ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical Chemical and Materials Engineering

Experimental Investigation on Characteristics of Sisal Fiber as Composite Material for Light Body Vehicles

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

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by

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Mechanical Systems and Vehicle Engineering Department

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Advisor: Mr Mekonnen Liben (Asst.Prof.)

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "**Experimental Investigation on Characteristics of sisal fiber as Composite material for Light Body vehicles** " in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my own work carried out from November 2017to June 2018 under the supervision of Mr Mekonnen Liben (Asst.Prof.), Department Mechanical systems and Vehicle Engineering Program, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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Student

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Name	Signature	Date
Mr Mekonnen Liben (Asst.Prof.)	-------------------------	-----------------

Advisor

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ABSTRACT

The studied research work has been approved out in consequence with make usage of Local Sisal plant leaves were gathered from Ethiopian highland. The objectives of this paper is to fabricate and describe the processing techniques of specimen preparation and to examine characteristics of sisal fiber as composite material for light body vehicles for experimental basis. The fibers are pullout through hand extraction with knife after extraction the fibers were immersed in 8 gram Sodium Hydroxide (NaOH) in powder form of 10 liter distilled water solution prepared. Fiber was soaked for 24 hours to remove impurity and increasing the surface roughness due to the disturbance in hydrogen bonding. The specimen is made-up by using the general purpose resin (Gp) as a matrix and the hardener and the sisal fiber as a reinforcement material with appropriate selection of fiber Orientation(0^0,$\pm45^0$,0^0 & 90^0) by using experimental (hand layup fabrication technique) and CATIA, the specimen is prepared and according to the ECAE and ASTM standard dimension of test specimens was prepared their testing behavior such as tensile, compression, flexural and water absorption properties of sisal fiber reinforced unsaturated polyester resin composite material were carried out by means of fiber reinforcement of unsaturated polyester resin composite samples were tested for samples for tensile strength using Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1)standards and for compression and bending strength is conducted as per ASTM standard using WP 310 UTM in Adama Science and Technology University (ASTU) laboratory. Based on the result (0,90) degree fiber orientation was found a tensile strength of 100.3 MPa and compressive strength of 80.3 MPa which is higher than 0 degree and +/- 45 degree fiber orientation furthermore the results of this study point out that using sisal fibers as reinforcement in polymer matrix could successfully prepared prototype of body panel(Fender) of automobile.

Key Words: *Body panel, lightweight, sisal fibers reinforced composites, tensile strength compression strength and flexural strength.*

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LIST OF ACRONYMS AND ABBREVIATIONS

FRP	Fiber Reinforced Polymer
FRC	Fiber Reinforced Composite
NFRC	Natural Fiber Reinforced Composite
PMC	Polymer Matrix Composite
DAVI	Dejen Aviation Industry
RH	Rice Husk
UPR	Unsaturated polyester resin
NFRPMC	Fiber Reinforced Polymer Matrix Composite
NBF	Natural Bio-Fiber
METEC	Metal and Engineering Corporation
ECAE	Ethiopian Conformity Assessment Enterprise
ASTM	American Standard for Testing Material
ISO	International Standards Organization
UTM	Universal Testing Machine
Gp-Resin	General purpose Resin
NaOH	Sodium hydro oxide
m	meter
mm	millimeter

CHAPTER ONE

1. INTRODUCTION

1.1 Background

In order to safeguard natural resources and economize energy weight reduction has been the main focus of vehicle manufacturers in the present situation. Weight lessening can be accomplished primarily by the launching of better material, design optimization and better manufacturing processes. Even though there are several causes that influence entire product development process to recognize a lightweight vehicle, from the point of view of vehicle structural design, the main leading criteria for material choice are rigidity and strength properties that will determine the overall capability of the vehicle during static and dynamic loading conditions[1].

Conventionally, the materials used in the construction of vehicle bodies are mostly different grades in steel. Although aluminum-intensive body concepts were used starting from managerial class cars, and then later on applied to other car classes. Plastics mainly control the vehicle interior, their external application being mostly limited to non-load bearing components even though recently some modern plastic materials are being approved out on some automobile parts such as engine frame and forward bumpers subsystems to decrease the vehicle weight and get better the occupant and pedestrian safety[1,2].

Fiber reinforced polymer composites are characterized as a polymer medium either thermoset or thermoplastic, that is combined with a fiber material with enough aspect proportion (length to thickness ratio) to give a noticeable reinforcing function of more than one direction. Fiber reinforced composites are different from conventional structural supplies such as mild steel or alloy of aluminum fiber reinforced composite are anisotropic (properties only noticeable in the path of the applied load) whereas mild steel or alloy of aluminum is isotropic (consistent positions in all directions free of applied load). Therefore fiber reinforced polymer composite behavior is directional sense that the most excellent mechanical properties are within the heading of the fiber arrangement. Composites are similar to reinforced concrete where the rubber is implanted in an isotropic matrix called concrete[3].

The reaction in using natural fibers such as different plant fibers and wood fibers as reinforcement in plastics has increased surprisingly during last few years. With regard to the surrounding aspects it would be fascinating if natural fibers could be used instead of glass fibers as reinforcement of some structural applications. Sisal fiber have numerous benefit than glass fibers, for instance they have low density, and they are eco-friendly and biodegradable. Moreover they are renewable raw materials and have moderately high strength and stiffness. Their low-density values permit producing composites that unite good mechanical properties with a small specific mass. In tropical countries fibrous plants are available in great quantity [4].

Natural fiber reinforced composite materials have been generally used in different transportation automobile structures of their high specific strength, strain and high damping capability. If composite materials are practical to automobiles, it is estimated that the vehicle weight, noise and vibration are reduced. In addition to that, composites have a very high resistance to fatigue and corrosion[5]. The utilize of natural filler for the reinforcement of the composites has established increasing awareness both by the academic sector and the industry. Natural filler have many important rewards for synthetic filler and fibers such as their light-weight, low cost, capacity to reduce abrasion of machinery and also non-toxicity. Further than that, rice husks as fillers have return in excess of mineral fillers, as they are free from abrasive, need less energy for giving out and ability to reduce the density of furnished products. Hence, these composites have attracted much attention, and are becoming increasingly important to the production of a broad variety of cheap lightweight environment friendly composites[6].Increasing anxiety regarding global warming and to reduce petroleum assets have made scientists to focus more on the employ of natural fibers such as bagasse, coir, sisal, jute etc. This resulted information in more consciousness about the exploit of natural fibers based materials mostly composites. In past ten years there has been many efforts to extend composites instead of petroleum and other non decaying materials based products. Plentiful availability of natural fiber in India gives attention on the development of natural fiber composites primarily to search value-added application avenues. Reinforcement of natural fiber in composites has usually gained notice due to low cost, easy accessibility, low density, good enough specific properties, simplicity of separation, improved energy revival, carbon dioxide neutrality, biodegradability and eco-friendly in nature [7]. The present research work is more interested in preparing a composite made of natural fiber as they are plentifully available and cheaper to compare to synthetic fiber which needed to processed and made-up of chemicals to gain the required property of a composite. The majority familiar natural fibers are Coir, Rice Husk, Jute, Hemp etc. all these natural fibers yield better mechanical strength added with thermoset and thermoplastics. Polymer matrix composites are gaining more importance compared to monolithic ally materials as being additional consistent and inexpensively accessible. Polymer matrix composites result use for household to engineering to approach. With the advancement of PMC their properties had been increased by one adding together of one additional fiber through as hybrid composite which boosted the property of polymer matrix composite where a solitary fiber composite develops slowly[8].Water absorption tested was organized and the results proved that the composites absorb more water as the weight percentage of RH increased, which recognized to the ability of rice husk fillers to immerse up water. In this research, sisal fiber polyester composites were made with sisal as reinforcement and unsaturated polyester resin as the matrix. More than a few percentages of filler loadings were used (25, 20, 15 and 10 wt %) to organize to increase insights into the result of filler content of the mechanical properties and water to absorb of the composites. From the consequences, the tensile stress of the sisal filled unsaturated polyester resin composites establish to be to reduce as the filler loading increase [9]. Natural fibers were used to strengthen materials for more than 2,000 years. The need for renewable fiber reinforced composite has not been as widespread as it currently is. Natural fibers are rising as cost effective and it seems that ecologically better substitutes for glass fibers in composites. In this review a relative life cycles evaluation of natural fiber reinforced polymer matrix composite materials has been accounted. The style and findings of mechanical and crack surface characterization of different natural fiber composites have been summarized. The use of Natural fiber as reinforcement of polymer based composites was reviewed for viewpoints of location and outlook prospect of natural bio-fibers, manufacture and properties of natural fiber, fiber surface adjustments, and physical and mechanical characteristics of natural bio-fiber polymer composites. Natural fibers have high-quality potential as reinforcements of polymers (thermoplastics, thermoset and elastomers) composites. The specific properties and small density of natural fibers composites has good import in industry. Furthermore, compact abrasion and resultant reduction of re-tooling makes these composites one of the most effective options [10].

In Ethiopia, the production of both A. americana and A. sisalana is quite minimal. Nevertheless, most part of the country is semi-arid (Gebre and Georgis, 1988) and it accounts for about 71% of the entire 1.115 million Km^2 land area and about 46% of the arable lands (Reda and Deressa, 1997). Most of the areas being dry land implies that there is a fertile ground and tremendous potential to produce A. americana and A. sisalana on small-scale basis (by farmers) and on large scale basis. Since the crop is quite labor intensive, it could offer a great deal of job opportunity for the large rural population (Bachthaler, 2006) [11].

1.2 Statement of the Problem

The automobile manufacturing companies in Ethiopia are growing and consist of assembling of various kinds of vehicles. The industries which achieved those activities are Bishoftu Automotive and Locomotive Industry under Metal and Engineering Corporation (METEC), Lifan Motors and Belayab motors. The components to be assembled are not manufactured right here as an alternative imported from different car production enterprise outside Ethiopia among this China. However, some of the fiber composite body components are manufactured here in Ethiopia by Dejen Aviation Industry (DAVI) but the inputs for those enterprise depends closely on imported synthetic fibers for the fabrication of light weight car body parts, however those artificial fiber can lead the company to extra cost, deny the country's useful resource to be used and also additionally motive environmental pollutants during in the course of 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 sisal fiber reinforced unsaturated polyester resin composite material for the production of automobile body component parts locally in both small and large vehicle body maintenance garage which contributes immediately to the Automotive industry and indirectly to Ethiopia's ability to generate or save hard currency and provides expanded opportunities for the rural people as the sisal fiber can be produced locally in Ethiopia.

1.3 General Objective

The general objective of this thesis work is to prepare light weight composite material using sisal fiber for the construction of vehicle body panels.

1.4. Specific objectives

The specific objectives are as follows:

- To prepare composite material using sisal fiber and unsaturated polyester resin.
- To characterize as mechanical properties such as tensile test, compression, bending and water absorption tests etc for fabricated composite material.
- To model body panel by using CATIA software.
- To compare the properties of prepared composite material with the properties prepared in previous work.
- To prepare prototype of body panel using sisal fiber reinforced composite.

1.5 Significance of the Study

Application of a successful result from the study to automobile body will render a light weight but of high strength and rigid body panel, enhanced fuel economy, less noisy, high vibration absorption, durable, higher impact, fatigue and corrosion resistance. The composite material has less life cycle cost than metallic one. There will be job opportunity for micro and middle level enterprises in manufacturing area. Saving of foreign currency as a result of reduced import of composite materials for automobile body.

Beneficiary: Automotive industries, vehicle owner, society, researcher and the country as a whole.

1.6 Scope of the study

The scope of this work includes the preparation of sisal fiber composite and testing its properties ,preparation of prototype of very simple body panel of a car is also included.

1.7 Limitations

Unavailability of journals and periodicals in the library, dependence on only materials from internet, frequent interruption of power which affected the survey of literature time is the first hand constraint.

Difficulties encountered in obtaining proper materials for the study such as fibers and chemicals is the second constraint.

A challenge of getting proper laboratory for conducting the experiment and perform the required tests is the third constraint

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

The major point of literature are to give special meaning of previous work, present study and to provide overview of work done till date towards mechanical description of ordinary fiber composites and its properties. The most important topics included in this review are:-

- Previous Works On natural fiber polymer composites
- On historical development of composites material
- On overview of composites
- On Natural fibers
- On test apparatus

2.1 Previous works on natural fiber polymer composites

M K Guptaa and R K Srivastava [11]. Discussed properties of sisal fiber reinforced epoxy composite. According in accordance with the literatures sisal fiber reinforced epoxy composites have been organized by hand lay-up approach taken after by inactive compression, utilizing different fiber weight divisions (15, 20, 25 and 30%). Mechanical properties, warm properties, moisture absorption properties and active mechanical investigation of sisal composites are investigated. The consequences appear that the growth of sisal fiber in epoxy framework up to 30 wt. % increments the mechanical, thermal and water absorption properties. The greatest values of tensile strength and tensile modulus are found for the composite S30 are 83.96± 6.94 MPa and 1.58±0.08 MPa due to due to strong grip between sisal fibers and epoxy matrix permits a uniform exchange of stretch from framework to fibers.

Madhusudhana Reddy H et al; [12]. Studied experimental investigation of mechanical properties of sisal fiber and rice husk reinforced polymer composite Within the think about they explored typical fiber sisal with rice husk fiber by including 20,15, 10, 5 and % wt of sisal fiber to the resin at most favorable percentage then add 5, 3, and 1% of Rice Husk and replicate the same handle to induce the crossover composite prepared utilizing hand layup procedure. At that point it's arranged for tests according to ASTM standard for testing tensile and flexural to test was carried out and found that 32.66 MPa tensile strength and 57.99 MPa bending strength .

R. Prasanna Venkatesh et al; [13]. Found Tensile property, Flexural, Impact property and Moisture Absorption Properties of NFRP Hybrid Composites. In that study work, the property of fiber behavior and concentration on the mechanical property of a short common fiber RPH composite are investigated. The fibers were constrained in imitation of 10% NaOH solution remedy for 24 hrs.. Fibers of distinctive lengths (5, 10 and 15 cm) and weight percentages (10, 15 and 20) were blended with unsaturated polyester for the beginning planning of the composites. The mechanical conduct concerning composites together with treated fibers is compared with UFC and watched that mechanical and moisture absorption properties of treated/untreated hybrid composites result gotten tensile strength treated/untreated (38.4Mpa/23.4 MPa), flexural strength treated/untreated(78.2MPa/56.7),water absorption treated/untreated (9.1/19.6).

R.Sakthivela, D.Rajendranb,[14] .Studied Experimental Investigation and Analysis a Mechanical Properties of Hybrid Polymer Composite Plates. Inside the think approximately they have point by point that ordinary fiber and glass half breed composites were made-up by utilizing epoxy resin blend of hand lay-up strategy and cold press method[14]. Specimen was cut from the made-up laminate according to the ASTM standard for particular experiments for flexural and tensile test and the result obtained tensile strength 54.5 MPa and flexural strength 133.16 MPa.

Olusegun David Samuel et al;[15]. Assessing Mechanical Properties of Natural Fiber Reinforced Composites for Engineering Applications. In this study natural fiber later on extracted, are washed with water to expel gums and the fiber become treated by NaOH solution after which the fibres are laid in the mold with the resin at the ratio of 30% to 70%[15]. The tensile and bending test were carried out according to ASTM D 038-01 ASTM D 790 standards respectively. The result obtained sisal fiber laminate(5.4 MPa Tensile), Banana fiber laminate(6.4 MPa tensile).

Anish V.M, et al;[16]. Experimental Investigation & Numerical Analysis on Mechanical Properties of woven Sisal & Banana mat with Glass fibre in Epoxy Resin Hybrid Composites In this discipline at first the sisal and banana woven mat along with glass fibre chopped strand mat are cut into 270mm x 270mm according to the mould size having thickness 3mm. The composite material is fabricated using hand lay-up system accompanied by compression moulding method and Composites are prepared according to the percentage of fibres are 45%, 40% and 35% by weight. next Test specimens for tensile and flexural are cut in accordance with the required size out of the composite manufactured after curing. The result obtained experimental and f.e.a results of tensile test are 50.91 and 51.70 respectively.

C.Srinivasan, et al; [17]. Experimental Investigation of Mechanical Properties of Glass Fiber, Sisal and Banana Fiber Reinforced Polymer Composite. Within the think about glass fiber as the major reinforcement and combination of sisal ,banana fiber as an extra fiber to move forward the mechanical properties of polymer composite with resin epoxy LY556 as a base material prepared by hand layup process according to ASTM standards. In this test comes about were conducted by pure glass fiber and combination of glass, banana, and sisal fiber composite materials to find the results on tensile strength, compressive strength, impact strength at various specimens . At last the comes about are test on glass fiber with natural fiber ultimate tensile strength 321MPa and compressive strength 10.16 MPa.

P.Srinivasa Kumar et al; [18]**.** Investigated Effect of Fiber Surface Treatments on Mechanical Properties of Sisal Fiber Polymer Composites–A Review. From the authors study, that is revealed that the foremost promising approach from chemical alteration appeared to be the one that gave rise to persistent covalent bonds between cellulose surface and network. They utilized sisal fiber obtained from Thailand and treated the fiber with 2% NaOH for 24 hrs and at that point dried it in an stove at 60°C over night. Three diverse fiber substance : 10, 20 and 30% sisal fiber with polypropylene were examined.. The 30 wt% fiber content appeared the most excellent property in terms of malleable quality and Young‟s modulus, with values of 26 MPa and 0.99 GPa, respectively.

Manjunath G. et al; [19]. Investigation of Mechanical Properties of Sisal Fiber Reinforced Polymer Composites. According to the writer , the point of this work is to study the impact on sisal fiber substance on mechanical (i.e. tensile, flexural, impact, hardness and abrasion resistance) and thermal properties of composites by shifting the fiber and epoxy rate. The short sisal fibers are blended with epoxy resin by straightforward mechanical blending and the mixture was poured into different molds, keeping in seeing the necessities of different testing conditions and characterization guidelines.. According to ASTM D3039 / D3039M standards for composites, the specimens have been organized for tensile test and the maximum test result obtained is 225 MPa and According to ASTM D7264 / D7264M standards for composites, the specimens were arranged for three point bending test the test result obtained was 55.54 MPa.

Maya M.G et al; [20]. Mechanical Properties of Short Sisal Fiber Reinforced Phenol Formaldehyde Eco-Friendly Composites. Within the lesson examined fibers are chopping within desired lengths (10, 20,30, 40 and 50 mm) yet after composites with diverse fiber loading (38, 46, 54 and 70 wt%) have been organized and properties were evaluated tensile testing machine according to ASTM D 638-76 (12 × 1.2 cm) at a strain rate of 50 mm/min. Three point flexure properties have been also examined the use of the identical machine according to ASTM D ultimately tensile strength tests result obtained through composites with fbre length 50mm [fbre loading 54 wt%] and composites with percentage of fiber by weight [fibre length 40 mm] ,fiber loading 70% by weight was 84 MPa and 51 Mpa respectively.

On the whole past further than literature so extraordinary researcher become attempted in conformity with analyzing mechanical properties, chemical properties and physical properties of various fiber resin combination however majority of them have not tried to study the consequences of fiber orientation on mechanical and structural properties of composites. Presented work desired to prepare composite body panel made from sisal fiber and different binding materials such as Gp resin, hardener and filler in order to produce better quality sisal fiber composite with varying fiber orientation i.e. different types of specimens with different interface between fiber (continuous fiber) [0^0, $(0,90)^0$, and $\pm$ 45^0] were prepared and ready for tensile, bending , compressive and water absorption properties test, and examine the composite materials based of experimental result that had better mechanical property to prepare composite body panel.

2.2 Composite Material

Historical Development / Historical overview

Overview of Past

After creation and controlling fire and inventing the wheel, spinning of continuous yarns is probably the most important development of mankind, enabling him to stay alive outside the tropical climate zones and extend over the surface of the Earth. Flexible fabrics made of nearby grow and spun fibers as jute, flax and cotton were a big step ahead compared to animal skins. More and additional natural resources were used, rapidly ensuing in the first composites, bows and straw reinforced walls (see figure 2.1)and chariots made of glue layer of horn, bone and timber. More tough materials as wood and metal soon changed these very old composites[21].

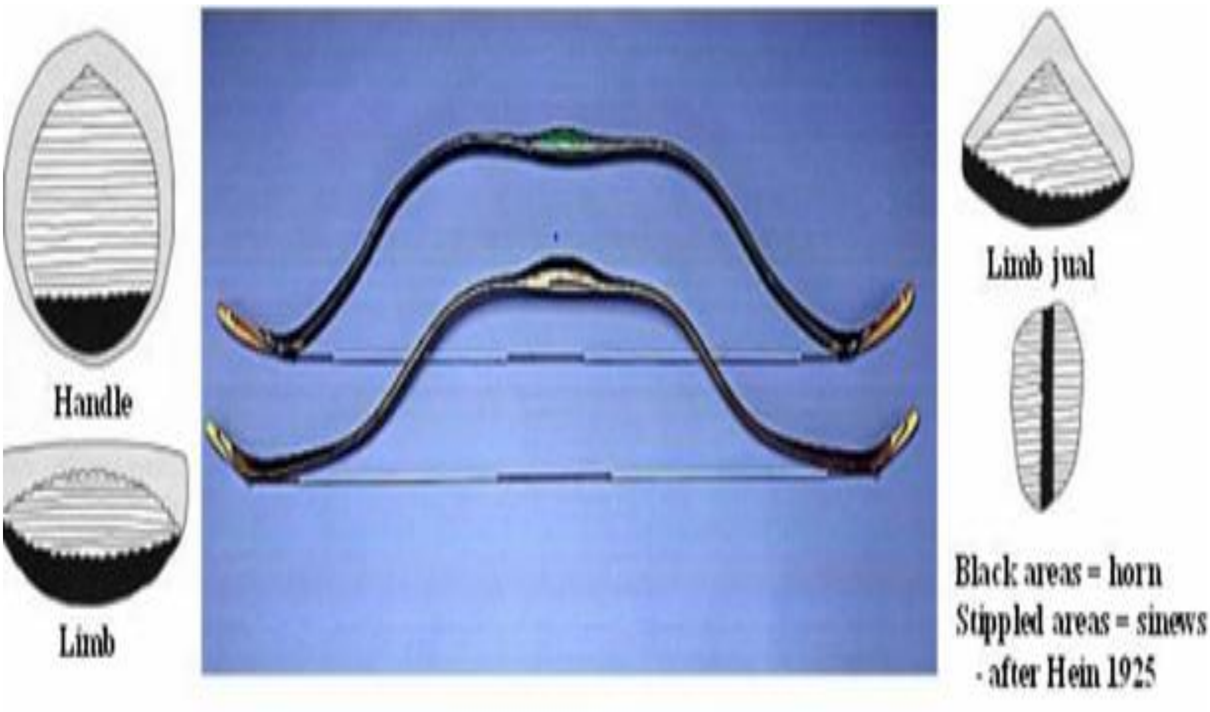


Figure 2.1 Composite Korean bow [22]

Overview of Present

Originating from early agricultural societies and being almost beyond after centuries, a true renewal started of using lightweight composite structures for many technical solutions to the following semi of the 20th century. After being only used for their electromagnetic properties (insulators and radar-domes), using composites to get better the structural performance of spacecrafts and military aircraft became accepted in the previous two decades of the previous century. First at any cost, with development of better resources with rising costs, these days cost reduction in manufacturing and process is the main technology drivers. Most recent development is the use of composites to protect man against fire and crash (see figure 2.2a) and a tendency towards extra ecological friendly design, most important to the reintroduction of natural fibers in the composite technology, (see figure 2.2b) . Increasingly nowadays, the achievement of composites in applications, by volume and by numbers, can be ranked by convenience and reproducibility of the applied manufacturing techniques.

a. Helmet

b. Part of Mercedes

Figure 2.2 Product of Composite a. Light weight composite military helmet b. Part of Mercedes [22]

Overview of Future

In prospect, composites will be manufactured even more according to an integrated design process resulting in the optimum construction as stated parameters such as durability, stiffness, shape, mass, strength and costs, etc. Newly developed design tools have to be immediately to show customers the influence of a design change in each one of these parameters[22].

2.3 Overviews of Composites

Over the previous thirty years composite materials, plastics and ceramics have been the main emerging materials. The amount and figure of fabrication of composite materials has grown progressively, penetrating and dominant new markets persistently. Modern composite materials constitute important amount of the engineered materials market ranging from everyday goods of sophisticated place applications. While composites have already established their value as mass-saving materials, the present challenge are to make them price efficient. The efforts to produce economically good-looking composite components have resulted in several inventive manufacturing techniques currently being used in the composites industry [23]. However since 1951 there was an enlarged demand for stronger and stiffer, yet light weight, composites, in fields such as aerospace, transportation and construction. This led to the mixing of high performance fibers for reinforcement. These newer composites have less specific gravity, better strength and strain when examined to the traditional engineering materials similar to metals [24, 25].

As a relationship between composites and metals, the composites materials have the following advantages as:

- Lightweight,
- High specific stiffness and strength,
- Simple moldable to complex forms,
- Easy bonding,
- Good dumping,
- As insulator and thermal expansion,
- Good fatigue resistance,
- Part joined(compact) due to lower overall system costs,
- Small radar visibility,
- Internal energy luggage compartment and release.

Disadvantages of composites are the followings:

- Extended development time,
- Complexity manufacturing,
- Low ductility,
- Temperature limits,
- Solvent or moister attack
- Hidden damages and damage weakness

2.4 Classification of Composite

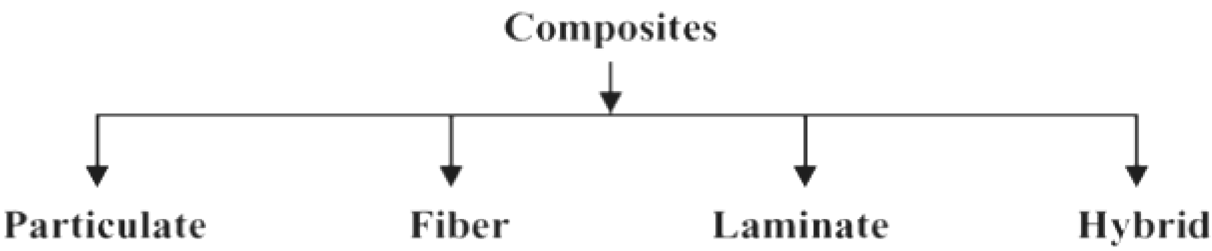


Figure 2.3 Composite materials classification

Based on the types of strengthening used, the composites are classified as (see figure 2.3)

2.4.1 Particulate reinforced composites

A composite which strengthening is a particle of all the dimensions more or less equal is called particulate reinforced composites. Particulate fillers are working to improve high temperature performance, reduce friction, increase to wear resistance and to reduce shrinkage [26]. The particles will also donate to the load with the matrix, but to a smaller extent than a fiber. A particulate reinforcement will therefore get better stiffness but will not normally strengthen.

2.4.2 Fiber Reinforced Composite

Fiber reinforced composites enclose reinforcements having lengths higher than cross sectional dimension. Fibrous reinforcement represents physical rather than a chemical means of changing a material to leave well with various engineering applications [27]. These can be usually classified as shown (see figure 2.4).

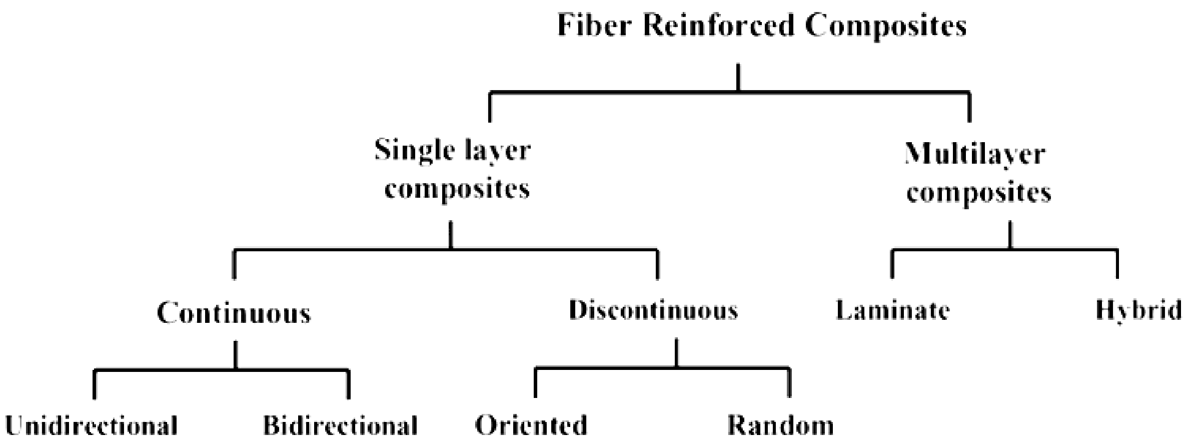


Figure 2.4 Fiber Reinforced Composite materials Sub classification[27]

Reinforcing fiber in a single coat composite may be short or long based on its overall dimensions. Composites with long fibers are called continuous fiber reinforcement and composite in which short or staple fibers are rooted in the matrix are termed as discontinuous fiber strengthening (short fiber composites). In constant fiber composites fibers are oriented in one direction to create improved strength properties. In short fiber composites, the length of short fiber are neither too high to allow individual fibers to grasp up at each other nor too small for the fibers to loss their fibrous nature. The reinforcement is homogeneous in the case of composites containing fine dispersed short fibers. There is a clear difference between the behavior of short and long fiber composites.

