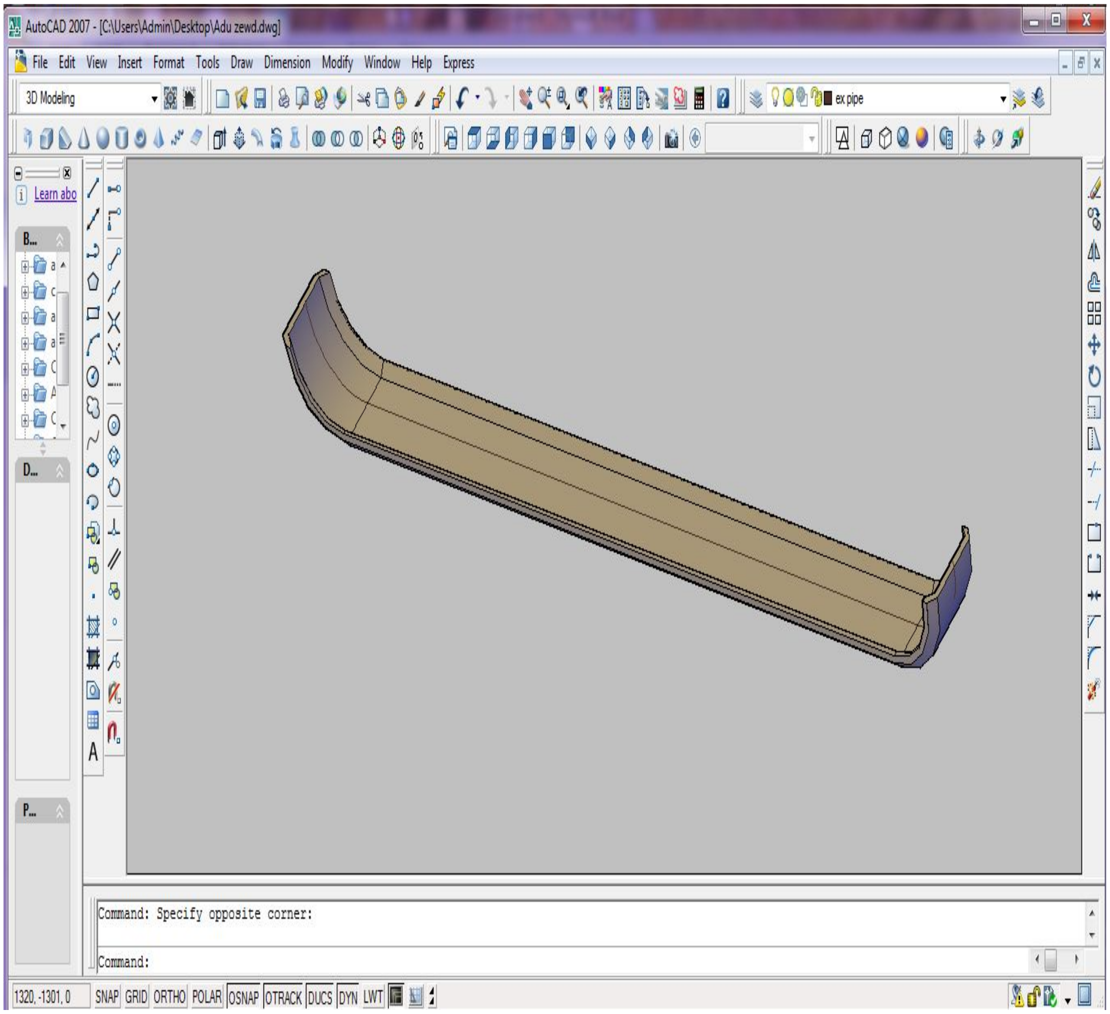


Figure 4.23: Bumper 3D AutoCAD drawing

Figure 4.24: Prototype bumper before top paint.

Figure 4.25: Prototype bumper after top paint

4.4 Comparison of the previous work

Table 4.12: Comparison of existing work to the new one.

Composition of materials (%)		Tensile Strength(MPa)	Bending strength(MPa)	Author	References
Resin/glass fiber	Banana				
80	20	56.5	340.625	Mahmud et.al.	[27]
66	33	93.11	73.4	Ashwani Kumar et. al	[28]
20	15	45	80	G Gupta et. al 2016	[30]
20	15	--	22.647	Shashank T.A et.al	[29]
50	50	59.13	87.66	Satish Pujari et al.	[26]
50	50	144.67	845	Current Researcher	Current work

The table 4.12 is indicating the detail of tensile, bending results and proportions of the materials to produce composite materials by previous researchers (authors).

The current price of vehicle bumper in Ethiopia is 4500-8000 birr from second hand (from Dubai) to the original genuine part (from MOENCO) but to manufacture such a bumper with the same shape it may cost only 2000 birr including all the necessary composite material and technician costs even though thickness and molding are challenging compared to the steel or plastic front and rear bumpers.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The false banana fiber was extracted manually from false banana plant in southern part of Ethiopia which is primarily used for food propose, and then it was treated using sodium hydroxide and distilled water solution for better strength and roughness property. Second, FBFGFERC specimen was produced in the shop from appropriate materials using the materials like fiber epoxy, resin etc. Its physical and mechanical properties such as the tensile, compression ,bending and water absorption properties is determined using proper testing procedure as per ASTM standard. All the necessary experimental test results were recorded and comparisons among different specimen were presented. Moreover these test results give fundamental confirmation of the availability and reliability of the hybrid composite of false banana and of its usage in vehicle body panel application.

Hybrid composite material which is made of false banana fiber and glass fibers are more environmental friendly compared to glass fibers reinforced composite. False banana fiber reinforcement composites have the advantages like renewability, low density, biodegradability, good insulation property; non-toxicity and durability compared to the normal E-glass fiber composite materials. The mechanical properties of a composite depend on the nature of resin-fiber adhesion, the resin, fiber, molding materials and not the least on the method of the processing. Therefore, any improvement in the property is evaluated and compared to that of the polymer matrix, undergoing the same process. The fibers are impregnated by the liquid resin usually at room temperature and then treated with some cross-linking agent for hardening.

5.2 Conclusion

Based on the tensile, compression, bending and water absorption properties experiment data results including material preparations in this thesis, the following conclusions are drawn;

- FBFGFERC containing the false banana fiber and glass fiber as reinforcement was successfully manufactured.

- Different mechanical and physical properties of FBFGFERC were determined from varying fiber orientations and keeping the percentages of false banana fiber and glass fiber equal in all orientations.
- From the Experimental Tensile test results it is found that the zero (0^0) degree false banana showed average 144.67 MPa up to maximum 161MPa. This false banana fiber orientation have better tensile property comparing to others two forty five (45^0) and ninety (90^0) degree orientation results of 72.23MPa and 95.67 MPa. Suggesting that zero degree fiber orientations are better than others to overcome more tensile load stress.
- From the Compression test results it is recorded that FBFGFERC with ($0,90^0$) degree orientations have higher compressive tensile strength of 77MPa maximum 44.54MPa average as compared as others two zero and forty-five degree orientations.
- Bending Experimental test results shows that 1571.63 MPa obtained from the ($0,90^0$) degree fiber orientation which was very highest than those of two zero and forty five degree fiber orientations.
- The effect of moisture content obtained from water absorption test is within the specifications and has good water absorption for auto body panels.
- From water absorption test results of each specimen obtained that the zero degree fiber orientation has 3.07% which is lower than others two fiber arrangements of 3.90% and 3.290%. In these test all of the FBFGFERC specimen's fiber orientations have minimum water absorption which is less than 15% of ASTM C220 standards.
- Considering all the mechanical and physical laboratory test obtained from the tensile ,compressive, bending and water absorption results concluding that it is better to manufacture vehicle body panel locally by combining the two more effective orientations of zero(0^0) degree and zero ninety(90^0)degrees even though the result is not as such equal as the E-glass fiber composite materials. Because those two fiber orientations exhibited good strength in all mechanical properties.
- The results of mechanical behavior of FBFGFERC determined in this work are useful for application in engineering composite materials especially for automotive body panels.
- Due to the high specific properties and low density of FBFGFERC based on these fibers may have very good implications in auto body industry.

Moreover, reduced abrasion and consequent reduction of re-tooling makes these composites one of the most effective alternatives. The false banana fiber as a source of raw material in polymer (composite) industry not only supports a renewable resource, but can also produce a source of income development for rural areas.

