FABRICATION AND CHARACTERIZATION OF MECHANICAL AND PHYSICAL PROPERTIES OF HYBRID BAMBOO, ELEPHANT GRASS AND E-GLASS FIBER REINFORCED POLYESTER COMPOSITE

Habtamu Abate Shitaye

A Thesis Submitted to
Department of Mechanical Engineering
School of Mechanical Chemical and Materials Engineering
Office of Graduate Studies

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Manufacturing Engineering

Office of Graduate Studies
Adama Science and Technology University

Jun, 2022
Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "Fabrication and Characterization of Mechanical and Physical Properties of Hybrid Bamboo, Elephant Grass and E-glass fiber Reinforced Polyester Composite" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Habtamu Abate Shitaye	________________________	________________
Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Fabrication and Characterization of Mechanical and Physical Properties of Hybrid Bamboo, Elephant Grass and E-glass fiber Reinforced Polyester Composite" Prepared under my guidance by Habtamu Abate Shitaye submitted in partial fulfillment of the requirements for the degree of Masters of Science Manufacturing Engineering.

Therefore, we recommend the submission of the revised version of the thesis to the Department following the applicable procedures.

Dr. Guteta Kabeta Woyessa	____________________	_______________
Advisor	Signature	Date

APPROVAL SHEET

I, the advisor of the thesis entitled "Fabrication and Characterization of Mechanical and Physical Properties of Hybrid Bamboo, Elephant Grass and E-glass fiber Reinforced Polyester Composite" and developed by Habtamu Abate Shitaye hereby certify that the Recommendations and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Guteta Kabeta Woyessa	____________________	______________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Habtamu Abate Shitaye have read and evaluated the thesis entitled "Fabrication and Characterization of Mechanical and Physical Properties of Hybrid Bamboo, Elephant Grass and E-glass fiber Reinforced Polyester Composite" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in manufacturing engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final Copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	America Society for Testing and Material
ASTU	Adama Science and Technology University
BHN	Brinell hardness number
CM	Composite materials
CMC	Ceramic Matrix Composites
DUEC	Defense University of Engineering College
DOE	Design of Experiment
DOF	Degree of Freedom
ECAE	Ethiopian Conformity Assessment Enterprise
FRP	Fiber Reinforced Polymer
GFRP	Glass Fiber Reinforced Polymer
ISO	International Organization for Standardization
MMCs	Metal Matrix Composites
NFs	Natural fibers
NFRPC	Natural fiber-reinforced polymer composite
OA	Orthogonal array
PC	Percentage contribution
PMCs	Polymer matrix composites
PP	Polypropylene
PRP	Particle reinforced polymer composites
PVC	Poly-vinyl-chloride
S/N	Signal to noise ratio
UP	Unsaturated Polyester Resin
UTM	Universal Testing Machine
UTS	Ultimate tensile strength
YS	Yield strength

NOMENCLATURE

$\mathcal{P}_c$	density of composite (g/cm^3)
$\mathcal{P}_f$	density of fiber (g/cm^3)
$\mathcal{P}_m$	density of matrix (g/cm^3)
M_c	mass of composite (g)
M_f	mass of fiber (g)
M_m	mass of matrix (g)
V_F	Volume fraction of fiber
V_M	Volume fraction of matrix
V_c	volume of composite (mm^3)
V_f	volume of fiber (mm^3)
V_m	volume of matrix (mm^3)
wt. %	Weight percentage
Hr	Hour
mm	millimeter
Mpa	Mega Pascal

ABSTRACT

Concerns about replacing non-biodegradable resources with biodegradable resources have piqued scholars' interest in recent decades. Composite materials are natural resources with desirable characteristics including low density, high specific strength, low cost, high toughness, corrosion resistance, and environmental friendliness. The primary purpose of this study was to fabricate and material characterization of hybrid chopped composite made from elephant grass, bamboo and glass reinforced fiber and polyester for automotive purposes. The technique applied was referred to as the hand layup technique for the fabrication of composite. Taguchi L9 orthogonal array was utilized for the design of the experiment. The specimen was prepared according to the ASTM standard for each test. The properties characterized ware tensile strength, flexural strength, compressive, hardness, impact strength, water absorption, SEM morphological analysis, density, and porosity of composite. Optimizations of parameters were done by using the Taguchi method. Data showed that the maximum tensile strength of 58.5Mpa, maximum compressive strength 69.33 MPa, maximum hardness 154.8HV, maximum flexural strength 253.13MPa and the highest impact strengthwas15.5J. The results revealed that elephant grass, bamboo, E-glass fiber content of (10, 10 and 15) wt.% respectively and polyester resin with 65 wt.% ware estimated to be the optimal parameters. The water absorption was a minimum value of 0.01432%. This shows that the bonding between the matrix and reinforcement was best. The minimum values of density and porosity of composite were 1.086g/cm^3 and 0.022% respectively. Porosity of was observed when SEM morphology analysis was taken. Analysis of variance (ANOVA) was conducted to identify the significant factors and established all the three factors as being significant. The amount of (E-glass and bamboo) fiber was found to be the most significant parameter which greatly affected the mechanical properties of the hybrid composites.

Key words: elephant grass, hybrid composite, hand-up, mechanical property, Taguchi

CHAPTER -1

INTRODUCTION

1.1. Background of the Study

1.1.1. Composite Materials

When two or more materials with distinct qualities are mixed, composite materials are created. Individual elements cannot compare to the qualities of composite materials. This has been the primary driving force behind composite materials research and development. Composites are composite materials that vary from alloys in that the individual components maintain their properties but are blended into the composite in such a way that "only their attributes, not their flaws," are exploited to generate superior materials. Composite materials are defined as heterogeneous materials made up of two or more solid phases that are in close contact on a microscopic scale. On a microscopic scale, they may also be termed homogenous materials in the sense that any component of them will have the same physical attribute (Elanchezhiana, 2018). One or more discontinuous phases are embedded in a continuous phase in composites. The discontinuous phase, which is generally tougher and stronger than the continuous phase, is referred to as the' reinforcement' or 'reinforcing material,' while the continuous phase is referred to as the 'matrix.' The qualities of composites are heavily influenced by the properties of their component materials, as well as their distribution and interaction. The composite attributes might be the volume fraction total of the elements' properties, or the constituents could work synergistically to produce improved or superior properties (Verma, 2012).

During recent years, Natural fibers have appeared to be the materials which will become a better replacement for non-renewable, abrasive and expensive synthetic fibers. They have been relatively used in different sectors of industrial production (shipbuilding, packaging) and above all, in automotive and civil sectors for non-structural applications where lightness and low cost are lower than those of any composite reinforced by synthetic fibers.in addition to this, natural composites are used for the advantage of good thermal and acoustic insulation capacity, availability in large quantities, bio degradability, low density, recyclability and ease of manufacturing Zuccarello and Marannano (2018). most importantly, among all the natural fibers the sisal fibers have the lowest embodied energy 2500 kJ/kg, b1/10 of the energy associated with glass fibers and b1/100 of the energy associated with carbon fibers i.e. the lowest environmental impact Cristaldi et al, (2010).

Hybridization of natural fiber with synthetic fiber, for example, glass or carbon fiber, can also improve the stiffness, strength, as well as the moisture resistant behavior of the composite. Hybridization of natural fiber with synthetic glass fiber significantly give better heat transportability and heat transfer coefficient. moreover, it enhances crack resistance of the composite Sanjay and Yogesha, (2017). due to serious challenges of natural fibers, including sever moisture absorption, weak fire resistance, durability and demanding manufacturing processing the need to hybridization with glass is increasing. Hybrid composites have their own mechanical property. in order to identify this property, mechanical characterization of hybrid composites must be done. Mechanical characterization includes tensile, compression, flexural, impact strength and hardness testing .these properties are affected by different parameters and conditions. The parameters include fiber orientation, weight percentage of fiber, Alkali treatment, type of fiber and Matrix, fabrication method and so on.

1.2. Statement of the Problem

Natural fiber materials have received little attention in the automobile and transportation industries in the modern world, according to study. This is because synthetic fiber is used in the fabrication of composite parts in the automotive and transportation industries around the world (Sirahbizu, 2021). The need of transportation is increasing adequately in Ethiopia. To balance this challenge the automotive industries in Ethiopia import the spare parts from abroad. If these spare parts replaced by light weight – fuel consumption minimized this also diminish air contamination, cheap- manufactured from locally available materials, improve vehicle performance and save foreign currency. Thus, Elephant grass and Bamboo is also plants which are abundant in Ethiopia specially Oromia and Benishangul Gumuz region. The problems mostly shown on the vehicle's dashboard, old model vehicle so it's difficult to get accessory of this model. When the vehicle dashboard become old degrade, bigger the cracks, the out gassing forms a waxy film on the inside glass that distorts their visibility and difficult to remove. Automobile vehicles dashboard simply scratched proof. Day time veiling glare in automobiles caused by dashboard reflectance and when the dashboard assembly is installed a vehicle; the heating and cooling cycles produce a different thermal expansion of the port of plastic material and of the metal part of hybrid supporting structure.

The current work was a fabrication and material characterization of hybrid composite made from Elephant grass, Bamboo and glass fiber reinforced polyester has a great opportunity for research development in our country by solving this problem.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of this thesis is to fabrication and characterization of mechanical and physical properties of hybrid bamboo, elephant grass and e-glass fiber reinforced polyester composite.

1.3.2. Specific Objectives

The specific objectives of this thesis are as follows:

- To fabricate chopped bamboo, elephant grass and glass fibers reinforced polyester hybrid composite material and specimen preparation.
- To study the influences of fiber content on physical and mechanical properties of composites using Design of experiment was carried out by Taguchi orthogonal array method.
- To investigate mechanical properties like tensile, compression, flexural, impact strength, Hardness of the composite.
- To study the SEM morphological analysis of the composite specimens
- To determine density and void fraction or porosity of composite specimens.

1.4. Significance of the Study

Natural fibers are emerging as low cost, lightweight and apparently environmentally friendly. Apex advantages of Producing from locally available reinforced composites like bamboo fiber and elephant grass fiber increasing the use and replacement of applications due to their overall production rate, mechanical performance, lightness, chemical stability, recovered energy, and end-of-life recyclability. Bamboo and Elephant fibers are biodegradable, easily available, and low cost and provide an opportunity for the utilization of agricultural product. For automotive components such as bumper, seatbacks, parcel shelves, door panels.

1.5. Beneficiary of Study

Bamboo and Elephant fibers are a renewable resource, for which production requires little energy, involves CO_2 absorption, whilst returning oxygen to the environment. Both Bamboo and Elephant grass fibers can be produced at lower cost, low density, high specific strength and stiffness and low hazard manufacturing Processes.

1.6. Scope of the Study

This study is delimited to the:

- Characterization of mechanical properties of copped hybrid composites of glass, bamboo and elephant grass fibers reinforced with polyester resin.
- Preparation of composite samples with varying composition proportion of copped hybrid composite of glass, bamboo and elephant grass fibers.
- The fabricated specimens were tested by several testing techniques such as tensile testing, flexural testing, compressive testing, Vickers hardness testing, impact testing, machinability testing, density, porosity and water absorption measuring as well as SEM morphological analysis of specimens was characterized.

1.7. Limitation of Study

Limitations during this study are as follow.

- The laboratories used in this work is found in different city of the country causing time waste.
- The non-availability of epoxy supply in Ethiopia was due to its flammable properties. Due to this case, an epoxy matrix was replaced by a polyester matrix.
- A compressive molding machine was not available in Adama Science and Technology University for fabrication of composite with the required accuracy.
- Non availability of extraction machine for bamboo and elephant grass fiber.

1.8. Research Motivation

In our country, Ethiopia, the demand for transportation systems is growing rapidly. Ethiopia's automobile companies import spare parts from other countries to meet these demands. However, if these spare parts can be replaced with lightweight, non-expansive, and locally available materials, the vehicle's performance can be improved while foreign currency is saved. As a result, elephant grass and bamboo, which are abundant in Ethiopia, could be appropriate materials for vehicle body parts. In terms of safety, environmental effect, and flexibility, public transit outperforms other modes of transportation. Over the near years, the efforts to find more environmentally friendly materials have spurred as a consequence of persistence of plastics in the environment, landfill space shortage and depletion of petroleum resources. Growing environmental problems has become a major influence on government policy in many countries by encouraging “greener” materials research.

1.9. Structure of the Thesis

This thesis entitled “Fabrication and Characterization of Mechanical and Physical Properties of Hybrid Bamboo, Elephant Grass and E-glass fiber Reinforced Polyester Composite” consists of five chapters that are organized as follows.

Chapter-1: provides the introduction, objectives, problem of the statement, significance of the study, Beneficiary of the study, Scope, and Limitation of the study. Chapter-2: presents the literature review on properties of natural fiber composites, mechanical properties of elephant grass, bamboo and glass Fiber Reinforced Polymer Composites, and Taguchi method. Finally, a summary of the literature and research gap was described. Chapter-3: deals with materials and methodology used for the study. This includes materials used, material preparation, equipment used for the study; experimental procedures, types of tests performed, and design of experiment is explained. Chapter-4: elaborates on the experimental results of physical and mechanical properties of the composites under study such as density, porosity, water absorption, tensile strength, flexural strength, hardness, impact strength, compressive test, and SEM morphological analysis on specimens are discussed. Chapter-5: contains specific conclusions drawn from the experimental and analytical results, recommendations, and future research directions.

CHAPTER -2

LITERATURE REVIEW

2.1. Introduction

This section focuses on the thesis work that has already been carried out for testing and Fabrication of chopped fiber reinforced hybrid composites. Literature review of such work needs to be done in order to understand the background information available, the work already done and to show the relevance of the current work. This chapter presents a general idea input parameters that affect the mechanical properties of hybrid fiber reinforced composites and specifically on polyester based reinforced composite with glass, elephant and bamboo fibers.

2.2. Properties of Natural Fiber Composites

. Natural fibers (NFs) are a widely available and easy-to-find substance in nature. They show biodegradability, cheap cost per unit volume, high strength, and particular stiffness as excellent material qualities. Composites composed using NF reinforcements appear to have a number of advantages to synthetic fibers, including lower weight, cost, toxicity, pollution, and recyclability. For current applications, NF composites outperform synthetic fiber-reinforced composites in terms of cost and environmental impact. Plant fibers are one of the most significant components utilized in polymer-based composites. This is because of their biodegradability, low cost, and ability to regenerate (Tripathi & Yadav, 2017b). Natural and synthetic fibers each offer a number of characteristics that make them particularly appealing to the vehicle industry. They have strong mechanical strength, low density, improved thermal and acoustic insulation, and are inexpensive. Different types of fiber composites (natural, synthetic, and natural-synthetic composites) can be reinforced depending on the necessity (Kumar et al., 2019). The phrase "natural fibers" can include a wide range of fiber types. All of the fibers are made from natural materials. Animal fibers (such as hair, chicken feathers, and so on) or plant fibers can be used (Leaf, seed, etc.). Natural fiber composites have additional environmental benefits, such as fewer pollutant emissions, greenhouse gas emissions, and component end-of-life biodegradability. Natural or synthetic fibers have found important applications in a range of areas, including construction, mechanical, car, aerospace, biomedical, and marine (Clyne & Hull, 2019). Natural fibers are extracted from different renewable resources, namely animals, vegetable plants, and minerals. The advantage and limitations of natural fiber were explained by (Mochane, 2019).

Table 2.1. Natural fibers advantages and disadvantages (Mochane, 2019).

Advantage	Disadvantages
Recyclable Low density i.e., lightweight Zero fingerprint CO_2 High specific mechanical properties than glass Non- abrasive to processing equipment Generate non-harmful gases during processing and no skin irritation Production energy is less than that of glass fibers i.e., one third Good thermal and acoustic properties	High moisture absorption Dimensional instability Flammable Low strength and thermal resistance than glass fibers Limiting processing temperatures as compared to glass

Natural fibers have an attracting the interest to engineers, researchers, professionals and scientists all over the world as an alternative reinforcement, because of its superior properties such as high specific strength, low weight, low cost, fairly good mechanical properties, nonabrasive, eco-friendly and bio-degradable characteristics (Elanchezhian et al., 2018).