2.4.3 Laminates

A cover is made-up by stacking a numeral of cover in the thickness direction. In general three layers are arranged otherwise for better bonding between reinforcement and the polymer matrix, for example plywood and paper. These cover be able to have two directional orientation of the fiber reinforcement as stated to the last part utilize of the composite. A hybrid laminate can also be fabricated by means of dissimilar constituent materials or of the similar material with different reinforcing pattern. In the majority of the applications of cover composite, manmade fibers is used owing to their good mixture of physical, mechanical and thermal behavior.

2.4.4 Hybrid Composite Material

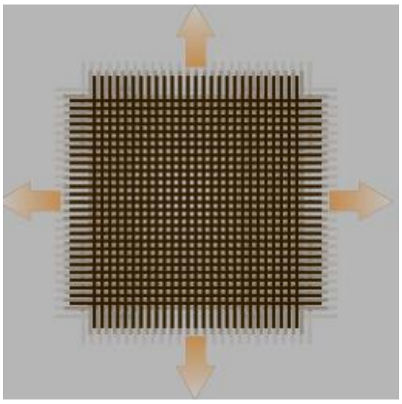
Composite materials integrated with more than two diverse types of fillers especially fibers in a solitary matrix are commonly known as hybrid composites. Hybridization is commonly used for civilizing the properties and for reducing the cost of traditional composites. There are diverse types of hybrid composites classified according to the way in which the component materials are integrated. Hybrids are nominated as i) sandwich type ii) interplay and iv) intimately mixed [28]. In sandwich hybrids, one material is compacted between layers of another, whereas in interplay, alternate layers of more than two materials are stacked in regular manner. Rows of two or more constituents are arranged in a regular or random manner in interplay hybrids while in closely mixed type, these constituents are mixed as much as possible so that no concentration of either type is present in the composite material.

2.4.5 Fiber Orientation

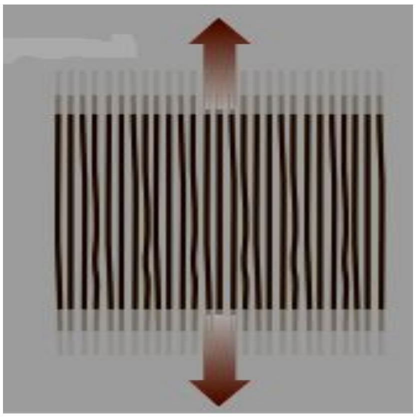
The force and rigidity of a composite buildup depends on the orientation series of the plies. Appropriate selection of ply orientation in advanced composite materials is necessary to give a structurally well-organized design. The part might need 90° plies to respond to side loads, ± 45° plies to respond to shear loads and 0° plies to respond to axial loads. Because the strength design necessities are a function of the practical load direction, ply orientation and ply sequence have to be correct. It is critical to fix and to restore each damaged to ply with plies with similar material and orientation of ply.

The fibers in a single directional material run in one direction and the stress and rigidity is only in the way of the fiber. Pre-impregnated (prepreg) tapes is an example of a unidirectional ply direction. The fibers in a bidirectional material run in two directions, naturally 90° apart. A plain weave fabric is an example of a bidirectional ply direction. These ply orientations have strength in both directions but not necessarily the same strength (see figure 2.5).

The plies of a quasi-isotropic layup is stacked in a 0°, –45°, 45°, and 90° sequence or in a 0°, –60°, and 60° sequence(see figure 2.6). These types of ply direction replicate the properties of an isotropic material. Many aerospace composite structures are made of quasi-isotropic materials [29].



a.



b.

a.Bidirectional(unequal Property)   b. Unidirectional(equal property)

Figure 2.5 Two directional and one directional material properties [29]

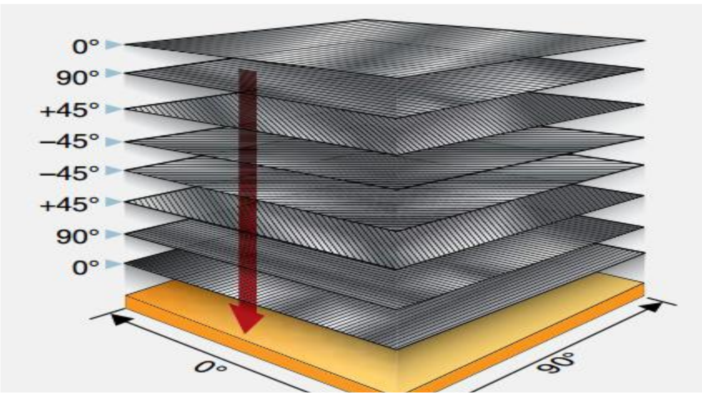


Figure 2.6 Quasi-isotropic material lay-up [29]

2.4.6 Fiber Reinforcement

Fiber is any single unit of matter characterized by elasticity fineness and high aspect ratio . It is a slender filament that is longer than 100 mms or the aspect ratio greater than 10. Fibers have a fine hair like structure and they are of animal, vegetable, mineral or synthetic origin [30]. Fibers are generally classified into types as natural and synthetic (see figure 2.7).

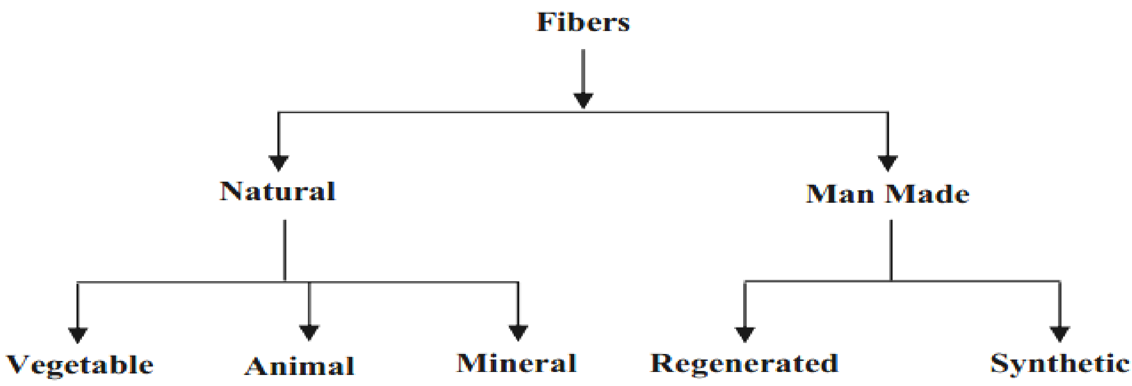


Figure 2.7 Fiber Classification [30]

2.5 Natural Fibers

The awareness in natural fiber-reinforced polymer composite materials is quickly growing both in terms of their industrial applications and basic research. They are totally or partly recyclable, renewable, biodegradable and cheap. Fibers obtained from the various parts of the plants are known as vegetable fibres. These fibers are classified into three categories depending on the part of the plant from which they are extracted.

1. Bast or Stem fibers (jute, mesta, banana etc.)
2. Leaf fibres (sisal, pineapple, screw pine etc.)
3. Fruit fibres (cotton, coir, oil palm etc.)

Many of the plant fibres such as coir, sisal, jute, banana, palmyra, pineapple, talipot, hemp, etc. find applications as a resource for industrial materials (Satyanarayana et al., 1990b; Thomas & Udo, 1997; Rowell et al., 1997)., locality in which it is grown, age of the plant, and the extraction method used. For example, coir is a hard and tough multi cellular fibre with a central portion called “lacuna”. Sisal is an important leaf fiber and is very strong. Pineapple leaf fibre is soft and has high cellulose content. Oil palm fibres are hard and tough, and show similarity to coir fibres in cellular structure. The elementary unit of a cellulose macromolecule is an hydro-d-glucose, which contains three alcohol hydroxyls (-OH) (Bledzki et al., 1996). These hydroxyls form hydrogen bonds inside the macromolecule itself (intra molecular) and between other cellulose macromolecules (intermolecular) as well as with hydroxyl groups from the air. Therefore, all plant fibres are of a hydrophilic nature; their moisture content reaches 8-13 % [31].

2.6 Sisal Plant

Agave sisalana (Agavaceae)is Scientific name: Common names: sisal(English); garingboom (Afrikaans) Sisal is Agave species of inhabitant to southern Mexico and broadly refined and familiarized in many countries. It yields a rigid fiber that is used in manufacture various products. In the past ten years more than a few species of Agave were used for fibre manufacture but currently *A.* sisalana is commonly grown species. The botanical title of the sisal plant is Agave sisalana and the sort Agave L. of the Agavaceae family, which contains almost 300 species [32].

2.7 Origin and Distribution

Sisal was initially grown in southern Mexico but extensively refined and familiarized in many further countries. It has been broadly introduced to the tropics and subtropics, in India between 1885 and 1892, in Tanzania in 1893, in Brazil at the end of 19th Century, and in Kenya between 1902 and 1907. The first profitable plantings in Brazil were made in the behind 1930s and the first sisal fibre exports from there were made in 1948.Until the 1960s, Tanzania was the chief producer of sisal, but since then Brazil has become the major world producer of sisal, followed by Tanzania, Kenya, Madagascar and China. Other cities in Africa that commercially create sisal include Guinea, the Central African Republic, Ethiopia, Malawi, Mozambique, Angola, South Africa and Morocco. Sisal has also been growing Uganda, Zimbabwe and Mauritius [32]. A figure of a sisal plant is shown in figure 2.9 and sisal fibers are removed from the leaves. The Sisal plant has a 8-10 year life-span and naturally produces 200 ± 250 commercially usable leaves. A sisal leaf weighing concerning 600 gs will yield to 3 % by weight of fiber with each leaf containing about 1000 fibers each leaf contains fiber bundles which is composed of 4 %fiber, 87.25 % water, 8 % dry matter and0.75 % cuticle [33]. It is grouped below the wide title of the “hard fibers” surrounded by which sisal is placed second to manila in strength and durability (see figure 2.8) [34].

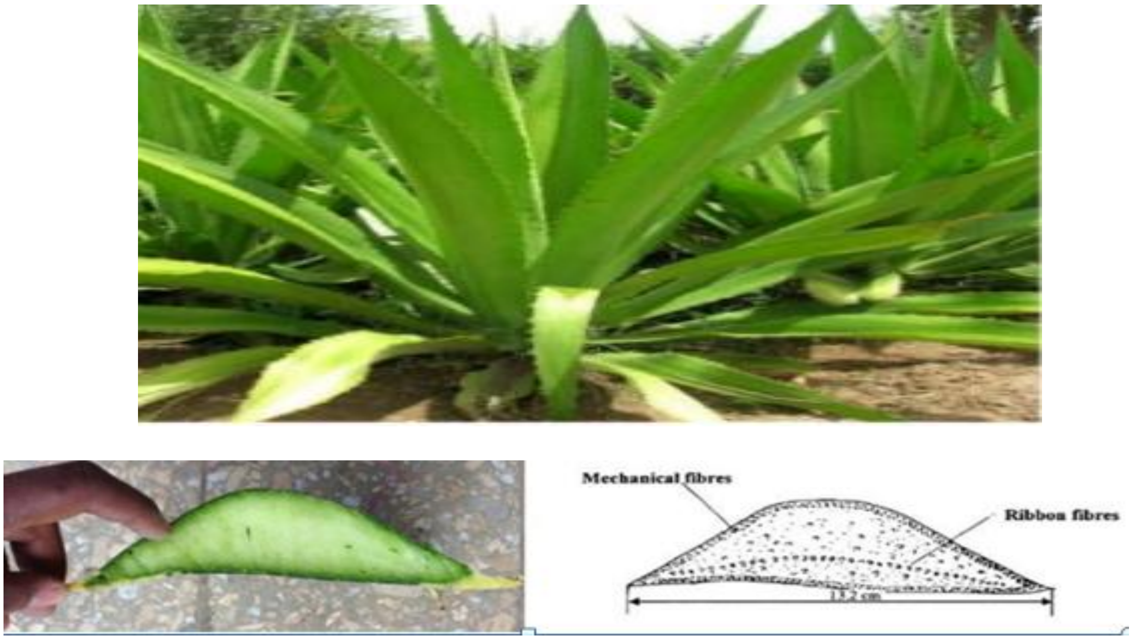


Figure 2.8 Sisal plant and the cross-section of a sisal leaf [35]

2.8 Sisal Plants With in Ethiopia

Sisal is a plant within the same position as aloe vera. It resembles a vast aloe vera plant, with very coarse leaves that are pointy on the ends, and it can grow to be six feet tall. It produces a rigid fiber that is used for fiber in a mixture of products, such as floor mats, twine, carpet, rope , and bags. It grows in Ethiopia, especially Southern Nation of Ethiopia Gamo gofa zone Arbaminch area and Amhara regional state around Shewarobit area and it could be harvested and together by local people. Here is a require for these products of Ethiopia, and there is a market for sisal in Addis Ababa, so it would go after that other belonging to people could advantage from the harvesting of the plant, as well. This would be a great opportunity to generate a more industrious people with hope for the future [35]. Appropriate amount of sisal plant leaves was gathered from mountain, after wounding at their base from the harvest. The fibers are removed from hand extraction with knife. Initially the leaves trimmed in longitudinal course into strips for simplicity of fiber removal the peel is clamped to the wood plank and knife and hand-pulled through in longitudinal direction gently, removing the resinous material as showed in figure2-9 then the extracted fiber washed with pure water in order to loosen, and separate the fiber until individual fibers are received then the extricated filaments are sun-dried which brightens the fiber

Once dried, the sisal fibers are prepared for manufacture of samples from extracted sisal fiber is appeared in (figure 2.9).

Figure 2.9 Sisal fiber extraction process (Serration process) &Extracted Sisal fiber [36]

2.9 Sisal fiber

Sisal fiber is received from the takes off of the plant sisalana Agave which was originally from Mexico and is now mostly cultivated in East Africa, Indonesia, India, Brazil, and Haiti . It is grouped beneath the wide heading of the “hard fibres” in the middle of which sisal is located moment to manila in strength and durability [36].The name “sisal” comes from Mexico, Maya and a harbor town in Yucatan. It resources cold water. Agave plants were full-grown by the Maya Indians before the entrance of the Europeans. They equipped the fibers by hand and used it for clothing, ropes and carpets. Some clothes was called “Neuquén”, and this is where the present name of Mexican agave, henequen most likely originates. It is one of the most widely refined hard fibre in the world and it accounts for half the whole production of textile fibres [36]. The cause for typically due to the simplicity of cultivation of sisal plants, which have short renewing times, and is quite easy to grow in all kinds of environments. A good sisal plants yields about 200 foliage with each leaf having a mass composition of 87.25 % moisture, 8 % cuticle, 0.75 % other dry matter and 4% fiber. Therefore a normal leaf weighing regarding 600g yields to 3.5 % by weight of fibre with each leaf containing about 1001 fibers [36]. The fibre is extracted from the leaf either by retting, by scrapping or by retting followed by scrapping or by mechanical means using decorticates . The diameter of the fibre diverse from 100μm to 300μm (Mukherjee & Satyanarayana, 1984) [36].

Table 2.1: Annual productions of natural fibers and sources [36]

Fiber type	Origin	World Production 10^3 Tons
Coir	Fruit	100
Banana	Stem	200
Bamboo	Stem	10,000
Jute	Stem	2,500
Hemp	Stem	215
Flax	Stem	810
Abaca	Leaf	70
Kenaf	Stem	770
Roselle	Stem	250
Ramie	Stem	100
Sisal	Leaf	380
Sun Hemp	Stem	70
Cotton Lint	Fruit	18,500
Wood	Stem	1, 750,000

2.10 Polymers and its type

Polymer is a general title given to a endless number of materials of high molecular weight. These materials exist on innumerable form and numbers because of very large number and kind of atoms present in their molecule. Polymer could have diverse mechanical behavior, physical properties, chemical structure and thermal characteristics, etc.,

Origin : On the foundation of their incidence in nature, polymers have been classified in three types [37]:-

A. Natural polymer:- The polymers which arise to nature are called natural polymer also known as biopolymers. Illustrations of such polymers are starch, silk, natural rubber, ,cellulose and proteins, etc..

B. Semi synthetic polymer:- They are chemically adapted natural polymers such as hydrogenated, natural rubber, cellulosic, cellulose nitrate, methyl cellulose, etc.

C. Synthetic polymer:- The polymer which has been synthesized within the research facility is known as synthetic polymer. These are also known as artificial polymers.

Examples of such polymers are polyvinyl alcohol, polyethylene, polystyrene, polysulfone, etc.

- **Thermal Response**

On the source of thermal response, polymers can be partitioned into two bunches [38]:-

A. Thermoplastic polymers:- They can be softened or plasticized frequently on request of thermal energy, without a great deal modify in properties if treated with certain protection. Example of such polymers is Poly olefins, nylons, linear polyesters and poly ethers, PVC, sealing wax etc..

B. Thermosetting polymers:- a number of polymers experience certain chemical changes in heating and change themselves into an infusible accumulation. The remedial or sett process involves chemical reaction leading to further growth and cross linking of the polymer chain molecules and producing giant molecules. For example, Phenolic, resins, urea, epoxy resins, diene rubbers, etc.

2.11 Introduction of Test Apparatus

2.11.1 Tensile Test

The main aim of this test was to evaluate the in-plane tensile properties of sisal fiber composites. The tensile test specimen was prepared according to the ASTMD3039 standards and the machine specifications are also chosen according to the ASTM D3039. According to the ASTM D3039 standard the dimensions of specimen used are 250 x 25 mm. This test involves placing the specimen in a machine and subjecting it to the tension according to specific load until it fractures. World Trade Organization Technical Barriers to Trade (TBT) Committee. 2 ICS Number Code 49.025.40 (Rubber and plastics). (see figure 2.10) [39].

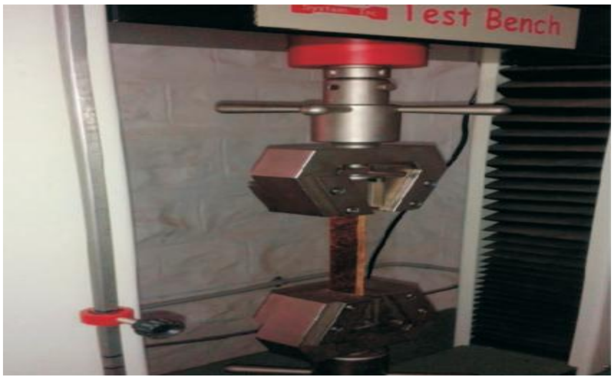


Figure 2.10 Tensile Testing machine[39]

2.11.2 Flexural (Bending) Strength Test

Flexural tests is comprises in applying a point load at the middle of composite material specimen. The bending tests were done on the universal testing machine according to ASTM with the crosshead speed. The flexural tests were done on the universal testing machine according to ASTMD790 with the crosshead speed of 10 mm/min. According to the ASTMD790 standard the dimensions of specimen used are 125 x 12.7 mm. Company Name: TINIUS OLSEN ... Flexural testing is performed according to ASTM D790 and ISO 178 (see figure 2.11) [39].

Working Principles:- The bending test is a ductility test, which is employed to evaluate the ability of metallic materials to undergo plastic deformation in bending. The test consists of submitting a test piece of round, square, rectangular, or polygonal cross-section to plastic deformation by bending without changing the direction of loading, until a specified angle of bend is reached.

Figure 2.11 Flexural(Bending) Testing Machines[39]

2.11.3 Compressive Strength Test

The specimen size of compression test the sample graph generated in a straight line from the machine for compression test with respect to load and displacement .The specimen size for compression test is 13x13x11mm. The Associated Cement Companies Ltd, Bombax. SMIII V. N. PAl (:t(i,"mll/!) Crete and the hardened concrete is an inseparable part of any quality .The compression testing machine is indicated in figure 2.12 [40].

Figure 2.12 Compression Testing Machine[40]

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

In this investigation which aims to substitute mild steel by composite material several variety of material and equipments are utilized for fabrication of composite materials and for testing in strategy was taken after by accomplishing the objectives. The materials and supplies utilized in this paper work are listed in the table below

Table 3.1: Materials and Equipments

	Name	Quantity
1	Sisal Fiber	5 Kg
2	General Purpose Resin(GP)TOPAZ-1110TP	6 liter
3	Hardner (catalyst)	1 liter
4	Gelcoat White TOPAZ-1900W,G.P	2 liter
5	Wax	0.5 Kg
6	Roller brush	2 pc
7	Normal brush	4
8	Gloves	100 pc
9	Permanent Marker	5 pc
10	Scissors	1 pc
11	Vernior caliper	1 pc
12	Steel Rule	1 pc
13	Weighing machine	1 pc
14	Band saw	1 pc

3.1.1 Sisal Fiber

Sisal fibre is obtained from the foliage of the plant Agave sisalana, It creates in Ethiopia and it can be accumulated and collected by local people. After cutting at their base of the yield. The fibers are detached by hand extraction with knife. At first the leaves trimmed in longitudinal direction into tiles for ease of fiber extraction. The strip is clamped to the wood flat timber and knife and hand-pulled from end to end in lengthwise direction smoothly, removing the resinous material, then the removed fiber washed by means of pure water in order to release, and separate the fiber until particular fibers are received then the removed fibers are dried in sun the fiber become white . Once dried, the sisal fibers are ready for market there is a need for these products of Ethiopia, and a market for sisal in Addis Ababa (merkato), shown in figure3.1.

Figure 3.1 Extracted sisal fiber

3.1.2 Matrix

3.1.2.1 Unsaturated Polyester Resin

The resin used for this study is general purpose unsaturated polyester resin with product name of TOPAZ-1110 TP , which is purchased from the local shop world fiber glass & water proof engineering in Addis Ababa Ethiopia (see figure 3.2). TOPAZ -1110 TP is a medium reactive unsaturated polyester resin based on phthalic anhydride with excellent laminate properties and thyrotrophic and has a built-in accelerator system giving lengthy gel time and fast curing for short de-moulding time and is designed for general purpose moulding for hand lay-up and spray up applications.

Figure 3.2 General purpose resin(TOPAZ-1110 TP)

3.1.2.2 Hardener (catalyst)

Unsaturated polyester resin is cured by adding a catalyst, which causes a chemical reaction without changing resins own composition. The catalyst (hardener) initiates the chemical reaction of the polyester resin and monomer ingredient from semi liquid to a solid state. Hardener can be purchased from the local shop world fiber glass and water proofing engineering in Addis Ababa, Ethiopia shown in figure 3.3 and the curing agent is applied in the ratio of 1 to hundred of hardener and general purpose resin.

Figure 3.3 Hardener (Topaz-380)

3.1.2.3 Sodium Hydroxide(NaOH)

Sodium hydroxide, also known as lye or caustic soda, has the molecular formula NaOH and is extremely caustic base and alkali salt. Pure sodium hydroxide is a pale solid, which is accessible in pellets, flakes, granules, In this work NaOH was used in pellets form(see figure 3.4), and performed chemical treatment of sisal fiber purchased from the local market yeshadam trading plc in Addis Ababa, Ethiopia.

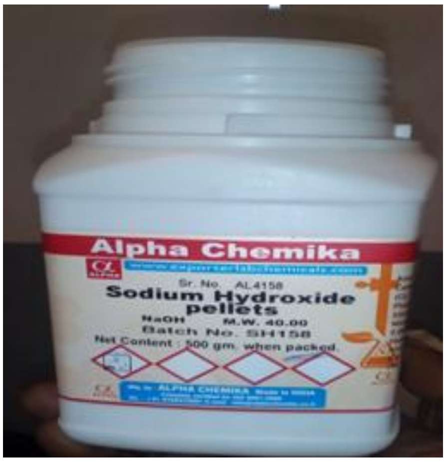


Figure 3.4 Sodium hydroxide pellet

3.2 Methods

The Steps involved in the methodology listed as follows:-

- Literature Review
- Selection of raw material
- Preparation of composite material
- Testing of composite Material
- Preparing CATIA model
- Prepare prototype of body panel

3.2.1 Sample Preparation Methods

Sisal Fiber Reinforced Composite Preparation

The guide line preparation of SFRUPR composite process approach is shown in figure 3.5.

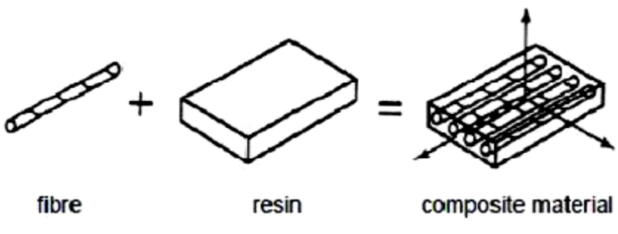


Figure 3.5 Fabrication approach [40]

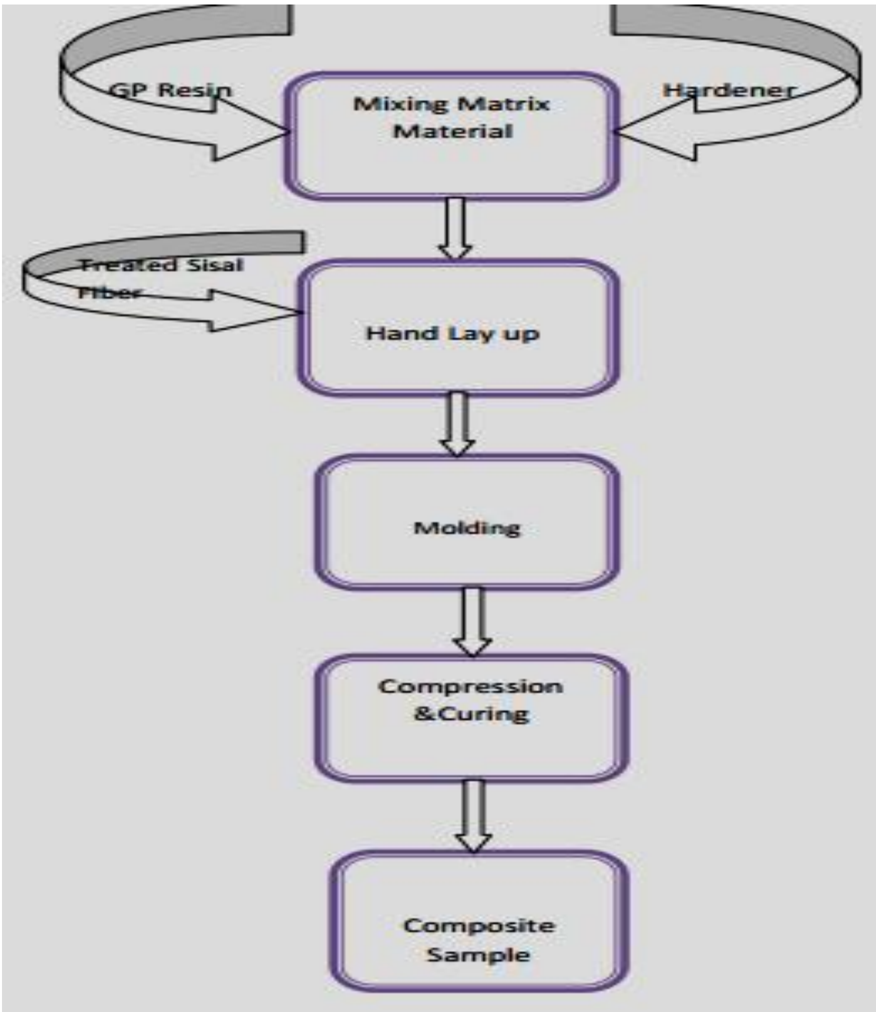


Figure 3.6 Flow diagram for fabrication of SFRUPR composites

The above figure 3.6 appears the scheme for the preparation of SFRUPR composites. The preparation of SFRUPR composite is performed by hand layup method different ply orientation of sisal fiber is utilized as reinforcement resin(General purpose resin) and hardener used as a matrix material. The reinforcement is chosen based on its weight reduction, tensile strength and bending. Fiber arrangement(orientation) was done for sisal fiber in this research is 0, 45, and 90 degree orientation of fiber.

3.2.2 Preparation of Unsaturated Polyester Resin (General purpose resin) and hardener:

Epoxy of general purpose resin (GP) mixed with hardener is used to prepare the composite plate. The mass ratio of mixture of resin and hardener is 100 : 1. Hardeners include acids amines, polyamides, dicyandiamide etc. The mixer is dispersed over with stirrer for about one minutes continuously. The mixing is performed in the mixing containers(bowl) the bowl is made of Nickel to prevent melting of the Bowl of the exothermic reaction as shown in the figure 3.7.

Figure 3.7 Mixing of epoxy with hardener

3.2.3 Hand Lay-Up

Hand-lay-up technique was embraced to fill up the prepared mould with a suitable amount of general purpose resin mixture and layers of random sisal fibers, such that opening and finish with layers of gum. The amount of quickening agent and catalyst included to resin at room temperature for curing was 1% by volume of resin each. Fiber buckle and movement should be minimized to give up good quality, random fiber composites. Therefore, at the time of curing a compression weight was connected on the form and the air gaps shaped b/n the fibers during the processing were delicately pressed out by pressure to power the air nearby in between the fibers and resin, and kept several hours to obtain the perfect samples the processed damp composite were at that point squeezed difficult and the abundance resin is evacuated and dried.