- It is suggested that these FBFGFERC composites can be used as an alternative material for glass fiber reinforced polymer composites, especially for medium load structural vehicle bodies like bumpers, heavy equipments engine covers, air dams, interior compartments etc as they significantly reduce the problems related to environmental concerns.

False Banana fiber has already proven to be better alternative natural fiber in composite formation, as it is a resource with vast availability and fast growth with biodegradation. The hybridization of false banana fiber and glass fiber not only improve the mechanical properties of composite but also reduce its cost and make it eco friendly composite. Thus, banana fiber in combination with glass fiber has proved to be excellent for making cost effective composite materials. From the above results concluding that the glass fiber provides toughness and banana fiber provides elasticity by making the composite cheaper, bio-degradable composites.

From the previous discussions, it is quite clear and evident that newer composites using abundantly available false banana fibers are on the horizon; this brings new trends in composite materials. Thus it can be concluded that there will be a good possibility and better expectations for false banana fiber composites in the future. Specially the combinations of both zero degree and zero – ninety degree has a good strength for all mechanical properties and the optimum values can be achieved for producing the vehicle body panel for those have relatively medium and less stressed parts.

5.3 Recommendations for future works

- It is recommended to you use false banana fiber in preparing the composite materials used in the construction of the vehicle body panel.
- It is recommended to encourage the growth of false banana plant which helps in minimizing the importation of some simple car body from abroad.
- It is recommended that the university has to develop the necessary facilities for preparation and testing of composite materials.

- It is recommended to use false banana hybrid fiber composites in other parts of vehicle to reduce the weight of the vehicle.

Finally from this study, it has been recommended that enough potential of false banana plant fiber for the applications are found in the following fields: in erosive environments, manufacturing of light weight body panels like, door panels, interior paneling, door-frame profiles seat backs, headliners, dash boards, car doors, pallets, trunk liners, decking, parcel shelves, spare tire covers, spare-wheel pan, of an automobiles.

5.4 Scope for future work

The present research work on FBFGFERC leaves a wide scope for future investigators to explore many other aspects of such hybrid composites. Some recommendations for future research include:

1. The other properties of composites such as impact strength, fatigue strength, hardness test, microstructure tests, cyclic load test and tribological (friction, lubrication and wear) behavior may be determined using extensive experimentations.
2. The experiments can be expanded by adding other chemicals and apparatus, by changing the fiber orientation and fiber percentage and their mechanical , physical and machining characteristics may be analyzed.
3. The experiments can be extended by increasing the number of machining parameters, such as die and tool geometry, tool materials, etc.
4. The experiments can be repeated by using different tool inserts with wider geometries.
5. The experiments can be extended to other machining processes, such as milling, reaming etc.
6. The experimental data can be modeled and analyzed using other MATLAB, ANSYS and others modeling techniques.

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APPENDICES

DATASHEETS

In this appendix, all the data have been collected at the time of experimental test work in the laboratory were provided.

Data collected in the laboratory during Compression strength specimens testing

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Ethiopian Conformity Assessment Enterprise

ቁጥር (No) 3/187/ዒ.2/78/1/18

ቀን (Date) 23 APR 2018

To: **Adugna Diriba**

Adama

On your request dated April 19, 2018 you have requested for the analysis on Composite Material.

Accordingly, the analysis is completed as per your request and hence you find the report attached here with.

Regards,

Tesfaye Solomon

Head, Branch Communication and Customer's Service

Enc: 3 Page of test reports MTR/1316-1318/18

CC. ECAE

- Customer's Service

  Addis Ababa

ወደ ላቀ ብቃት የሚያደርስ!

Moving you forward!

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No: TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No: MTR/1318/18
Test order No: ---

1	Name and address of client	Adugna Diriba Tel: +251-912-22-45-93, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	19/04/18
5	Client's sample code	Adama Science & Technology University
6	Laboratory designated sample No	10221026
7	Type of sample	Composite material fiber glass with false banana 0^0 fiber orientation
8	Test method	As per clients agreement
9	Test date(s)	23/04/18
10	Date of Submission of test report	23/04/18

L.D.S No.	No.	Test Result Tensile strength (Mpa)
10221026	1	136
	2	137
	3	161

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Liyew Wudie Position Analyst I Sign.

✉ 11146 ☎ 011 6 46-05-89, Fax. 011 6 45-[illegible], E-mail info-c[illegible].com Web site: www.eca-e.[illegible]
BOLE SUBCITY, WOREDA [illegible]
ADDISABABA, ETHIOPIA

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No: TL/DF5.10-1 Copy No: - Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1 Effective Date: 1Jan 13

Report No: MTR/1318/18
Test order No: ---

1	Name and address of client	Adugna Diriba Tel: +251-912-22-45-93, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	19/04/18
5	Client's sample code	Adama Science & Technology University
6	Laboratory designated sample No.	10221028
7	Type of sample	Composite material fiber glass with false banana $\pm 45^0$ fiber orientation
8	Test method	As per clients agreement
9	Test date(s)	23/04/18
10	Date of Submission of test report	23/04/18

L.D.S No.	No.	Test Result: Tensile strength (Mpa)
10221028	1	57
	2	84
		76

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Liyew Wudie Position: Analyst I Sign.

✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 46-05-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA
ADDISABABA, ETHIOPIA

ECAE	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No: TLD/F5.10-1
		Copy No: - / Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1 / Effective Date: Ehar 13

Report No: MTR/1317/18
Test order No: —

1	Name and address of client	Adugna Diriba Tel: +251-912-22-45-93, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	19/04/18
5	Client's sample code	Adama Science & Technology University
6	Laboratory designated sample No.	10221027
7	Type of sample	Composite material fiber glass with false banana $(0,90)^0$ fiber orientation
8	Test method	As per clients agreement
9	Test date(s)	23/04/18
10	Date of Submission of test report	23/04/18

L.D.S No.	No.	Test Result Tensile strength (Mpa)
10221027	1	111
	2	80
	3	96

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Liyew Wudie Position Analyst I Sign. for [signature]

✉ 11145 ☎ 011 6 46-05-89, Fax. 011 6 45-97 E-mail info-ca@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA
ADDISABABA, ETHIOPIA

Some data for the previous work like fiber glass, epoxy resin, wax, gel coat and hardener quantity are taken from the data's bellow

WORLD FIBER GLASS AND WATER PROOFING ENGINEERING

1. Technical Data
2. Application Method
3. Product Code
4. Safety Data Sheet
5. Iso Certificate

شركة كيماويات الراتنجات الصناعية المحدودة
Industrial Chemicals & Resins Co. Ltd.
Chamber of Commerce No. 35012

647 5m²

TOPAZ – 1110 TP, GENERAL PURPOSE RESIN
UNSATURATED POLYESTER RESIN

TECHNICAL DATA SHEET

INTRODUCTION

TOPAZ - 1110 TP is a medium reactive unsaturated Polyester Resin based on Phthalic Anhydride, with excellent laminating properties.

TOPAZ - 1110 TP is Thixotropic and has a built-in accelerator system giving long gel time and rapid curing for shorter demoulding time.

TOPAZ - 1110 TP impregnates the fiberglass quickly and the laminate gives a smooth tackfree surface due to the presence of wax.

TOPAZ - 1110 TP is designed for general purpose moulding for hand lay-up and spray up applications.

PHYSICAL PROPERTIES (at 25° C)

PROPERTIES	VALUES	UNIT	TEST METHODS
Appearance	pinkish Viscous liquid		
Viscosity	575-675	cps	ISO 2555-1974
Specific Gravity	1.13	g/cc	ISO 2811-1974
Acid Value	23-28	mg/koh/gm	ISO 2114-1974
Styrene Content	38±3	% Weight	ISO 2114-1974
Flash Point	34°	Centigrade	ASTM D 3278-73
Storage Stability	4	Months	
Gel Time (1.5% MEKP)	15-20	Minutes	
Peak Exotherm	150-165	Centigrade	

PACKING
Available in 220 kg. Metallic Drums and in 25kg, 10kg, and 4kg packing, to suit the bulk as well as small requirements.

STORAGE
Recommended to be stored below 25°C. Storage life decreases with increase in storage temperature. Avoid exposure to heat source, such as sunlight or hot pipes. Keep containers sealed to prevent moisture entering or monomer escaping out.