(Mittal, 2016) they studied the Natural fiber-mediated epoxy composites. The influence of the fiber content, fiber geometry, fiber size, surface treatment technique, and coupling agent on different properties like mechanical, thermal, and water absorption were presented. The epoxy resin is a feasible polymer, which has effective strength, good toughness, and appreciable resilience. Vegetable, animal, and mineral fibers are part of the natural fiber. These fibers give superior strength to a composite when reinforced with the polymer matrix. They concluded that natural fibers filled with epoxy composites have great potential for engineering applications due to their environmental suitability, technical feasibility, and economic viability. Various researchers used different treatments like alkaline, silane, ultrasonic, and coupling agent to improve the performance of natural fiber-epoxy composites However, alkaline treatment is the most widely used technique for enhancing the mechanical, thermal and water absorption properties of the natural fiber-based epoxy composites due to economy and high efficiency.

Gairola,(2020) Investigated fabrication and mechanical property evaluation of non-woven banana fiber epoxy-based polymer composite. The non-woven banana fiber reinforced epoxy composite was fabricated with different weight percentages of fiber content (10, 20, 30, 40, and 50) %. The tensile, flexural, impact and hardeners were performed. From the result the maximum value of tensile strength is 55.6 Mpa and flexural strength 38 Mpa at 30% of fiber. Whereas the maximum values impact strength is 2.8 joule and hardness 45.6 HV at 40% of fiber.

According to (Laxmana et al., 2015) reported concerning about natural fibers like bamboo and Elephant glass FRPs are rich in cellulose and they are cheap and easily renewable source of fibers with the potential for polymer reinforcement. Natural fibers are chemically treated to remove lignin, pectin, waxy substances, and natural oils covering the external surface of the fiber cell wall this is cleaned by Sodium hydroxide (NaOH) this is done by 5 % NaOH solution by immersing the fibers at room temperature by avoid oxidation for four (4) hours and this also changes the fine structure of the native cellulose I to cellulose II by a process known as alkalization. After that it was washed in overflowing tap water until neutral pH is attained. The fibers dried in sun light for 24 hours.

Table 2.2. Mechanical properties of bamboo and elephant grass fibers (Laxmana et al., 2015)

Fiber	Bamboo	Elephant Grass
Density (g/cm3)	1.1	0.817
Elongation at break (%)	6-7	2.50
Tensile strength (MPa)	350 ± 7	185
Tensile modulus (GPa)	12.8	7.4
Flexural strength (MPa)	29.28 - 62.50	57.33
Flexural modulus (MPa)	1.29 - 3.16	8.9
Impact strength (kJ/m2)	8 - 36	13.25

Finally, the paper concluded that NFs have well prospective as reinforcements in polymers (thermoplastics, thermosets and elastomers) composites. Due to the high specific properties and low density of natural fibers, composites based on these fibers may have very good application in industry. Moreover, reduced abrasion and consequent reduction of re-tooling makes these composites one of the most effective alternatives.

Gupta and Srivastava, (2014) conducted a research on the tensile and flexural properties of sisal fiber reinforced epoxy composite by using both unidirectional and mat form of fibers. The researchers are prepared the composite by using Hand lay-up method with 15, 20, 25 and 30 wt. % of SFs into the mixture of epoxy resin AY-105 and hardener with ratio of 10:1 by weight. From the testing results, the authors concluded that the tensile and flexural properties of sisal fiber epoxy composite both in unidirectional and in the mat, form are maximum at 30 wt.%, and also composite in unidirectional orientation of fibers gives better tensile, flexural and adhesion properties in comparison to the mat form.

Sudhir et al., (2014) were conducted a research on the tensile and flexural properties of Sisal/jute hybrid natural fiber composites. The goal of the researcher is to describe the development and characterization of this new set of hybrid natural fiber composites. In order to prepare the composites and carried out the tensile and flexural test, the authors first extracted the natural fibers by using retting and combing process manually. Then they reinforced sisal/jute fibers of 0/40, 10/30, 20/20, 30/10, 40/0 weight fraction ratios with epoxy resin in matrix by using hand layup techniques. From the testing results, they finally concluded that the jute/sisal (20/20) weight fraction hybrid composite samples have maximum tensile and flexural strength, and also addition of sisal fiber in jute/epoxy composite up to 50 % weight fraction results increasing the material properties.

2.3. Reinforcements

2.3.1 Glass fibers

Glass fibers are used to make structural composites, printed circuit boards, and a variety of other specialty items. Glass fibers account for almost 95% of the fibers used in reinforced plastics because they are affordable, simple to make, and have great strength and stiffness in comparison to the plastics they are reinforced with. Glass' low density, chemical resistance, and insulating capacity are all advantages, yet one major downside is that it is prone to breaking when subjected to severe tensile stress for an extended period of time (Sonwane et al., 2020). E-glass fibers usually exist in three principal types including, continuous glass fiber, chopped glass fiber and unidirectional glass fiber. The type of E-glass fiber that was used in this 33 study is unidirectional (UD) E-glass type. UD fiber type has good mechanical properties as compared to other fiber types and most of the time it uses in the fabrication of wind turbine blade structure (Reinforced, 2013).

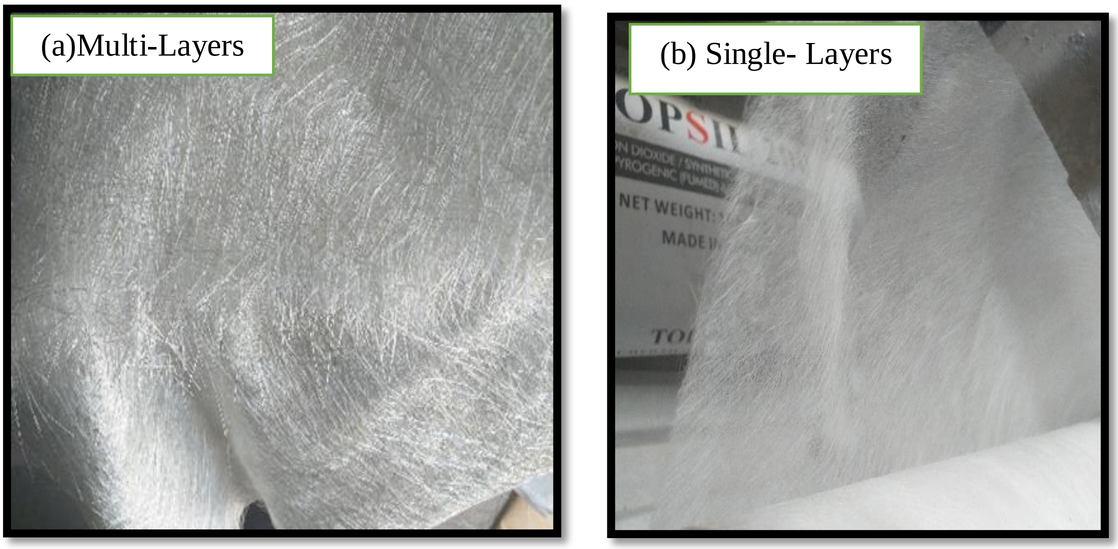


Figure 2.1. Random oriented glass fiber: (a) multi- Layers and (b) Single Layers.

Because of its high specific strength, stiffness, and modulus, glass fiber reinforced polyester composites have long dominated a range of applications. By hand lay-up approach with variable fiber percentages, an E-glass fiber with random oriented reinforced polymer composite was generated in this study work (15 percent, 30 percent, 45 percent, and 60 percent by weight percentage). The effects of glass fiber % on mechanical parameters like tensile strength, bending strength, and impact strength were studied. Brinell hardness tester was used to determine the hardness of composites. The results showed that increasing the glass fiber content improved the mechanical characteristics of the manufactured composite significantly. The tensile strength ranges from 28.25 and 78.83 MPa. As a function of fiber weight fraction, flexural strength ranges from 44.65 MPa to 119.23 MPa, and impact energy ranges from 3.50 Joules to 6.50 Joules. From 31.5 BHN to 47 BHN, the hardness value will skyrocket. The best mechanical characteristics of manufactured composites were found at 60% glass fiber content. (Wazery et al, 2017).

2.3.2. Elephant grass fibers

Elephant grass is a tall grass that originated in Africa and was discovered in 1913. This grass grows in clumps and can reach a height of 5 meters. It has green to yellowish or green purplish leaves with a sharp edge, as well as a rough and hairy stem. The leaves reach a height of 2 to 3 meters and have a width of 1 inch. It weighs 817.53 kg/m3 and has a density of 817.53 kg/m3 (Chauhan et al., 2019). Bier hybridization is a promising strategy to toughen composite materials. In Ethiopia, in the past and even in present, the economic potential of elephant grass has not been explored and the role of elephant grass resources in national economies is negligible. Source of elephant grass plants in Assosa, Gimbi, Ambo, Gurage, Bale, Masha and Chencha.

By combining two or more fiber types, these hybrid composites offer a better balance in mechanical properties than non-hybrid composites (Dawit et al., 2019).The bending properties of elephant grass fiber by varying its volume fraction and extracting the fibers manually. Hand lay-up process used to prepare the composite specimens with 5%, 10% and 15% volume fraction. This method is the simplest method and requires a low cost. The results showed that filler volume fraction has effect to its bending strength. Specimen with 5% filler volume fraction has the highest bending stress whereas 15% filler volume fraction specimen has the highest elasticity modulus value (Alwiyah et al, 2015).

Elephant grass fiber reinforced polyester resin composites have been created and their mechanical properties, such as bending qualities, have been studied. The specimen was created by changing the volume percent of the filler. After immersing the elephant grass fiber in water for three days, the strips were gently beaten to release and separate the fiber, then scraped with a sharp knife and combed until individual fibers were recovered and cut consistently in 2 cm length and 1 mm diameter width. The composite specimens with 1%, 3%, and 5% volume fractions were prepared using a hand layup procedure. The specimen dimensions utilized in the test were adapted from ASTM D 3379-75 for Bend testing. The results revealed that the filler volume percent has an impact on the bending strength of the material. The highest bending stress is found in a specimen with 1% filler volume fraction, while the highest elasticity modulus value is found in a specimen with 5% filler volume percent (Alwiyah et al, 2015).

2.3.3. Bamboo fibers

Bamboo fibers are a plentiful natural resource with mechanical qualities similar to glass fibers, which are often utilized in fiber reinforced plastic composites. Bamboo fibers stand out among natural fibers because of the plant's rapid growth and great production (Tinoco, 2011). Instead of manufacturing strong reinforcing fillers, bamboo might be used as biodegradable filler at the end of usage in polymeric composite materials to reduce pollution. Bamboo may be utilized as a reinforced composite material if the necessary fibers are extracted properly. Many natural fibers have been investigated as reinforcing materials for synthetic and biopolymer polymers. Free proteins, extractives, and inorganics are also present in minor concentrations. Cellulose is the most prevalent naturally occurring polymer on the planet and is the fundamental structural component of plant fibers. Polysaccharide polymers with shorter polymer chains than cellulose are known as hemicelluloses. Lignin is a phenol-propane-based amorphous polymer. It's possible that a trustworthy agent is responsible for the stiffness of plant cell walls. Bamboo fibers contain more lignin than many other natural fibers, which can make them brittle (Tripathi & Yadav, 2017b).

Resources and Properties Bamboo Plant

Ethiopia has a variety of bamboo species to choose from. Ethiopia has Africa's largest bamboo resources, with 30 percent to 40 percent of mature culms harvested every two years in sustainable cycles. Ethiopia's overall resource base is limited to two indigenous bamboo species, out of more than 1500 species worldwide, 43 of which are found in Africa. The highland bamboo (Yushania Alpina), with solid culms at mature age and a diameter of 8cm and a height of 17m, covers 15% of the area, while the monotypic genus lowland bamboo (Oxythenantera Abyssinica), with solid culms at maturing age and a diameter of 5cm and a height of 7m, covers 85%. The Ethiopian natural bamboo forest covers about 1 million hectares, which is about 7% of the world total and 67% of the African bamboo forest area. In Ethiopia, in the past and even in present, the economic potential of bamboo has not been explored and the role of bamboo resources in national economies is negligible. From the figure 2.1 Assosa, Injibara, Gimbi, Ambo, Gurage, Bale, Masha, Chencha and Hagere-Selam are rich in bamboo sources. The largest source of bamboo plant present in Assosa was presented by (Siyoum Kelemwork, S.(2008).

Figure 2.2. Diversity of bamboo in Ethiopia (ECBP-Documentation, (2007)).

The feasibility of using a newly discovered mechanical process for extracting long bamboo fibers as reinforcement in composite materials for high-end applications was studied. Bamboo has a large number of culms. In terms of stiffness, strength, and fracture toughness, different culms differ. The Culm of a bamboo plant is a natural functionally graded ligno-cellulosic composite material. The outer cortex, as well as the top of the Culm, is densely packed with fibers. Primary cellulose, hemicellulose, and lignin are the chemical components of bamboo. The bamboo has 60 % cellulose and a significant amount of lignin (about 32 percent). The strength distribution of the fibers was studied using a unique method to assess the impact of defects induced by the extraction process as a function of fiber length, fiber surface area, and fiber volume. They claim that a simple model with only three parameters accurately captured the fiber strength distribution at varied gauge lengths. The average fiber strength fell as gauge length increased, from 943 MPa at L = 1 mm to 733 MPa at L = 40mm, and it was essentially independent of mean fiber volume by (Trujillo et.al, 2010). Because bamboo fibers are coated with lignin, they are generally fragile when compared to other natural fibers. As a result, a method for extracting bamboo fibers for composite material reinforcing should be established. However, once the right process of fiber extraction is chosen, the end product is equivalent to that of glass fiber.

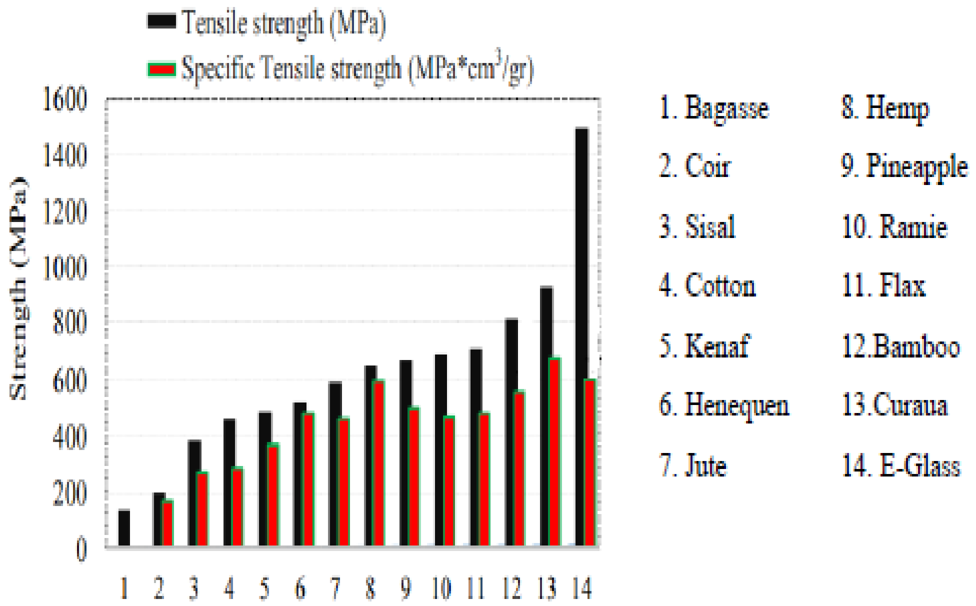


Figure 2.3. Comparison of natural fiber strength and specific strength (roslan et. al, 2005).

The reduction in harmful destruction of ecosystem and to produce low cost polymeric reinforced composites, the researchers are emerging with policies of manufacturing the composites using natural fibers which are entirely biodegradable was described. These policies had generated safe strategies to protect our environment. The utilization of bamboo fibers as reinforcement in composite materials increased tremendously and undergoes high-tech revolution in recent years. Bamboo fiber is stronger as well as can be utilized in generating high quality sustainable industrial products were presented (Abdul Khalil et.al 2012). The advantages of natural fibers over synthetic fibers comprise low density, low cost, availability, recyclability and biodegradability was investigated. Due to their numerous advantages they are supposed to be analogous to those of synthetic fibers used as reinforcements was stated (Begum et. al, 2015).