3.2.4 Materials Requirements of Hand-lay-up method

- Mould
- Roller brush
- Normal brush

3.2.5 The steps of preparation of SFRUPR composite was shown below:-

The primary step for the utilize of the sisal fibers was the surface cleaning since when they were acquired contained some contaminating agents on the surface. After this cleaning process and before the surface treatments (when applied), then the fibers were arranged according to fiber orientation with the aim at preparing the fibers for the generation of composite material.

3.2.6 Alkali Treatment of Sisal Fiber Protocol

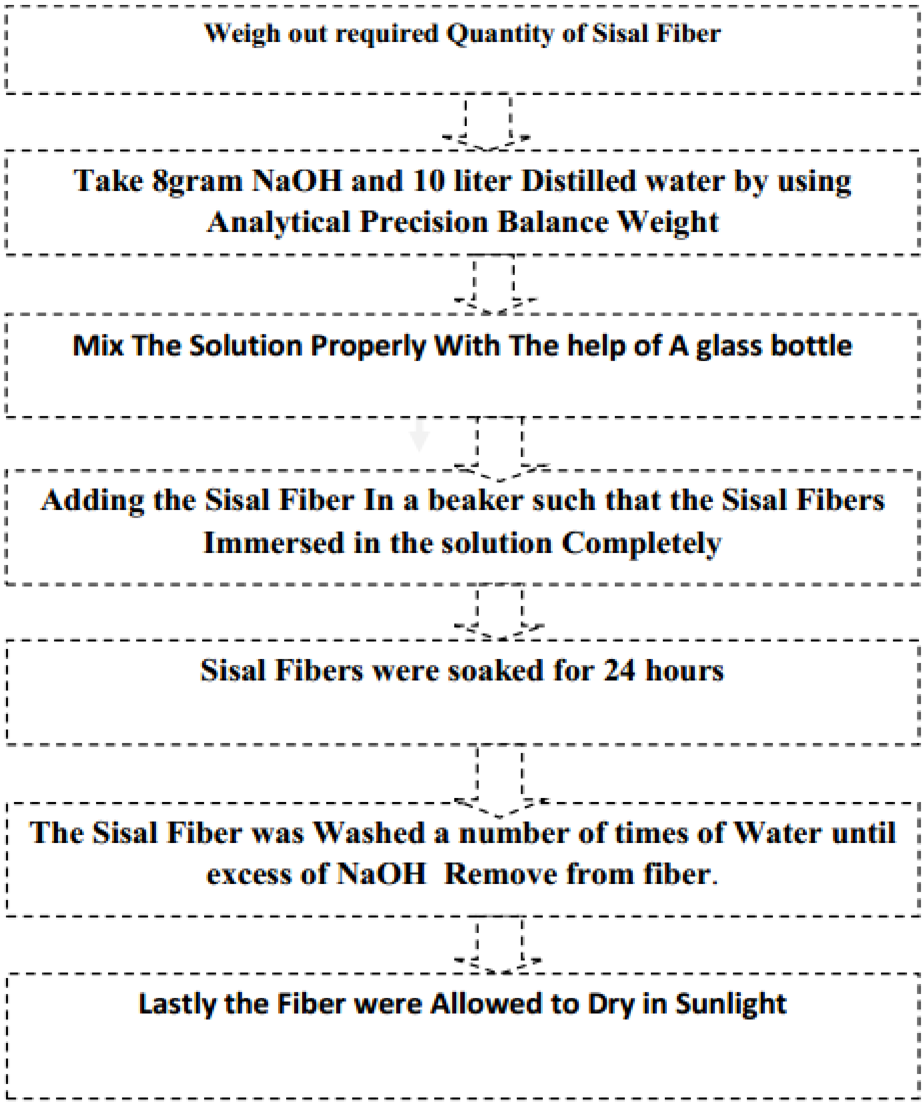


Figure 3.8 Schematic Flow Diagram Alkali Treatment of Sisal Fiber

Alkali treatment is the easiest technique of chemical treatment of fibers; it leads to the increment in the quantity of cellulose at the expenditure of crystalline cellulose. The important alteration happening at this point is the removal of hydrogen bonding with the network structure. The next reaction takes place as effect of Alkali treatment

$$\text{Fiber-OH} + \text{NaOH} \longrightarrow \text{Fiber-O-Na} + H_2O$$

According to literature, alkali solutions has a good effect on treating natural fibers. In this investigate, 8 gram NaOH with 10 liter distilled water solution was utilized to treat the raw sisal fibers, in arrange to modify their fiber structures. This proportion was done in material science engineering of ASTU (Adama science and technology university) Laboratory.

The proportion was done in the laboratory as follows:-

Assume If $P^H = 12$

$P^H + P^{OH} = 14$ -- (3.1)

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

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

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

Morality = Number of mole/Volume = $M = \frac{N}{V}$

N= M x V

N=2 x 10^{-2} M x 10 liter

N= 0.02 x 10= 0.2 mole

Mw of NaOH= 40

N= mass/molecular weight= M/Mw

0.2 mole = m/40

Mass= 0.2 x 40= 8 gram (see figure 3.9)

Figure 3.9 Weight measuring of Sodium hydroxide Utilizing Analytical Precision Balance

Figure 3.10 Mixing of sodium hydroxide with distilled water

Mix 8 gram of NaOH with 10 liters of distilled water. During this prepare dried and appropriately arranged sisal fiber accordingly the fibers were immersed in a bath of Sodium Hydroxide solution (NaOH), prepared with distilled water (see fig 3.11). Fiber were soaked for 24 hours to remove impurity and rising the surface roughness due to the disturbance in hydrogen bonding.

Figure 3.11 Sisal fiber immersed in sodium hydroxide solution

Next, the sisal fibers were washed a number of times for water, until the water P^H comes to neutral and to get rid of the surplus of NaOH sticking to the fiber (see fig 3.12 a).

a.  

Figure 3.12 a. Washing process b. After washing of sisal fiber

- Lastly the fiber were allowed to dry in sunlight as shown in fig 3.13.

Figure 3.13 Fiber were dried in sun light

3.2.7 Cutting and Arrangement of Sisal Fiber

Cutting and organizing of sisal fiber was performed in Adama Science and Technology University(ASTU) Automotive workshop utilizing scissors & design making rectangular device (see figure 3.14).

Figure 3.14 Locally weaving (loom) equipment

Figure 3.15 Arranging the fiber using weaving (loom) equipment

Mould pattern was made up of mild steel of dimension of 400 x 320mm x 4mm as shown in fig 3.16 .

Figure 3.16 Mould (400mm x 320mm x 4mm)

To observe the result of fiber orientation 0^0, (0^0 , 90^0) and $\pm45^0$ were chosen under this study using a pair of sisal fiber as shown in fig 3.17.

a. b. c.

Figure 3.17 Fiber orientation a.0 degree b. (0 , 90)degree c. ± 45 degree

Fundamentally estimation of weight of distinctive orientation of fiber was taken utilizing digital machine as follows (see fig 3.18).

Figure 3.18 Weight measuring of 0 and (0,90) degree Ply orientation

Epoxy(General purpose resin) and hardener(catalyst) were taken in a steel bowl at that point blended well and made prepared for layup reinforced sisal fiber with a ratio of 100 gram : 1gram respectively (see fig 3.19 a &b).

a.

b.

Figure 3.19 a. Pouring Resin   b. Pouring hardener

At to begin with Applying wax/gel on the fiber side of lower mold at that point a plastic was put on bottom part of the mould for ease of removal (as shown in fig 3.20 a &b)

a.

b.

Figure 3.20 a Wax/gel   b. Mould

Start laying up the first ply and apply the matrix unit see figure 3.21

.

a   b

Figure 3.21 Hand lay up using normal brush b. Hand lay up using Roller Brush

The prepared resin and hardener mixture spread evenly on the fiber. After that a plastic was put on taking after beat portion of the mold(Lid). Safety was taken to avoid formation of air bubbles during pouring. Next Pressure applied to the top and the mould was allowed to compress in to room temperature for 24 hours. After 24 hours the tests were taken out of the form after compressing the cover were cut into required estimate (see fig 3.22).

Figure 3.22 Moulding Under Compression

3.2.8 Samples Manufactured by Different Orientation of SFRUPR

Three bunches of tests were made by distinctive orientation of sisal fiber reinforced unsaturated polyester resin composite such as 0^0, (0^0 , 90^0) and $\pm 45^0$.

0^0 sisal fiber orientation reinforced Gp resin composite boards to begin with 100% of 0^0 orientation of sisal fiber arrangement bonded utilizing matrix material. During this sort of arrangement layer by layer until the preferred thickness is achieved .Binding with matrix material consisting of resin Gp and hardener in the ratio of 100:1. Finally estimation of weight was done after curing.

(0^0 , 90^0) sisal fiber orientation reinforced epoxy composite boards 100 % of 0^0,90^0 orientation (see figure 3.23) of sisal fiber arrangement bonded utilizing matrix material. During this type of preparation layer by layer until the specified thickness is accomplished Binding with matrix material consisting of resin Gp and hardener in the ratio of 100:1. Finally estimation of weight was done.

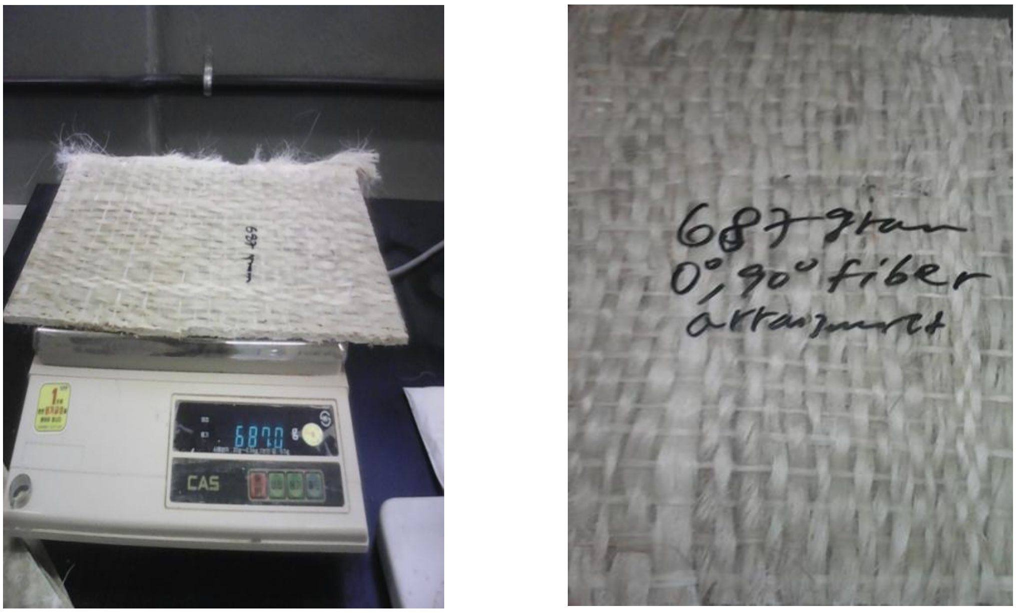


Figure 3.23 Weight Measuring of (0,90) degree Composite Sample

Table 3.2: Sample Specimen Compositions used in this Study

Orientation of Fibers	Mass (grams) (400mmx 320mmx 4mm)		
	Sisal	Gp Epoxy resin	Composite Sample
0 degree orientation	151	503	654
0 ,90 degree orientation	163	524	687
+/- 45 degree orientation	200	578	778

3.3 Experimental Process and Setups

3.3.1Specimen sampling procedure

The test specimens utilized in this study required a total of about 27 specimens sisal fiber. Band saws are recommended for cutting sisal fiber composite specimens after fabrication in to the required dimensions the machine has a cutting speed of 915 m/minute cutting was performed in Addis Ababa Institute of Technology(AAiT) mechanical engineering work shop as shown in fig 3.24 :

Figure 3.24 Cutting of composite sample using band saw

3.3.2 Dimension of Test specimens

The appropriate Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1) standards was followed while preparing the specimens for SFRUPR composite for tensile test and their standards are illustrated with figure and specimens for bending, compression and water absorption test using American Society of Testing Materials (ASTM) standards ASTM D-790 , ASTM D 3410 and ASTMD-570 (see fig 3.25) respectively.

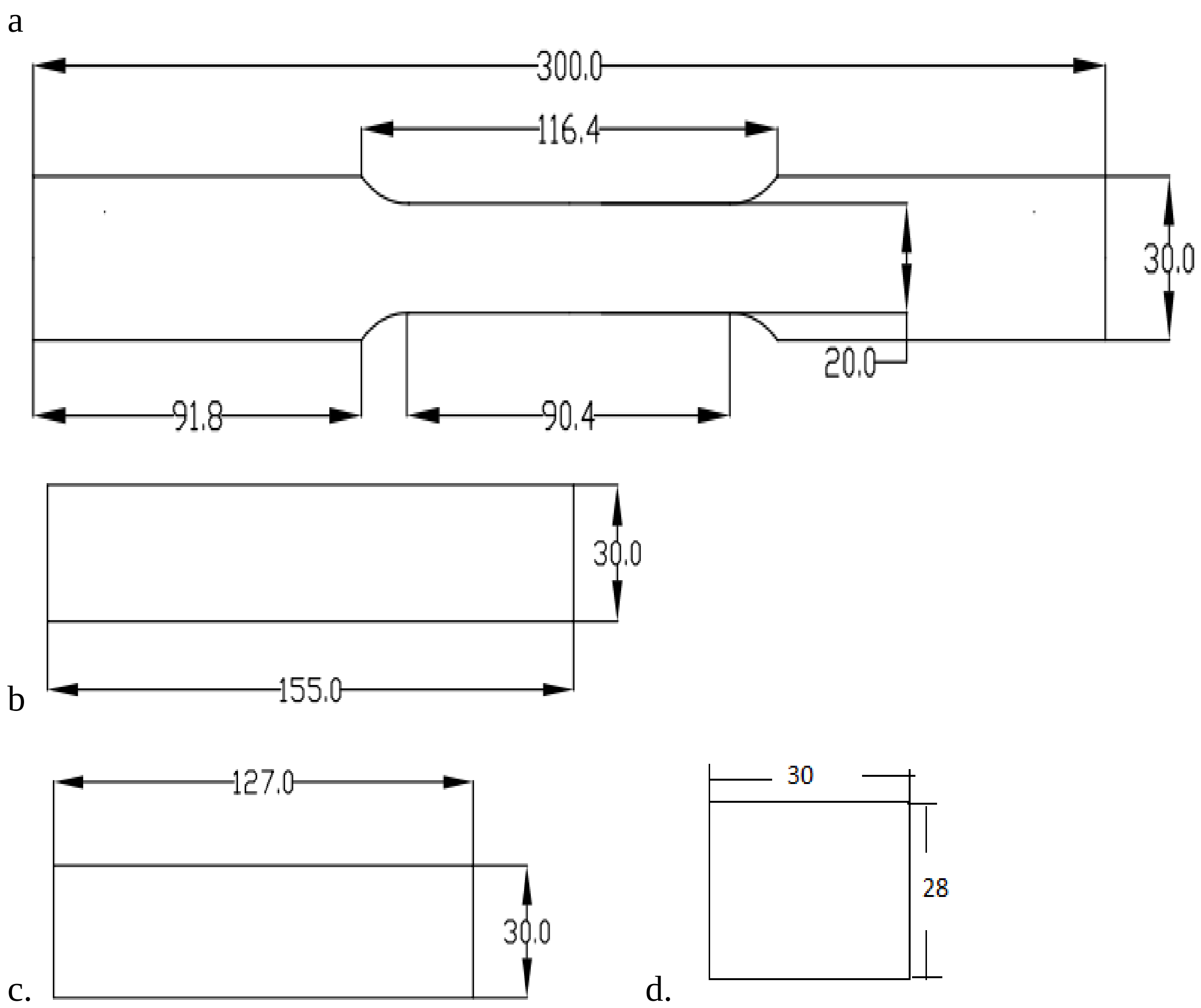
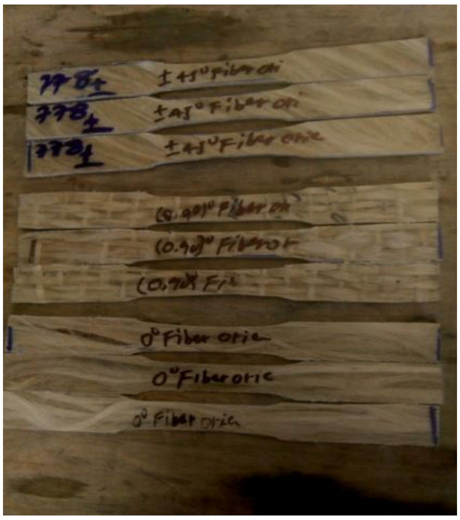
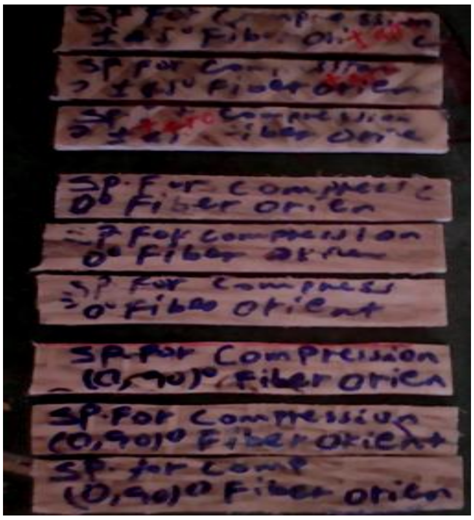


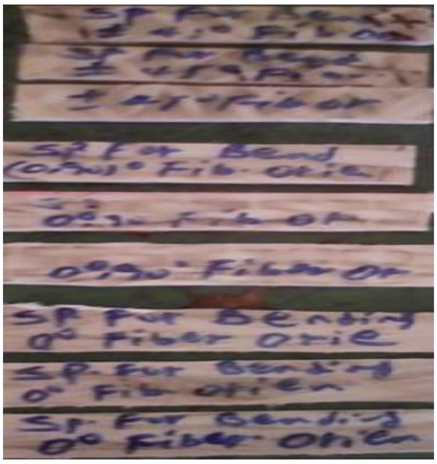
Figure 3.25 Test Specimen Dimensions- (a) Tensile Test Specimen (b) Compression Test Specimen (c)Bending Test Specimens d. Water Absorption Test Specimen.



a. Tensile test



b. Compression test



c. Bending test

d. Water absorption test

Figure 3.26 Sisal Fiber Composite Sample Specimen After Cutting

3.3.3 Composite Specimen Testing Procedure

After the SFRUPR composite Specimen cut in to the desired dimension based on the respective orientation of fiber such as 0^0, (0^0 , 90^0) and $\pm 45^0$ were tested using the three different strength testing procedures: tensile test, compression test, the bending test and water absorption test for each specimen.

3.4 Introduction To Test Apparatus

Mechanical testing for tensile, compressive, bending sisal fiber reinforced composites is tested using Computer Controlled Electro-Hydraulic Servo Universal Testing Machine and GUNT WP 310 Hydraulic Universal Testing Machine. Each includes a load unit with integrally mounted actuator and servo valves, a hydraulic power unit, and the control system, as illustrated in figures 3-27 and figures3-28. The control system has three major parts: the system software running on a personal computer, the digital controller, and a remote station control panel. Three specimens were prepared from each strain rate value of the proposed material in order to show the repeatability of the results.

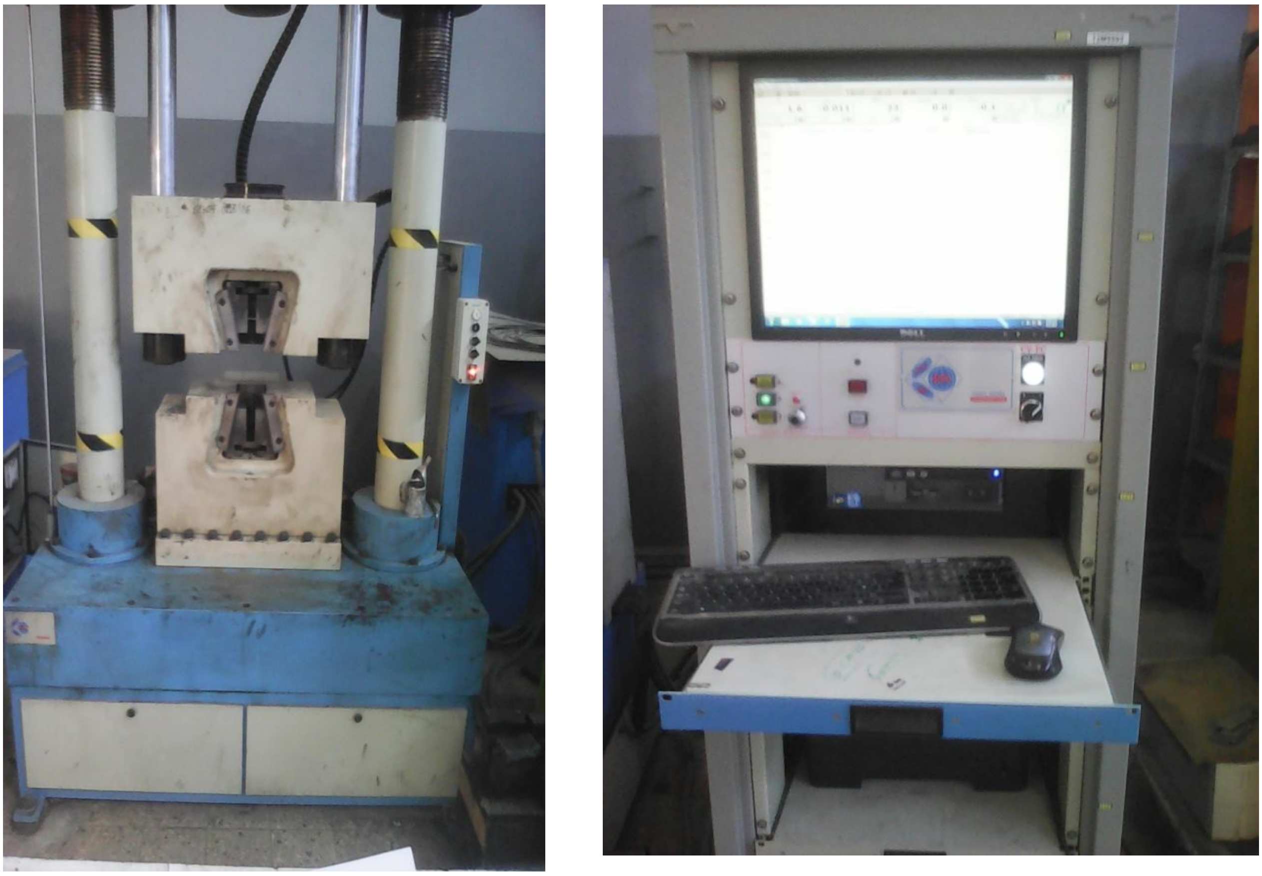


Figure 3.27 Universal testing machine (UTM) Material Testing System in Ethiopian Conformity Assessment(ECAF) Mechanical Testing laboratory

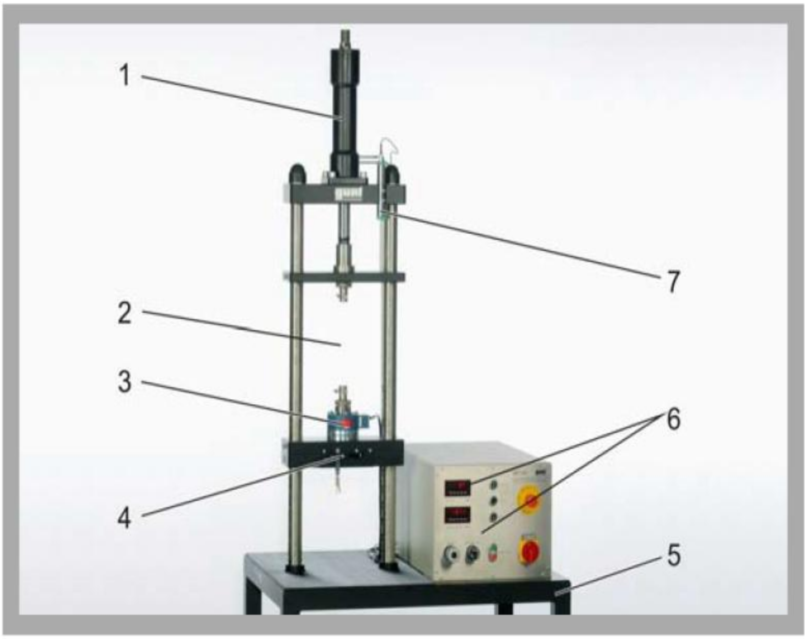


Figure 3.28 Main Parts of GUNT WP 310 Hydraulic Universal Testing Machine (ASTU)

Main Parts of GUNT WP 310 Hydraulic Universal Testing Machine (1: double-acting hydraulic cylinder, 2: working area, 3: force sensor, 4: height adjustable lower cross-member with lock, 5: frame, 6: displays and controls, and 7: displacement sensor) Elements of the “displays and controls” unit are shown in Figure 3.29.

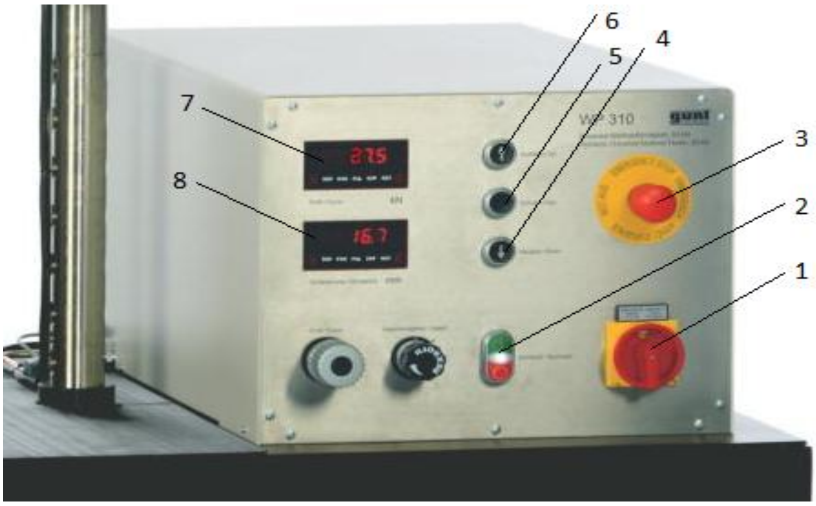


Figure 3.29 Elements of the display and control unit

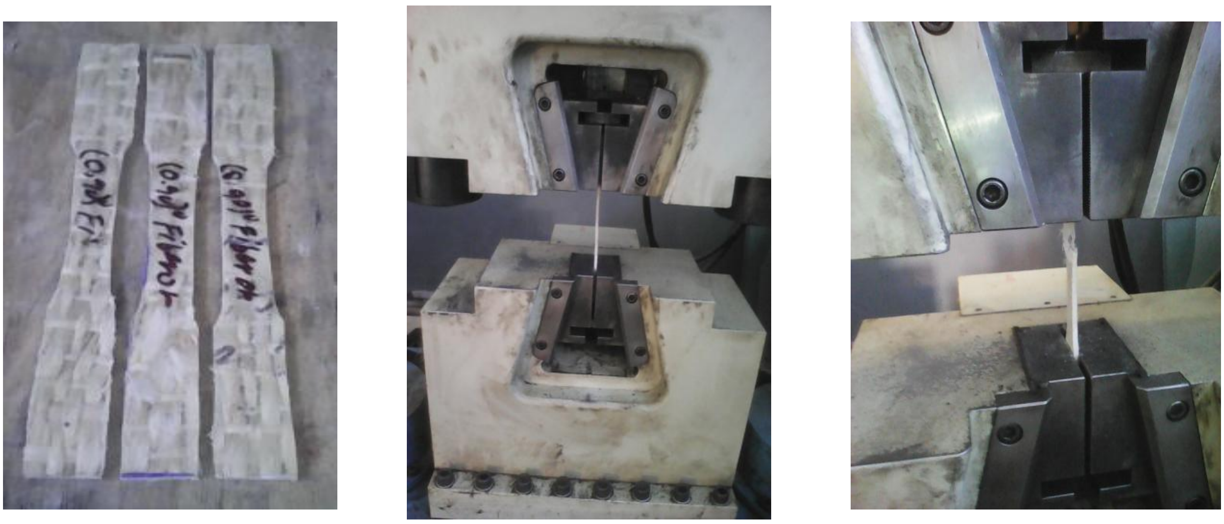
Figure 3-29. (1: main switch, 2: on/off switch, 3: emergency switch, 4: button for moving upper grip downwards, 5: button to make grip movement fast, 6: button to move upper grip upwards, 7: force display, and 8: elongation display).

3.5 Description of Sisal fiber reinforced Unsaturated Polyester Resin Composite

The composites were then characterized as tensile properties using Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1)standards ,compression properties ASTM D3410 and flexural properties using test method ASTM D790-2010 at least 5 replicate specimens were checked and the outcome were presented as an average of tested specimens. For each composite specimen the thickness was determined The thickness measurements were performed at 3 places across the length of each specimen. Overall sample thickness was measured by mean measurements of three specimens the tests were conducted at a room temperature.