The product has a shelf life of three months, stored in accordance with the conditions mentioned above. On request, however, the Resin can be modified for prolonged shelf life.

P. O. Box 7958 - Dammam 31472 - Saudi Arabia - Tel.: 8122083 (3 Lines) 8122080 Fax: 8121995
e-mail: icr@zajil.net Web: www.icr.com.sa e-mail: icr@icr.com.sa

2

475 m^2

No TP

SUGGESTED APPLICATIONS

- Suitable for Potable Water Storage Tanks.
- Interior Decoratives Furniture, Cabinets, Partitions, Airport Counters, Flower Boxes, Garden Benches, Domes, Car Parking Shelters, Window Shades, Watchman's Cabin, Portable Toilets, T. V. Antenna Etc.
- Sanitary ware, Bath tubs, Sinks.
- Fishing and Pleasure Boats, Water Scooters and Slides.

APPLICATION METHOD

For general use in hand lay up, properly catalysed resin is used freely to wet out thoroughly each layer of fiberglass mat to build a required thickness, it is recommended that a laminate thickness of 3mm should be developed for any service.

MECHANICAL AND PHYSICAL DATA IN CURED STATE

PROPERTIES	PURE RESIN	REINFORCED	UNIT
Glass Content		33%	% Weight
Specific Gravity	1.20	1.45	g/CC
Tensile Strength	50	80	N/mm^2
Tensile Modulus	3000	6000	N/mm^2
Elongation (Min.)	2.5	2.0	%
Flexural Strength	80	120	N/mm^2
Flexural Modulus	3000	6000	N/mm^2
Volume Shrinkage	7		%
Heat Distortion Temp	75±5		Centigrade
Barcol Hardness	40	45	

The surface area of a cured laminate must be abraded prior to further lamination for a good bonding. Prolonged or unfavourable storage conditions may cause some separation, therefore, agitation of the resin prior to use, is recommended.

Exposed to moisture and water has no effect on the performance. A laminate made without a gelcoat will tend to yellow, when exposed directly to sunlight due to lack of U. V. stabilizer, however, the mechanical properties will not be affected.

CAUTION : **NEVER MIX ACCELERATOR AND CATALYST TOGETHER. IT IS DANGEROUS AND CAN CAUSE EXPLOSION.**

3

شركة كيماويات الراتنجات الصناعية المحدودة
Industrial Chemicals & Resins Co. Ltd.
Chamber of Commerce No. 3801/9

TOPAZ – 1900 W, G. P. GELCOAT WHITE

TECHNICAL DATA SHEET

GENERAL DESCRIPTION

TOPAZ 1900 W is a high quality Gelcoat based on Phthalic Anhydride, Polyester Resin.

TOPAZ 1900 W is easy to apply and handle. It is well suited for potable water storage tank, furniture, automobile components and allied industrial general purpose products.

Special additives which substantially reduce the discolouration (yellowing) of the Gelcoat when exposed to sun light (UV light) can be added on request or depending on the requirement of the customer

Recommended peroxide dosage : min 1.0 – 2.0 %
Recommended film thickness : 0.55 – 0.65 mm (Wet film)

PHYSICAL DATA IN LIQUID STATE AT 30° C

PROPERTIES	VALUE	UNIT	TEST METHOD
Viscosity (Brookfield digital 5/20)	5000 – 12000	[illegible]	ASTM D 2196
Sp Gravity	1.10 – 1.13	[illegible]	
Gel Time : with 1.5% MEKP	12 – 20	M	
Storage stability	3	M	

MECHANICAL/PHYSICAL DATA FOR THE GELCOAT BASE CURED STATE

PROPERTIES	VALUE	UNIT	TES
Tensile Strength	45	N/Sq mm	
Tensile Modulus	2800	N/Sq mm	
Tensile Elongation	3	%	
Heat distortion temp	70 – 75	° C	
Barcol Hardness	40 – 42	934 – 1	
Water absorption	70 – 85	mg / Test piece	

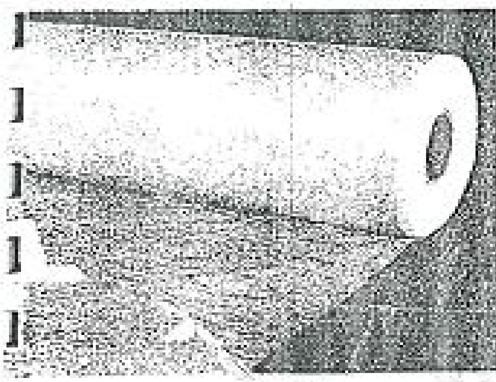
Tensile elongation in cured state varies depending on the pigme

CAUTION

Above information is based on the result of test carried out at ou
our ability. The figures are intended to give a general indication
above material, but no liability must be assumed or implied as s

4

Binani



CHOPPED STRAND MAT (EMULSION)

DESCRIPTION

Binani chopped strand mat is made of randomly yet evenly distributed strands chopped from continuous "E" glass fibres into 50 mm length bonded with "emulsion binder," possesses excellent surface bonding efficiency.

PROPERTIES

- Easy air removal and rapid resin impregnation.
- Drapes well to suit the surface of intricate moulds.
- Fast wet-through and wet-out due to excellent styrene solubility of binder.
- Easy handling and better appearance of the composite parts.
- Good surface bonding and high strand integrity. Compatible with unsaturated polyester resins.

APPROVALS

- Lloyd's Register of Shipping, England.
- Det Norske Veritas, Norway.
- Germanischer Lloyd's, Germany.
- Indian Register of Shipping, India.

PRODUCT CHARACTERISTICS

CONFORMING TO :- IS:11551/BS:3496

Characteristics	Limits	Nominal values			
		225 g / m2	300 g / m2	450 g / m2	600 g / m2
Width (cm)	+1, -0	100	100	100	100
Average mass / area (gsm)	±8 (%)	225	300	450	600
Moisture content (%)	0.20 max.	0.20 max	0.20 max	0.20 max	0.20 max
Loss on ignition (%)	±2	5.0	5.0	5.0	5.0
Strand length (mm)	±2	50	50	50	50
Filament diameter (micron)	±2	11	11	11	11
Roll length (meters)	±5	125	95	62	48
Roll weight (kilos)	±5	29	29	29	29
Pallet weight (kilos) - [illegible]	±20	460	460	460	460

- Other densities and widths available on request, e.g. 95, 125 and 150 cms. Normally supplied with one trimmed edge.

APRIL 99

7

CERTIFICATE OF REGISTRATION

MOODY INTERNATIONAL CERTIFICATION

This is to certify that the
Quality Management Systems of:

Saudi Industrial Resins - Plant
Kingdom of Saudi Arabia

have been assessed and registered against the
following quality assurance standard/s:

BS EN ISO 9001: 2000

The scope of the registration is detailed on the
certificate schedule bearing this certificate number:

Certificate Number: **27103**

Date: 23 January 2004

For the Company

For the Governing Board

UKAS QUALITY MANAGEMENT

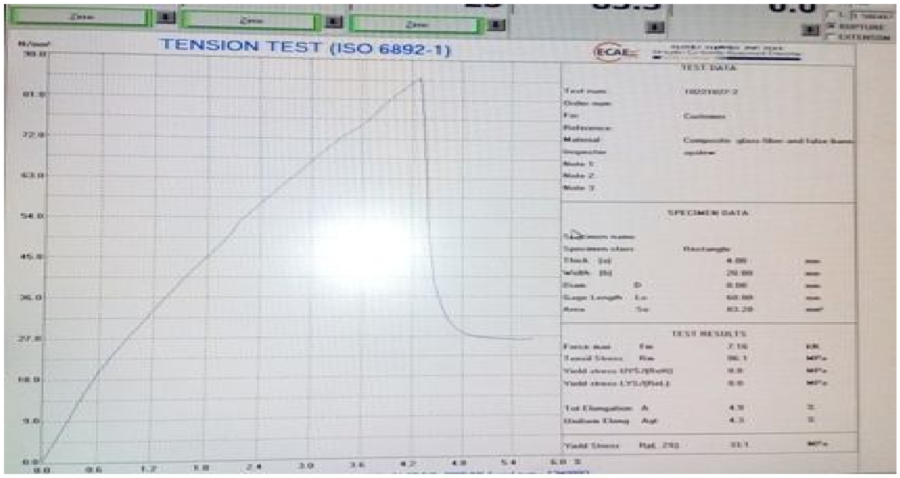
This is not a legal document and cannot be used as such. The use of the Accreditation Mark indicates accreditation in respect of those activities covered by the Accreditation Certificate 014. The certificate remains the property of Moody International Certification Limited to whom it must be returned on request.