2.4. Matrix

Among the main groups of the matrix material, thermoset resin is the major one, which includes polyester, phenolic, polyurethanes and epoxy. In the hybrid composites of polypropylene reinforced with bamboo and glass fibers (BGRP), Maleic anhydride grafted polypropylene (MAPP) has been used as a coupling agent to improve the interfacial interaction between the fibers and matrix. The mechanical properties of the hybrid composites were studied from tensile, flexural, and impact tests. Mechanical tests indicated an increase in tensile, flexural, and impact strength of the BGRP hybrid composites at a bamboo: glass fiber ratio of 15:15 in the presence of 2wt% of MAPP Thermoset resin, which comprises polyester, phenolic, polyurethanes, and epoxy, is the most common type of matrix material. Maleic anhydride grafted polypropylene (MAPP) was employed as a coupling agent in the hybrid composites of polypropylene reinforced with bamboo and glass fibers (BGRP) to increase the interfacial contact between the fibers and matrix. Tensile, flexural, and impact tests were used to investigate the mechanical characteristics of the hybrid composites. In the presence of 2wt% MAPP, mechanical testing revealed an improvement in tensile, flexural, and impact strength of the BGRP hybrid composites at a bamboo: glass fiber ratio of 15:15 (Nayak et al., 2009).

2.4.1. General Purpose Polyester Resin

General Purpose Polyester Resin is an unsaturated polyester resin. Unsaturated polyester resin thermoset and is capable of being cured from a liquid to a solid state when subject to the right condition. Low viscosity for fast wet-out, convenient for hand lay-up applications, low cost, low density, exhibits good mechanical and good chemical resistance, low-pressure molding capabilities and capability to cure at room temperature are the advantages of unsaturated polyester when compared to other thermosetting resins (Andargie, 2020).

2.5. Hybridization of Elephant grass/ Bamboo/glass fiber

Hybrid composites are systems in which one kind of reinforcing material is integrated in a combination of multiple matrices, two or more reinforcing and filling materials are present in a single matrix, or both techniques are used in the case of polymer composites. Hybrid composites have been created by combining two or more different cellulosic fibers into a single matrix. The behavior of hybrid composites is a weighted total of the separate components in which the inherent benefits and limitations are better balanced. It is now typical to use a hybrid composite that comprises two or more types of fiber (Tripathi & Yadav, 2017b). Artificial fibers, natural fibers, and a mix of both artificial and natural fibers can all be used to create hybrid composites. In comparison to fiber reinforced composites, hybrid composites can help us obtain a superior mix of qualities (Nunna et al., 2016). Glass fiber (6mm, density 2.56g/cm3) and bamboo fiber (4–6mm length, diameter 85–120m, density 0.863g/cm3) were utilized as reinforcement (Sanjay k. Nayak et al., 2009). The random orientation fibers with a thickness of 0.3mm were chosen. The hybrid composite was made with a glass-chopped strand mat (Rajulu & Reddy, 2010). Fiber orientation reinforced hybrid polymer nanocomposites combining bamboo/e-glass and epoxy polymer in the ratios of 0.1wt%, 0.2wt%, and 0.3wt% of volume are to be studied (Mahesh et al., 2017).

2.6. Review on the Taguchi Method

Because of its practicality and resilience, the approach has been used with great success in experimental designs for issues with several parameters. Taguchi experimental design approaches are a simple, efficient, and systematic way for optimizing testing parameters and determining their contribution to goal parameters. This approach employs a one-of-a-kind design of orthogonal arrays to decrease experiment variation while optimizing process parameters (Prabhu et al., 2019). The Taguchi technique is used to determine and optimize the fabrication parameters of the reinforced vinyl ester (RFRVE) composite material with mechanical qualities, particularly fiber length, fiber content, and fiber diameter. In comparison to fiber length and diameter, the results demonstrate that the fiber content is the most important fabrication parameter that has a substantial impact on the mechanical characteristics of reinforced vinyl ester (RFRVE) composites. This technology was shown to successfully improve the numerous performance aspects of plant-based natural fiber and particle reinforced polymer composites (Navaneethakrishnan & Athijayamani, 2015).

Untreated bamboo fiber and treated bamboo fiber were compared, and treated bamboo fibers outperformed untreated bamboo fibers. The experiment was designed using a Box–Behnken design (BBD) of the response surface methodology (RSM) to evaluate the mercerization impact of bamboo fiber-reinforced epoxy composites. The analysis of variance (ANOVA) of the quadratic model was used to assess the expected tensile strength as a variable parameter of bamboo fiber (Bambusa vulgaris) reinforced epoxy composite constructions (Jenarthanan et al., 2019). The output response values of tensile strength and strain are optimized after optimizing the input parameters of the glass fiber and coir fiber reinforcement epoxy hybrid composite (Kumar et al., 2019). Optimizing the alkaline treatment variables, including sodium hydroxide (NaOH) concentration, soaking, and drying time, that influence the mechanical behavior of bamboo fiber-reinforced epoxy composites. The evaluation of predicted tensile strength as a variable parameter of bamboo fiber (Bambusa vulgaris) reinforced epoxy composite structures was determined using analysis of variance (ANOVA) of the quadratic model. It was found that the optimum mercerization condition lies at 5.81 wt. % of the NaOH, after a soaking time of 3.99 h and a drying time of 72 hr. This optimum alkaline treatment once again had a great effect on the structures whereby all the treated composite cores with square and triangular structures impressively outperformed the untreated bamboo structures (Hassan et al., 2018).

2.7. Adhesion properties of Hybrid composites

In comparison to non-renewable petroleum-based goods, natural fiber reinforced polypropylene composites are a renewable material with efficient degradability. Polypropylene and natural fibers are both hydrophilic, and it is expected that this feature will help with adhesion. In comparison to non-renewable petroleum-based goods, natural fiber reinforced PLA composites are a renewable material with efficient degradability. PLA and natural fibers are both hydrophilic, thus it's expected that this quality will help with adherence (Tripathi & Yadav, 2017a). The results of physical and chemical treatments that increase fiber matrix adherence, as well as their influence on the physical characteristics of composites, were shown in a research. The hydrophilic nature of the natural fibers is altered as a result of these treatments, reducing moisture effects in the composite (Bledzki & Gassan, 1999). The morphological traits were discovered through SEM examination. The mechanical characteristics of the E-glass fiber-reinforced epoxy composite were superior to those of the other composite samples. The characteristics of the E-glass epoxy fiber-reinforced composite were improved by increasing the cross-linking density of epoxy resin monomers and adding short chopped E-glass fibers (Jenarthanan et al., 2019). In some applications where significant load bearing capabilities are not required, bamboo fiber has the potential to substitute glass fiber. However, when producing a composite with specific needs, the proper fiber and filler material must be chosen to optimize the composite system (Mahesh et al., 2017).

2.8. Automotive body materials and analysis

Deep drawing steel sheets with good formability were developed in the 1950s, followed by the development of anti-corrosive steel sheets in the 1960s. In this time, mass production technologies were developed because of higher vehicle demand. High-strength steel sheets were developed in response to this issue and have contributed to lightening vehicles by reducing sheet thickness. In the 1990s, safety and environmental issues became primary concerns in the automotive industry, and further work was done on developing technologies for weight reductions. Aluminum alloy sheets were developed in this connection and applied to various body panels such as the engine hood, and have contributed to achieving lighter vehicles (Mahesh et al., 2017). The composite materials used for automotive bumper in passenger vehicles. Determining the right material during the selection process is very important. The material selected should meet the expectation of the engineer. The material should be mechanically feasible and should have low cost. Other than the manufacturing of bumpers, the composite materials have a wide range of other potential automotive applications such as body panels, suspension, steering, brakes and other parts of the automobile. Apart from body panels, the current, limited automotive application of composites include bumper systems, leaf springs, drive shafts, fuel tanks, instrument panels, cross wheel beam, intake manifold (Alen John et al, 2014). Automobile bumpers are found front side i.e. in front of cabin and rear side. , Higher strength materials are especially required to provide sufficient impact and collusion resistance. New materials for the vehicle bumpers have been developed to improve corrosion resistance and to reduce the dead weight of the vehicle (Cantor et al., 2008).

2.9. Summary of Literature Review

From the above literature, the following summary was presented.

- Flexural strength and tensile strength of the fiber was depending on the fiber loading. If fiber loading is increased flexural strength and tensile strength increase up to the optimal level then decreases
- The chemically treated natural fiber composites improved the mechanical properties of the composite
- As the percentage of fiber increases, the water absorption increases
- The hardness of the composites increases with the increase in fiber and filler loading. After reaching the optimal level then decreases

2.10. Research gaps

In this review paper, composite materials can be manufactured by combining natural and synthetic fibers. However, there has not been much work conducted yet on optimizing the parameters and characterization of the mechanical properties of the hybrid composite. On automotive bodies are made of lightweight metals such as aluminum alloys or thin steel plates. However, in recent years the price of aluminum and plastic materials continues to increase, so the demand for a replacement material with similar properties and low price also increases. And composite laminate transfer load among the reinforcement. But not considered properties of composite. Natural fibers are chosen because they have advantages with biodegradable and low prices. Natural fiber reinforced composites in addition to having low-cost, lightweight and eco-friendly.

CHAPTER -3

MATERIALS AND METHODS

3.1. Introduction

In this chapter, the materials and methods used for the fabrication of composites are explained. For this study, the materials such as elephant grass, bamboo fibers, E-glass, fiber, and polyester resin with its corresponding hardener, Mold release, normal water, distilled water, and sodium hydroxide were utilized to manufacture the hybrid composite materials sample. The apparatus such as Plastic container, beaker, stirrer, sieve, and Mold plate was used for this work. The equipment such as Digital mass balance, Grinding machine, specimen Cutter machine, Universal testing machine, scanning electron microscope, Vickers hardness testing machine, and drilling machine used.

3.2. Materials

3.2.1. Elephant Grass

In composite material one of the main components is the reinforcement material that is fiber. So Elephant grass fiber is a natural fiber which is extracted from local Elephant grass plants. Elephant grass is one of tall grass comes from Africa which was found in 1913. This kind of grass grows in clump and reaches until 6 meters. The bending properties of elephant grass fiber by varying its volume fraction and extracting the fibers manually. Hand lay-up process used to prepare the composite specimens with 5%, 10% and 15% volume fraction. This method is the simplest method and requires a low cost.

Table 3.1. Physical - Mechanical properties of elephant grass fiber (Mahesh et al, 2013).

Properties	Values
Density (g/cm3)	0.817
Tensile strength (MPa)	185
Young modulus (GPa)	7.4
Elongation (%)	3

Extraction process of Elephant grass fiber

The extraction of the fiber was not taken part as the main objective. Rather the fiber as a byproduct. In this work, Elephant grass fiber was extracted using a manual extraction technique due to the following reasons.

- No need of advanced equipment, such as roller, mechanical dryer, boiler, autoclave, etc.
- Low energy consumption and,
- Easy control of fiber property

Cut the Elephant grass which is ripe and ready for the process, from the ground level

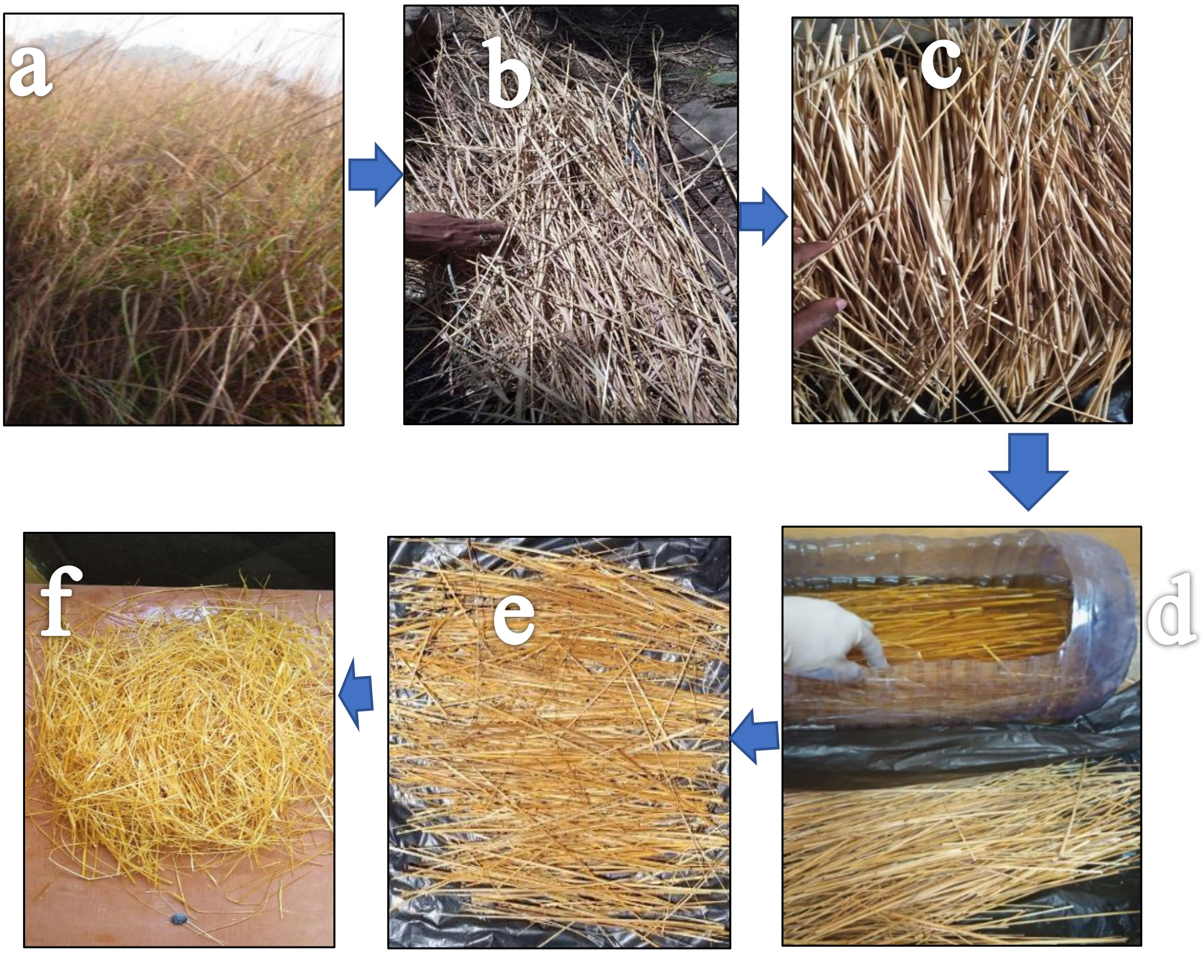


Figure 3.1. Elephant grass fiber extraction technique (a) elephant grass plant (b) trimming culms and dry elephant grass plant (c) separated bark (d) alkaline treatment (e) washed and dried (f) treated elephant grass fiber.

3.2.2. Bamboo

Bamboo seeks to preserve and to stimulate the growth of a worldwide natural resource, with the advantage that it absorbs and stores large amounts of CO_2. In this work the composite material was fabricated from natural plant typically from the Lowland bamboo. Lowland bamboos are abundantly available in the lowland part in Ethiopia. They cover around 85% of bamboo resource in our country. Specifically the bamboo was selected from Assosa, Ethiopia for investigation. The preparation of this composite material required different techniques beginning from the selection of bamboo up to the final stage in which the composite was fabricated for the investigation of different mechanical properties.

Table 3.2. Physical-mechanical properties of bamboo fiber (Sushanta et al, 2009).

Properties	Values
Density (g/cm3)	1.1
Tensile strength (MPa)	500–575
Young modulus (GPa)	27–40
Elongation (%)	1.9–3.2

Fibers were selected it has lower thermal conductivity, low density, are environmentally friendly, renewable, cheap, have good stability, are no toxic, and high strength.

Techniques of Bamboo Fiber Extraction

Bamboo trees have high strength and stiffness at maturating age in between 3-5 years. This property of bamboo is special from other natural polymers. Fiber extraction technique is the method in which the required fiber (reinforcing phase) for the preparation of composite material is obtained. This fiber extraction plays vital role for the composite material strength as well as different properties. For this work the selected way to extract the fiber is mechanical fiber extraction method (retting).