3.5.1 Tensile Strength Test (ISO 6892-1)

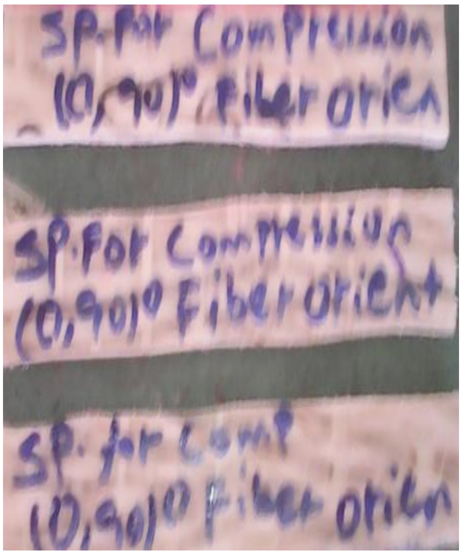
The primary objective of this test was to evaluate the in-plane tensile properties of sisal fiber composites. For each sample, 3 specimens were tested for each machine and cross-machine direction Each specimen was 300 by 30 mm by 4mm. During the test the specimens were placed in the grips of UTM and axial load is applied through both ends of the specimen. Typical points of interest when testing a material includes: ultimate tensile strength (UTS) or peak stress; and gauge length were 116.4 mms. Typical specimen under tensile strength test as shown in figure 3.30.



a. b . c

Figure 3.30 a. SFRUPR C Specimen for Tensile Test b. Specimen under UTM tensile load test c. load is applied and the specimen breaks

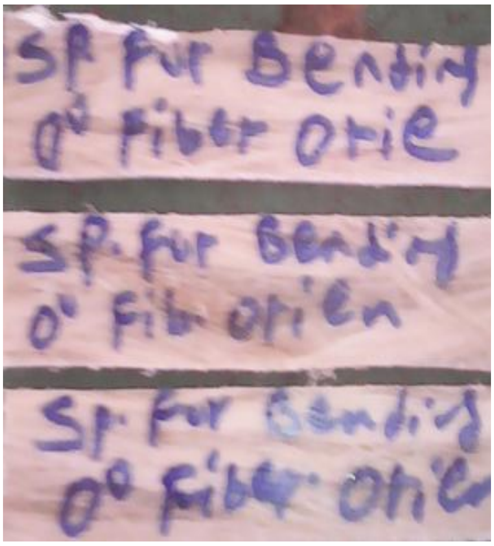
3.5.2 Compressive Strength Test(ASTM D3410) :-Laboratory experiments involved in subjecting sisal fiber reinforced composite specimen to axial compression loading using the UTM The dimension of the specimen is (155 x 30x 4) mm the samples the samples were then placed between the compression anvils to commence compression testing for testing, the maximum load attained were recorded by WP 310 Hydraulic Universal Testing Machine (UTM**)** testing system after the specimen failed. Each specimen was documented (by pictures) before and after failure. A typical specimen failure is shown in Figure 3.31.



a.   b.

Figure 3.31 a. SFRUPRC specimen for Compression Test   b. Specimen Under Compressive load   c. Specimen breakdown under compression loadingc.

3.5.3 Bending Strength Test(ASTM D790-2010):- Bending strength is defined as a materials ability to resist deformation under load. The three point bending tests are performed on the composites samples to evaluate the value of interring laminar shear strength (ILSS). It is a single point bend test, which normally promotes breakdown by inter laminar shear. This test is conducted as per ASTM standard using WP 310 Hydraulic Universal Testing Machine (UTM**)** in Adama Science and Technology University (ASTU) laboratory. The loading arrangement is shown in figure 3.32. The dimension of the specimen is (127 x 30 x4) mm. The flexural strength is expressed as modulus of rupture(MR) in psi (MPa) .



a. b.

Figure 3.32 a. SFRUPRC specimen for bending Test b. Specimen Under Bending load
c. Specimen failure under bending loading

3.5.4 Water Absorption Test (ASTMD-570)

For the moisture absorption test, the specimens are dried in an oven for a particular time and temperature and then located in a desiccators to cool. Immediately upon cooling the specimens are weighed. The material is then submerged in water at determined upon conditions, often 23°C for 24 hours or until equilibrium see (figure 3.33).

Tendency towards moisture absorption in humid air or in water was found by natural fibres reinforced polymer composite. The effect of moisture absorption results the poverty of fibre-matrix interface region as resulting in a reduction of mechanical properties along with change in dimensions of composites. Property of water absorption on composites were investigated in accordance with ASTM D570.

Figure 3.33 Specimen under Water Absorption Test

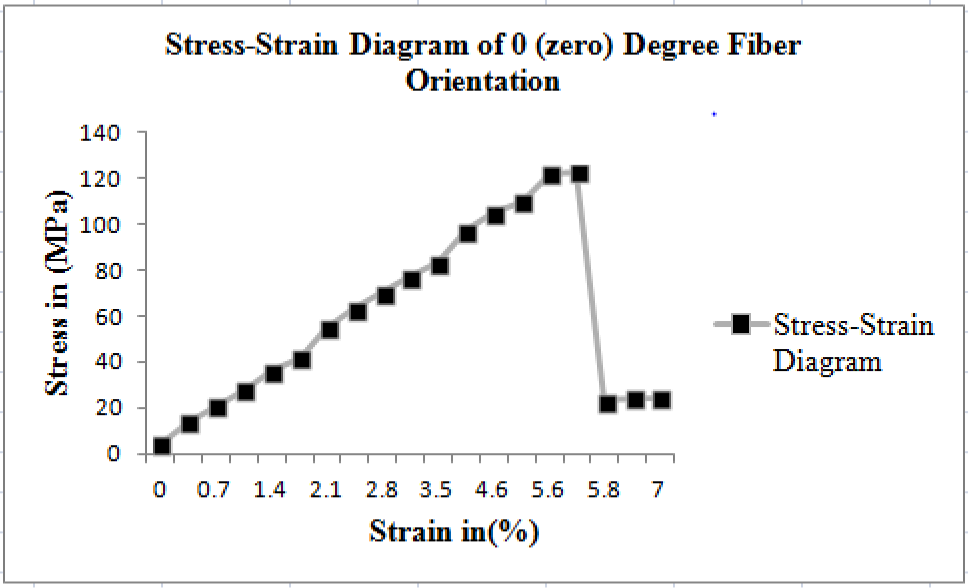
CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Experimental Results

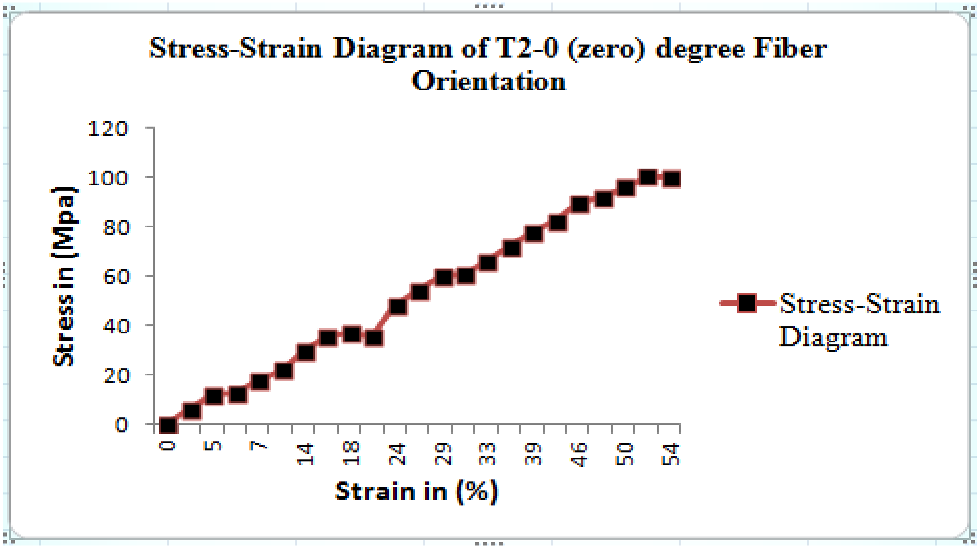
4.1.1 Tensile Test

The tensile specimen is set according to Ethiopian Conformity Assessment Enterprise (ECAE) Testing material (ISO 6892-1)standards According to the ISO 6892-1standard the dimensions of specimen used are 300x30 mms. There were 3 specimen groups of each fiber orientation (0^0, $0,90)^0$ and $\pm$ 45^0) total of 9 specimens while the typical stress strain curve of SFREC under tensile loading with different sisal/general purpose resin composite specimen (see fig 4.1).



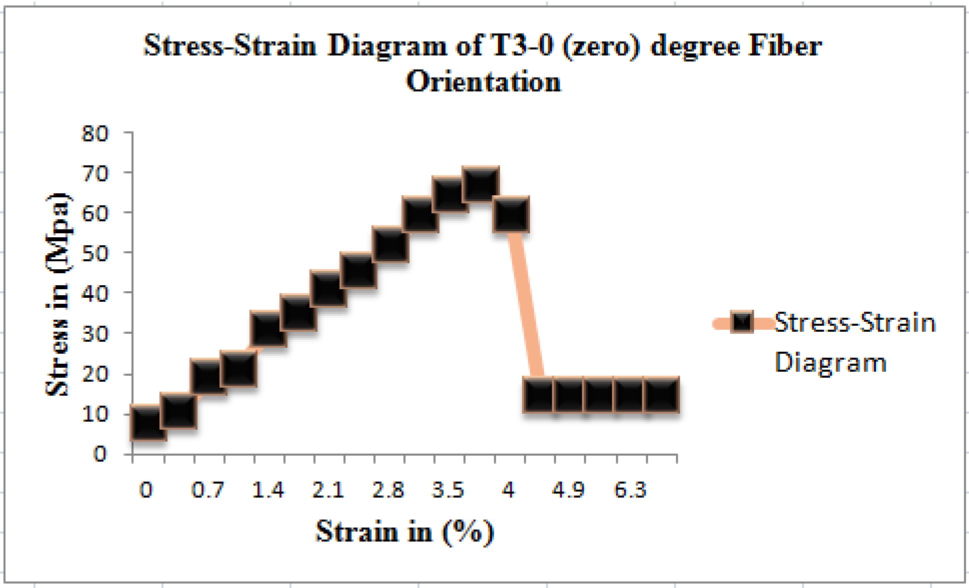
(a) T1 (47.8mm x17.85mm x4mm) - 0^0 fiber orientation (T_{str} =93 MPa)

Figure 4.1a present the result concerning tensile strength test, the percentage strain rate increases because the first elongation beyond 0 % upon in conformity with 5.7 % durability yet after 5.7 % failure is happened.



(b) T2 (57mm x 21.15mm x 4mm) - 0^0 fiber orientation (T_{str} = 111 MPa)

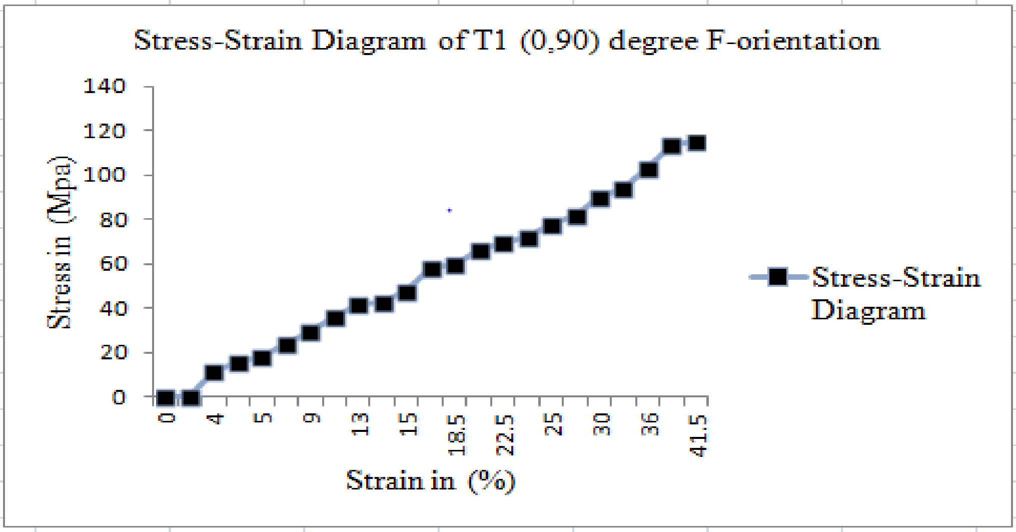
Figure 4.1b shows the result of tensile strength test 0 degree fiber orientation, the percentage strain rate increases for the first elongation from 0 % up to 53.2 % and afterwards failing happened.



(c) T3 (57.5mm x 21.37mm x 4mm) - 0^0 fiber orientation (T_{str} = 62 MPa)

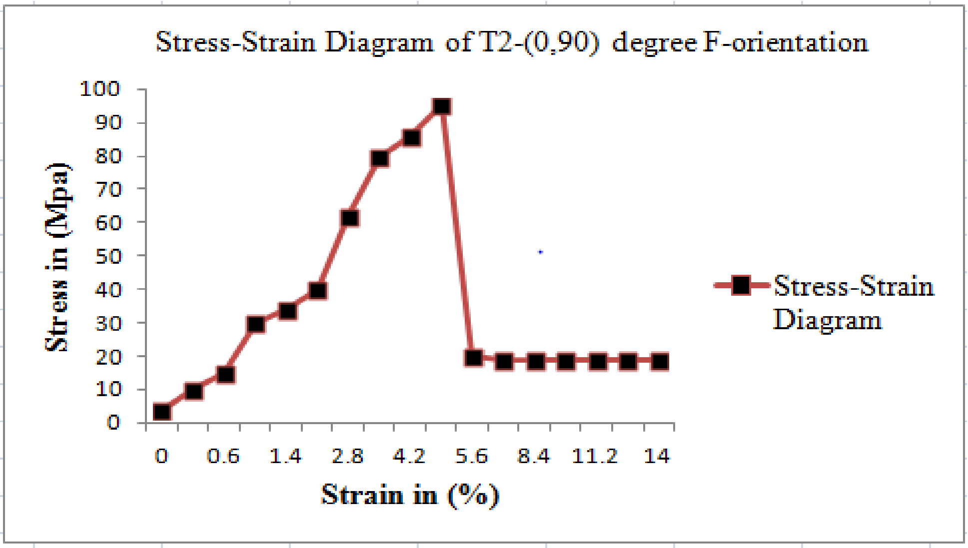
Figure 4.1c shows the result of tensile strength test of 0 degree fiber orientation, the percentage strain rate will increases for the primary elongation from 0 % up to 3.6 % the failure occur after 3.6 %.

Figure 4. 1 a, b, c are 0 (zero) degree tensile strength test



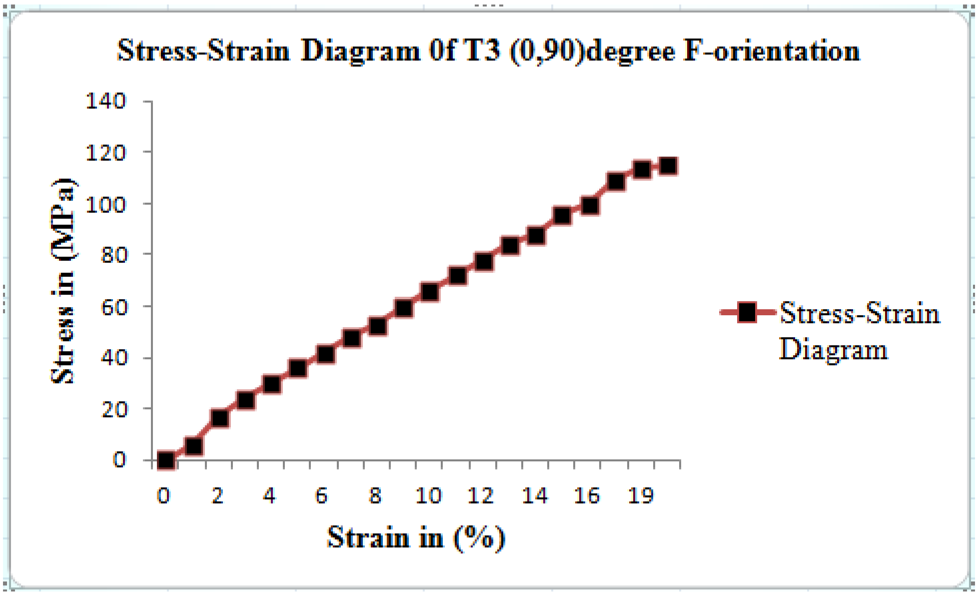
(a) T1(55mm x 20mm x 4mm)- $(0,90)^0$ fiber orientation (T_{str} = 107 MPa)

Figure 4.2a present the result regarding tensile strength test(0,90) degree fiber orientation, the percentage strain rate will increase because the forward elongation beside 0 % up according to 41.3 % toughness and afterward 41.3 % the failure is happened.



(b) T2 (60mm x 21.3 x 4mm)-$(0,90)^0$ fiber orientation (T_{str} = 87 MPa)

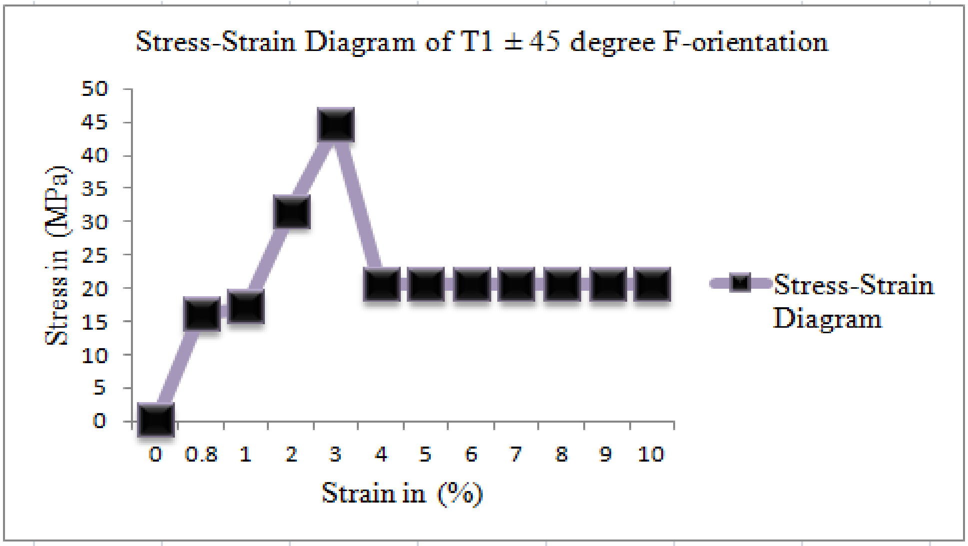
Fig 4.2b demonstrate the result of tensile strength test (0,90) degree fiber orientation, the proportion stress rate increases because of the forward elongation beyond 0 % above to 4.8 % durability then below 4.8 % the failure is came about



(c)T3 (60mm x 20mm x 4mm)-(0,90)^0 fiber orientation (T_{str} = 107 MPa)

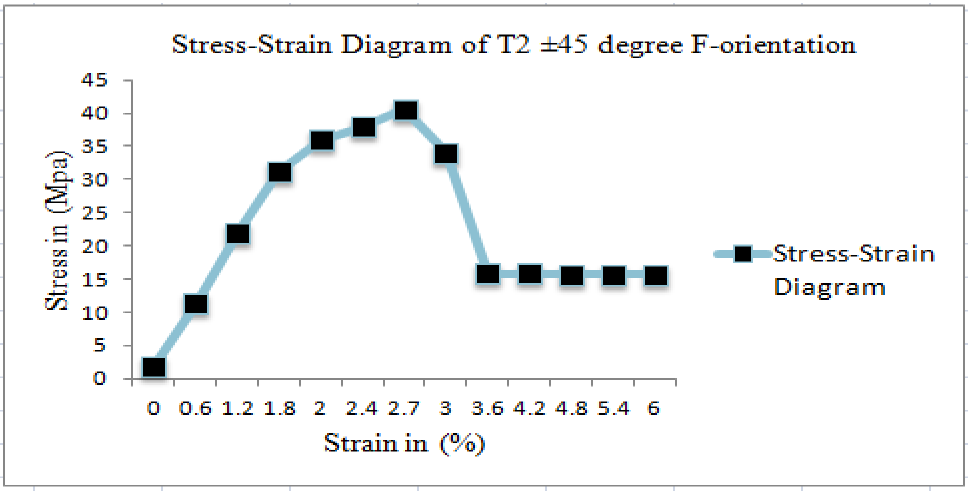
Fig 4.2 c display the result regarding tensile strength test (0,90) degree fiber orientation, the percentagestrain rate increases because the advance elongation beside 0% on inconform ity with 19.1 % stability or after 19.1 % the failure is happened.

Figure 4. 2 a, b, c (0,90) degree tensile strength test



(a) T1 (60mm x 20.5mm x 4mm) ± 45^0 fiber orientation(T_{str} = 39 MPa)

Fig 4.3a present the result of tensile strength test ± 45^0 fiber orientation, the percentage strain rate increases for the first elongation from 0 % up to 3 % and after 3 % the failure is happened .



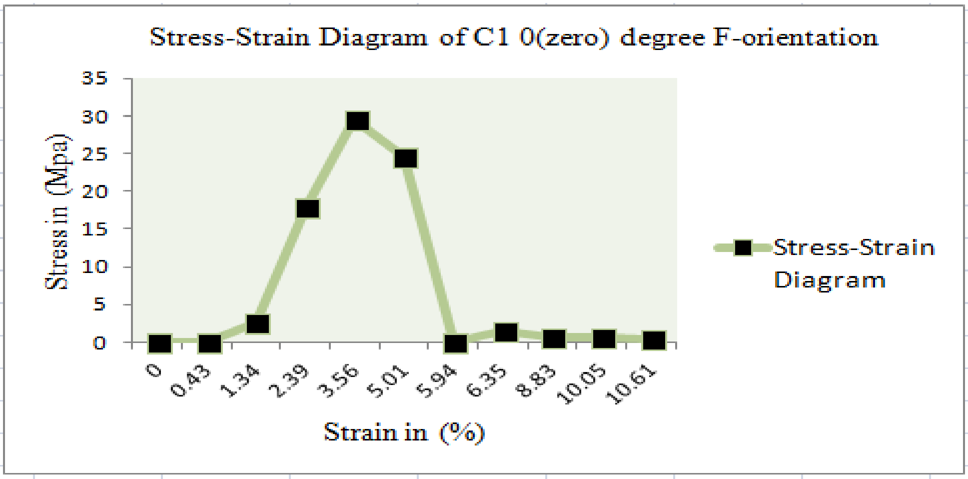
(b) T2 (60mm x 20.5mm x 4mm) ± 45^0 fiber orientation (T_{str} = 35 MPa)

Figure 4. 3 a, b, ± 45 degree tensile strength test

Figure 4.3b Present the result of tensile strength test ± 45 degree fiber orientation, the percentage strain rate increases for the first elongation from 0 % up to 2.7 % and after 2.7 % the failure is happened.

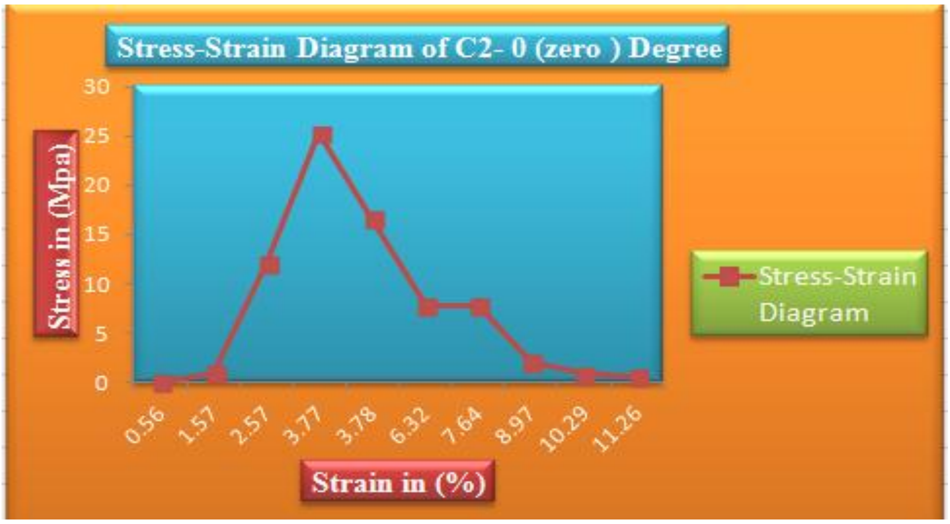
4.1.2 Compression Test

Compression tests is defined as the load carrying ability of the material. Compression testing for SFREC was important to establishing crash limits as well as material quality control. So the planned material for body panel was tested for this test. The specimen is prepared based on ASTM 3410 and it is 155 mms long, 30mm wide and a 4 mm thickness. Nine Compressive tests specimens were prepared for samples as fiber orientation of (0^0,$(0,90)^0$ and ± 45^0).



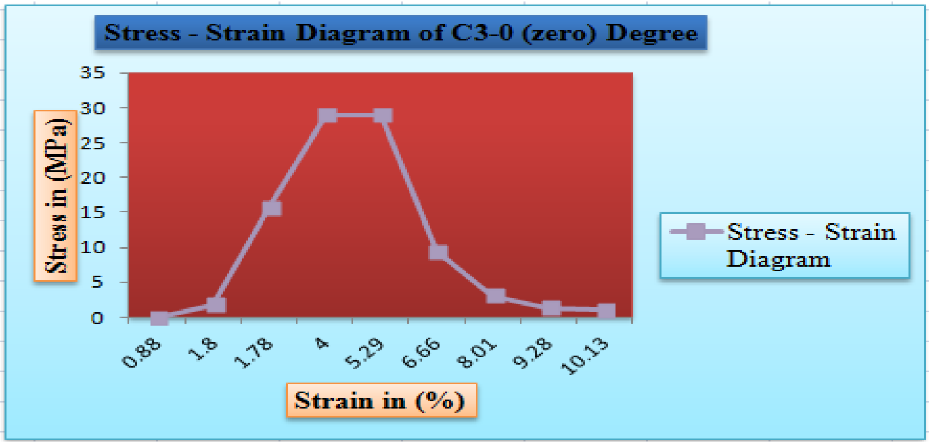
(a) C1 (155mm x 30mm x 4mm) 0 (zero) degree fiber orientation (C_{str} = 29.58 MPa)

Figure 4.4a shows compressive strength test of 0 degree fiber orientation the compressive strength follows an increasing trend from 0 % to 3.56 % after 3.56 % failure happen.



(b) C2 (155mm x 30mm x 4mm) 0 (zero) degree fiber orientation (C_{str} = 25.25 MPa)

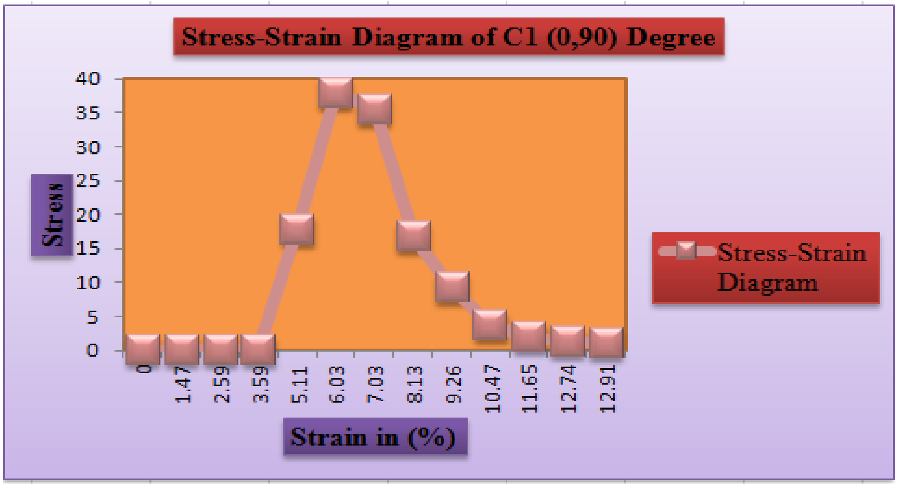
Figure 4.4b introduced are compressive strength test of 0 degree fiber orientation the compressive strength follows an increasing trend from 0% to 3.77 % after 3.77% failure happened.



(c) C3 (155mm x 30mm x 4mm) 0 (zero) degree fiber orientation (C_{str} = 28.92 MPa)

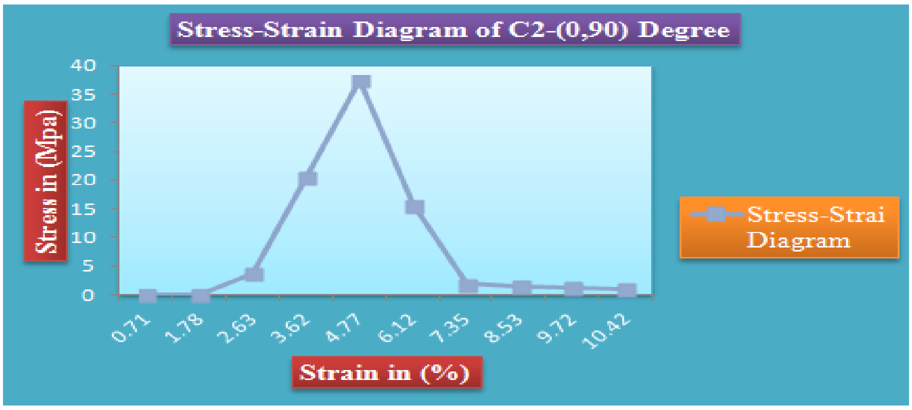
Figure 4.4c presents are compressive strength test of 0 degree fiber orientation the compressive strength follows an increasing trend from 0% to 4 % after 4% failure happen.