13

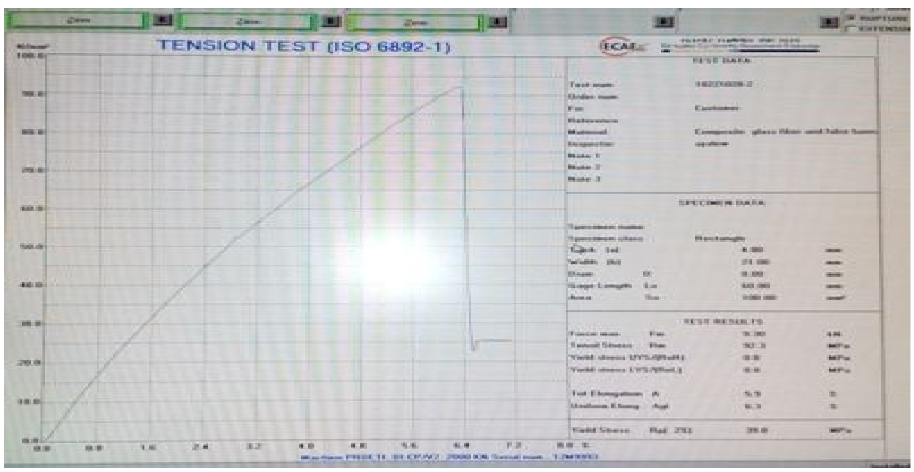
(a)   0(zero) degree tensile test -1   (136 MPA).

(b) 0(zero) degree tensile test -2   (137MPa).

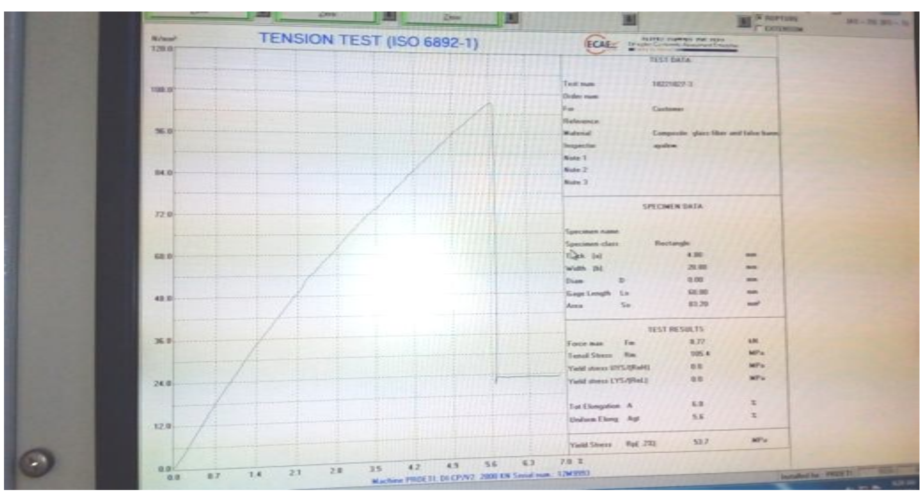
(c) 0(zero) degree tensile test -3 (161 MPa).



(a) ±45 degree tensile test -1 (57MPa).

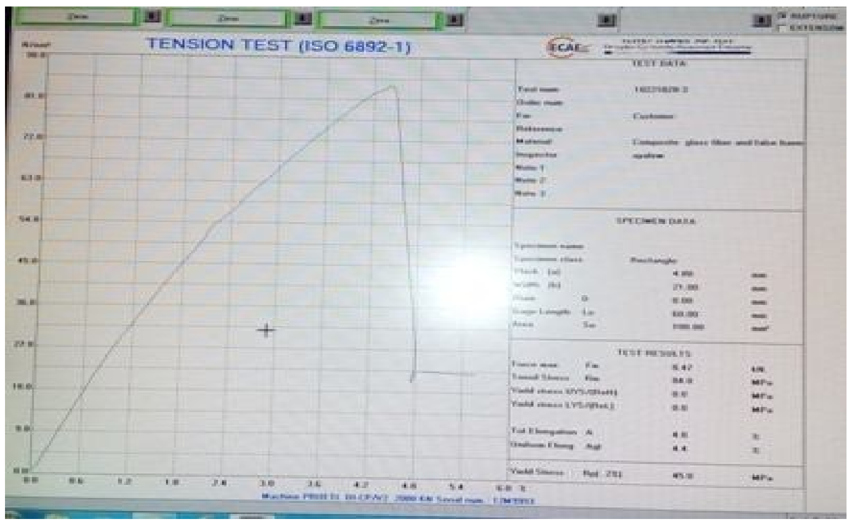


(b) ± 45 degree tensile test -2 (84MPa).

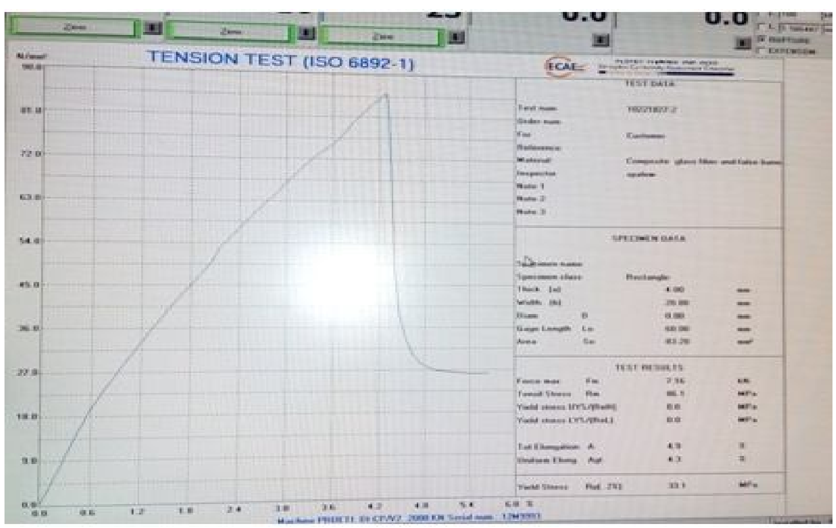


(c) ±45 degree tensile test -3 (76MPa).

(a) (0,90) degree tensile test -1 (111MPa).

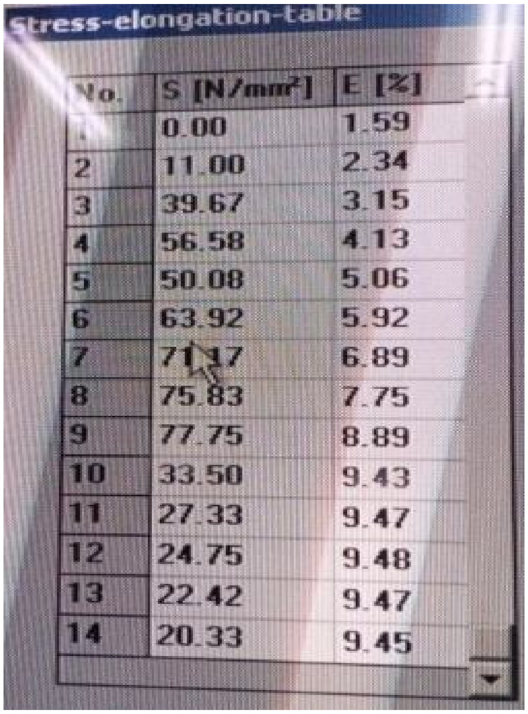


(b) (0,90) degree tensile test -2 (80MPa).