Mechanical Extraction

There are many forms of mechanical extraction methods such as steam explosion, crushing, grinding, rolling in a mill and retting. These methods are used for the extraction of bamboo fiber for application in various industries for making bamboo fiber reinforced composites. In this work, the extraction of bamboo fiber was carried out by mechanical extraction technique (retting). In general, the extraction process of the bamboo fibers is summarized as below. The lowland bamboo in maturating age was cut in its nodal. Then, scrap the outer cover of cylindrical part of the bamboo Culm and peel to obtain the strips. In order to remove the dirty particle, the bamboo Culm was cleaned using sand paper. Bundles of strips were kept in water for seven days in order to soften and separate the non-cellulose part. The wetted strips was beaten with a rubber hammer slowly in order to avoid damage occur on the fiber, then scrap and comb the fiber using wire or metal comb. The process of beating and combing was repeated until individual fibers are separated. In this method, the process of scraping had strong effect on the fiber quality.

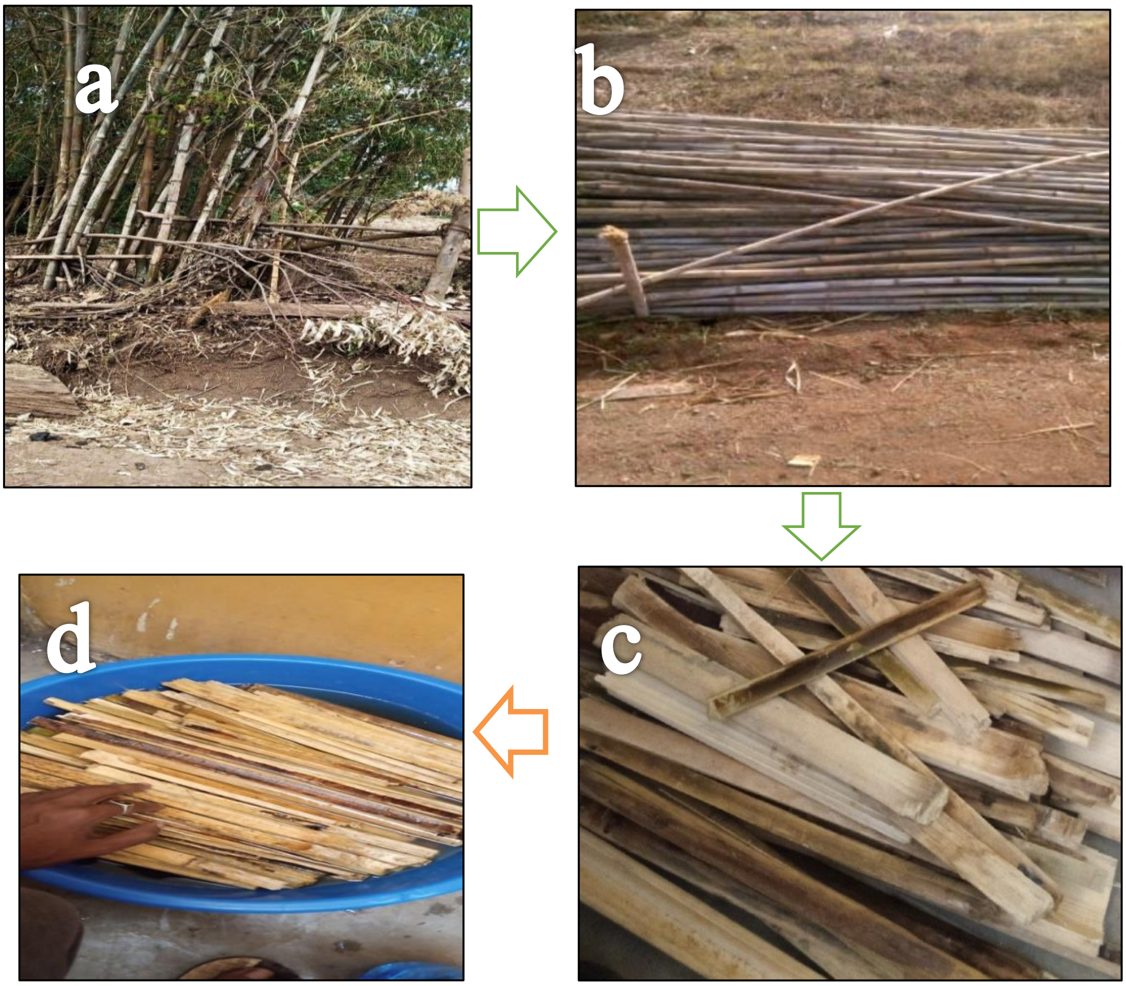


Figure 3.2. Bamboo fiber extraction technique (a) bamboo plant (b) dry bamboo plant, (c) split bamboo clam, (d) the cleaved bamboo strips are socked under the water in the bath (e) wetted bamboo strips are hammered with a rubber hammer (f) illustrates the outcome of the extracted bamboo fiber (g) alkaline treatment (h) treated bamboo fiber.

3.2.3. Glass fiber

Fibers are one of the most adaptable industrial materials currently available. When exposed to high tensile stress over an extended period of time, it is prone to breaking. In most fiberglass materials, the reinforcing glass layers have distinct fiber orientations, resulting in a laminate structure. Anisotropy of material qualities in the plane parallel to the laminates is caused by different glass fiber orientations. By far the most prevalent kind of fiber found in composites is E-glass. Chemical resistance, mechanical qualities, and insulating properties are all good in these kinds. Furthermore, the economics of E-glass are more appealing. When compared to other forms of glass fibers, E-glass has a number of benefits. E-glass fiber is inexpensive, has superior electrical insulating properties, is stronger mechanically than conventional glass fiber, and is resistant to moisture (resists attacks from water). E-glass fiber was chosen as the bamboo fiber reinforcement for this investigation because to the aforesaid promising characteristics. Continuous glass fiber, chopped glass fiber, and unidirectional glass fiber are the three most common varieties of E-glass fibers. The kind of E-glass fiber employed in this research was unidirectional (UD) E-glass. When compared to other fiber types, UD fiber has superior mechanical qualities, and it is frequently used in the manufacturing of wind turbine blade structures (Reinforced, 2013).

Table 3.3. Properties of E-glass (Wazery et al, 2017).

Properties	Values
Density (g/cm3)	2.58
Tensile strength (MPa)	3445
Compressive strength	1080
Elastic modulus (GPa)	73

3.2.4. General Purpose Polyester Resin

Unsaturated polyester resin known as General Purpose Polyester Resin. When the right conditions are met, an unsaturated polyester resin thermoset can be cured from a liquid to a solid state. When compared to other thermosetting resins, unsaturated polyester offers low viscosity for quick wet-out, convenience for hand lay-up applications, cheap cost, low density, strong mechanical and chemical resistance, low-pressure molding capabilities, and the ability to cure at room temperature (Andargie, 2020). For this study, Unsaturated

Polyester resin with the brand name (TOPAZ-1110 Phthalic Anhydride) was used. This Unsaturated polyester resin is purchased from the local supplier World Fiber Glass and Water Proofing Engineering in Addis Ababa, Ethiopia.

Table 3.4. Characteristics of UPR (Sirahbizu, 2021).

Properties	Values
Density (g/cm3)	1.09-1.35
Tensile strength (MPa)	40
Young modulus (GPa)	3.3
Elongation (%)	1

3.2.5. Hardener

The addition of a hardener or a catalyst, which induces a chemical reaction, cures unsaturated polyester resin. The catalyst starts the liquid-to-solid chemical reaction between the polyester resin and monomer component. As a result, the hardener (curing agent) employed in this investigation is a hardener branded as methyl ethyl ketone peroxide (MEKP). MEKP Catalyst should be mixed with GP Polyester Laminating Resin at a weight ratio of (1-3) percent (Andargie, 2020). It is purchased from the local supplier World Fiber Glass and Water Proofing Engineering in Addis Ababa, Ethiopia.

Figure 3.3. UPR and hardener.

3.2.6. Mold Release Agents

Mold release is essential for preventing the polyester from sticking to the mold when the composite are apart. Even though, there are several types of mold release used depending on the mold material and desired characteristics of the finished part, the most common type and used for this thesis work is paste wax (oil), and polyethylene plastic for better surface finish of the composite.

A).PVA (Polyvinyl Alcohol)

To start directly into the process, coat the surface of both sides' plates by PVA softly and uniformly. The purpose of this fluid was to facilitate the release process.

B). Apply Wax

Wax was first used as a release agent in the composites industry in the 1950's. Carnauba wax-based products are the most suitable for use with composite materials and these are widely employed, particularly in contact molding applications. Wax release agents are available in several forms but those most commonly used are pastes or liquids. Among the advantages of wax release agents are their ease of use, convenience and economy. Waxes are used mostly in low volume contact molding applications, as the need for regular re-application can be time consuming.

Figure 3.4. Wax-release agent.

3.2.7. Sodium Hydroxide

Sodium hydroxide, often known as lye or caustic soda, is a very caustic metallic base and alkali salt with the chemical formula NaOH. Pure sodium hydroxide is a white solid that comes as pellets, flakes, granules, and as a 50% saturated solution (Getahun, 2019). Water, ethanol, and methanol are all soluble in sodium hydroxide. This alkali is deliquescent, absorbing moisture and carbon dioxide from the air quickly. Sodium hydroxide is utilized in a variety of sectors, most notably in the production of pulp and paper, textiles, drinking water, soaps, and detergents. NaOH in the form of flakes was used to treat bagasse fiber in this study, and it was acquired from local providers.

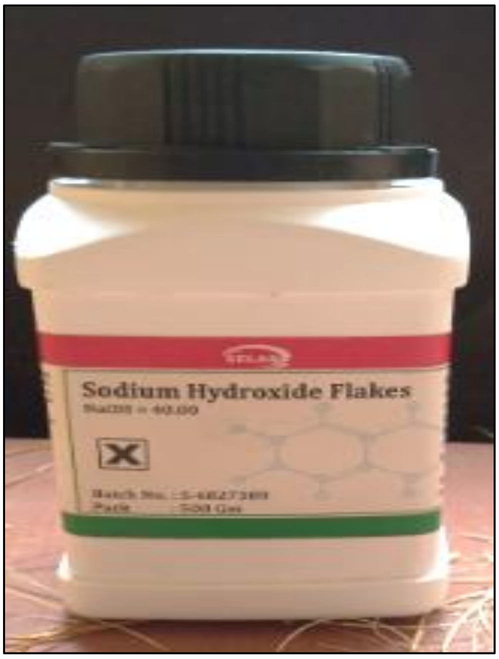


Figure3.5. Sodium hydroxide.

3.2.8. Chemical treatment of fibers

During the creation of composites, it is critical to characterize the contact between fiber and matrix. Natural fibers that are hydrophilic and polymer matrixes that are hydrophobic do not bind properly. Chemical treatment is required to enhance the interface in order to produce composites with superior mechanical characteristics. Treatments of fibers are used to improve the surface of reinforcement as a result of this improvement (Mohit Sooda, 2017). Bamboo and elephant grass fibers are commonly treated with mercerization. It enables chemical modification of the bamboo/elephant grass fiber's surface and bulk characteristics. Some mercerization, also known as alkali treatment, involves soaking bamboo and elephant grass fibers in sodium hydroxide (NaOH) to break hydrogen bonds and eliminate contaminants and amorphous cellulose.

Furthermore, this procedure cleans the fiber surface, improving smoothness and encouraging chemical bonding between the natural fiber and the polyester resin matrix. Furthermore, this process allows for the removal of some lignin and hemicellulose from the fiber's surface, improving the tensile strength of composites reinforced with bamboo fiber. The removal of the lignin and hemicellulose that link the internal organization of the fibers results in the dissociation of the macro fiber bundle into elementary fibers, which is another benefit of this treatment. The alkali pretreatment causes fibers to expand, resulting in an increase in internal surface area and, as a result, dissociation of structural connections that link lignin and carbohydrates, eventually leading to lignin disorder.

Treatment with sodium hydroxide permits active hydroxyl groups to form on the fiber surface, which improves the chemical interaction between the fiber and the matrix, resulting in effective stress transmission at the interface.

In general, removal of these fatty like components from bamboo fiber leads the fibers to:

- Improve an adhesive properties for fiber–matrix interface
- Improve fiber’s shear strength
- Improve fiber’s rigidity and stiffness
- Reduce fiber’s weight etc.

Bamboo fiber -OH +NaOH → FIBER-O-Na+ H2O …………………………….. eq (3.1)

Elephant grass fiber-OH +NaOH → FIBER-O-Na+ H2O………………………… eq (3.2)

Alkaline/ Mercerization / treatments Elephant grass fibers

First Prepare elephant grass fiber bundles. Then prepare 5% concentration of NaOH solution. Next soaked the fibers in NaOH solution for 4 hours in distilled water in order to neutralize it, the fiber washed many times with tap water. .Finally these fibers dried in sunlight for two days. After the fiber dried chopped fiber

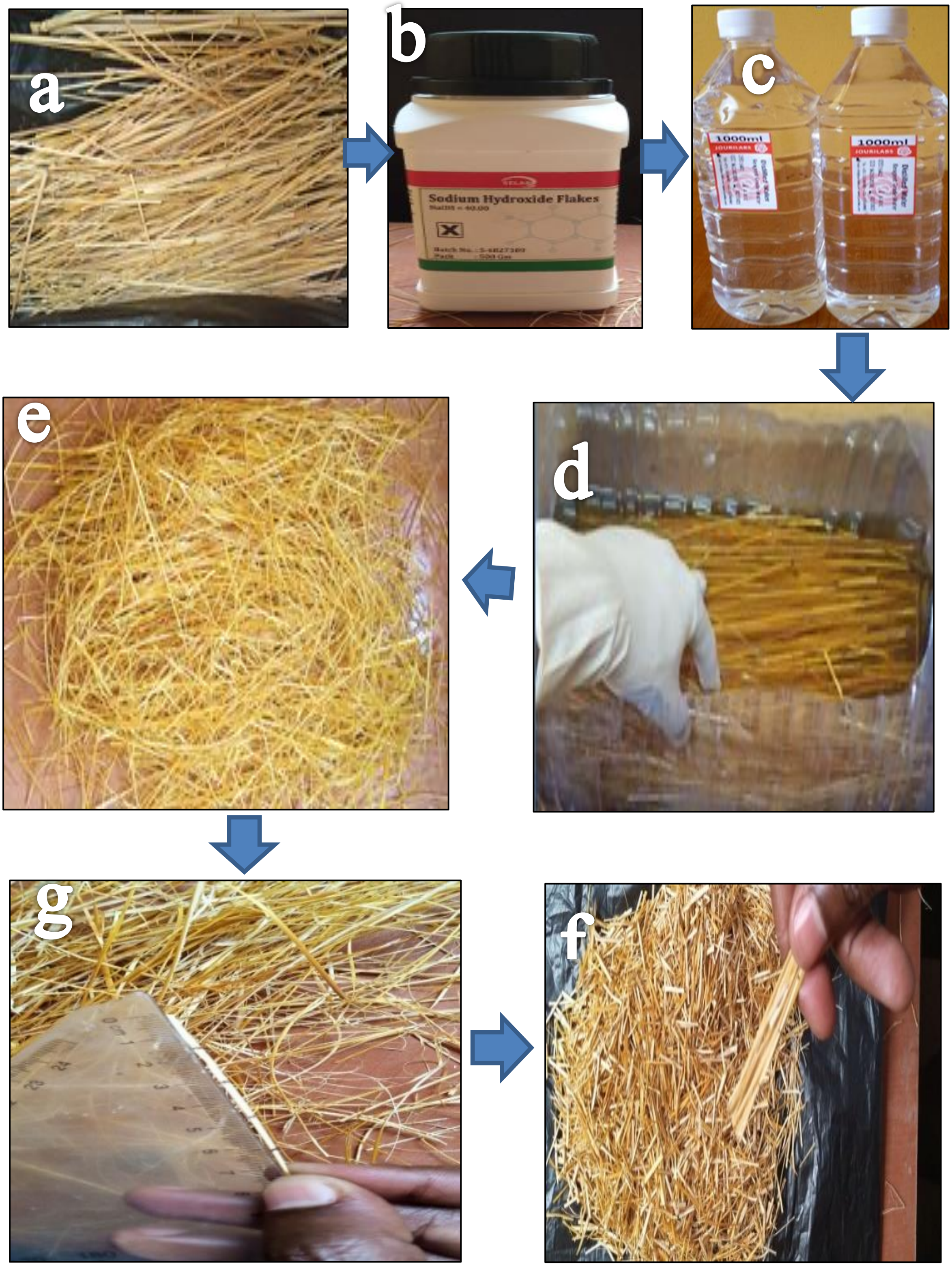


Figure 3.6. Alkali treatments and chopped of elephant grass fiber (a) elephant grass (b) NaOH (c) distilled water (d) soaked elephant grass fiber (e) kept in sunlight (f) measure the length of fiber (g) chopped fiber.