Figure 4. 4 a, b, c are 0 (zero) degree compressive strength test



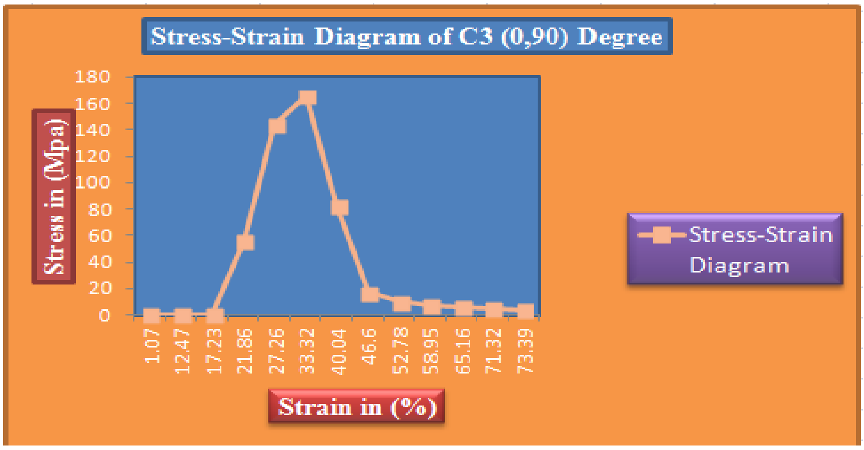
(a) C1 (155mm x 30mm x 4mm) (0,90) degree fiber orientation (C_{str} = 37.92 MPa)

Figure 4.5a shows compressive strength test of (0,90) degree fiber orientation the compressive strength follows an increasing trend from 0 % to 6.03 % after 6.03 % failure happen.



(b) C2 (155mm x 30mm x 4mm) (0,90) degree fiber orientation (C_{str} = 37.42 MPa)

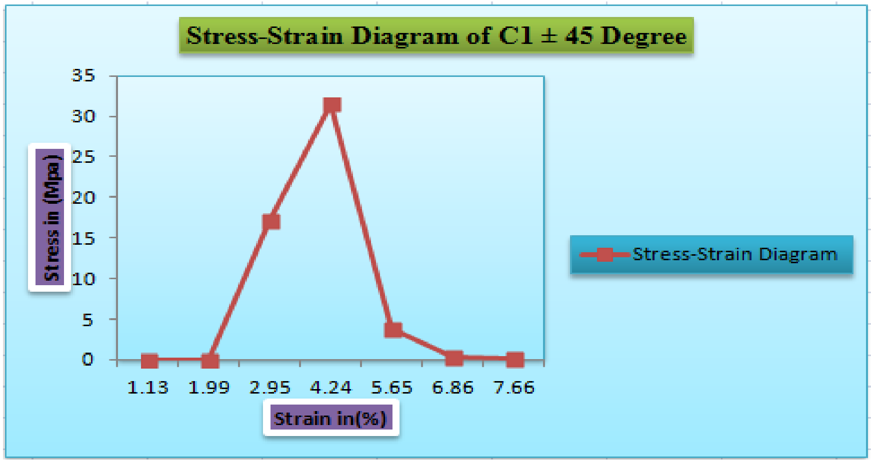
Figure 4.5b demonstrate compressive strength test of (0,90) degree fiber orientation the compressive strength follows an increasing trend from 0 % to 4.77 % after 4.77 % failure happen.



(c) C3 (155mm x 30mm x 4mm) (0,90) degree fiber orientation (C_{str} = 165.52 MPa)

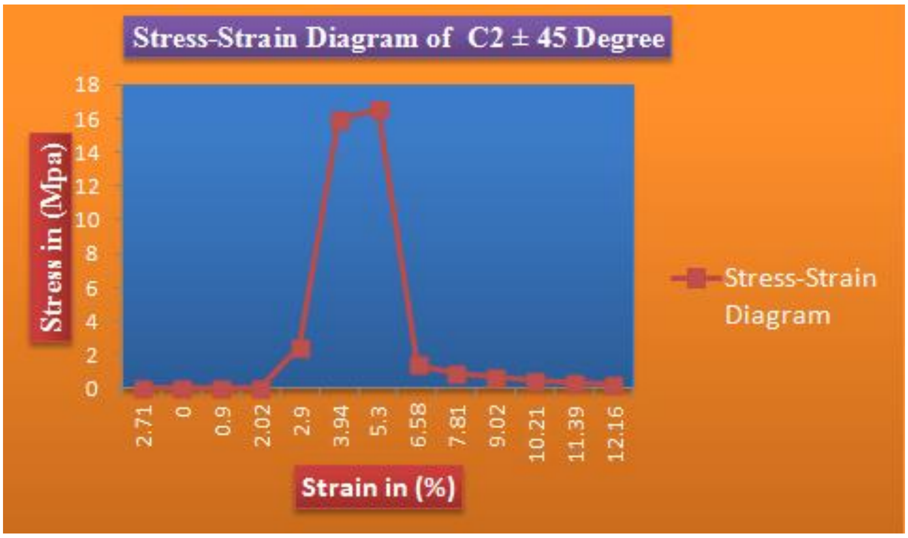
Figure 4.5c presents compressive strength test of (0,90) degree fiber orientation the compressive strength follows an increasing trend from 0 % to 33.32 % after 33.32 % failure happen.

Figure 4. 5 a, b, c are (0,90) degree compressive strength test



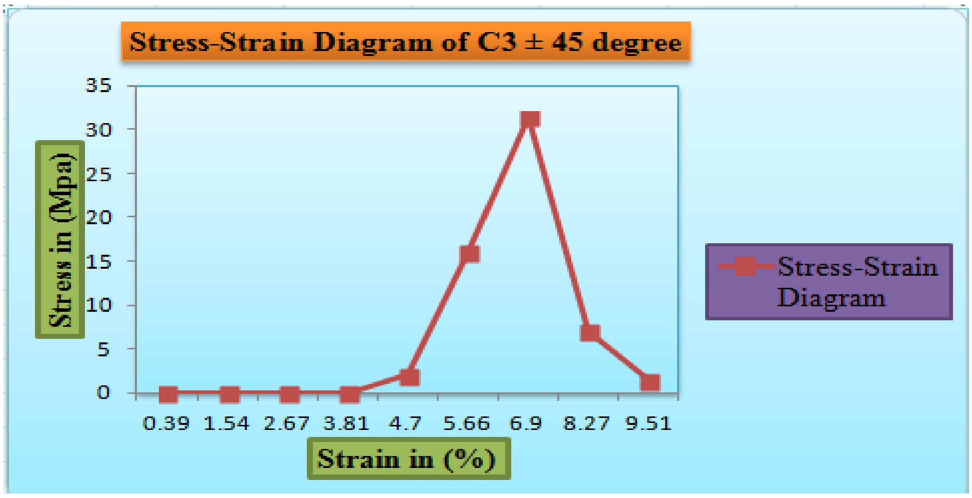
(a) C1 (155mm x 30mm x 4mm) ± 45 degree fiber orientation (C_{str} = 31.5 MPa)

Figure 4.6a shows compressive strength test of ± 45 degree fiber orientation the compressive strength follows an increasing trend from 0 % to 4.24 % after 4.24 % failure happen.



(b) C2 (155mm x 30mm x 4mm) ± 45 degree fiber orientation (C_{str} = 16.58 MPa)

Figure 4.6 b shows compressive strength test of ± 45 degree fiber orientation the compressive strength follows an increasing trend from 0 % to 5.3 % after 5.3 % failure happen.



(c) C3 (155mm x 30mm x 4mm) ± 45 degree fiber orientation (C_{str} = 31.42 MPa)

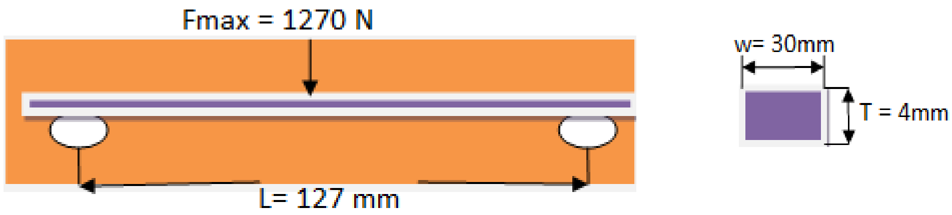
Figure 4.6 c shows compressive strength test of +/-45 degree fiber orientation the compressive strength follows an increasing trend from 0 % to 6.9 % after 6.9 % failure happen.

Figure 4. 6 a, b, c are ± 45 degree compressive strength test

4.2.3 Bending Test

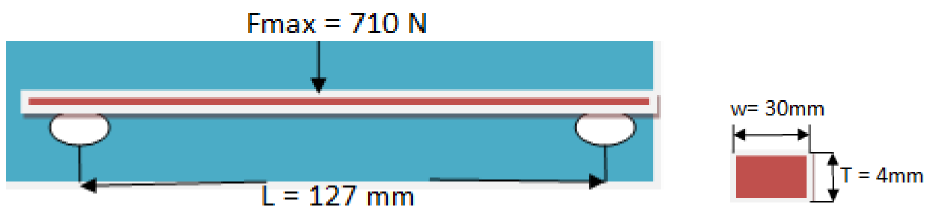
Flexural test is also known as bending tests and consists in applying a point load at the centre of composite material specimen. The flexural tests were done on the universal testing machine according to ASTMD790-2010 According to the ASTMD790-2010 standard the dimensions of specimen used are 127 x □30 mms. Point bending to figure 4.7 when the load is applied to middle of a rectangular specimen of span L between two rollers, The bending properties of the SFRUPR composite samples tested in the universal testing machine and the characteristic property generated for sisal fiber reinforced composite sample presented (see table 4.1).The highest bending strength is determined by:

$$\sigma bB = \frac{Mbmax}{Wb} \quad \text{--(4.1)}$$



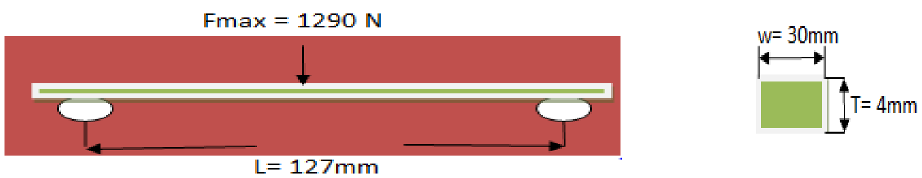
(a) B1 (127mm x 30mm x 4mm) 0(zero) degree fiber orientation (B_{str} = 504.03 MPa)

Figure 4.7a displays bending strength test of zero degree fiber orientation the bending strength follows the maximum force applied at the center 1270 N and then the bending strength of 504.03 MPa the stress experienced by the material at the time of breaking.



(b) B2 (127mm x 30mm x 4mm) 0(zero) degree fiber orientation (B_{str} =281.78 MPa)

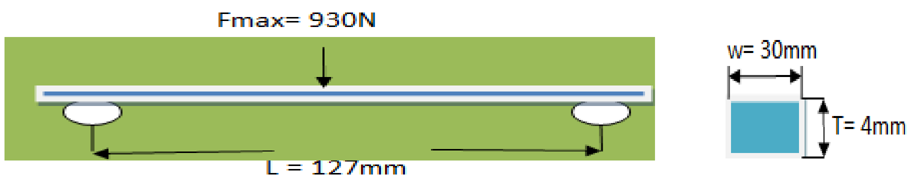
Figure 4.7b shows bending strength test of zero degree fiber orientation follows the maximum force carried out on the middle 710 N and then the bending strength indicates the highest stress applied in the material at its moment of break.



(c) B3(127mm x 30mm x 4mm) 0(zero) degree fiber orientation (B_{str} =281.78 MPa)

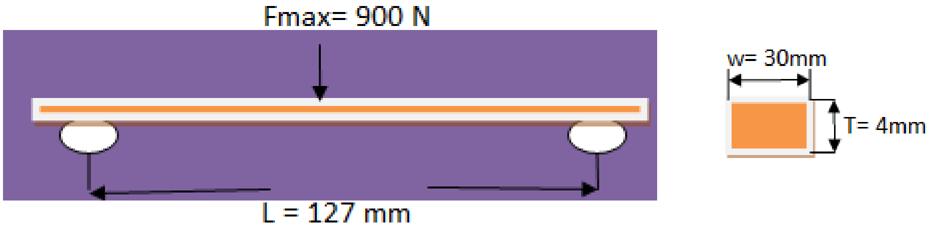
Figure 4.7c shows bending strength test of zero degree fiber orientation the bending strength follows the maximum force applied at the center 1290 N and then the bending strength indicates the highest stress applied in the material at its moment of break.

Figure 4. 7 a, b, c are 0 (zero) degree bending strength



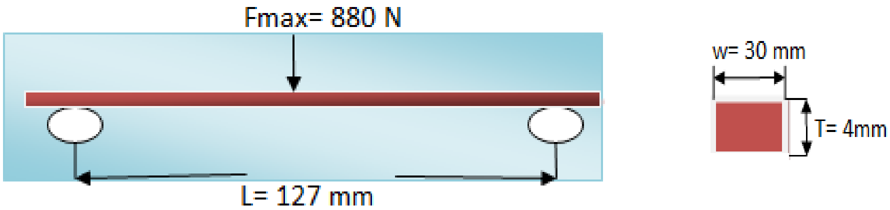
(a) B1 (127mm x 30mm x 4mm) (0,90) degree fiber orientation (B_{str} = 369.09 MPa)

Figure 4.8a shows bending strength test of (0,90) degree fiber orientation the bending strength follows the maximum force applied at the center 930 N and then the bending strength of 369.09 N/mm^{2}the stress applied in the material at its moment of break.



(b) B2 (127mm x 30mm x 4mm) (0,90) degree fiber orientation (B_{str} = 388.94 MPa)

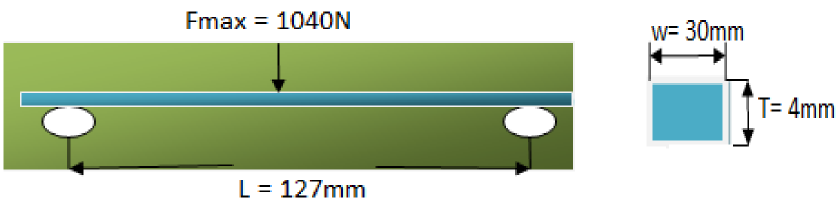
Figure 4.8b shows bending strength test of (0,90) degree fiber orientation the bending strength follows the maximum force applied at the center 900 N and then the bending strength of 388.94N/mm^{2}the stress applied by the material at the time of breaking.



(c) B3 (127mm x 30mm x 4mm) (0,90) degree fiber orientation (B_{str} = 349.25 MPa)

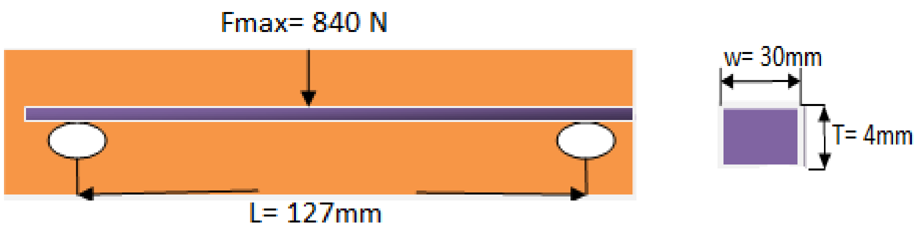
Figure 4.8c shows bending strength test of (0,90) degree fiber orientation the bending strength follows the maximum force applied at the center 880 N and then the bending strength of 349.25N/mm^{2}the stress applied in the material at its moment of break.

Figure 4. 8 a, b, c are (0,90) degree bending strength test



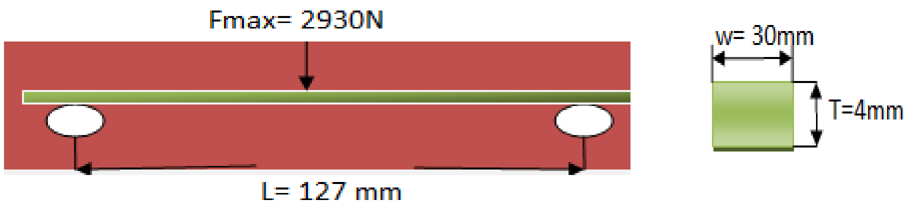
(a) B1 (127mm x 30mm x 4mm) ± 45 degree fiber orientation (B_{str} = 412.75 MPa)

Figure 4.9a shows bending strength test ± 45 degree fiber orientation the bending strength follows the maximum force applied at the center 1040 N and then the bending strength of 412.5 N/mm^{2}the stress applied in the material at its moment of break.



(b)   B1 (127mm x 30mm x 4mm) ± 45 degree fiber orientation (B_{str} = 333.38 MPa)

Figure 4.9b shows bending strength test of ± 45 degree fiber orientation the bending strength follows the maximum force applied at the center 840 N and then the bending strength of 333.38 N/mm^2 the stress experienced by the material at the time of breaking .



(c)   B1 (127mm x 30mm x 4mm) ± 45 degree fiber orientation (B_{str} = 960 MPa)

Figure 4.9c shows bending strength test of ± 45 degree fiber orientation the bending strength follows the maximum force applied at the center 2930 N and then the bending strength of 96.9N/mm^{2}the stress experienced by the material at the time of breaking.

Figure 4. 9 a, b, c are ± 45 degree bending strength test

4.2 Discussion

4.2.1 Tensile Test

The competence to oppose breaking with tensile stress is one of the majority significant and broadly precise properties of materials used in automobile body applications. The force per unit area (MPa) mandatory to break a material in such a method is the vital tensile strength or tensile strength at break. Tensile properties point out how the material would respond to forces being useful in tension. A tensile test is a basic mechanical test where carefully ready specimen is loaded with a very controlled way although measuring the practical load and the elongation of the specimen in excess of some distance. Tensile tests are used to decide tensile strength, yield point, yield strength, modulus of elasticity, reduction in area, elastic limit, elongation, proportional limit and other tensile properties.

When sisal fiber reinforced composite materials are considered, the reinforcements are always oriented in the load direction. Though if the load direction is uneven and not parallel to the fibers it becomes more important to investigate the laminate mechanical behavior. To investigate the effect of fiber orientation, 0^0 , $\pm 45^0$and($0,90)^0$ were selected under this research. Specimens with unlike fiber orientations were prepared for the same conditions as discussed before. The test results are shown and discussed in this part tabulated and accessible in the table 4.1 based on the maximum values of the 3 specimens for each test condition.

Table 4.1 shows the tensile test results from different orientations of SFR composites such as 0^0,$(0,90)^0$and $\pm 45^0$) a total of 9 specimens are listed and compare them.The modulus of elasticity (Young's Modulus) is the ratio of stress in Mpa to strain in millimeters per millimeter (mm./mm.)

$$\text{Modulus (Mpa)} = \frac{\textbf{Stress in } (\textbf{Mpa})}{\textbf{Strain } (\frac{mm}{mm})} \text{---(4.2)}$$

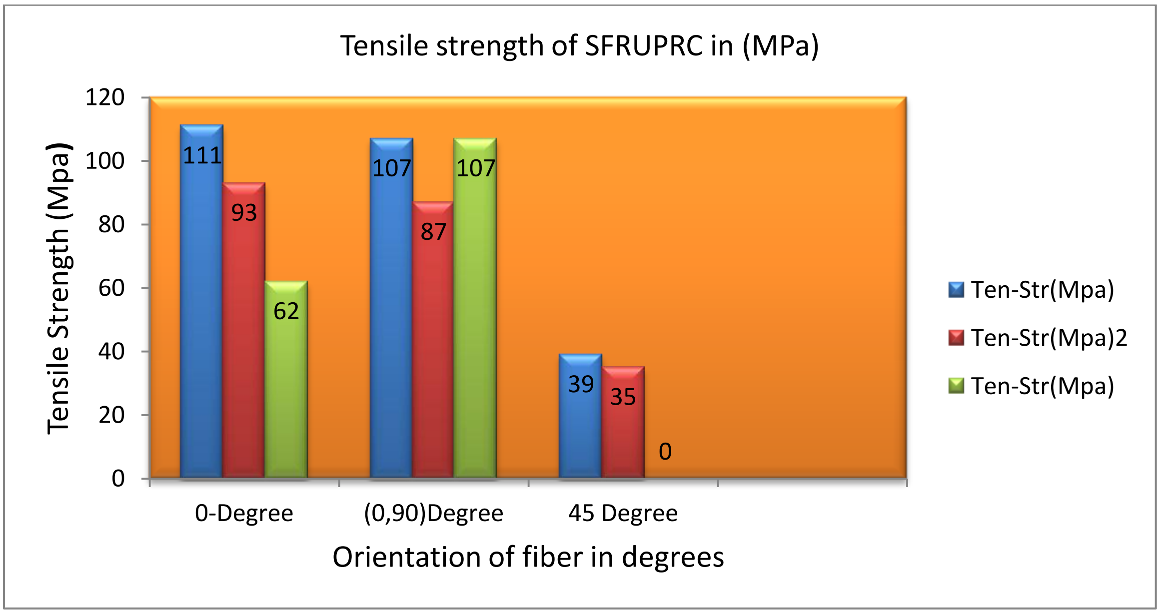
Table 4. 1: Tensile Tests Result

Fiber orientation in degree	No of sample	Thickness	F_{max}(N)	T-stress (MPa)	T-strength(MPa)	Strain(%)	Modulus(MPa)
0	Ts-1 Ts-2 Ts-3	4 4 4	10200 8750 6940	100.4 122.5 67	111 93 62	53.2 5.7 3.6	188.72 2149.12 1861.11
Mean			8630	96.6	88.7	20.83	463.3
0/90	Ts-1 Ts-2 Ts-3	4 4 4	11030 9730 11030	114.9 95.2 114.9	107 87 107	41.3 4.8 19.1	278.2 1983 601.6
Mean			10596.7	108.3	100.3	21.73	498.4
± 45	Ts-1 Ts-2 Ts-3	4 4 4	4600 4000 -	44.5 40.6 -	39 35 -	4.8 4.1 -	927.1 990.2 -
Mean			4300	42.55	37	4.45	956.2

Observation

From table 4.1 the experimental results illustrate that the tensile strength is influenced by the fiber orientation from those three specimens for testing tensile strength considerably as summarized below: Suggests the tensile test results from different orientations of SFR composites are recorded and compare them.

- The tensile strength is maximum in case of $(0,90)^0$ fiber orientation.
- More loads was required for rupture of laminates in case of $(0,90)^0$ fiber orientation.
- Maximum elongation is observed in $(0,90)^0$orientation.



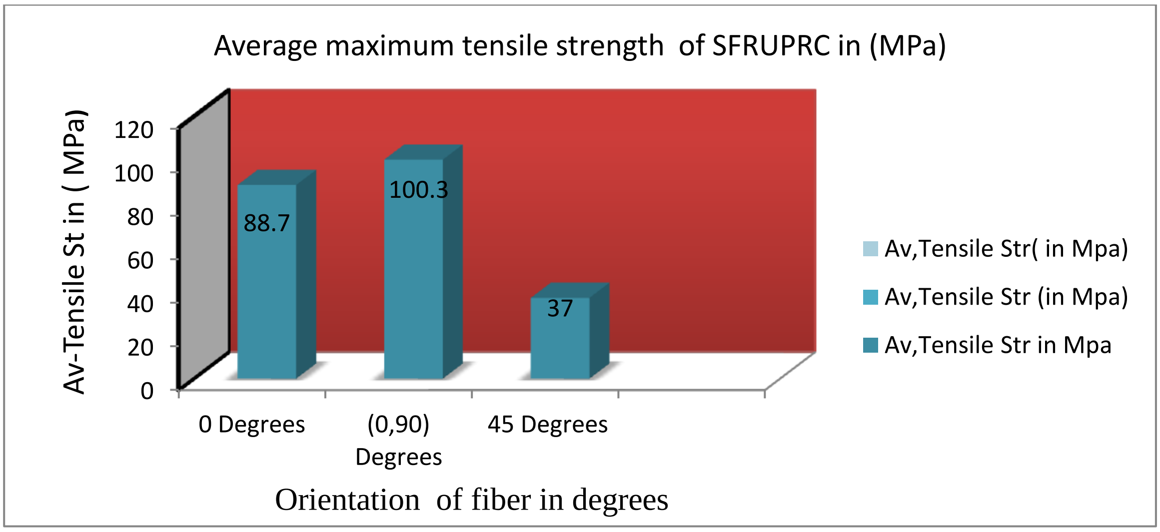
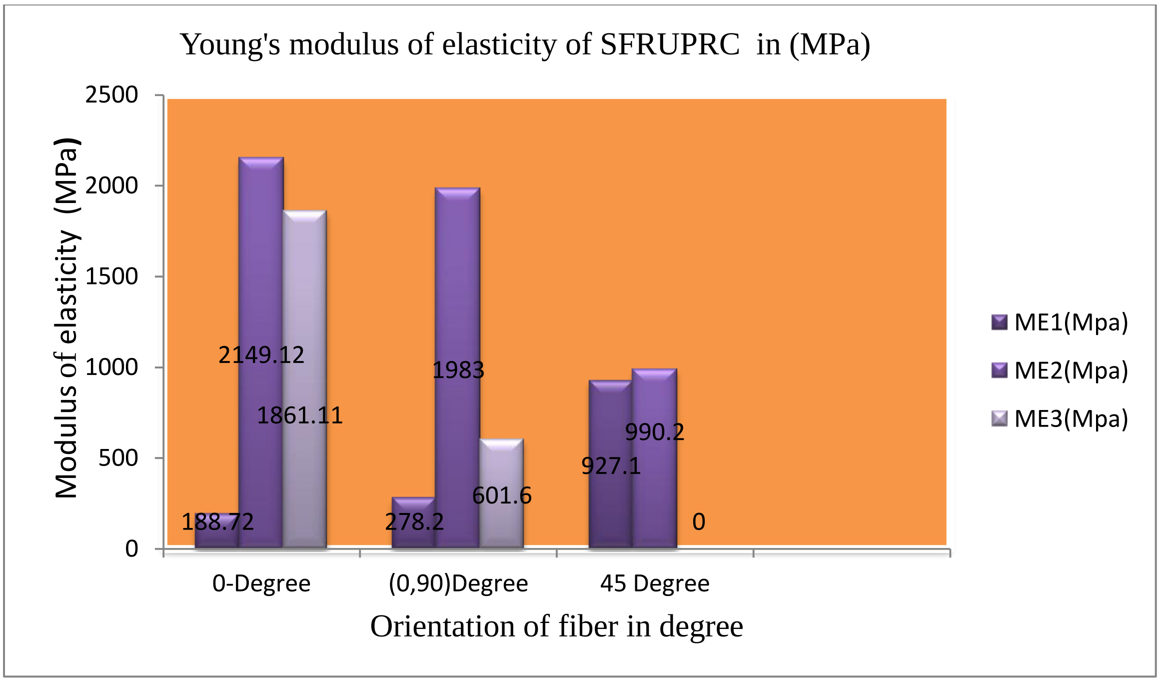


Figure 4. 10 Tensile strength comparison of different Orientation of fibers in degrees

Figure 4.10 appears the tensile strength of SFRUPR composites on their distinctive orientation. From these three samples of specimens Among these (0,90)^0 orientation shows maximum tensile strength.