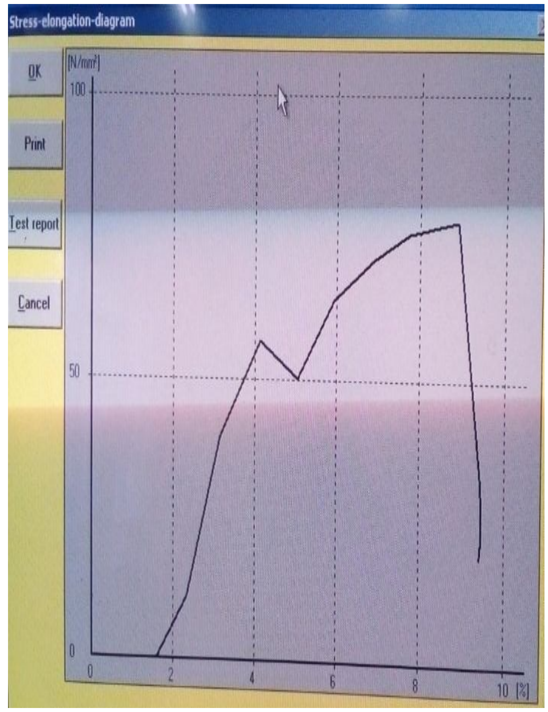
(c) (0,90) degree tensile test -3 (96MPa).

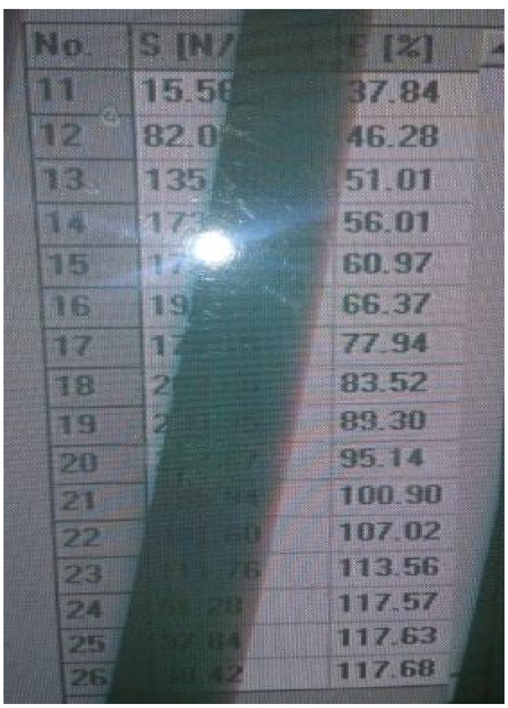
The data for compression strength test taken from the universal testing machine results.



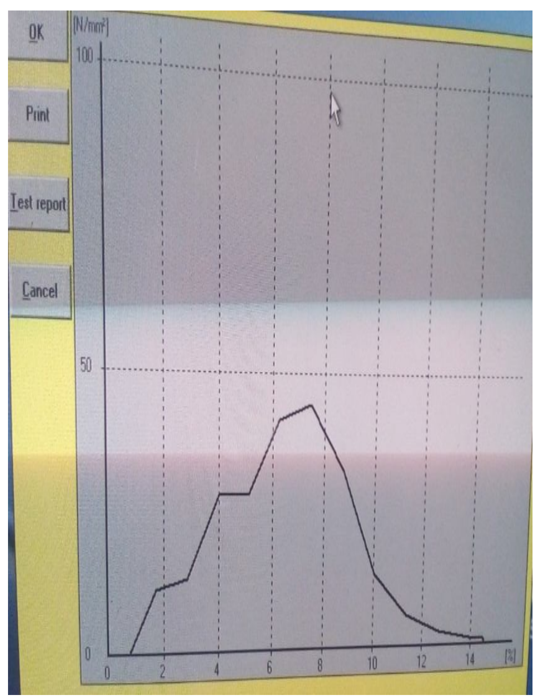
Stress-elongation-table

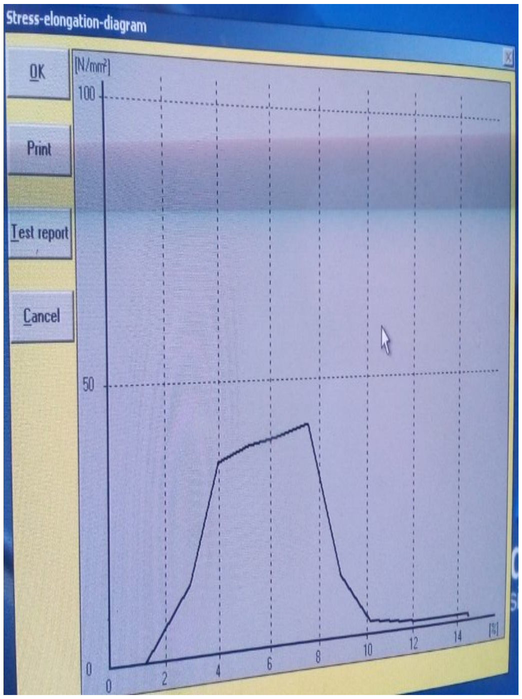
No.	S [N/mm²]	E [%]
1	0.00	1.59
2	11.00	2.34
3	39.67	3.15
4	56.58	4.13
5	50.08	5.06
6	63.92	5.92
7	71.17	6.89
8	75.83	7.75
9	77.75	8.89
10	33.50	9.43
11	27.33	9.47
12	24.75	9.48
13	22.42	9.47
14	20.33	9.45

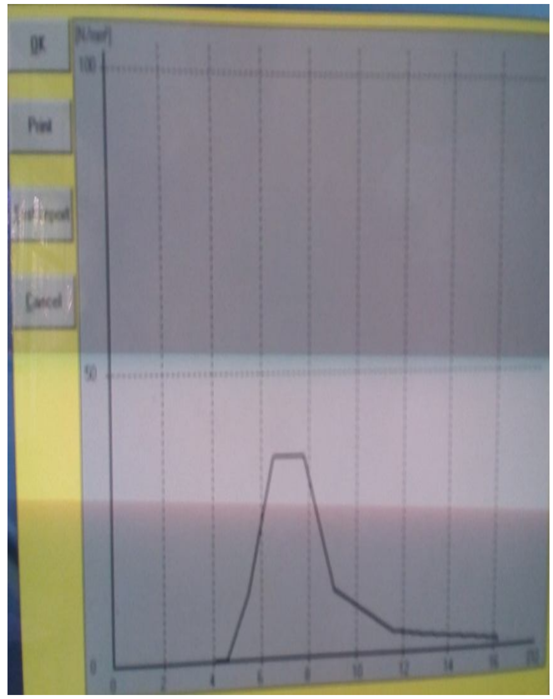




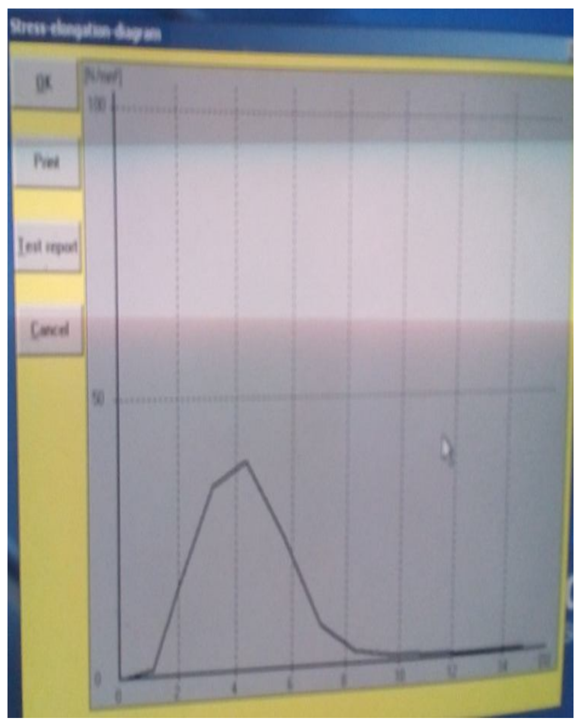
No.	S [N/mm²]	E [%]
11	[illegible]	37.84
12	[illegible]	46.28
13	[illegible]	51.01
14	[illegible]	56.01
15	[illegible]	60.97
16	[illegible]	66.37
17	[illegible]	77.94
18	[illegible]	83.52
19	[illegible]	89.30
20	[illegible]	95.14
21	[illegible]	100.90
22	[illegible]	107.02
23	[illegible]	113.56
24	[illegible]	117.57
25	[illegible]	117.63
26	[illegible]	117.68