Alkaline/ Mercerization / treatments bamboo fibers

First Prepare bamboo fiber bundles. Then prepare 5% concentration of NaOH solution. (As shown in fig 3.6 (a). Next soaked the fibers in NaOH solution for 4 hours in distilled water in order to neutralize it, the fiber washed many times with tap water. . Finally these fibers dried in sunlight for two days. After the fiber dried chopped fiber

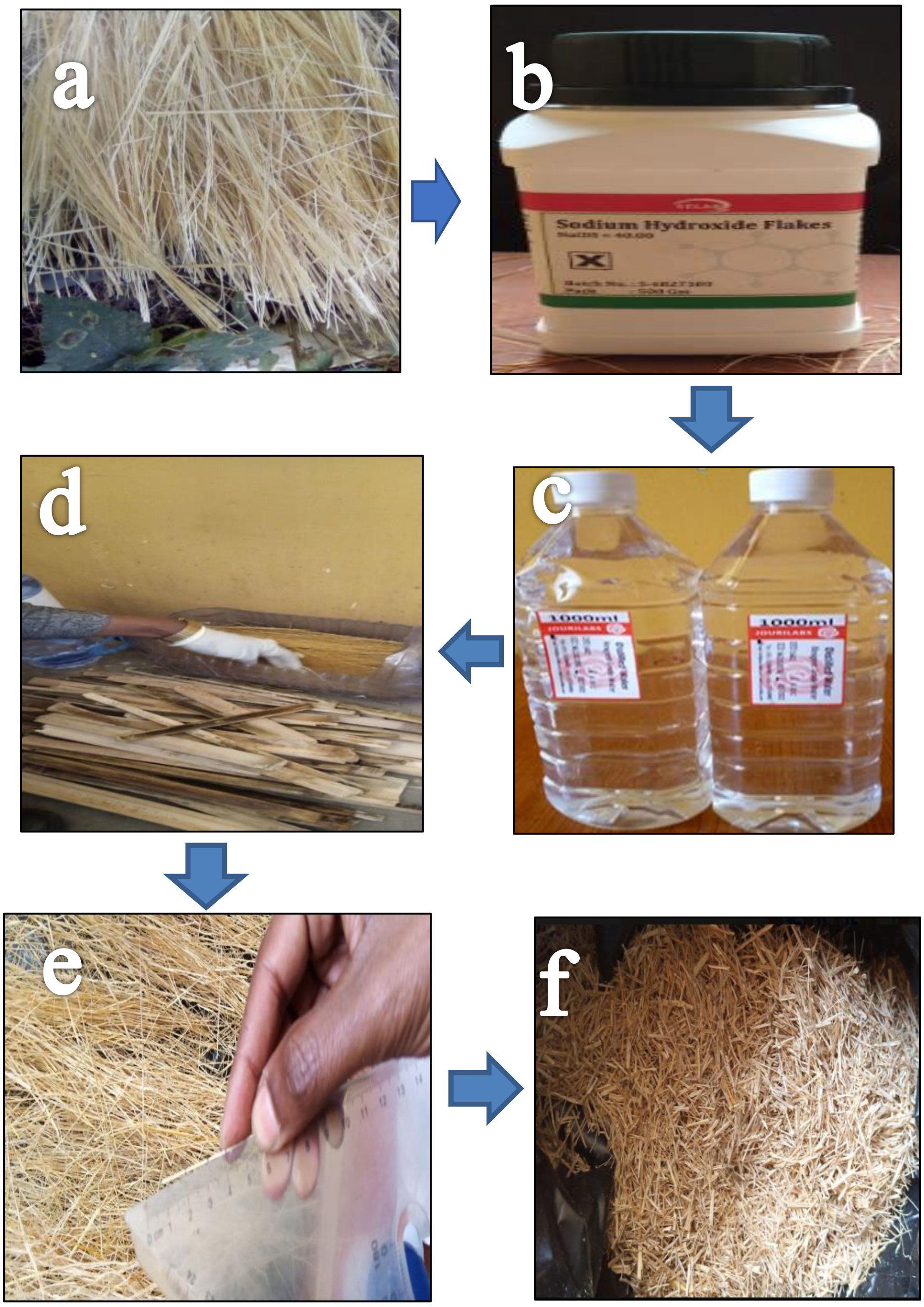


Figure 1. alkali treatments and chopped of bamboo fiber (a) bamboo fiber (b) NaOH (c) distilled water (d) soaked bamboo fiber (e) kept in sunlight (f) measure the length of fiber (h)chopped fiber.

3.3. Methods

3.3.1. Design of Experiment

In the design of experiment Taguchi method used because it is a problem - solving tool which can improve the performance of the product, process design and system. This method combines the experimental and analytical concepts to determine the most influential parameter on the result response for the significant improvement in the overall performance (Lakhvir Singh, 2013).The Taguchi method is described as an efficient design of experiment (DOE) technique for a systematic approach and for optimizing parameters with a minimum number of experiments. The process of performing a Taguchi experiment follows several distinct steps given by (Nitin Mukesh Mathur K. B., 2018).

Step1: Problem Formulation

Step 2: Identify Output and Input parameters that affect the outcome of the problem.

Step 3: Identify the control factors, noise factors, and signal factors. The Control factors are those, which can control under regular making conditions. The noise factors are those, which are either too difficult or too expensive to control under usual making conditions. The signal factors are those which affect the mean performance of the process.

Step 4: The selection of factor levels, possible interactions with the degrees of freedom related to each factor, and the interaction effects.

Step 5: Design an appropriate orthogonal array (OA).

Step 6: Preparation of experiment.

Step 7: Run the experiment having appropriate data collection.

Step 8: Statistical analysis with the interpretation of the experimental results.

Step 9: Undertaking a confirmatory run of the experiment

Orthogonal Array

The selection of a specific orthogonal array was based on the number of levels of various factors using the Taguchi method. The steps to go through are as follows:

Selection of factors to be evaluated Selection of number of levels

Selection of appropriate orthogonal array Experiment and analyze the results

The fabrication of hybrid composites made from elephant grass, glass fiber and bamboo reinforced with polyester was carried out by hand lay-up technique three levels and three factors. To observe the most influential process parameters in the fabrication of elephant grass, bamboo and glass fiber reinforced polyester matrix composite namely particulate fiber content at three levels were considered. In this work to experiment with three factors and three levels by using taguchi method L9 orthogonal array with Minitab 18 Software.

Table 3.5. Process parameters and levels.

S. No	**Factors**	**Parameter's designation**	**Level 1**	**Level 2**	**Level 3**
1	Elephant grass fiber (wt. %)	A	5	10	15
2	Bamboo fiber (wt. %)	B	5	10	15
3	Glass fiber (wt. %)	C	5	10	15

The degrees of freedom (DOF) is defined as the number of comparisons from the process parameters that require determining which level is good and precisely how much better it is (Mathur et al., 2018).Taguchi supports the use of signal to noise ratio (SNR) the essential to maximize the performance of system or product by minimizing the effect of noise with maximizing the mean performance. The SNR treated as a response (output) of experiment. It is a measure of deviation when uncontrolled noise factors were present in system (Nitin Mukesh Mathur K. B., 2018). The response values are transformed into a signal-to-noise ratio to measure the quality characteristics deviating from the desired value; a larger S/N ratio has higher-quality characteristics (Kanthavel Karuppusamy, 2015). The degree of freedom (DOF) can be calculated by the formula given below.

$$\mathrm{DOF} = \mathrm{P}' \times (\mathrm{L} - 1) \tag{3.1}$$

Where, P' = number of factors and

L = number of levels

$\mathrm{DOF} = 3 \times (3 - 1) = 6$

However, the total number of experiments of the orthogonal array (OA) should be greater than or equal to the DOF required for the experiment. Thus, the L9 orthogonal array was selected to make the further experiments are shown table 3.6.

Table 3.6. The L9 orthogonal array (OA) and its level of control factors.

Exp. No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

For this study A (elephant grass fiber wt. %), B (bamboo fiber wt. %), and C (glass fiber wt. %). In this nine different composite were fabricated with different parameters and at different levels. The effects of these parameters on the response i.e. the hardness, compressive, impact, flexural, tensile strength of the composite were studied using Analysis of variance (ANOVA).

Data Analysis

Data collected from Taguchi/Orthogonal Array (OA) experiments can be analyzed using response graph method or Analysis of Variance (Shahabudeen, 2012).

A. Analysis of Variance

The statistical foundations for design of experiments and the Analysis of Variance (ANOVA) were first introduced by Sir Ronald A, Fisher, and the British biologist. ANOVA is a method of partitioning total variation in to accountable sources of variation in an experiment. It is a statistical method used to interpret experimented data and make decisions about the parameters under study (P.Shahabudeen, 2012). The basic equation of ANOVA is given by

$$\text{Total sum of squares} = \text{sum of squares due to factors} + \text{sum of squares due to error}$$

$$SS_{\text{Total}} = SS_{\text{Factors}} + SS_{\text{Error}} \tag{3.2}$$

(A. Athijayamani, 2016) Stated Taguchi experimental design with signal-to-noise (S/N) ratio and analysis of variance was used to prepare and for analysis of composite. S/N ratios help in data analysis and the prediction of the optimum results. ANOVA was employed to identify the important fabrication process parameters and to calculate the percentage contribution (PC) of each process parameter on the quality characteristics (responses) such as tensile strength, flexural strength, compressive, impact, hardness, water absorption, and density and porosity. The larger the better characteristic was selected to determine the S/N ratio for tensile strength, flexural strength and hardness tests as to be maximized.

The smaller the better characteristic was selected to determine the S/N ratio for water absorption to be minimized.

From the analysis of variance Percentage contribution of each influential parameter was calculated by the following formula: -

$$\text{PC} = \frac{\text{Sum of squares or treatment sum of squares}}{\text{Total sum of squares}} \times 100 = \frac{\text{SSTR}}{\text{SST}} \times 100 \tag{3.3}$$

Where, PC: Percentage contribution of individual factor,

SSTR: Sum of squares or treatment sum of squares, and

SST: Total sum of squares.

In the analysis of variance, the percentage contributions of each control factor were used to measure the corresponding effects on the performance characteristics. The significance level of 5%, i.e., for 95% level of confidence was considered in this analysis. ANOVA results indicate whether there is statistical significance indifference or not in output characteristics. ANOVA analysis involves when α values are below 0.05 is significant and above 0.05 is not significant. Percent contribution measures the contribution of each model term relative to the total sum of squares. It is often a rough but effective guide to the relative importance of each model term. The variance (V) of any factor/component is given by its sum of squares divided by its degrees of freedom. It is also referred to as Mean Square (MS). It is individual variation divided by the degree of freedom of that factor.

$$\text{V} = \frac{\text{Sum of the square}}{\text{degree of freedom}} \tag{3.4}$$

F-test is used to test whether the effects due to the factors are significantly different or not. F-value is computed by dividing the factor variance/mean square with error variance/mean square. However, in the case of multi-factor designs with random effects or mixed effects model, the denominator for computing F-value shall be determined by computing expected mean squares (P.Shahabudeen, 2012). F-test is a qualitative analytical tool to observe which process parameters have a significant effect on the process.

$$F_A = \frac{S_A}{S_E} = \frac{V_A}{V_E} = \frac{\text{Sum of the square of factor}}{\text{sum of the square of the error}} \qquad (3.5)$$

The weight fraction of the Fibers and the Matrix Content of the Composite

The mechanical properties of the composite were affected by the content of fibers and matrix materials. This can be expressed either as volume fractions or as mass fractions. During fabrication using the mass, fractions are easier. Volume fractions are used in the theoretical analysis of composite

Table3.7. Designation and Composition in weight percentage of the composite.

Designation	Composition in weight percentage of the composite			
	Polyester	Elephant grass fiber	bamboo fiber	Glass fiber
S1	85	5	5	5
S2	75	5	10	10
S3	65	5	15	15
S4	75	10	5	10
S5	65	10	10	15
S6	70	10	15	10
S7	65	15	5	15
S8	70	15	10	5
S9	60	15	15	10

Mass Fraction of Fiber and Matrix Content of the Composites

$$\text{The total mass of composite}$$
$$= \text{mass of fiber} + \text{mass of matrix}$$

$$M_c = M_f + M_m \tag{3.6}$$

$$\text{Fiber mass fraction} = \frac{\text{mass of fiber}}{\text{total mass}} = M_F = \frac{M_f}{M_m}$$

$$\text{Matrix mass fraction} = \frac{\text{mass of matrix}}{\text{total mass}} = M_M = \frac{M_m}{M_m}$$

$$M_F + M_M = 1$$

Volume Fraction of Fiber and Matrix (V_F, V_M) of Composites

$$\text{Volume of fiber} = \frac{\text{mass of fiber}}{\text{density of fiber}} = V_f = \frac{M_f}{\mathcal{P}_f}$$

$$\text{Volume of matrix} = \frac{\text{mass of matrix}}{\text{density of matrix}} = V_f = \frac{M_m}{\mathcal{P}_m}$$

$$V_c = V_f + V_m$$

$$\text{fiber Volume fraction} = \frac{\text{volume of fiber}}{\text{total volume}} = V_F = \frac{v_f}{v_f + v_m}$$

$$\text{matrix Volume fraction} = \frac{\text{volume of matrix}}{\text{total volume}} = V_M = \frac{v_m}{v_f + v_m}$$

Where:

V_c= Volume of composite (cm^3), V_f = volume of fiber (cm^3), V_m = volume of matrix (cm^3), M_c= Mass of composite (g), M_f = mass of fiber (g), M_m = mass of matrix (g), $\mathcal{P}c$ = density of composite, $\mathcal{P}_f$ = density of fiber (g/cm^3), $\mathcal{P}_m$ = density of matrix (g/cm^3) , Volume fraction of fiber and V_M =Volume fraction of matrix

Calculation of the Mass of the Fiber and Matrix for Samples

The volume of the composite was calculated by multiplying the length, width, and breadth of the mold prepared for molding the composite material (Biraj Dhibar, 2018).

$$\text{volume of the composite} = l \times w \times t \tag{3.7}$$

Where, l = length, w = width and t = thickness

l = 300 mm, w = 300 mm and t = 4 mm

$$\text{Volume of the composite} = 300\ \text{mm} \times 300\ \text{mm} \times 4\ \text{mm}$$

$$\text{Volume of the composite} = 360000\ \text{mm}^3 = 360\ \text{cm}^3$$

According to the density of elephant grass fiber, polyester resin, glass fiber, bamboo fiber was given bellow in g/cm3.