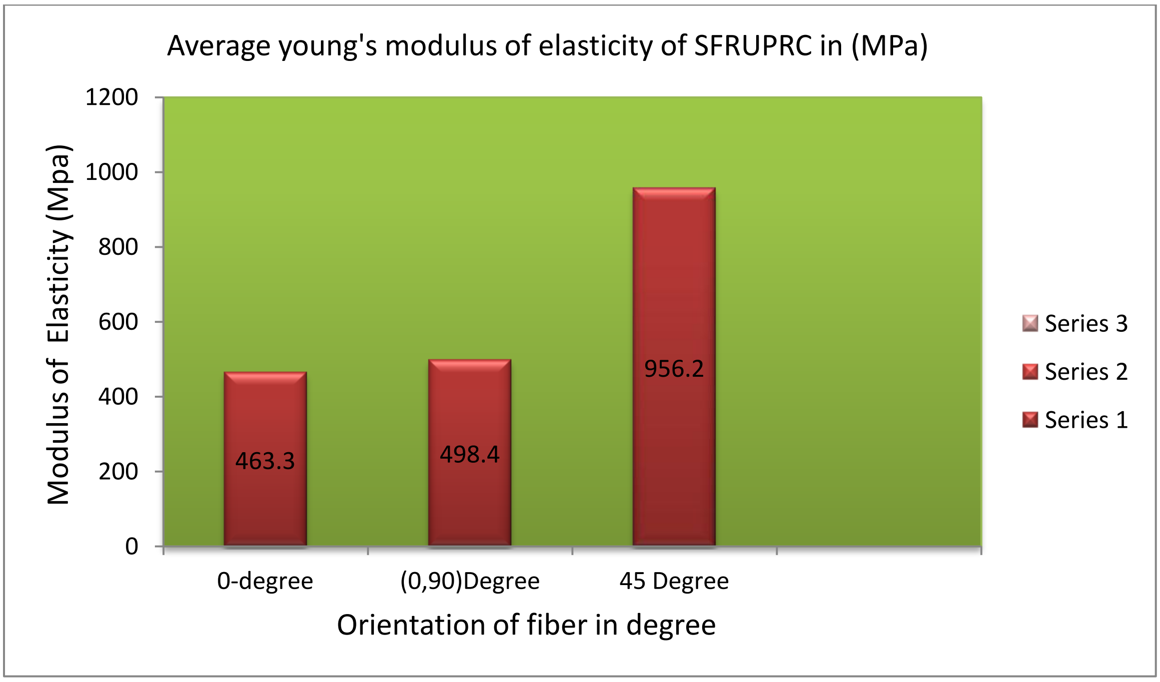
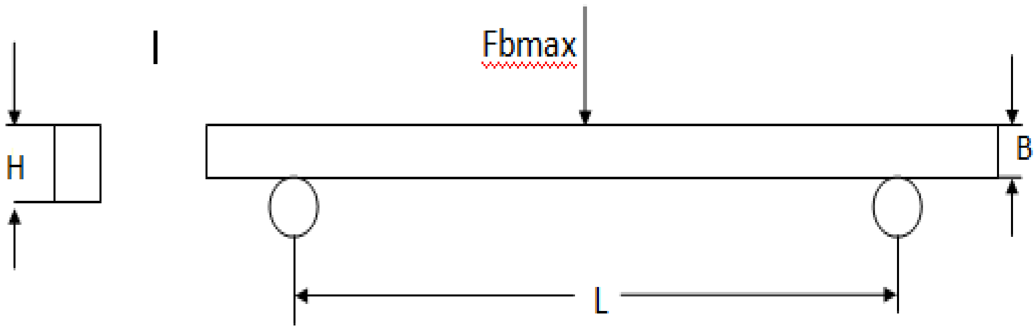


Figure 4. 11 Tensile strength comparison of different orientation of fibers in degrees

4.2.2 Bending Test

Bending strength, also known as flexural strength, is defined as a material's ability to oppose deformation under load. The disposed flexural test is most often working in which a bar example having either a circular or rectangular cross area is bowed until break employing a three point bending test strategy. The bending strength indicates the maximum stress practiced within the material at its moment of break. It is calculated in terms of stretch, here given the image δ .When an object formed into a particular material, like a wooden shaft of light or a steel rod is bending it experiences a series of stresses across its depth. At the border of the object within the bending (concave confront) the push will be at its highest compressive stress value. At the outside of the bending (convex face) the push will be at its highest tensile value. These inside and external edges of the bar or rod are known as the 'extraordinary fibers'. Most materials not pass in tensile stress before they fail in compressive stress, so the highest tensile stress value that can be sustained before the bar or pole fails is its bending (flexural) strength.

The bending test results are calculated, tabulated and presented in the table 4.2 based on average most extreme values of the specimens and the maximum result obtained.



$$W_b = \frac{B \times h^2}{6} \qquad (4.3)$$

$$Mb_{max} = \frac{F_{max} \times L}{4} \qquad (4.4)$$

$$\delta_{bB} = \frac{M_{bmax}}{W_b} \qquad (4.5)$$

Where:-

W_b is bending section (elastic) modulus in m^3 or mm^3

M_{bmax} is maximum bending moment in Nm

σ_{bB} is maximum bending(flexural) strength in Mpa

Using the above Equation 1,2 &3 the bending test result become as follows

- Example 1 for specimen fiber orientation 0(zero) degree fiber orientation sample 1.

Given:- h= 4mm L=127mm Fmax (N), for B1= 1270N

B=30mm

Required- Wb(m3) and σ_{bB} (Mpa)

Solutions

$$Wb = \frac{30*}{6}4^2 = 80m^3$$

$$Mbmax = \frac{1270N*127mm}{4} = 40{,}322.5 \text{ Nmm}$$

$$\sigma_{bB=} \frac{40{,}322.5\ Nmm}{80m3} = 504.03 \text{ N/mm}^2 \text{ or } 504.03 \text{ Mpa}$$

- Example 2 for specimen fiber orientation(0,90) degree fiber orientation sample 1.

Given:- h= 4mm L=127mm Fmax (N), for B1= 930N

B=30mm

$$Wb = \frac{30*}{6}4^2 = 80m^3$$

$$Mbmax = \frac{930N*127mm}{4} = 29{,}527.5 \text{ Nmm}$$

$$\sigma_{bB=} \frac{29527.5\ Nmm}{80m3} = 369.09 \text{ N/mm}^2 \text{ or } 369.09 \text{ Mpa}$$

The rests values are in the same procedure tabulated in the table 4.2 :-

Table 4.2: Bending Tests Results

Fiber Orientation in Degree	Sample	Height(H) Thickness	Width(B)	Length(L)	Fmax (N)	Wb(m^3)	Maximum Bending in (MPa)
0	B-1	4	30	127	1270	80	504.03
	B-2	4	30	127	710	80	281.78
	B-3	4	30	127	1290	80	511.97
Average					1090		432.6
0/90	B-1	4	30	127	930	80	369.09
	B-2	4	30	127	900	80	388.94
	B-3	4	30	127	880	80	349.25
Average					906.7		382.9
± 45	B-1	4	30	127	1040	80	412.75
	B-2	4	30	127	840	80	333.38
	B-3	4	30	127	2930	80	960.9
Average					160.3		569.01

Observation:- Table 4.2 shows the flexural(bending) test results from different orientations of SFRUPR composites. From these three samples of specimens for testing bending strength. Among that the ± 45^0orientation appears the greatest flexural strength.

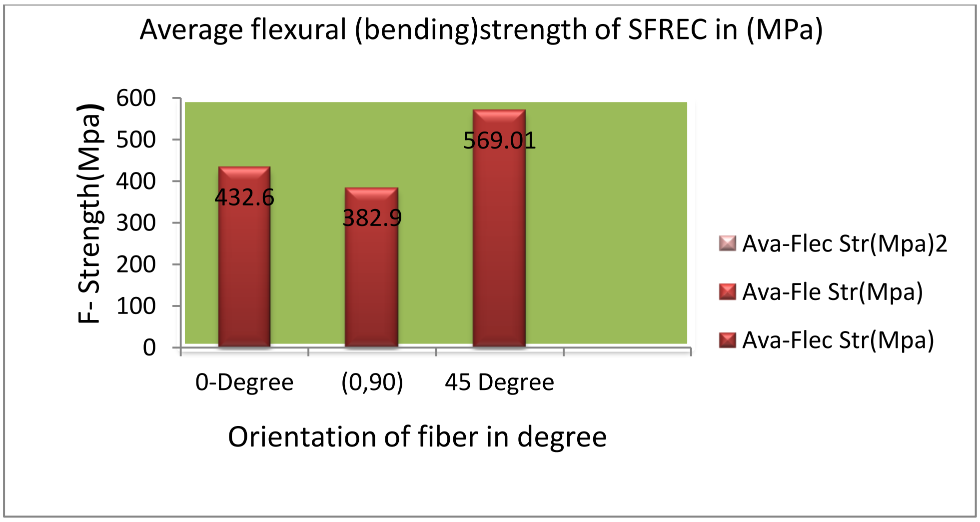


Figure 4. 12 Bending(flexural) strength comparison between different orientation of fiber in degree

Figure 4.12 seems the flexural(bending) test comes about from distinctive orientations of sisal fiber reinforced unsaturated polyester resin composites. From these 3 samples of specimens for testing twisting quality. Among these the ± 45^0 orientation appears most extreme flexural quality.

4.2.3 Compression Test

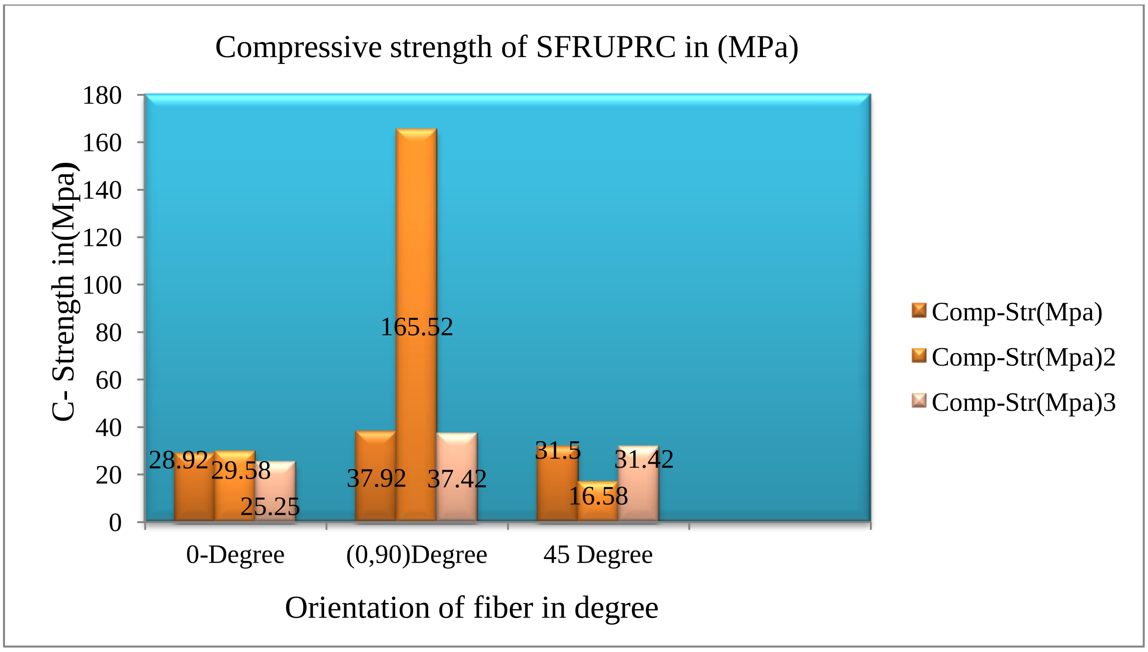
The test results are arranged and displayed within the table 4.3 based on the average compressive result of tests is given in table below.

Table 4.3: Compression Tests Results

Orientation in Degree	No of Samples	Thicks mm	Load in(N)	Compressive Strength in(Mpa)	Elongation (%)
0	C-1 C-2 C-3	4 4 4	3470 3550 3030	28.92 29.58 25.25	5.29 3.56 3.77
	Mean		3350	27.9	4.21
0/90	C-1 C-2 C-3	4 4 4	4550 4680 4490	37.92 165.52 37.42	6.03 33.32 4.77
	Mean		4573.3	80.3	14.7
+/- 45	C-1 C-2 C-3	4 4 4	3780 1990 3770	31.5 16.58 31.42	4.24 5.3 6.9
	Mean		3180	26.5	5.48

Observation

The compressive quality of sisal fiber reinforced unsaturated polyester resin composites is displayed in table. It is observed that the $(0,90)^0$ sisal fiber reinforced unsaturated polyester resin is showing higher compressive strength than 0^0 and ± 45^0 sisal fiber reinforced unsaturated polyester resin .The increment in compressive strength of composite is since of two diverse combinations orientations of specimens.



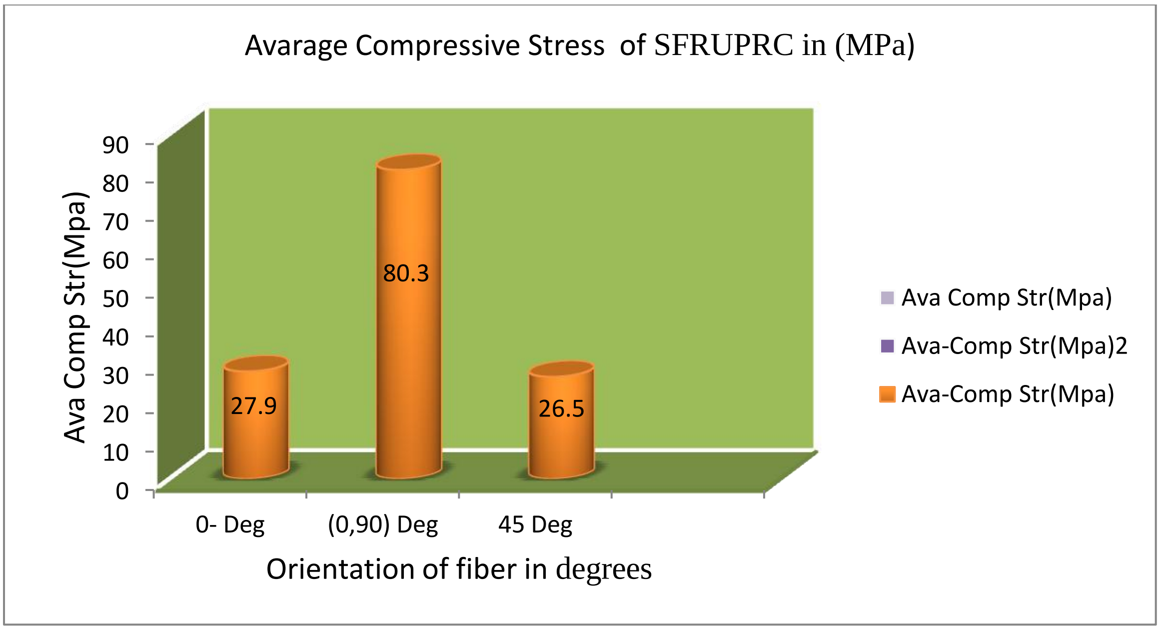


Figure 4.13 Compressive strength comparison between different orientation of fiber in degree

Figure 4.13 appears the compressive strength of sisal fiber reinforced unsaturated polyester resin composites on their different orientation. Among these the $(0,90)^0$orientation shows maximum compressive strength.

4.2.4 Water Absorption Test

Moisture absorption is utilized to choose the capacity of water absorbed by a composite .It was observed that the percentage of water assimilation is found to be increased from increasing fiber content of all cases. The rising water absorption is owing to the hydrophilic nature of sisal fiber and more prominent interfacial region between fiber and matrix. The moisture retention by epoxy is nearly insignificant due to its hydrophobic nature. To study the behavior of water absorption of sisal fiber reinforced unsaturated polyester resin composites, moisture absorption tests were carried out according to ASTMD570 [41]. Composite samples have been immersed in a water bath at 23°C for the duration of a term until the saturation was reached. Three specimens from each fiber a total of 9 specimen volume fraction were cut from composite panels. An oven was used, firstly to dry all the samples at 50°C during 24 hrs .After 24 hrs the samples were eliminated from the water and have been weighed (mass) the usage of a virtual scale right now once they had been dried with dry material to weigh. The weight was measured to accuracy of 0.0001g utilizing four digit equalizations (analytical precision balance) shown in figure below.

Figure 4.14 Analytical precision balance machine

The following Equation is used to determine the water absorption test:-

$$\text{Water Absorption} = \frac{W2-W1}{W1} \text{ x } 100 \text{ in } (\%) \quad \text{------------------------------------}(4.6)$$

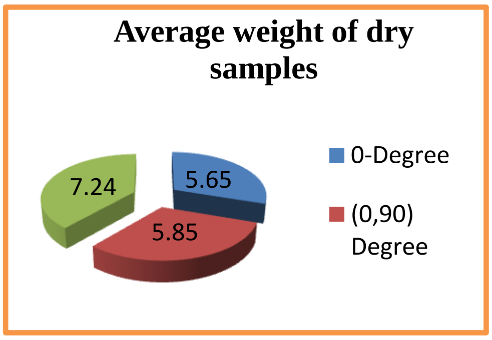
Where

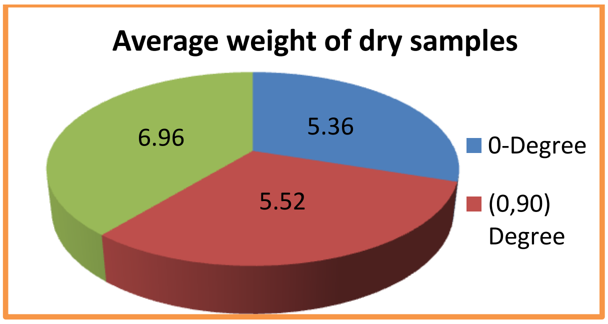
W1 is the weight of the dry samples (weight before soaking into water) & W2 is the weight of wet samples, (weight after soaking into water (g)).

The test results are tabulated and existing in the table and figure based on the percentage of moisture absorption result of tests is given in table 4.4 below.

Table 4. 4:Water Absorption Tests Results

Orientation in (degree)	No of Sample	Thickness	Dry Samples(W1)	Wet Samples(W2)	W-Abs= $\frac{W2-W1}{W1}$ 100 i n(%)
0- Degree	Ws_1 Ws_2 Ws_3	4 4 4	5 5.64 5.44	5.28 5.89 5.78	5.6 4.43 6.25
Average			5.36	5.65	5.41
(0,90) Degree	Ws_1 Ws_2 Ws_3	4 4 4	5.1 5.94 5.52	5.42 6.24 5.88	6.27 5.05 6.52
Average			5.52	5.85	5.98
± 45 Degree	Ws_1 Ws_2 Ws_3	4 4 4	7.46 6.71 6.71	7.7 7.06 6.96	3.22 5.21 3.72
Average			6.96	7.24	4.02





Average Weight of Water Absorption Test

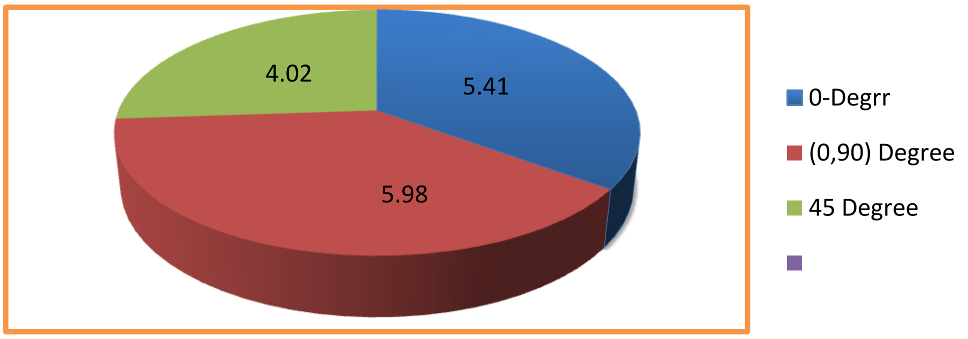


Figure 4.15 Water absorption property between different orientation of fiber in degree

Observation

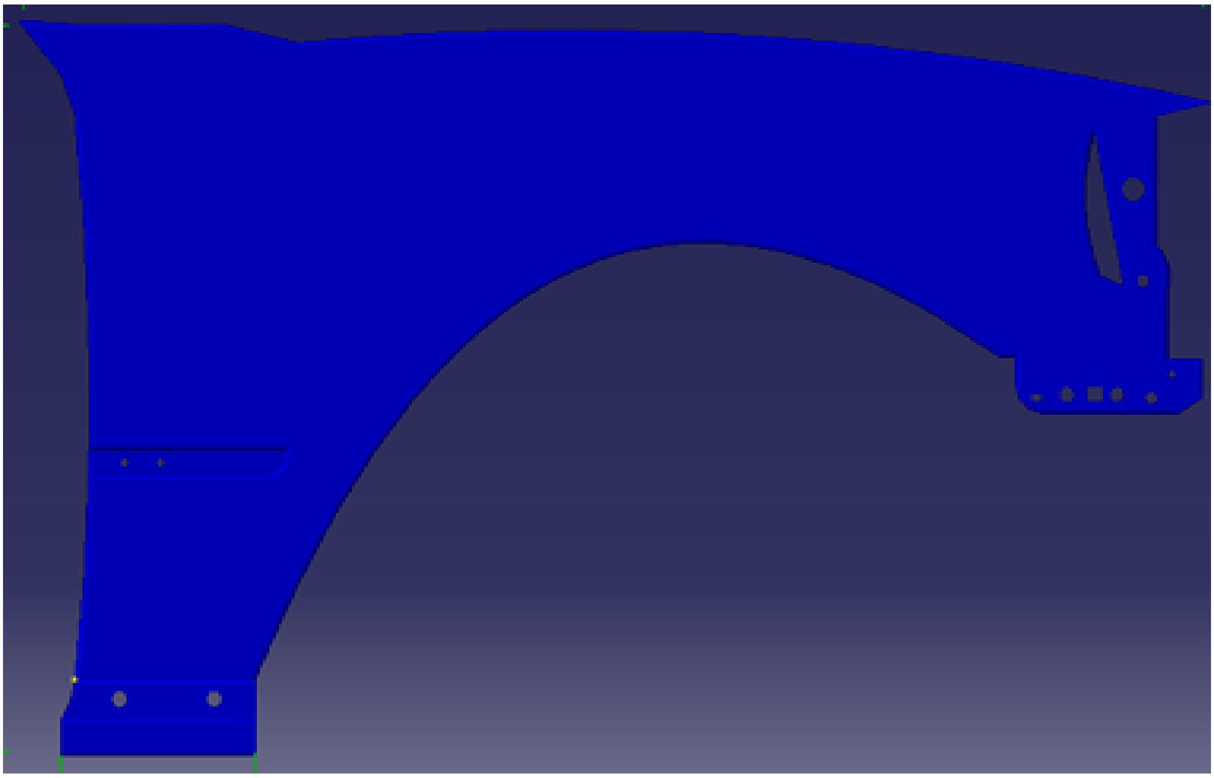
In these test all of the sisal fiber reinforced unsaturated polyester resin composite specimen's fiber orientations have minimum water absorption which is less than 15% of ASTM C220 standards.

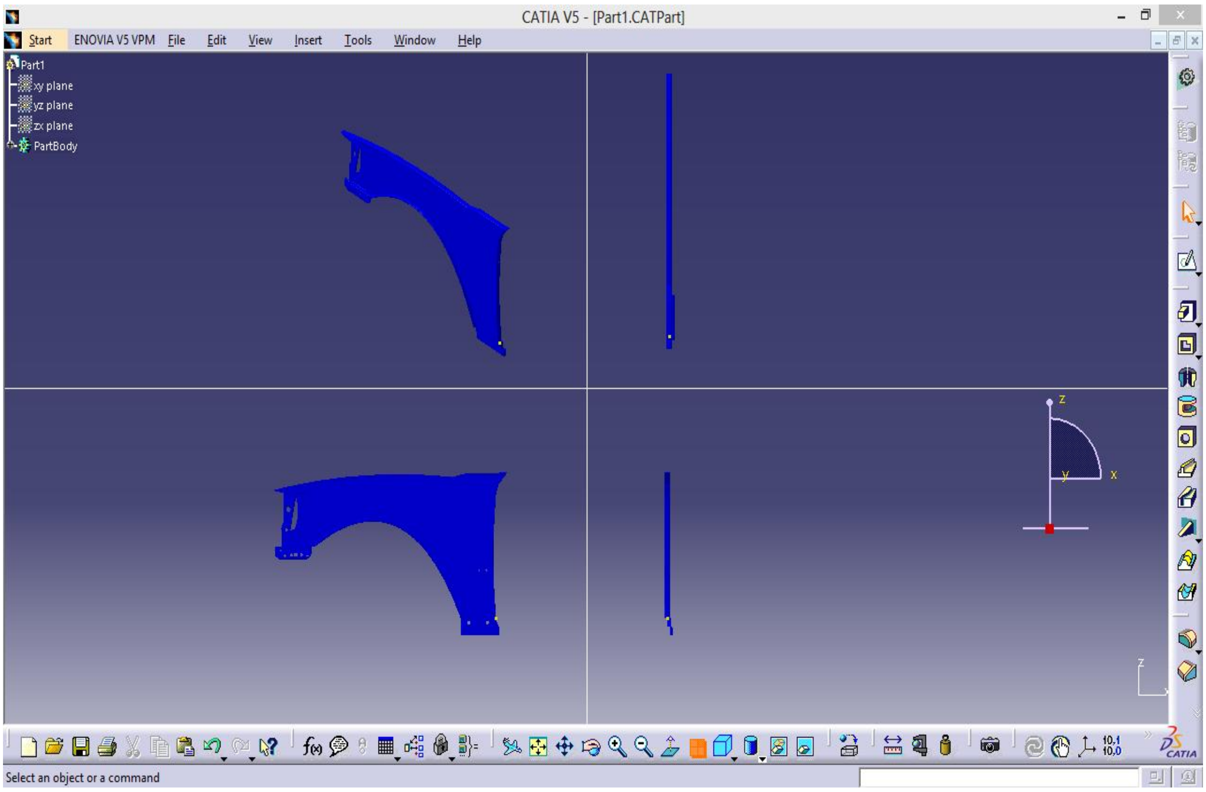
4.3 Preparation of Fender Prototype

In this work the samples with three different fiber orientation are prepared successfully and the test were conducted as per ECAE and ASTM standards. The experiment reflect on consideration at the result of fiber orientation on the sisal fiber reinforced unsaturated polyester resin composites lead to taking after conclusion:- Considering all the mechanical and physical laboratory test obtained from the tensile, compressive, bending and water absorption results the highest value of 100.3 Mpa tensile strength and 80.3 Mpa compressive strength in (0,90) degree fiber orientation when compared to 0 degree and ± 45 degree fiber orientation. In general sisal fiber reinforced unsaturated polyester resin composite of (0,90) degree possesses good mechanical properties. In this manner fruitful manufacture of vehicle body (fender) was accomplished utilizing (0,90) degree fiber orientation of sisal fiber reinforced unsaturated polyester resin composite.

4.3.1 Fender

Fenders are those complicated panels of sheet metal that you see on the side of your car, right by the door and over and around the front and rear wheels. frequently times they take the shape of the wheels. Some fenders are included into the anatomy of the automobile but some are stand alone panels which may be bought in dealer shops and installed easily. The curve that forms a fender begins where the front and back doors end and runs ahead or backward either to the front and rear bumpers, and ends at either the hood or the lid of the trunk(see fig 4.9) drawing using CATIA.





b.

Figure 4.16 Drafted model of fender using CATIA software a. All dimension in mms, b, isometric view

4.3.2 Fabrication of Fender

Based on the results obtained from the mechanical and physical laboratory test of tensile, compressive, bending and water absorption concluding that it is best to manufacture vehicle body panel(fender) that have relatively less stress specially fender body panel locally by 0(zero) and 90 degree fiber orientation using hand lay-up procedure, make uniform dispersion of the matrix all through the surfaces the part is then cured at room temperature for 24hrs (see figure 4.17) and once solidified it is evacuated from shape. The selected fiber orientation exhibited good strength in all mechanical properties

a.  **b.** 

a. 

Figure 4. 17 Prototype of Fender

4.4 Comparison of the Previous Works

4.4.1 Tensile Strength

Most of the analysts working concerning tensile properties of natural fiber RUPR composites are compared with the present day work. From table 4.5 the tensile strength which is found in the current work is not similar but researcher work which is used Composites had been organized using various fiber weight fractions (15, 20, 25 and 30 wt. %) with unidirectional alignment of sisal fibers epoxy resin for the initial preparation of the composites. it can be concluded that the result getting from the current work is good. Orientation of fiber in degree is important to a SFRUPR composite feature if the sisal fiber is (0,90) degrees fiber tensile properties are high comparing 0 degrees and +/_ 45 degree fiber orientation. So SFRUPRC of (0,90)degree fiber orientation have a hopeful future of Automotive body application of fiber reinforced polymer composite.

Table4. 5: Comparison with Previous Works on Tensile Properties of Sisal fiber composite

Matrix material	Fiber	Average Max-Tensile Strength(Mpa)	Reference	Author
Epoxy + Hardener	Sisal	83.96 ± 6.94	Previous work	M K Guptaa & R K Srivastava
unsaturated polyester resin+catalyst(hardener)	Sisal/Bamboo 25 % / 75 %	23.5	Previous work	R. Prasanna Venkatesh1, K. Ramanathan2,
Unsaturated polyester resin + Hardner	Rice husk and Sisal Fiber 20 % / 80 %	32.66	Previous work	Madhusudhana Reddy H1, Bharath S Kodli2, Ravi B Chikmeti
Unsaturated Polyester Resin+ Hardener	100 % Sisal Fiber	100.3	Current Work	Current Researcher

4.3.1 Bending Strength

Some of the other researchers working regarding bending strength of natural fiber composites are compared with the Current work. From table the bending strength which is found in the current work is higher when compared to previous work.

Table4. 6: Comparison with Previous works on Bending properties of sisal fiber composite

Matrix material	Fiber	Average Max-Bending Strength(Mpa)	Reference	Author
Epoxy + Hardener	Sisal	252.39□12.11	Previous work	M K Guptaa & R K Srivastava
unsaturated polyester resin+catalyst(hardener)	Sisal/bamboo 25 %/75 %	57.8	Previous work	R. Prasanna Venkatesh1, K. Ramanathan2,
Unsaturated polyester resin + Hardner	Rice husk and Sisal Fiber 20 %/80 %	57.99	Previous work	R.Sakthivela*, D.Rajendranb
Unsaturated Polyester Resin+ Hardener	100 % Sisal Fiber	569.01	Current Work	Current Researcher

The current price of vehicle fender in Ethiopia is 8000-12000 birr from second hand (from Dubai) to the original genuine part (from MOENCO) but to manufacture such a fender with the same shape it may cost only 3500 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 RECOMMENDATION

5.1. Conclusion

The sisal fiber was extracted manually from Ethiopian highland sisal plant, it was treated using sodium hydroxide and distilled water solution for better strength and roughness property. Second, sisal fiber reinforced unsaturated polyester resin composite 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 ECAE and 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 sisal fiber reinforced unsaturated polyester resin composite its usage in automotive body application.