No.	S [N/mm²]	E [%]
0	0.00	0.00
1	0.00	0.20
2	0.00	1.30
3	0.00	2.46
4	0.00	3.63
5	0.50	4.57
6	11.86	5.46
7	35.43	6.50
8	35.36	7.77
9	11.93	9.05
10	4.07	11.56
11	3.14	12.77
12	2.57	13.98
13	1.93	15.20
14	1.50	16.14



ress-elongation-table

No.	S [N/mm²]	E [%]
1	0.00	0.87
2	1.57	1.71
3	21.57	3.97
4	13.29	5.11
5	14.86	6.34
6	10.21	7.61
7	4.93	8.88
8	3.36	10.19
9	0.79	11.51
10	0.36	12.48

Stress-elongation-table

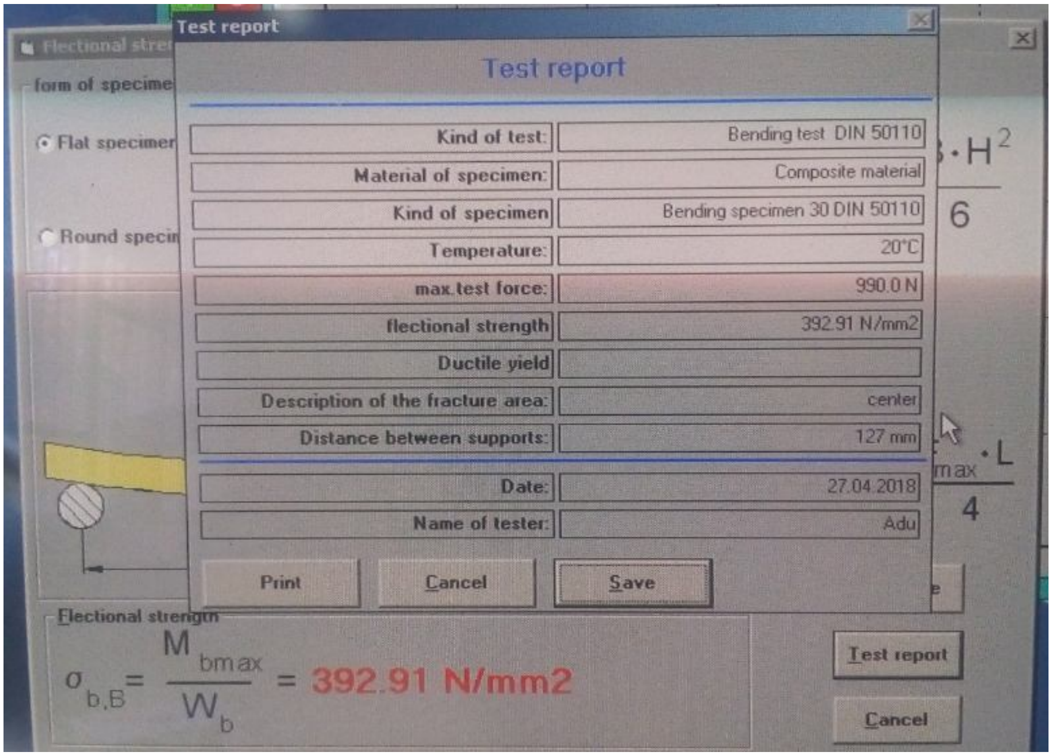
No.	S [N/mm²]	E [%]
1	0.00	0.14
2	0.14	1.05
3	5.93	1.93
4	20.57	4.30
5	10.07	5.53
6	9.00	6.79
7	4.64	8.05
8	3.71	9.32
9	1.36	10.63
10	0.57	11.89
11	0.50	12.62

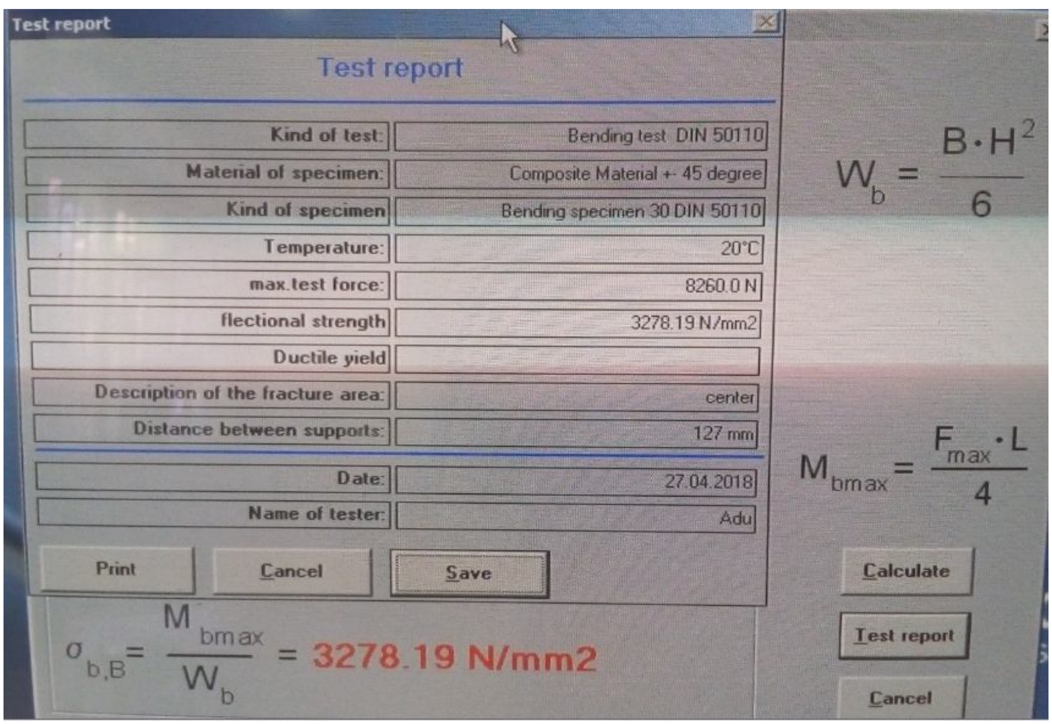
Stress-elongation-table

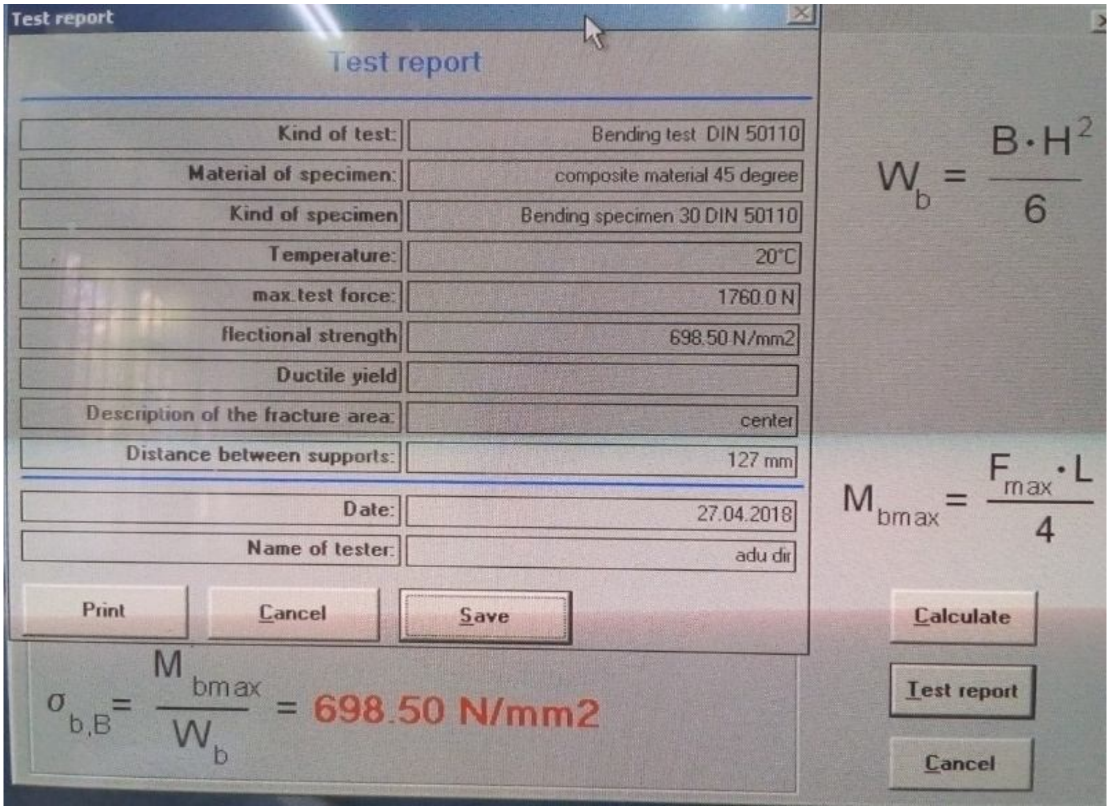
No.	S [N/mm²]	E [%]
1	2.57	0.48
2	23.71	1.58
3	25.64	2.79
4	16.07	4.08
5	5.86	5.38
6	3.21	6.70
7	0.07	8.01
8	0.57	9.26
9	0.71	10.48
10	0.86	12.86
11	0.86	13.76