- Elephant grass fiber = 0.817 g/cm3
- Polyester resin = 1.15 g/cm3
- Glass fiber = 2.58 g/cm3
- Bamboo fiber = 1.1 g/cm3

$$V_c = V_{polyester} + V_{Elephant\ grass} + V_{Bamboo} + V_{Glass\ fiber} \tag{3.8}$$

For sample – 1

Elephant grass fiber = 5wt. % = 0.05

Glass fiber = 5 wt. % = 0.05

Polyester resin =85 wt. % = 0.85

bamboo fiber = 5 wt. % = 0.05

The density of the composite was calculated by the rule of law of the mixture method and obtained first by adding the volume fraction of polyester resin, bamboo fiber, elephant grass fiber and glass fiber for each composite ratio (Biraj Dhibar, 2018).

$$\frac{M_c}{\mathcal{P}_c} = \frac{m_{polyester}}{\mathcal{P}_{polyester}} + \frac{m_{elephant\ grass}}{\mathcal{P}_{elephant\ grass}} + \frac{m_{Bamboo}}{\mathcal{P}_{Bamboo}} + \frac{m_{glass}}{\mathcal{P}_{glass}} \tag{3.9}$$

The density of composite obtained from equation above.

$$\frac{1}{\mathcal{P}_c} = \frac{0.85}{1.15} + \frac{0.05}{0.817} + \frac{0.05}{1.1} + \frac{0.05}{2.58}$$

$$= 0.865$$

$$\mathcal{P}_c = 1.156\,{}^{g}/_{cm^3}$$

Mass of composite was calculated by using equation of (Biraj Dhibar, 2018).

$$\text{mass of composite} = \text{density of composite} \times \text{volume of composite} \tag{3.10}$$

$$m_c = \mathcal{P}_c \times V_C$$

After getting the density of the composite, it is multiplied by the volume of the composite the mass of composite obtained.

$$m_c = \mathcal{P}_c \times V_c$$

$$m_c = 1.156\,{}^{g}/_{cm^3} \times 360cm^3$$

$$m_c = 416.18g$$

The mass of the composite is multiplied by each particulate /fiber/matrix ratio. Then the mass of each elephant grass, bamboo, E-glass fiber, and unsaturated polyester resin was obtained.

$$\text{Mass of Elephant grass fiber} = 0.05 \times m_c$$

$$\text{Mass of elephant grass fiber} = 0.05 \times 416.18\ g = 20.8\ g$$

$$\text{Mass of bamboo fiber} = 0.05 \times m_c$$

$$\text{Mass of bamboo fiber} = 0.05 \times 416.18g = 20.8g$$

$$\text{Mass of glass fiber} = 0.05 \times m_c$$

$$\text{Mass of glass fiber} = 0.05 \times 416.18\ g = 20.8g$$

$$\text{Mass of Polyester} = 0.85 \times m_c$$

$$\text{Mass of polyester} = 0.85 \times 416.18\ g = 353.753\ g$$

By calculating for other sample of the composites in similar ways the results were given

Table 3.8. Mass of each specimen of composites.

	Composition (wt. %)				**Mass (g)**				
Designation	Polyester	Elephant grass	bamboo	glass fiber	Polyester	Elephant grass	bamboo	glass fiber	Total
S1	85	5	5	5	353.75	20.8	20.8	20.8	416.2
S2	75	5	10	10	320.22	21.348	42.696	42.696	426.96
S3	65	5	15	15	285.01	21.924	65.772	65.772	438.48
S4	75	10	5	10	314.55	41.94	20.97	41.94	419.4
S5	65	10	10	15	279.86	43.056	43.056	64.584	430.52
S6	70	10	15	5	284.1	40.586	60.879	20.293	405.86
S7	65	15	5	15	274.52	63.35	21.116	63.35	422.33
S8	70	15	10	5	279.22	59.83	39.889	19.944	398.89
S9	60	15	15	10	245.45	61.36	61.36	40.91	409.1
Total					2636.6	374.19	376.54	380.28	

3.3.2. Hand lay-up Technique

Composites were fabricated by hand lay-up technique. The composites with (5, 10, and 15) wt. % of elephant grass, bamboo and glass fibers were used for composites fabrication. The polyester resin and its hardener are also used as matrix materials. The fabrication process was conducted at room temperature. The mold plates with 300 mm x 300 mm are made from steel. The mold plates were covered with mold release wax and the mixture was poured into the mold plate. Then level the mixture to have a uniform thickness. Finally closing the mold plates by applying for the upper plate and high load materials. High load material are loaded on the mold to remove excess GP resin and curing for 24 hours at room temperature. After curing period, the hybrid elephant grass, bamboo and glass fiber chopped GP matrix were removed from mold. Nine experimental runs were finished in the same ways.

Figure3.8. Composites samples fabrication process.

3.3.3. Specimens Preparation Procedures

Chopped glass, bamboo and elephant grass reinforced fibers and polyester matrix composite fabricated based on Taguchi's L9 experimental design using the hand-layup method. The following steps are used for the prepared sample.

Bamboo and elephant grass fibers were collected and extracted manually from Oromiya and Benishangul region then treated by using 8 grams of NaOH with 10 liters of distilled water in the plastic container. The fibers are then soaked in the solution for 4 hours. Then, treated fibers were washed many times till it becomes neutral by means of down runner water. Finally, it dried in air for one day in sunlight. The chopped glass, bamboo and elephant grass fibers according to the desired Wight ratio by weighing individually and hybridize them. Polyester resin and hardener (catalyst) were bought from local market and also brushes; gloves, roller wax, steering wood and scissors were purchased from the local pharmacy and market centers. Prepare the Mold from timber wood to fabricate samples.

Simple hand lay-up composite production method was used that followed by compression molding for 48 hours to remove excess resin and air bubbles and curing for 48 hours. The samples were cut to specimens according to the standard dimensions for each test (tensile, flexural, hardness, impact, water absorption, morphological analysis, density, and porosity) using the specimen’s cutter or grinder machine. All tests were performed at room temperature. The result was analyze and optimal hybrid composite fabrication Wight ratio was identified.

Generally, methodology flow chart for preparation of hybrid composite shown in Fig below.

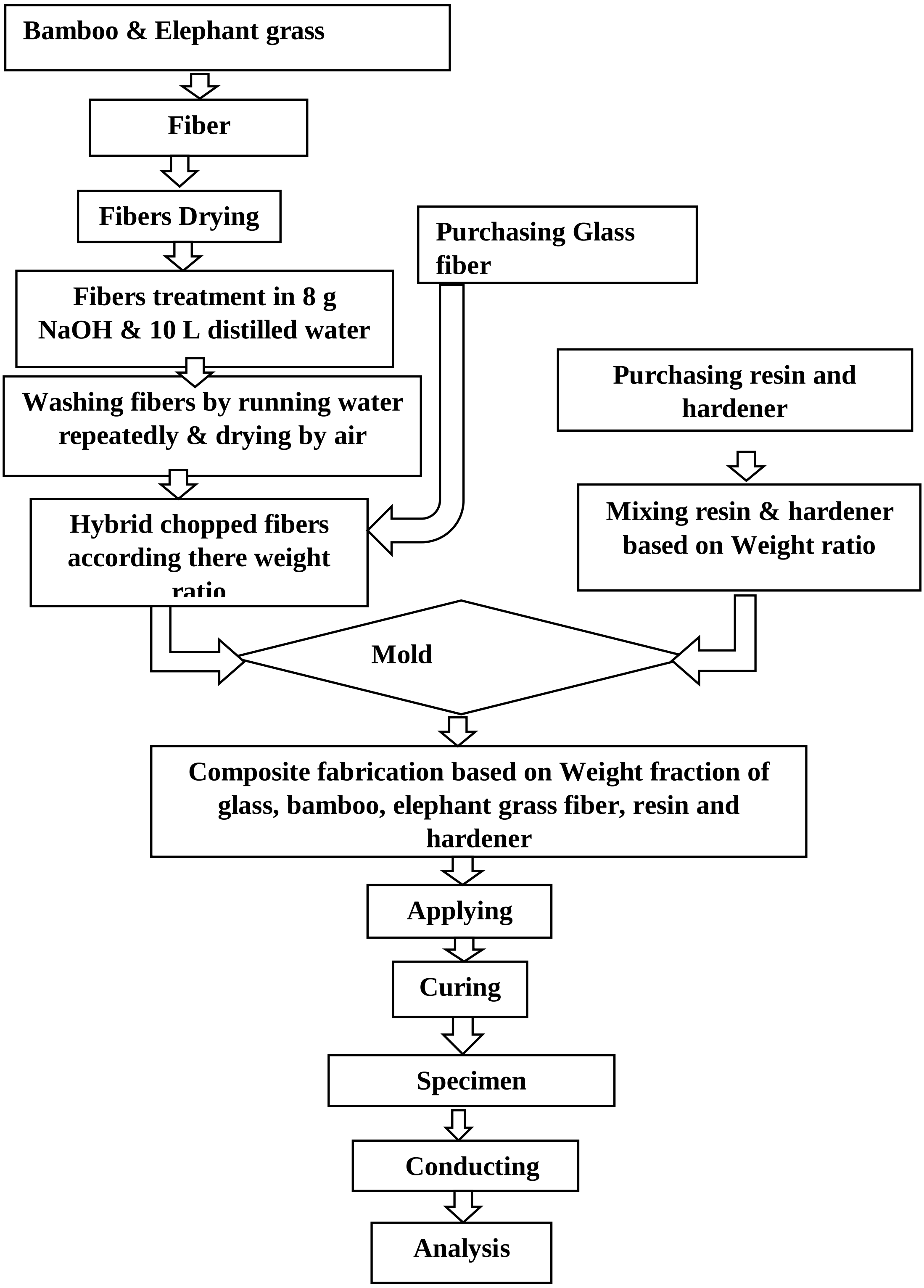


Figure 3.9. Flow diagram of the specimen's preparation process.

3.4. Research methodology

Various steps followed in methodology of the thesis work were shown in the form of flow chart shown below

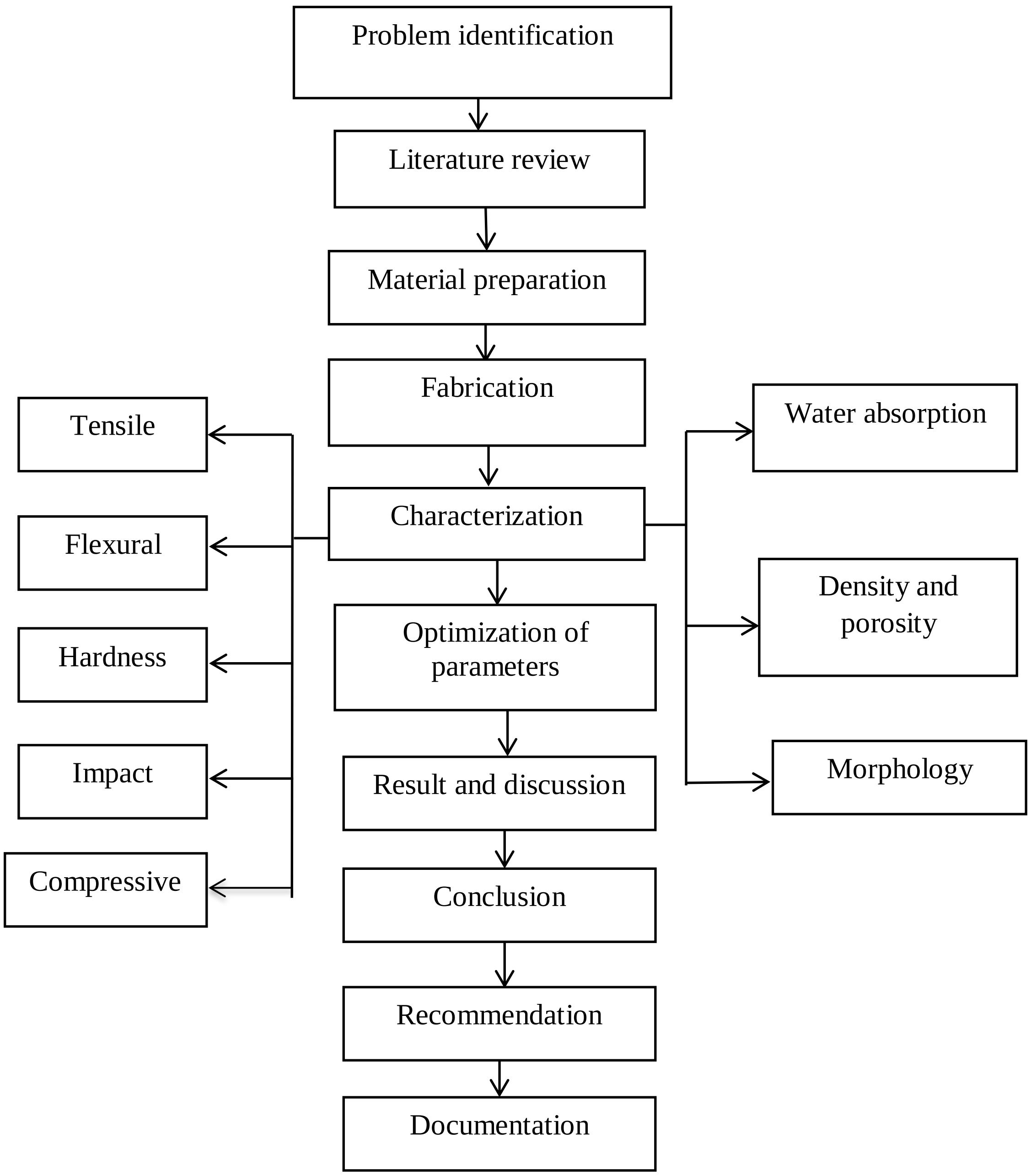


Figure 3.10. Research methodology.

3.5. Equipment Used for Study

Equipment was used for performing tests as well as all tasks needed in studies. These include Analytical (digital) mass balance, Specimen cutter, Universal testing machine (UTM), Vickers hardness testing machine, drilling machine, impact test machine and, Scanning electron microscope.

3.5.1. Analytical (Digital) Mass Balance

The digital mass balance is used for weighting the amount of Bamboo, elephant grass, glass fiber and Polyester resin used for sample preparation. The balancing equipment was used for the physical characterization of composite property. It was found in the chemistry lab.

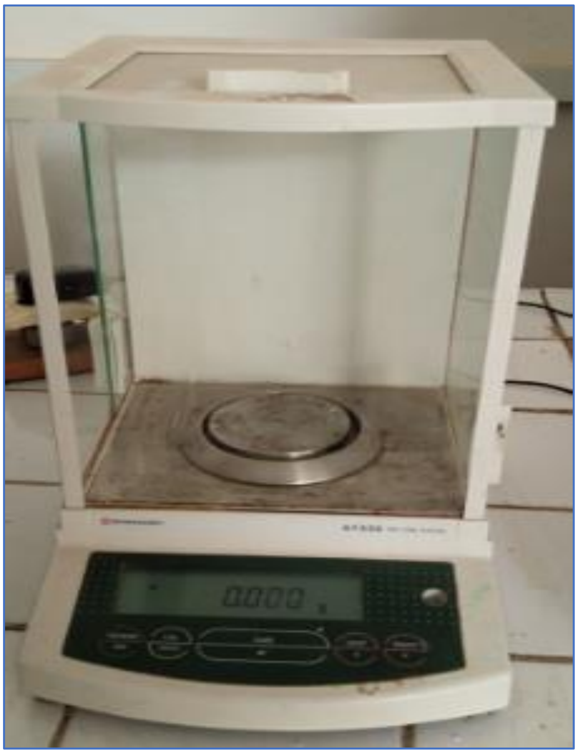


Figure 3.11. Mass balance.

3.5.2. Specimen Cutter Machine

Specimen cutter machine is a grinder used for cutting samples into specimens according to ASTM Standard test. Then prepared specimens were finally polished by polished paper.

Figure3.12. Specimen Cutter machine.

3.5.3. Universal Testing Machine

The universal testing machines are a computer equipped machines used to measure the Mechanical properties of materials under different load conditions. This can measure tensile, Compressive and bending strength of the materials by simply by changing the jaws and modes of operations (Diriba, 2018). The main parts of the UTM are main frame, drive system, movable crosshead, load cell, and digital indicator. The main frame includes the rectangular base where the gearbox is placed, the fixed crosshead and the two vertical parallel columns. The drive system includes a stepper motor with variable speed. The gearbox is formed by a worm shaft, and two worm gears, which moves the two drive screws. The movable crosshead is integrated by the bottom grip, two conical fastener tools with internal thread and an adjustable conical ring. The conical fastener tools provide stabilization to the movable crosshead when moving along the drive screws. The load cell can be used for tension or compression testing; it is located on the upper side of the frame and supports the upper grip. The digital indicator measures the crosshead displacement and consists of a digital micrometer from Starret with 0.001 mm of resolution, which is connected with an RS232 interface to a computer to acquire data (E. Huerta, 2010). The UTM is connected with a computer display which allows us to print the test output (stress-strain curve). Specimen dimensions, speed of the machine, alignment and others were fixed before machine startup. This UTM was found in Ethiopian Conformity Assessment Enterprise (ECAE) in Addis Ababa, Ethiopia

Figure 3.13. Universal testing machine.