Sisal fiber reinforced unsaturated polyester resin composite material which is made of sisal fiber and unsaturated polyester resin are more environmental friendly compared to synthetic fiber. Sisal fiber reinforcement composites have the advantages like renewability, low density, biodegradability, good insulation property; non-toxicity and durability compared to synthetic materials

Based on the tensile, compression, flexural and water absorption properties experiment data studies in this work, few points can be concluded as follows:

- From the experiment result it was observed that different orientation of fiber has shown enhanced mechanical properties of the sisal fiber composite material.
- From the Tensile Experimental test results it was found that 0^0 and 90^0 (bi directional) treated sisal fiber reinforced unsaturated polyester resin composite have better tensile strength than 0^0 and $\pm 45^0$.
- From the flexural Experimental test results it was found $\pm 45^0$ treated sisal fiber reinforced unsaturated polyester resin composite have better flexural strength than 0^0 and $\pm 45^0$.

- The effect of moisture content obtained from water absorption test is within the specifications and has minimum water absorption for auto body panels.
- From water absorption tests results of each specimen obtained ± 45 degree fiber orientation has 4.02 % which is lower than others two fiber arrangements of 5.41 % (0-degree) and 5.98 % (0,90) degree. In these test all of the SFRUPRC specimen's fiber orientations have minimum water absorption which is less than 15 % of ASTM C220 standards.

5.2 Recommendations for Prospective Applications

- Sisal fiber reinforced unsaturated polyester resin composite materials are appropriate for structural automotive applications, such as interior and exterior body panels and carry out to a comparable standard as steel components.
- Sisal fiber reinforced unsaturated polyester resin composites were fabricated and evaluated for their mechanical and physical characteristics. From this investigation, it has been found that sufficient potential applications are found in the following fields: manufacturing of light weight sports goods such as, tennis rackets, balls, bicycle frames, snowboards, Spur and helical gears etc.
- The present study have recognized that these sisal fiber reinforced unsaturated polyester resin composites are used when cost reduction is the prime reflection, and can effectively replace the conventional and relatively expensive materials. Their use may be recommended in house hold applications like the fabrication of tables, chairs, door panels, interior paneling, door-frame profiles, food trays, partitions, bath units, lampshades, suitcases, helmets, etc.
- Production of some other vehicle structure that may be substituted by means composite material and display the comparable advantage of sisal fiber composite to the auto enterprise, the educational area and to the government..
- Eventually I strongly recommend Department of Mechanical System and Vehicle Engineering at Adama Science and Technology University(ASTU) to facilitate organized work shop for the manufacturing of composite material and testing laboratory installation for the description of natural fiber composite material.

5.3 Scope for Future Work

The area that must be done in continuation with this work is presented in this sub topic. The following area is suggested for further study:

- Impact, Fatigue and shear test behavior of sisal fiber reinforced unsaturated Polyester resin composite
- Modification of the mechanical properties of SFRUPR by adding Nano clays.
- Scanning Electron Microscope (SEM) and Finite Element Analysis can be approved out
- Tri- bological assessment of sisal fiber reinforced unsaturated polyester resin composite has been a much less studied area. There is a very wide scope for future scholars to explore this area of research.

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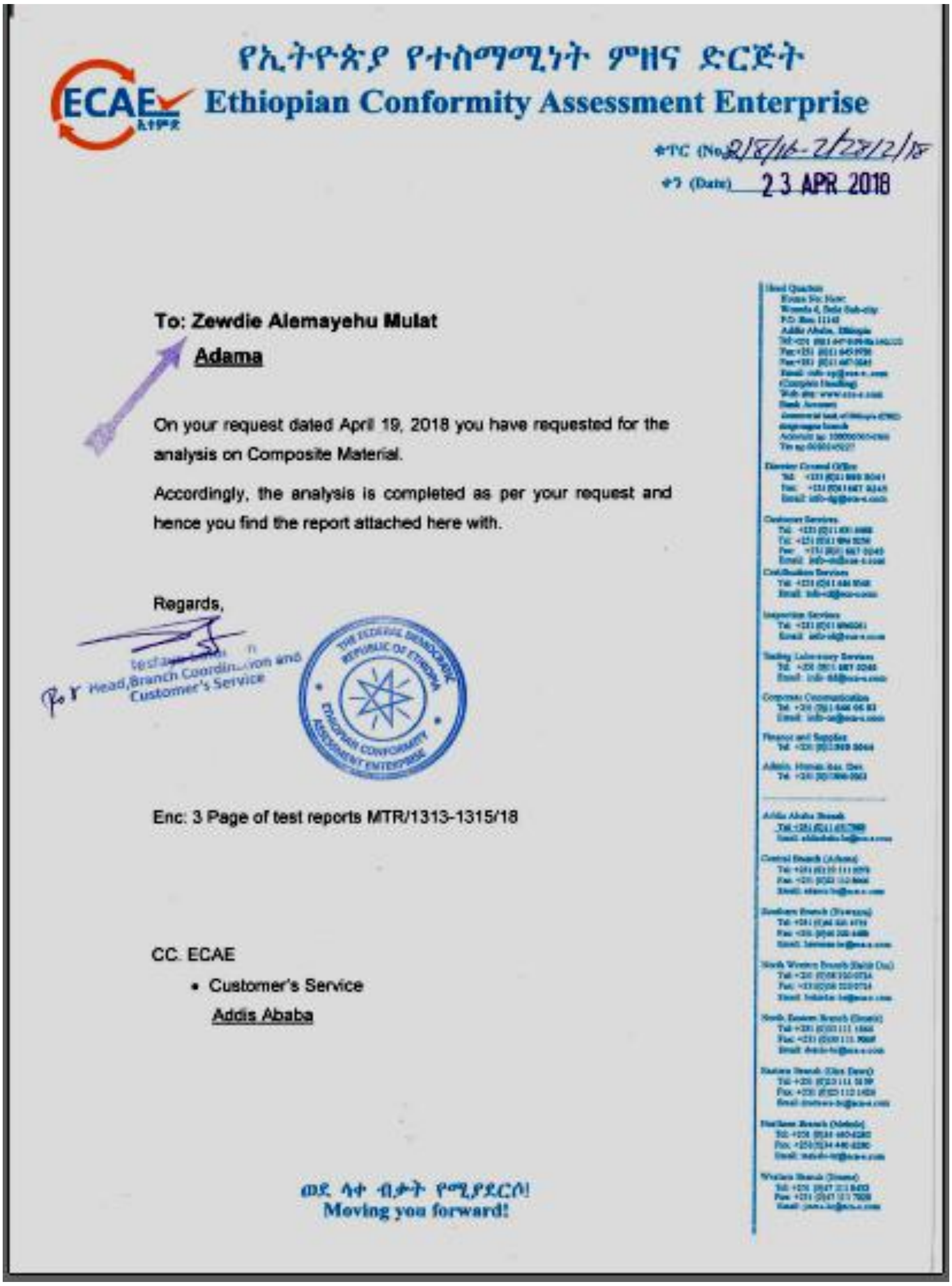
APPENDIX

Datasheets

In this appendix, all the data have been collected during the laboratory specimens testing were provided.

Data during the laboratory Tensile specimens test Report



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Ethiopian Conformity Assessment Enterprise

ቁጥር (No.) 2/8/16-2/23/2/18

ቀን (Date) 23 APR 2018

To: Zewdie Alemayehu Mulat

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,

Head, Branch Coordination and Customer's Service

Enc: 3 Page of test reports MTR/1313-1315/18

CC. ECAE

- Customer's Service

  Addis Ababa

ወደ ላቀ ብቃት የሚያደርስ!

Moving you forward!

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 1 Jan 13

Report No: MTR/1312/18
Test order No: —

1	Name and address of client	Zewdie Alemayehu Mulat Tel: +251-912-03-15-60, 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.	10221023
7	Type of sample	Composite material sisal 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)
10221023	1	111
	2	93
	3	62

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 45-97-20, E-mail info@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

ECAE	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
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Report No: MTR/1314/18
Test order No: —

1	Name and address of client	Zewdie Alemayehu Mulat Tel: +251-912-03-15-60, 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.	10221024
7	Type of sample	Composite material sisal fiber $(0,90)^{0}$ 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)
10221024	1	107
	2	87
	3	107

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 45-97-20, E-mail info@eca-e.com Web site: www.eca-e.com
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ADDISABABA, ETHIOPIA

This is a test report not a certificate
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Ethiopian Conformity Assessment Enterprise

TEST REPORT

Document No. TLD/F5.10-1 | Issue No. 1 | Page No. 1 of 1 | Effective Date 1 Jan 13

Report No: MTR/1315/18
Test order No: —

1	Name and address of client	Zewdie Alemayehu Mulat Tel: +251-912-03-15-60, 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	10221025
7	Type of sample	Composite material sisal fiber ± 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)
10221025	1	39
	2	35

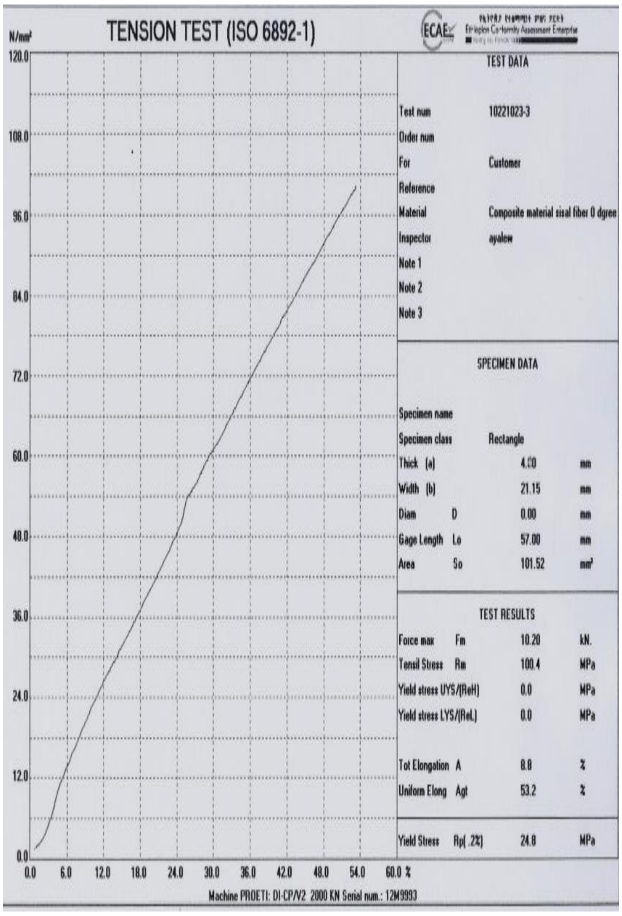
Remark:

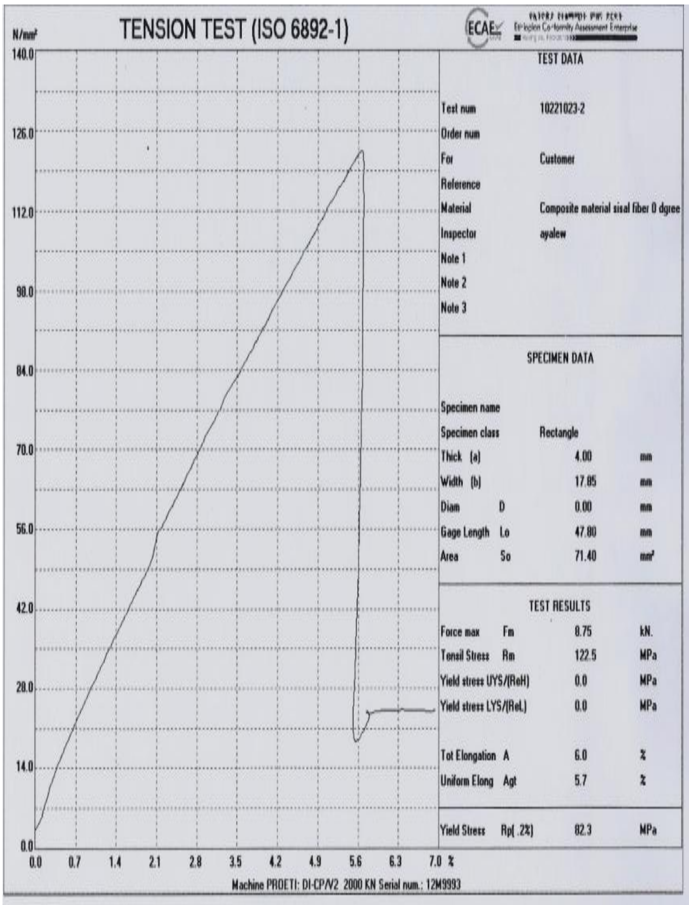
1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

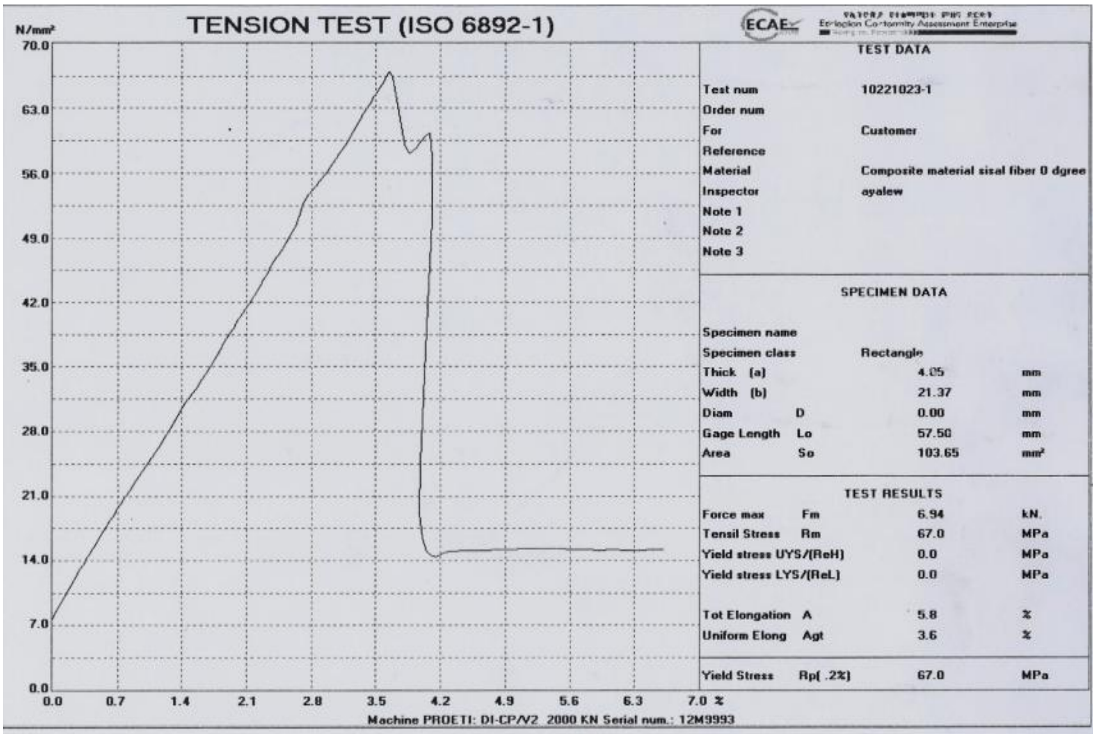
Test report authorized by. Name Liyew Wude Position Analyst I Sign.

BOLE SUBCITY, ADDIS ABABA, ETHIOPIA

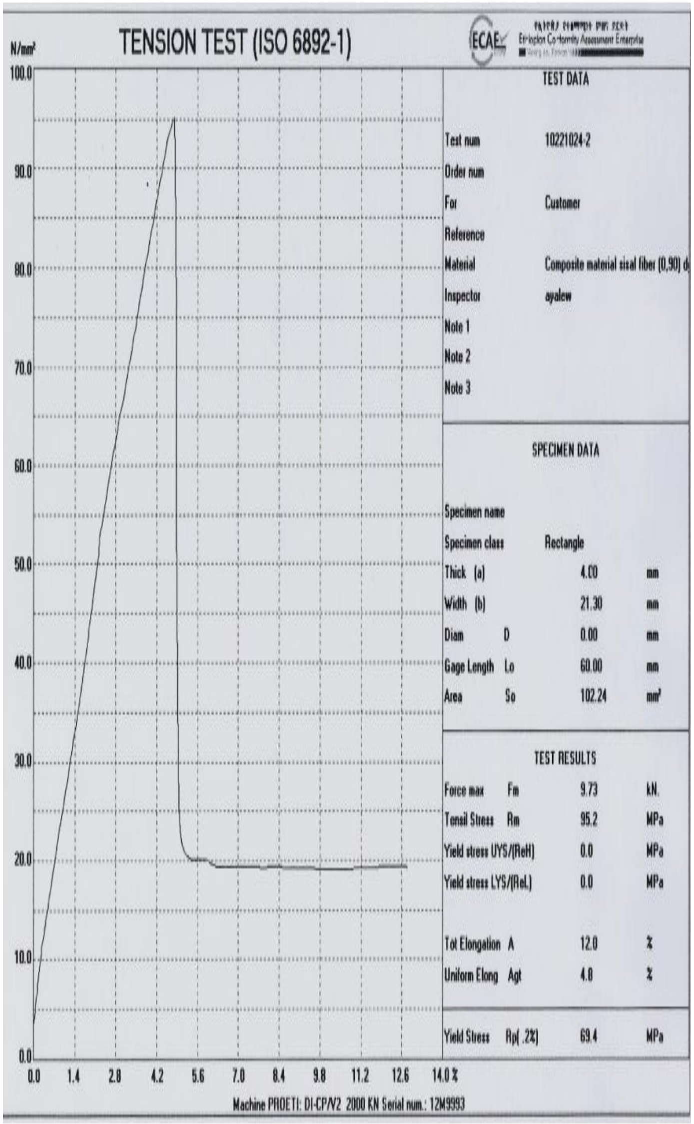
1-Data collected during the laboratory Tensile Specimens Testing

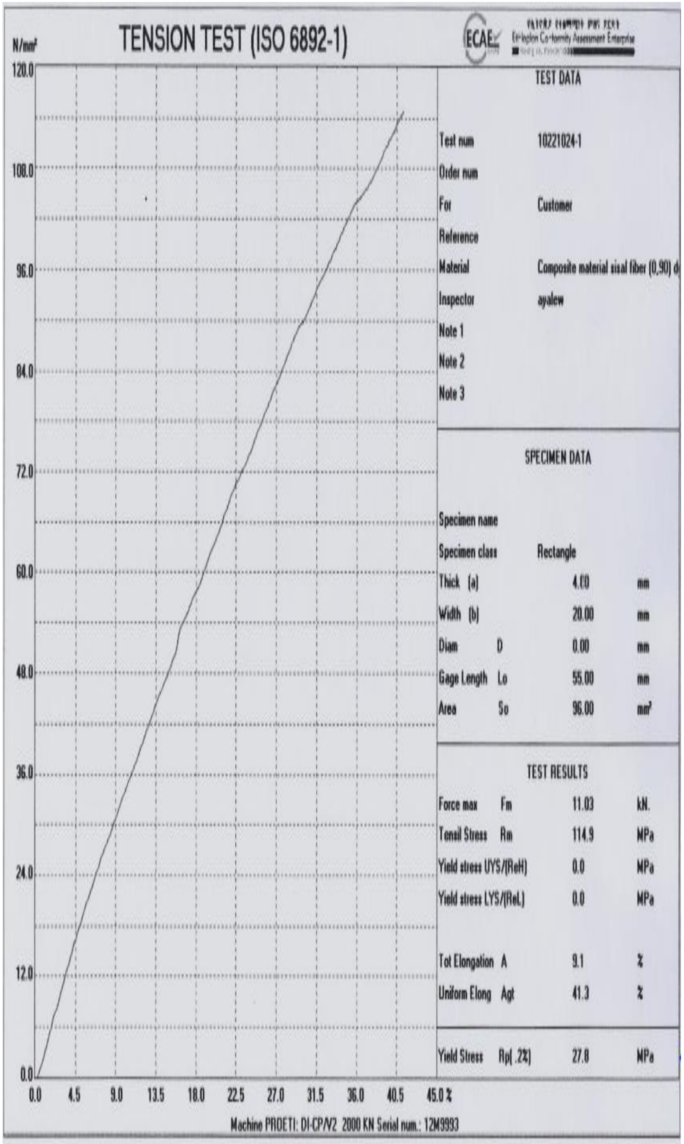


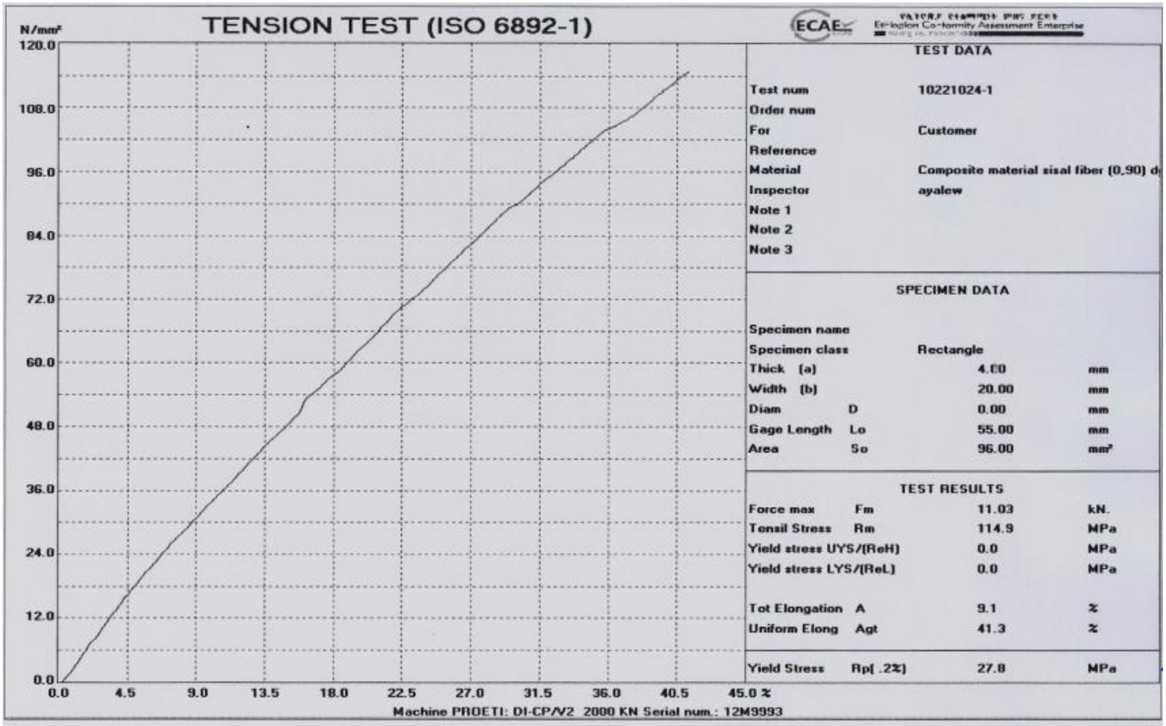




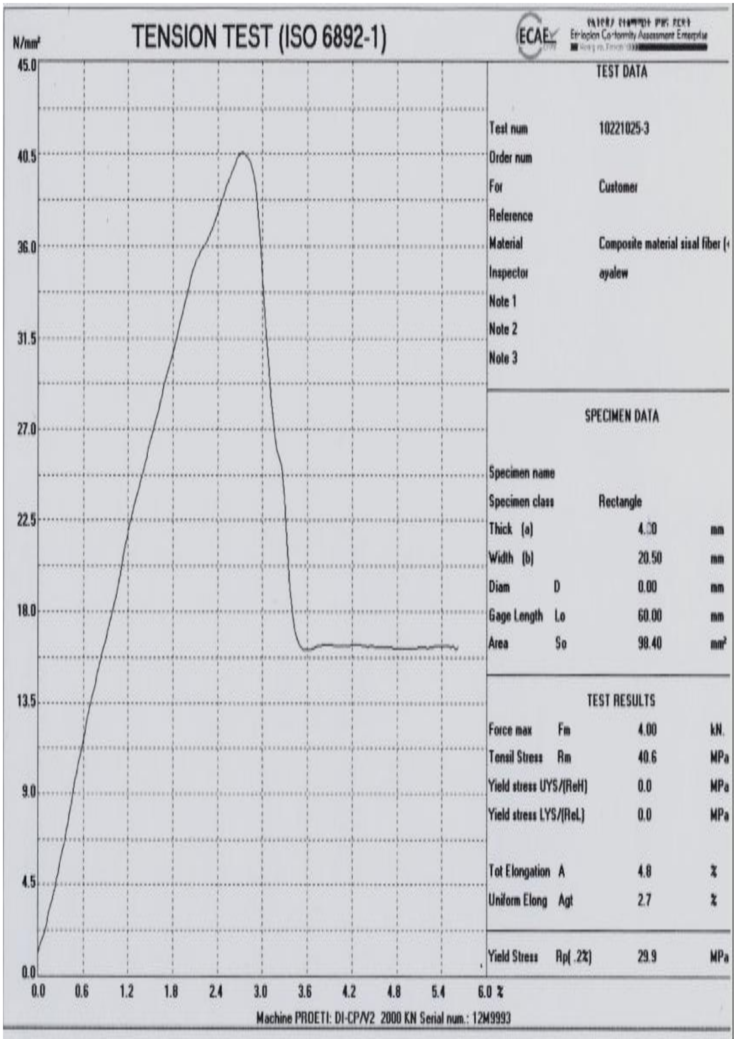
Zero (0) Degree Fiber Orientation

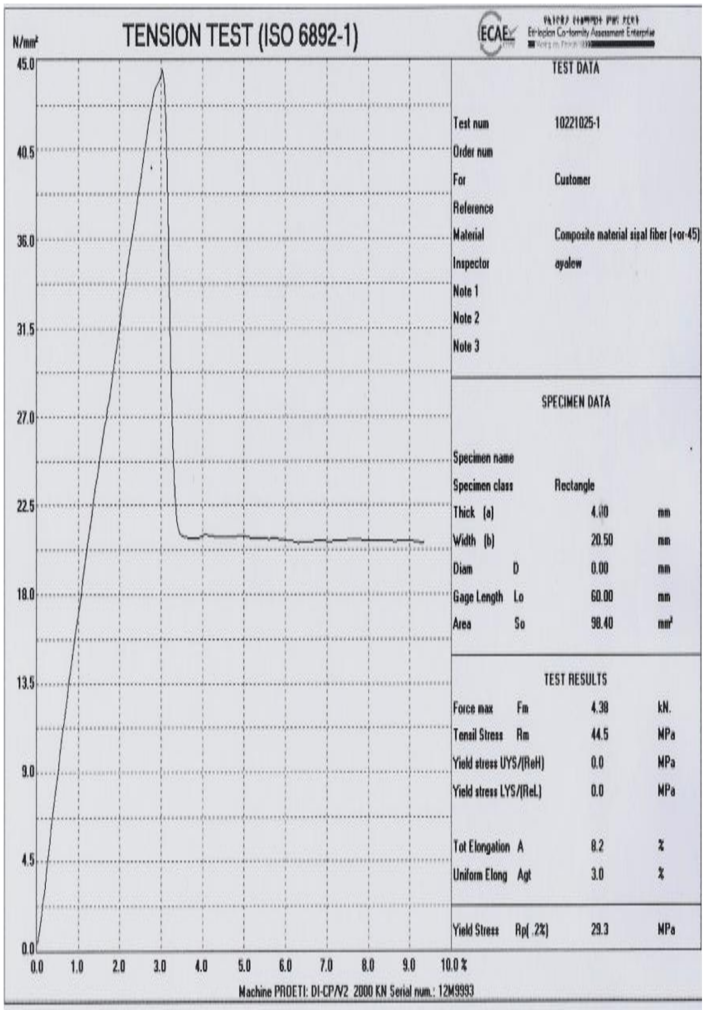






(0,90) Degree Fiber Orientation



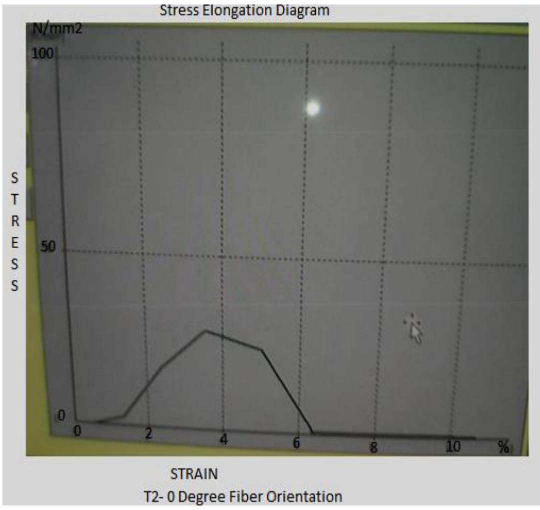


± 45 Degree Fiber orientation

2-Data collected during the laboratory Compression specimens testing

Stress-elongation-table

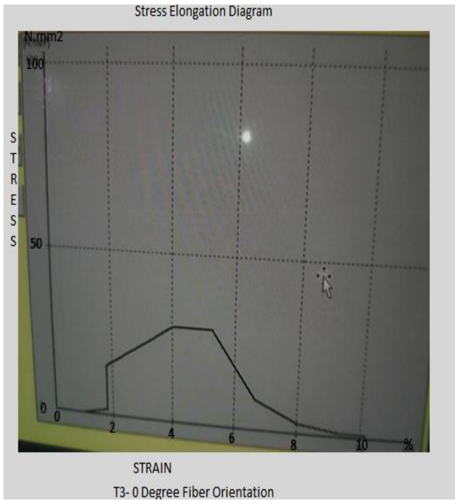
No.	S [N/mm²]	E [%]
1	0.00	5.94
2	0.00	0.00
3	0.00	0.43
4	2.67	1.34
5	18.00	2.39
6	29.58	3.56
7	24.58	5.01
8	1.58	6.35
9	0.67	8.83
10	0.67	10.05
11	0.50	10.61