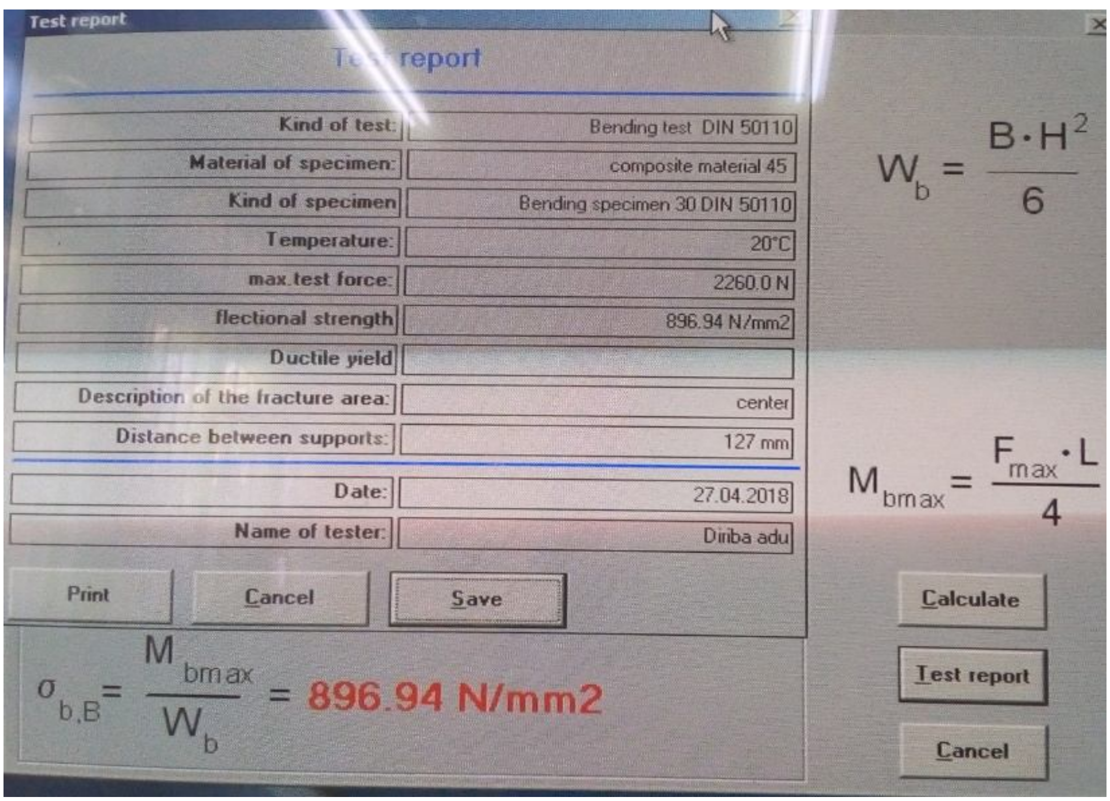
Stress-elongation-table

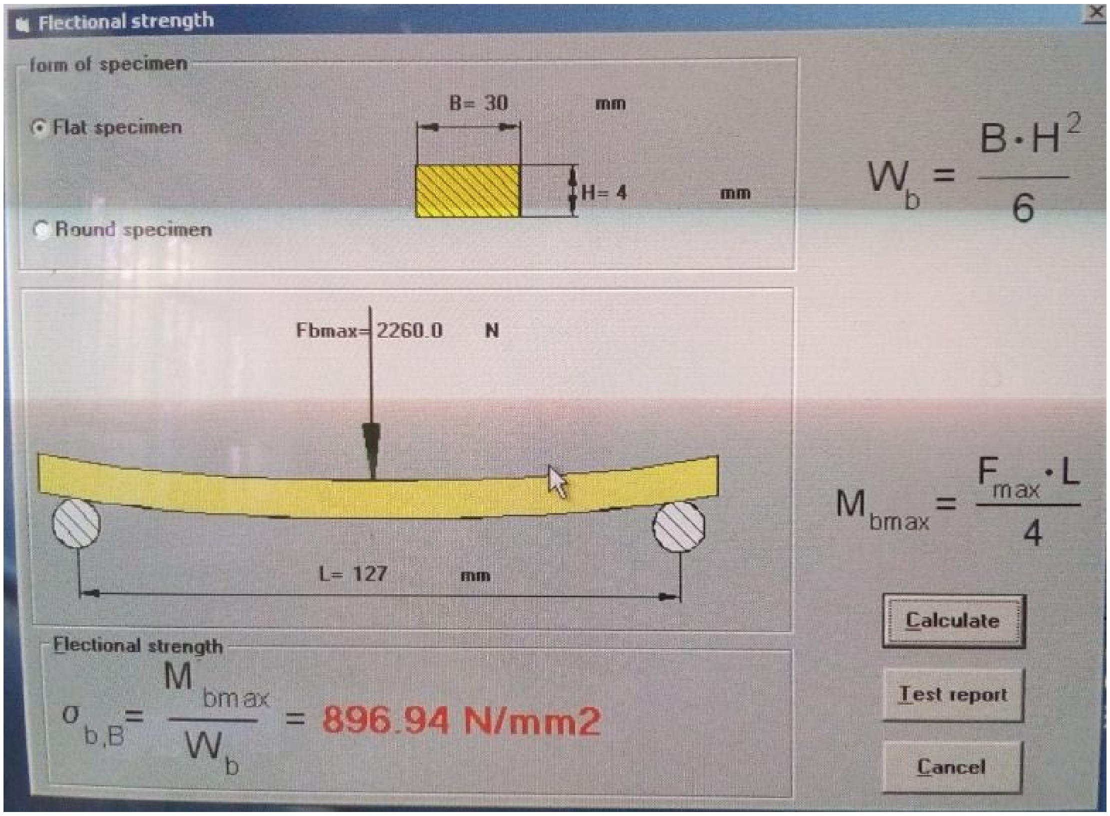
No.	S [N/mm²]	E [%]
1	0.00	0.75
2	11.64	1.72
3	13.36	2.85
4	28.29	4.00
5	28.71	5.14
6	41.64	6.26
7	44.36	7.46
8	32.79	8.74
9	13.64	10.03
10	5.86	11.32
11	2.64	12.67
12	1.14	13.93
13	0.86	14.49