3.5.4. Vickers Hardness Machine

The Vickers hardness machine was used HV50. It was used for surface hardness testing. This machine found in Adama science and Technology University in material science engineering laboratory.

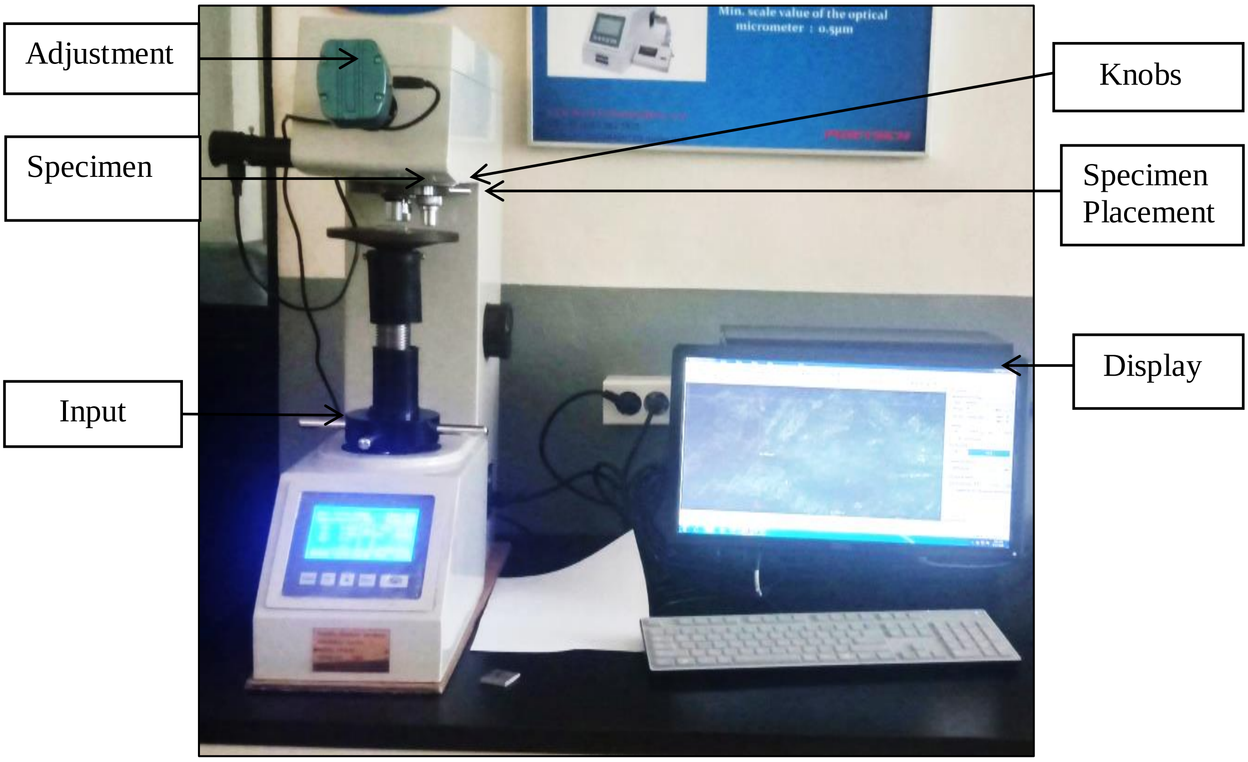


Figure 3.14. Vickers Hardness Machine.

3.5.5. Impact Test Machine

The impact strength of material provides information regarding the energy required to break a specimen of a given dimension, the magnitude of which reflects the material's ability to resist a sudden impact (Elanchezhiana, 2018). The Charpy impact test is also known as the Charpy V- notch test. It is a standardized high Strain-stress test that determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study \temperature-dependent ductile-brittle transition. It is widely used applied the industry since it is easy to prepare and conduct, results can be obtained quickly and cheaply (Negash, 2021).

This machine was found at Defence University of Engineering College, Bishoftu, Ethiopia.

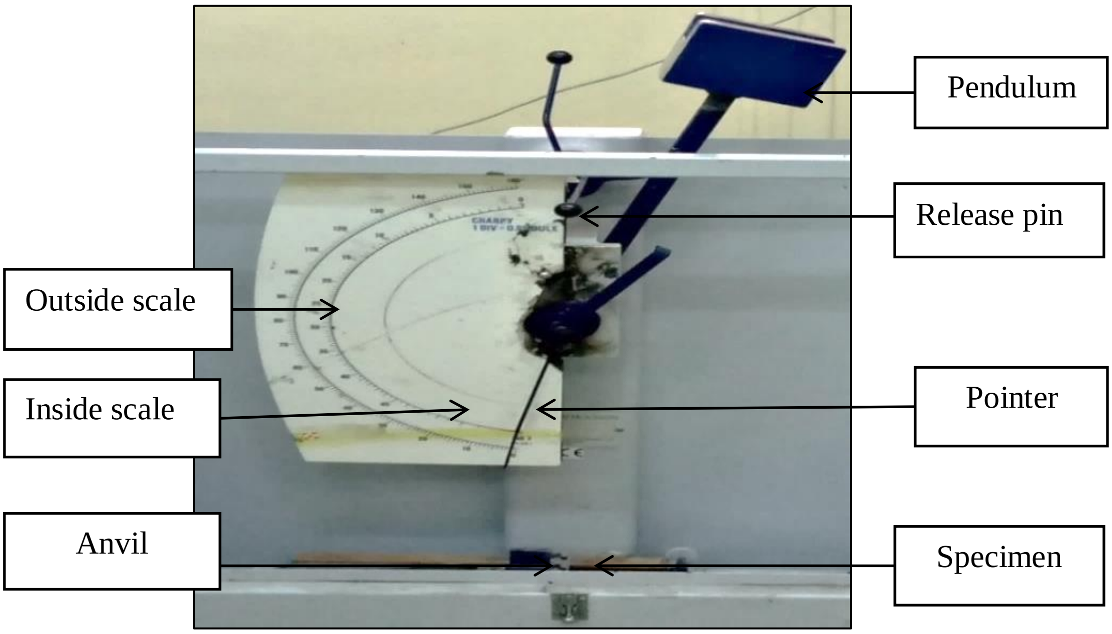


Figure 3.15. Impact testing machine.

3.5.6. Scanning Electron Microscope

A JEOL JSMS310 model scanning electron microscope was used to observe the morphology of the composite surface. Specimens to be observed under the SEM were mounted on conductive adhesive tape, sputter-coated with gold, and observed in the SEM using a voltage of 15kV. This Scanning Electron microscope was found at Adama Science and University Technology, in Biology Department.

Figure3.16. Scanning Electron Microscope.

3.6. Composite Characterization

The composite characterization involves both mechanical and physical characterization of the fabricated specimens. These characterizations were performed at room temperature and by using the ASTM standard for each test performed.

3.6.1. Mechanical Characterization

The mechanical characterization consists of the tensile strength, flexural strength, compressive strength, Vickers hardness, and impact test of fabricated composite specimens.

1. Tensile Strength Testing

The tensile test is a measurement of the ability of a material to withstand forces that tend to pull it apart and to what extent the material stretches before fracture. The tensile strength of a material is the maximum amount of tensile stress obtained before failure. The tensile strength can be calculated as force per unit area applied to the material. It is maximum tensile stress, which is the limit of the material to withstand exerted tension force without causing faulty. The specimen used for the tensile test is the flat type. During the tests, a uniaxial load is applied through both ends of the sample. The samples were positioned vertically in the grips of the testing machine. The grips were then tightened evenly and firmly to prevent any slippage. As the tensile test starts, the specimen elongates; the resistance of the specimen increases and is detected by a load cell. This load value (F) is recorded until a rupture of the specimen occurred. Instrument software provided along with the equipment will calculate the tensile properties for yield strength and elongation at break. Tensile strength at yield = Maximum load recorded/Cross-section area (Kumar, 2016). Tensile test was conducted in Ethiopian Conformity Assessment Enterprise (ECAE) in Addis Ababa, Ethiopia. Tensile strength test performed according to the ASTM D3039 on the computerized USM with a capacity of up to 2000KN. The specimen size tensile strength test was 300 mm × 30 mm × 3.5mm. The tensile Strength of the composite was given by (Suresh, 2020) as follows.

$$\text{Tensile strength} = \frac{\text{load}}{\text{area}} \tag{3.11}$$

$$\sigma_t = \frac{P}{w \times t}$$

Where, P = load Applied (N)

w = width (mm)

t = thickness (mm)

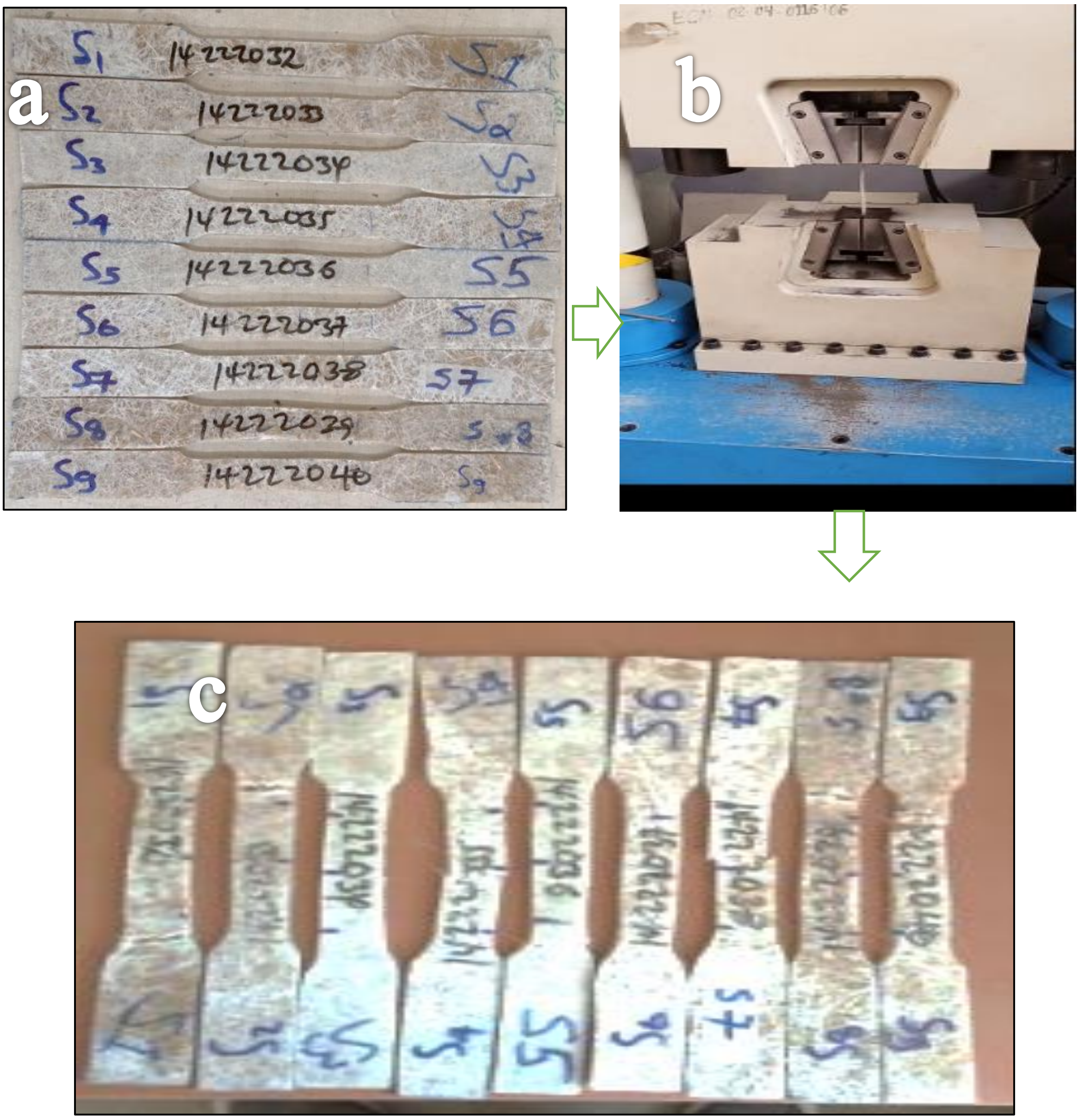


Figure 3.17. Tensile test specimens (a) before test (b) specimen machine (c) after test.

2. Flexural Strength Testing

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometimes it is referred to as cross-breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. This stress decreased due to the flexural load is a combination of compressive and tensile stresses. Two methods cover the determination of flexural properties of the material: three-point loading system and four-point loading system. Flexural Strength Test performed with ASTM D790-2010 (Andargie,

2020) . Specimens dimension of 150 mm × 25 mm × 4 mm. The flexural strength was given by (Suresh, 2020) as follows.

$$\sigma_f = \frac{3pl}{2wt^2} \tag{3.12}$$

Where, p = Load Applied (N), l = length (mm), w = width (mm), and t = thickness (mm)

A flexural strength test was done in Defense University of Engineering College in Bushoftu, Ethiopia by using Computer Controlled universal testing machine which has a capacity of up to 50 KN.

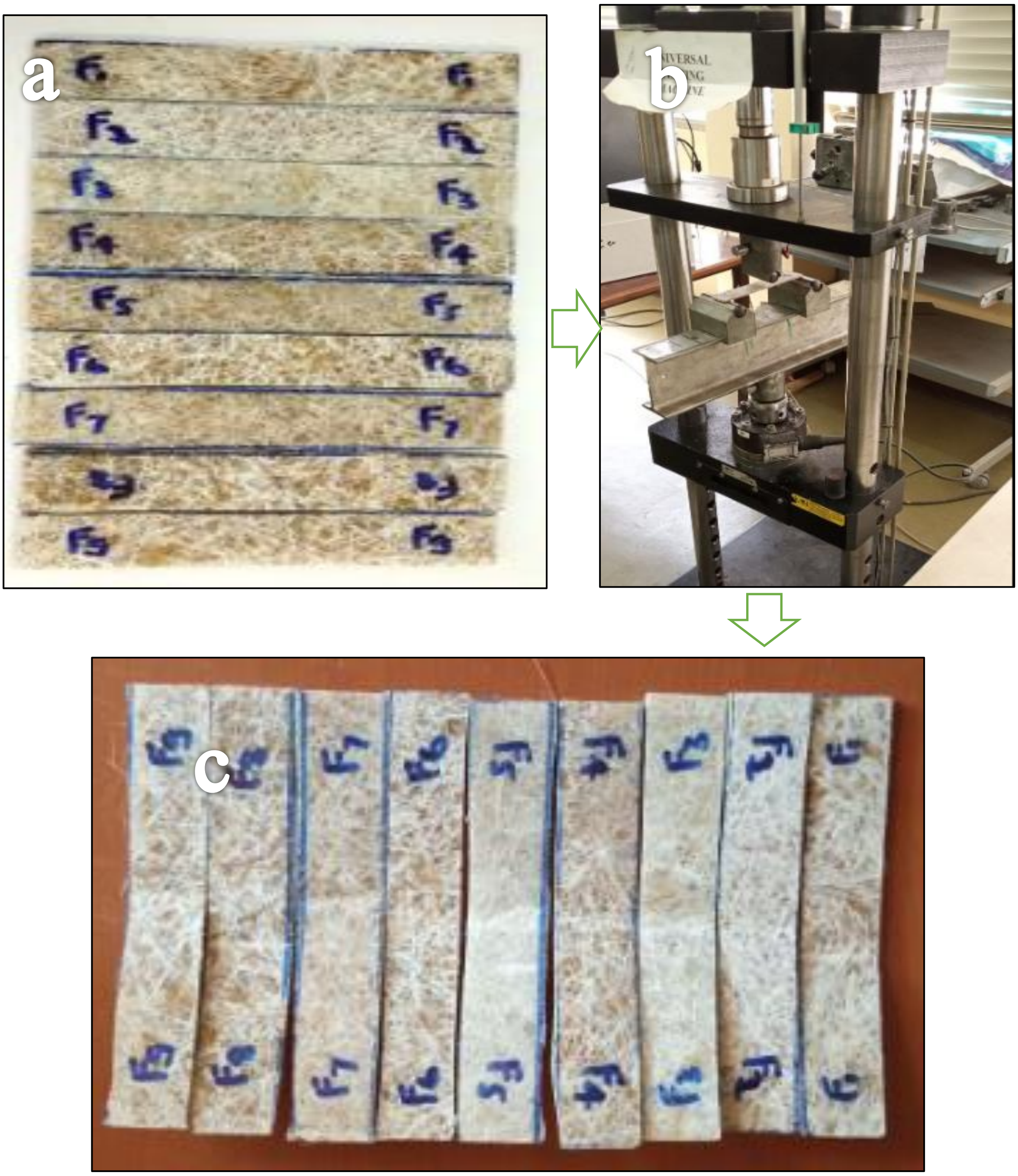


Figure 3.18. Flexural test specimens (a) before test (b) under machine (c) after test.