T2- 0 Degree Fiber Orientation

Stress-elongation-table

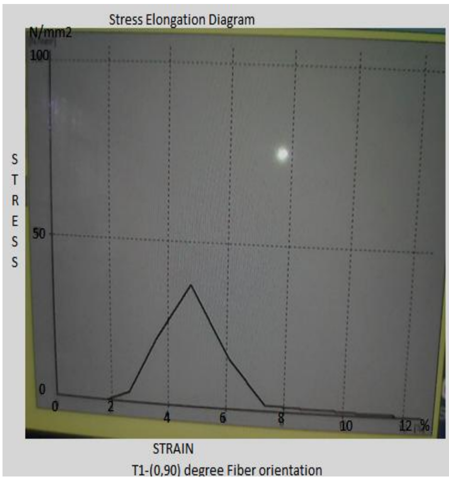
No.	S [N/mm²]	E [%]
1	0.00	0.56
2	0.92	1.57
3	12.08	2.57
4	25.25	3.77
5	16.67	3.78
6	7.75	6.32
7	7.75	7.64
8	2.00	8.97
9	0.83	10.29
10	0.58	11.26



T3- 0 Degree Fiber Orientation

Stress-elongation-table

No.	S [N/mm²]	E [%]
1	0.00	0.88
2	1.75	1.80
3	15.58	1.78
4	28.92	4.00
5	28.92	5.29
6	9.50	6.66
7	3.08	8.01
8	1.33	9.28
9	1.00	10.13

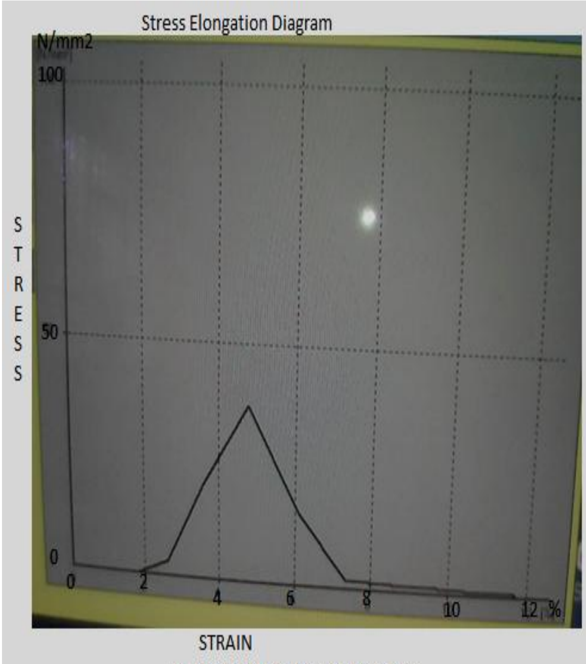


T1-(0,90) degree Fiber orientation

Compression 0 (zero) Degree Fiber Orientation Test Result

Force-elongation-table

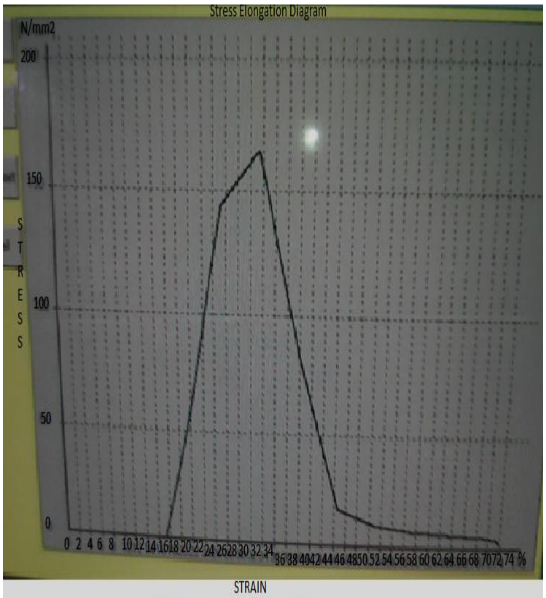
No.	F [kN]	dL [mm]
1	0.00	0.32
2	0.00	3.74
3	0.00	5.17
4	1.58	6.56
5	4.07	8.18
6	4.68	10.00
7	2.35	12.01
8	0.48	13.98
9	0.28	15.83
10	0.21	17.69
11	0.17	19.55
12	0.14	21.40
13	0.11	22.02



T1-(0,90) degree Fiber orientation

Stress-elongation-table

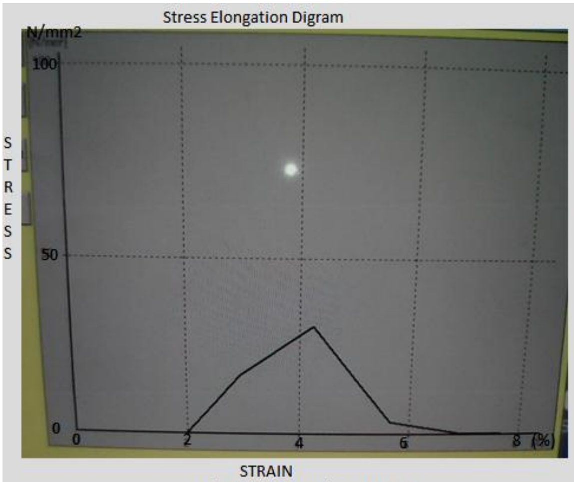
No.	S [N/mm²]	E [%]
1	0.00	1.07
2	0.00	12.47
3	0.00	17.23
4	55.88	21.86
5	143.95	27.26
6	165.52	33.32
7	83.11	40.04
8	16.98	46.60
9	9.90	52.78
10	7.43	58.95
11	6.01	65.16
12	4.95	71.32
13	3.89	73.39



T2-(0,90) Degree Fiber Orientation

Stress-elongation-table

No.	S [N/mm²]	E [%]
1	0.00	0.71
2	0.00	1.78
3	3.17	2.63
4	20.50	3.62
5	37.42	4.77
6	15.67	6.12
7	1.92	7.35
8	1.58	8.53
9	1.33	9.72
10	1.00	10.42
11	0.75	10.57
12	0.67	11.70

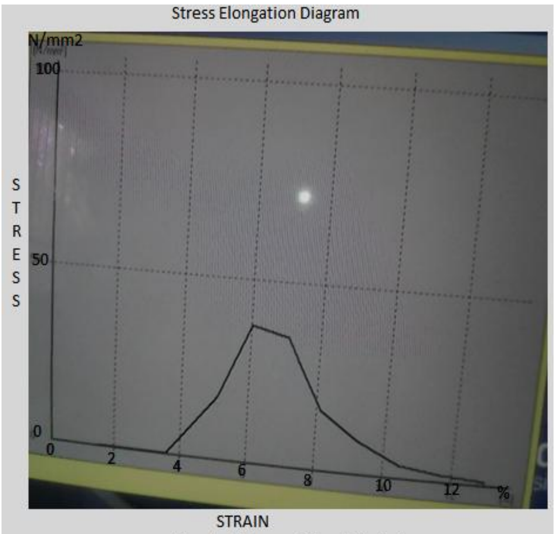


T3-(0,90) Degree Fiber Orientation

(0,90) Degree Fiber Orientation Test Result

Stress-elongation-table

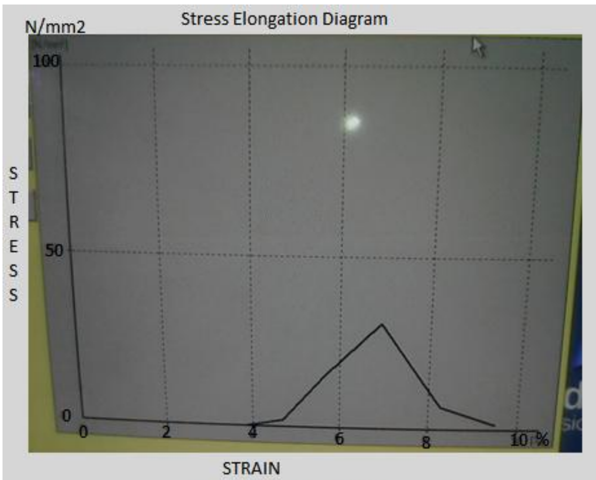
No.	S [N/mm²]	E [%]
1	0.00	1.13
2	0.00	1.99
3	17.17	2.95
4	31.50	4.24
5	3.75	5.65
6	0.33	6.86
7	0.08	7.66



T1, +/- 45 Degree Fiber Orientation

Stress-elongation-table

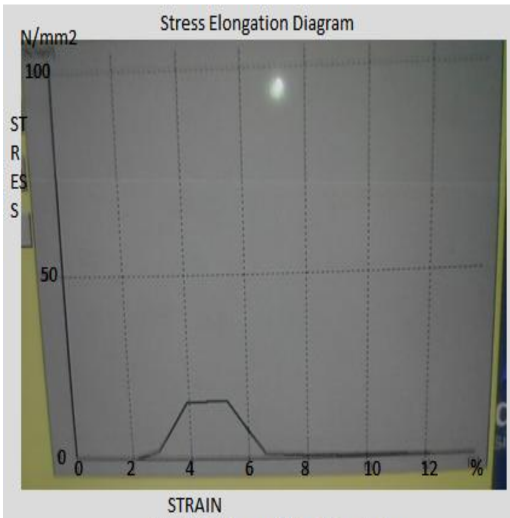
No.	S [N/mm²]	E [%]
1	0.00	2.71
2	0.00	0.00
3	0.00	0.90
4	0.00	2.02
5	2.42	2.90
6	16.08	3.94
7	16.58	5.30
8	1.42	6.58
9	0.92	7.81
10	0.67	9.02
11	0.50	10.21
12	0.33	11.39
13	0.25	12.16



T3, +/- 45 Degree Fiber Orientation

Stress-elongation-table

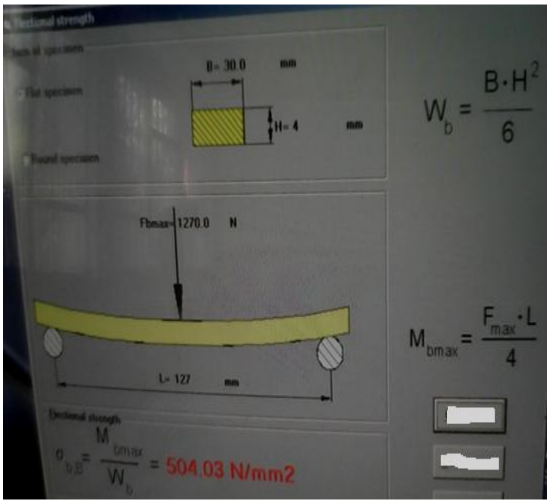
No.	S [N/mm²]	E [%]
1	0.00	1.13
2	0.00	1.99
3	17.17	2.95
4	31.50	4.24
5	3.75	5.65
6	0.33	6.86
7	0.08	7.66

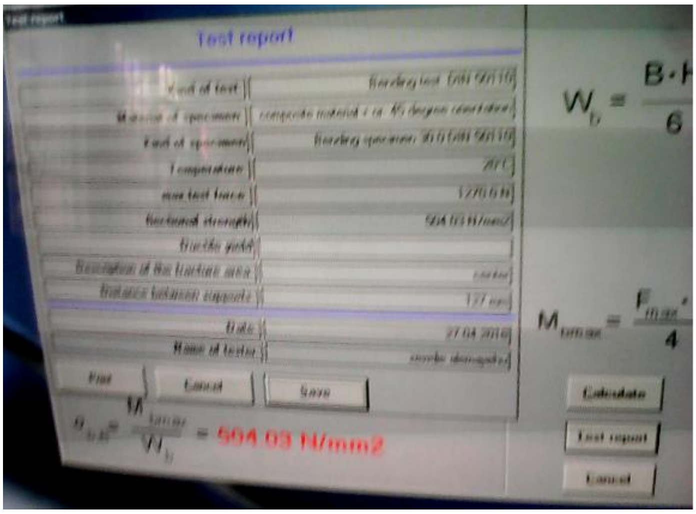


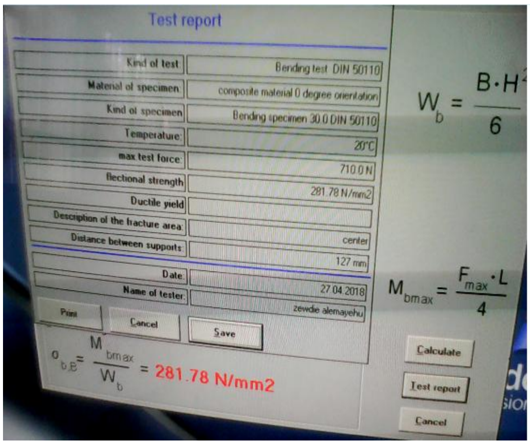
T2, +/- 45 Degree Fiber Orientation

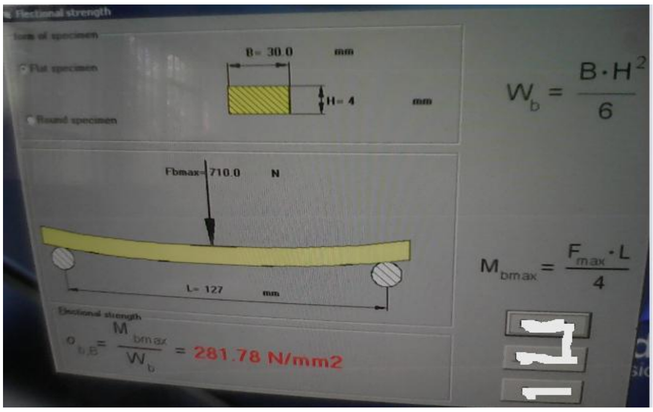
± 45 Degree Fiber Orientation Test Result

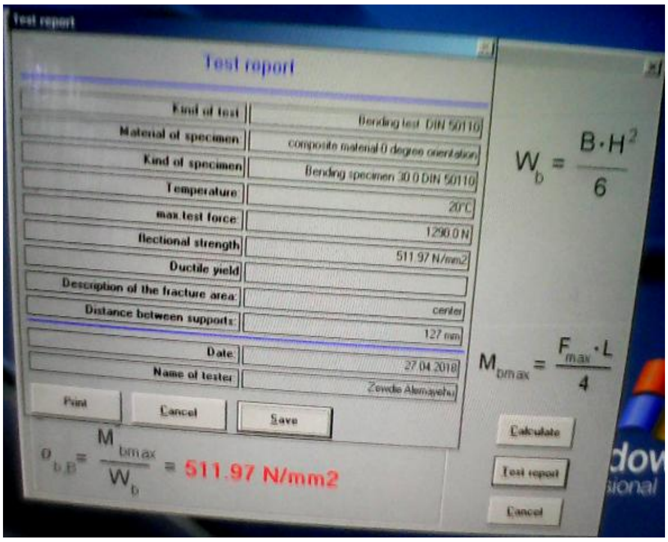
Data collected during the laboratory Bending specimens testing

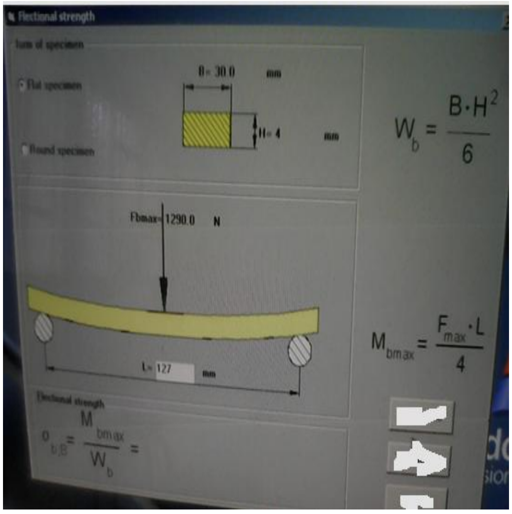




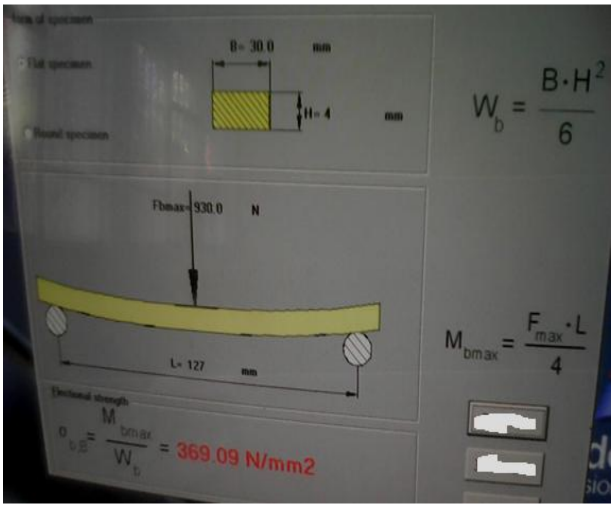


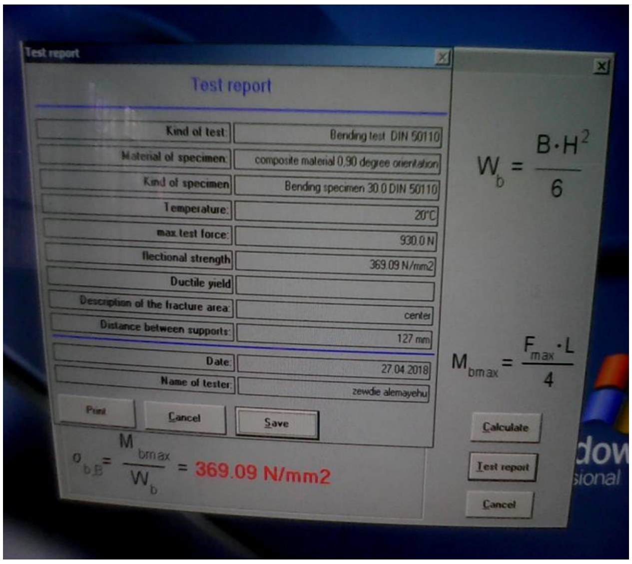


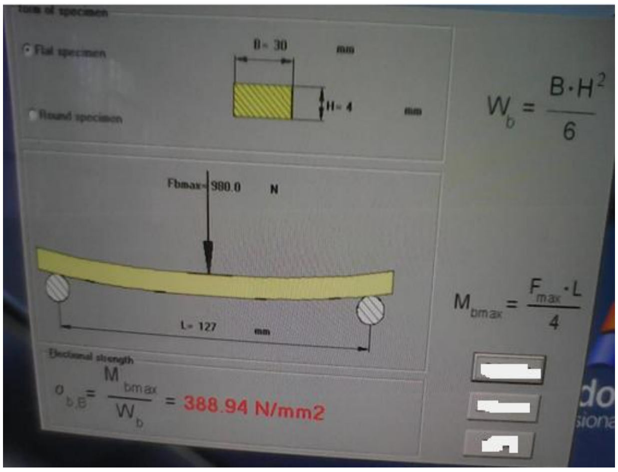


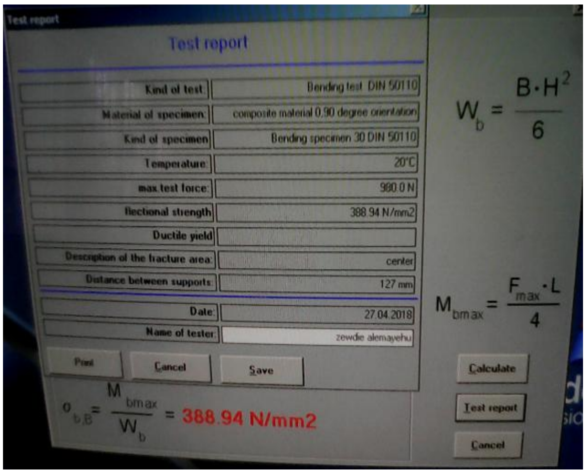


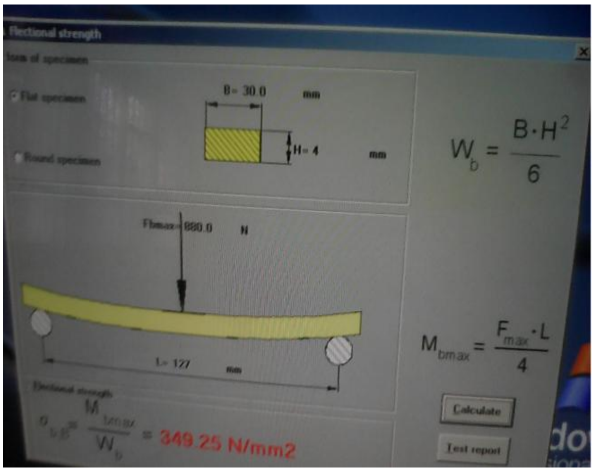
Bending 0 (zero) Degree Fiber Orientation Test Result

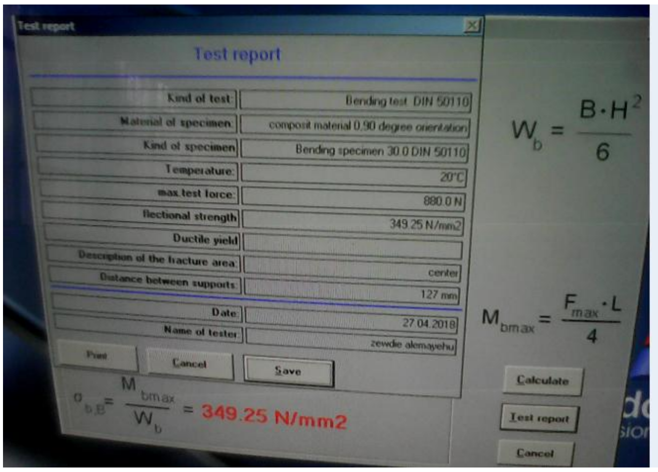




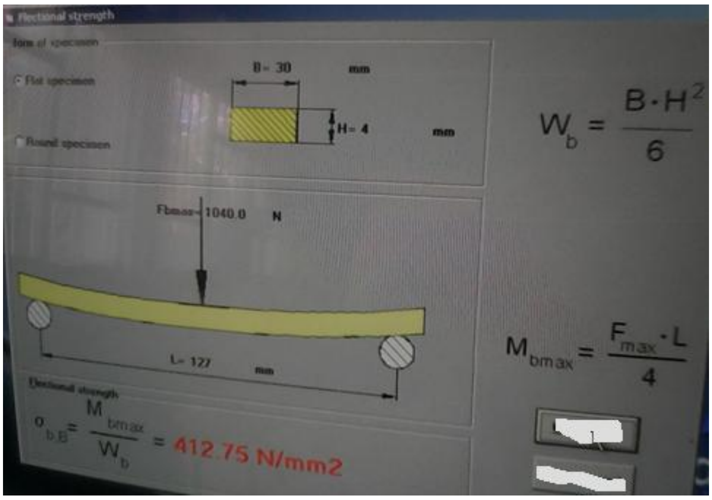


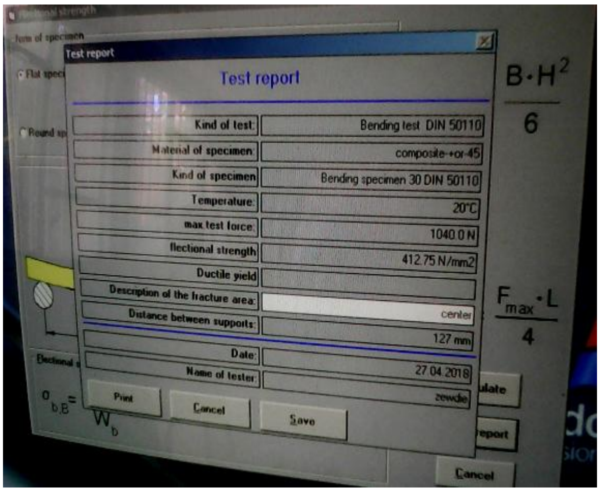


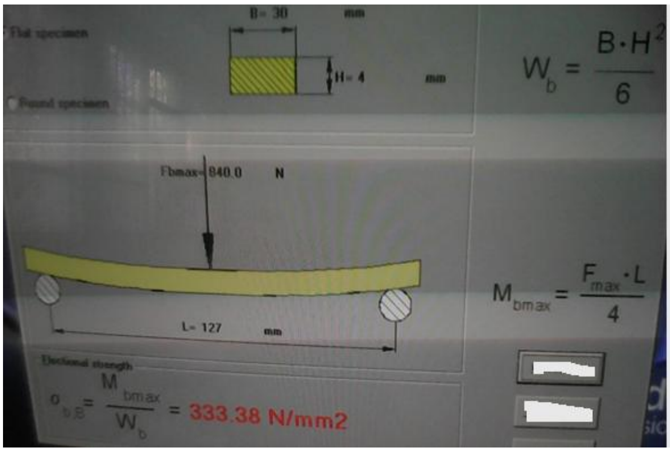


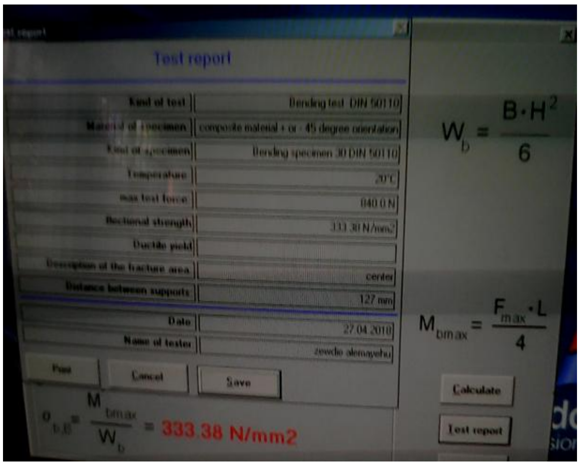


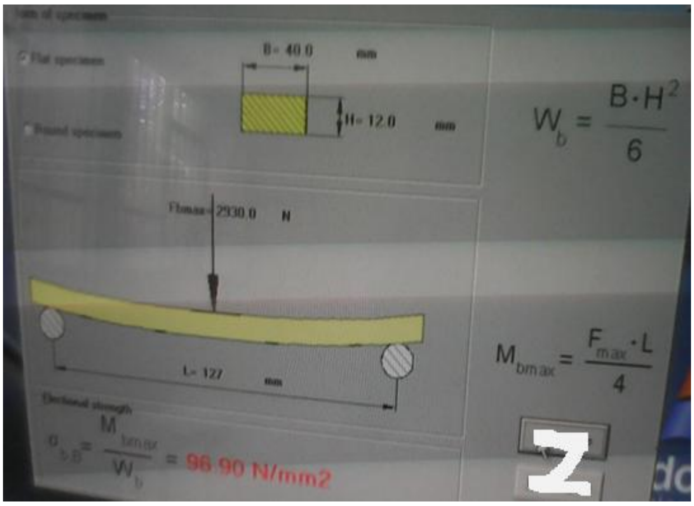
Bending (0,90) Degree Fiber Orientation Test Result

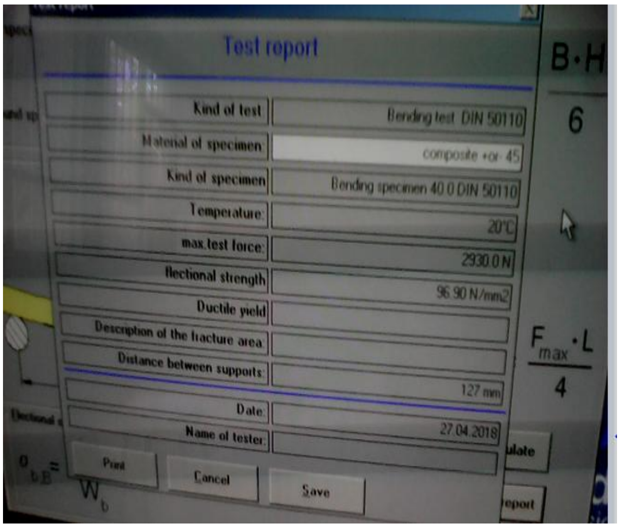












Bending ±45 Degree Fiber Orientation Test Result

TOPAZ-1110TP,GENERAL PURPOSE RESIN UNSATURATED POLYESTER RESIN TECHNICAL DATA SHEET

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. 3801/2

647 5 m^2

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	575-575	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.

C.R. 2050034056 - P. O. Box 7952 - Dammam 31472 - Saudi Arabia - Tel.: 8122088 (3 Lines) 8122089 Fax: 8121995
e-mail : icr@zajil.net Web : www.icr.com.sa e-mail : icr@icr.com.sa

SUGGESTED APPLICATIONS

- Suitable for Potable Water Storage Tanks.
- Interior Decorative 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 abreaded 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.