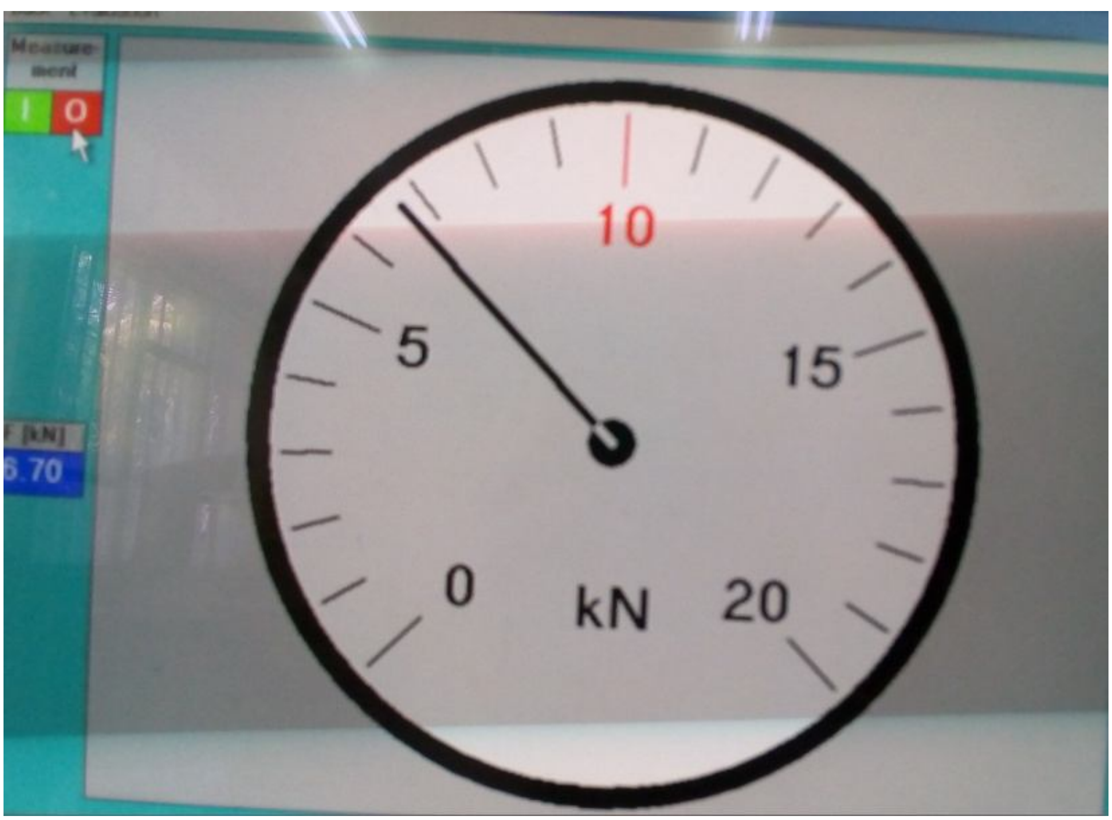

Test report
Test report
Kind of test: Bending test DIN 50110
Material of specimen: Composite material
Kind of specimen: Bending specimen 30 DIN 50110
Temperature: 20°C
max.test force: 990.0 N
flectional strength: 392.91 N/mm2
Ductile yield
Description of the fracture area: center
Distance between supports: 127 mm
Date: 27.04.2018
Name of tester: Adu
Print
Cancel
Save
Flat specimen
Round specim
Flectional strength
$\sigma_{b,B} = \frac{M_{bmax}}{W_b}$ = 392.91 N/mm2
Test report
Cancel

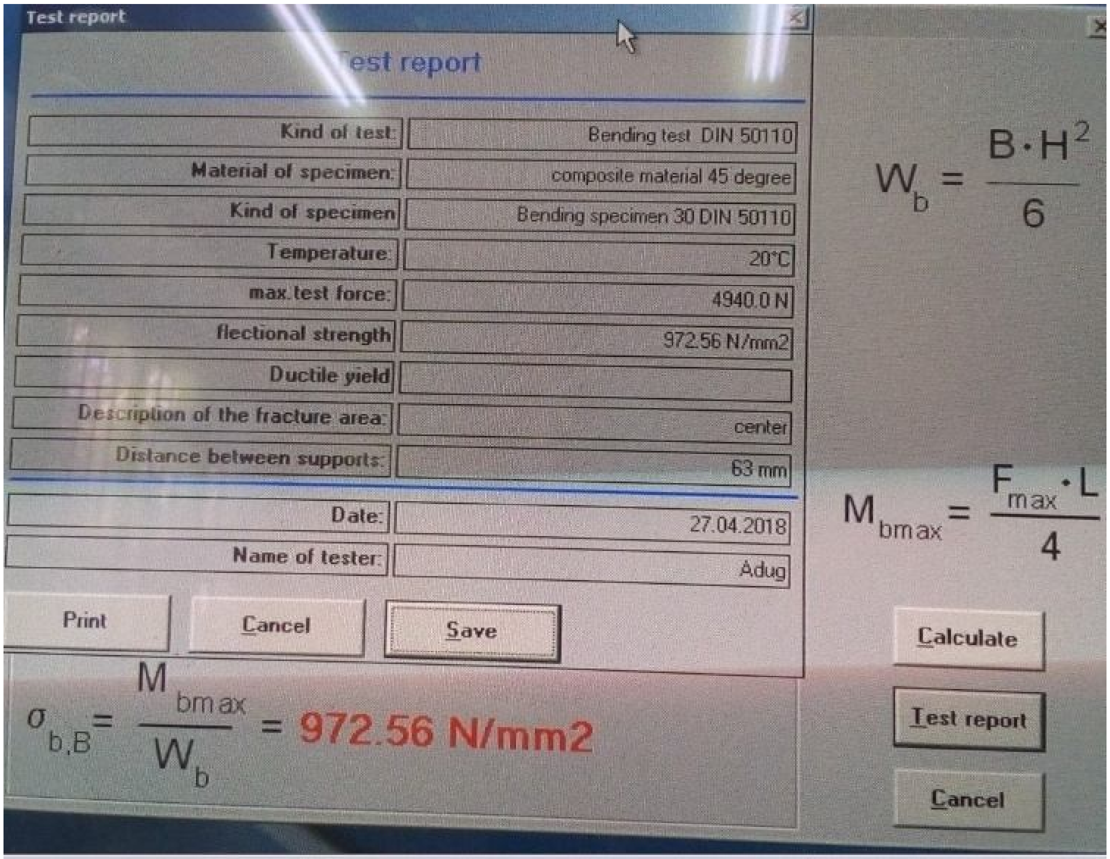

Test report
Test report
Kind of test: Bending test DIN 50110
Material of specimen: Composite Material +- 45 degree
Kind of specimen: Bending specimen 30 DIN 50110
Temperature: 20°C
max.test force: 8260.0 N
flectional strength: 3278.19 N/mm2
Ductile yield
Description of the fracture area: center
Distance between supports: 127 mm
Date: 27.04.2018
Name of tester: Adu
Print
Cancel
Save
$W_b = \frac{B \cdot H^2}{6}$
$M_{bmax} = \frac{F_{max} \cdot L}{4}$
Calculate
Test report
Cancel
$\sigma_{b,B} = \frac{M_{bmax}}{W_b}$ = 3278.19 N/mm2


Test report
Test report
Kind of test: Bending test DIN 50110
Material of specimen: composite material 45 degree
Kind of specimen Bending specimen 30 DIN 50110
Temperature: 20°C
max.test force: 1760.0 N
flectional strength 698.50 N/mm2
Ductile yield
Description of the fracture area: center
Distance between supports: 127 mm
Date: 27.04.2018
Name of tester: adu dir
Print
Cancel
Save
$W_b = \frac{B \cdot H^2}{6}$
$M_{bmax} = \frac{F_{max} \cdot L}{4}$
$\sigma_{b,B} = \frac{M_{bmax}}{W_b}$ = 698.50 N/mm2
Calculate
Test report
Cancel


Test report
report
Kind of test: Bending test DIN 50110
Material of specimen: composite material 45
Kind of specimen Bending specimen 30 DIN 50110
Temperature: 20°C
max.test force: 2260.0 N
flectional strength 896.94 N/mm2
Ductile yield
Description of the fracture area: center
Distance between supports: 127 mm
Date: 27.04.2018
Name of tester: Diriba adu
Print
Cancel
Save
$W_b = \frac{B \cdot H^2}{6}$
$M_{bmax} = \frac{F_{max} \cdot L}{4}$
$\sigma_{b,B} = \frac{M_{bmax}}{W_b}$ = 896.94 N/mm2
Calculate
Test report
Cancel


Flectional strength
form of specimen
Flat specimen
Round specimen
B= 30 mm
H= 4 mm
Fbmax= 2260.0 N
L= 127 mm
Flectional strength
= 896.94 N/mm2
Calculate
Test report
Cancel


10
5
15
0
kN
20


Test report
Test report
Kind of test:
Bending test DIN 50110
Material of specimen:
composite material 45 degree
Kind of specimen
Bending specimen 30 DIN 50110
Temperature:
20°C
max.test force:
4940.0 N
flectional strength
972.56 N/mm2
Ductile yield
Description of the fracture area:
center
Distance between supports:
63 mm
Date:
27.04.2018
Name of tester:
Adug
Print
Cancel
Save
$\sigma_{b,B} = \frac{M_{bmax}}{W_b} = 972.56\ N/mm2$
$W_b = \frac{B \cdot H^2}{6}$
$M_{bmax} = \frac{F_{max} \cdot L}{4}$
Calculate
Test report
Cancel