3. Compressive Strength

Compression strength Test performed with ASTM D790-2010 (Andargie, 2020) . Specimens dimension of 120 mm × 30 mm × 4 mm. The compression strength was given by (Suresh, 2020).

Where, p = Load Applied (N), l = length (mm), w = width (mm), and t = thickness (mm). A compressive strength test was done in Defense University, of Engineering College in Bushoftu, Ethiopia by using Computer Controlled universal testing machine which has a capacity of up to 50 KN.

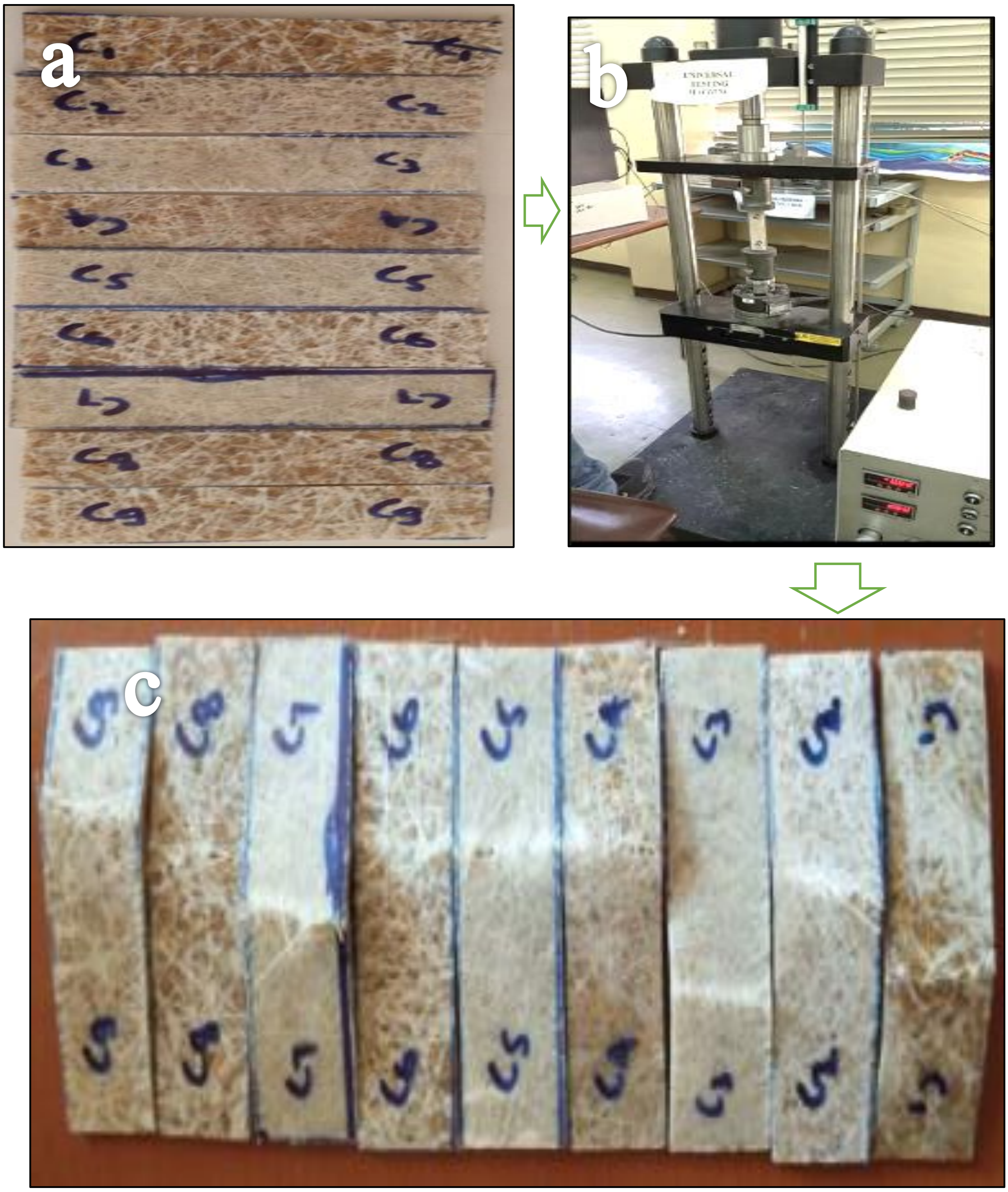


Figure 3.19. Compressive test specimens (a) before test (b) under machine (c) after test.

4. Impact Strength Testing

Impact strength is defined as the ability of a material to resist the fracture under stress applied at high speed. The impact properties of composite materials are directly related to overall toughness and composite fracture toughness is affected by inter laminar and interfacial strength parameters (K. Devendra and T. Rangaswamy, 2012). Impact strength test of the composite was prepared as per ASTM D (prepared to a size of (55 ×13 mm × 5 mm). A notch has been prepared with a depth of 2.5 mm at 45° inclination. Impact strength test performed in Defence University of Engineering College, Bishoftu, Ethiopia.

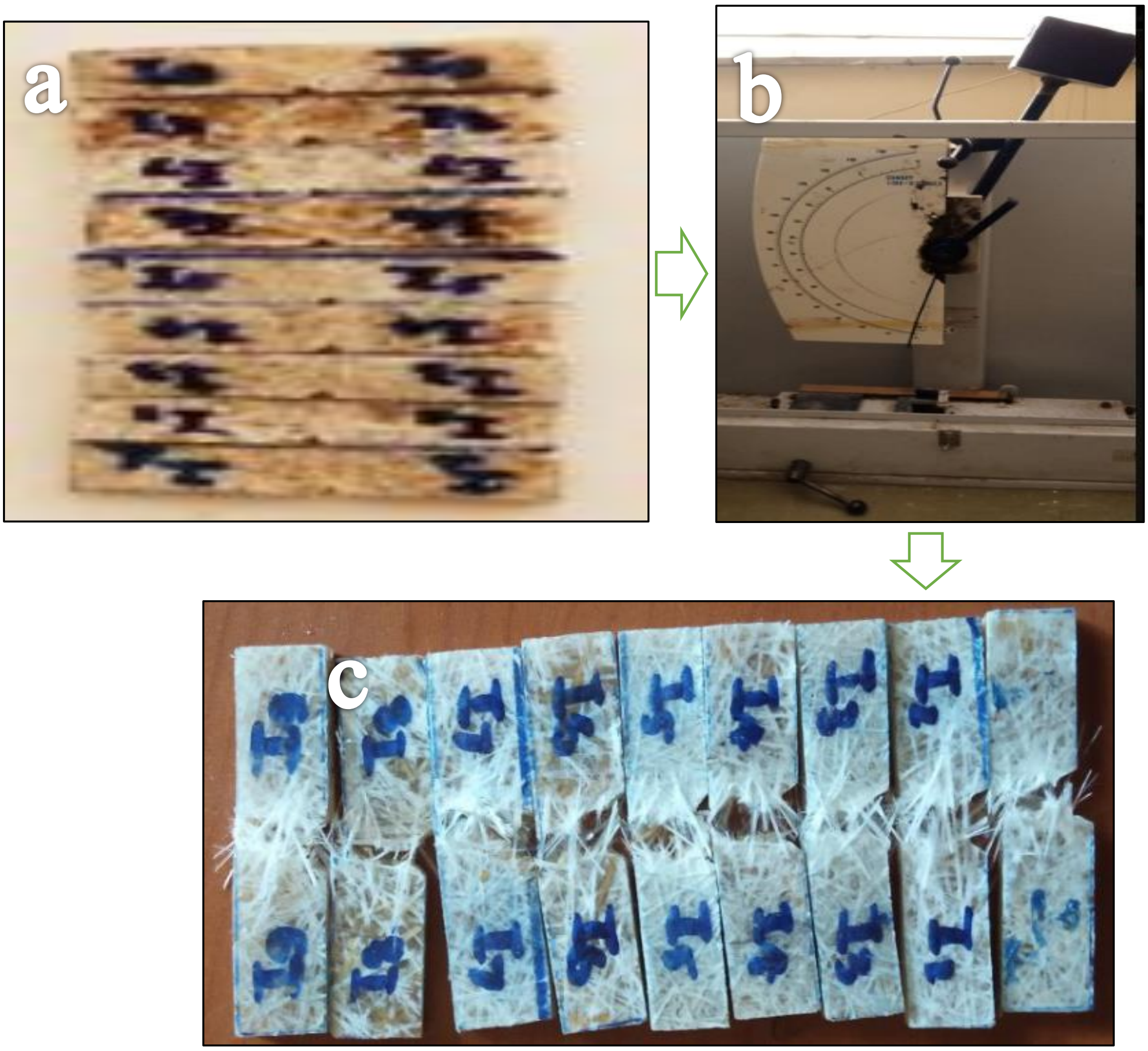


Figure 3.20. Flexural test specimens (a) before test (b) under machine (c) after test.

5. Vickers Hardness Testing

The Vickers hardness test involves measuring the amount of force required to implant a specified indentation on the surface of the specimen. A diamond indenter, in the form of a right pyramid with a quadrangular base and an angle of 136° among reverse faces is pressed into the material under a load p. Two diagonals x and y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic means L is calculated. Vickers hardness number was calculated using the given by (Biswas P. T., 2014).

$$H_v = 0.1889\frac{p}{L'^2} \text{ and } L' = \frac{x+y}{2} \tag{3.13}$$

Where P is the applied load (N), L′ is the diagonal of square impression (mm), x is the horizontal length (mm) and y is the vertical length (mm).

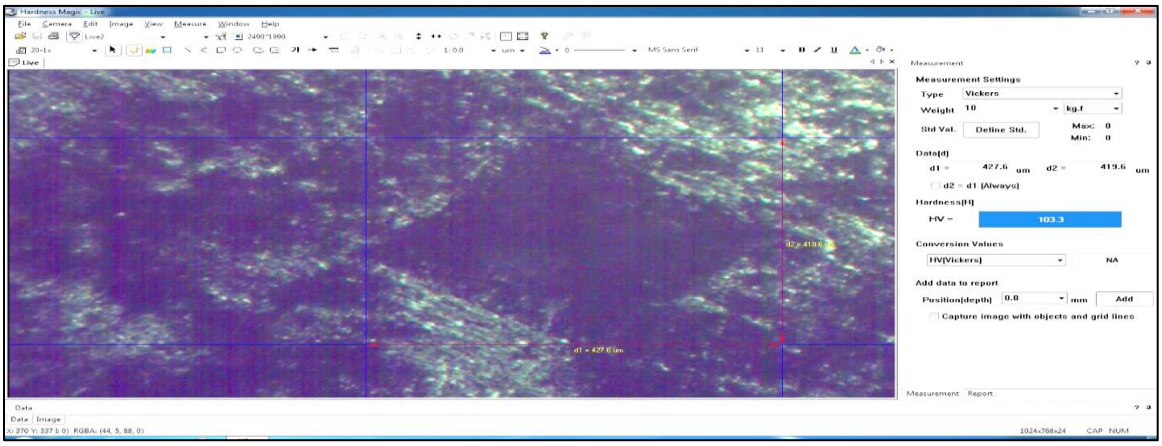


Figure 3.21. Hardness.

3.6.2. Physical Characterization

Physical characterization involves the characterization of physical properties of fabricated composite specimens. These include the studies of Water absorption, Density, and void fraction.

1. Water Absorption

Water absorption of composites is one major concern in their outdoor applications. Water absorption of composites was performed as per ASTM D570 (Yogesha, 2016). The water absorption tests of hybrid composites made from elephant grass, bamboo and E-glass fiber reinforced with polyester were done with Specimens dimension were 30 mm x 28 mm x 4 mm by immersion in distilled water at room temperature. The specimens were taken out periodically and after wiping out the water from the surface of the specimens weighted immediately using a digital mass balance to find out the content of water absorbed. The specimens were weighed regularly at (24, 48, 72, 96, 120, 144, 168 and 192) hours. The water absorption is calculated by the weight difference. The percentage weight gain of the specimens is measured at different time intervals by using the following equation (Biswas G. D., 2016).

$$\text{Water absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \tag{3.14}$$

Where, W_1 and W_2 are the weight of the dry and wet specimens.

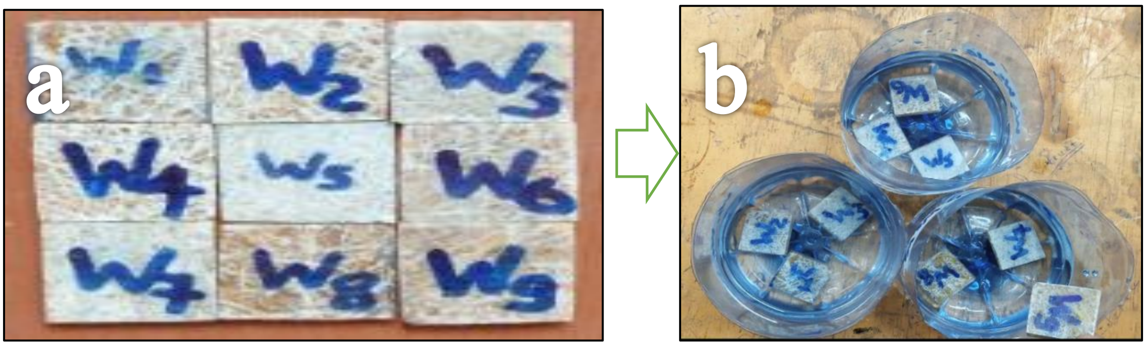


Figure 3.22. Water absorption test (a) specimens (b) drop in water.

2. Density and porosity

Density is the degree of compactness of a substance. Density is a measure of mass per volume of material. The density of composite is given by (Nor Azlina Ramlee, 2019).

$$\rho = \frac{m}{v} \tag{3.15}$$

Where ρ is the density of composite, m is mass of composite and v is volume of composite The reciprocal density of a substance is called its specific volume. The density of the material is directly related to the weight of the material. So as the density is reduced, the weight of the material will get reduced. The density of composite materials and their component can be calculated by any of the three methods. Archimedes method, the sink float method and the density gradient method. For this work, the actual density (ρ_a) of composite is determined by the Archimedes principle using rainwater as the medium. This method used the ASTM D792-13 standard (Luiz Guilherme Meira de Souza, 2020). The dimensions of the specimens were 30 mm length, 25 mm width, and 4 mm thickness of the materials. As per this principle when any object is immersed in the liquid the apparent loss in its weight is the same as the up thrust and equal to the weight of the liquid displaced (Pradhan, 2016). The density actual of the composites fabricated can be calculated as

$$\rho_a = \frac{\rho_w W_a}{W_a - W_w} \tag{3.16}$$

Where, ρ_a = actual density of composite or experimental density ρ_w = density of water W_a = weight of the composite in air and Ww = Weight of composite in water

The theoretical density of composite materials in terms of weight fraction is calculated using the following equation given by (Biswas P. T., 2017).

$$p_r = \frac{1}{\frac{W_f}{\rho_f}+\frac{W_m}{\rho_m}+\frac{W_p}{\rho_p}} \tag{3.17}$$

Where W and ρ represent the weight fraction and density, respectively. The suffixes f, m, p, and ct stand for the fiber, matrix, particulate filler, and composite materials, respectively.

The volume fraction of voids (Vv) in the composites is calculated using the following equation: (Nor Azlina Ramlee, 2019).

$$V_v = \frac{\rho_t - \rho_a}{\rho_t} \tag{3.18}$$

Where, ρ_t and ρ_a are the theoretical and experimental densities of the composite, respectively.

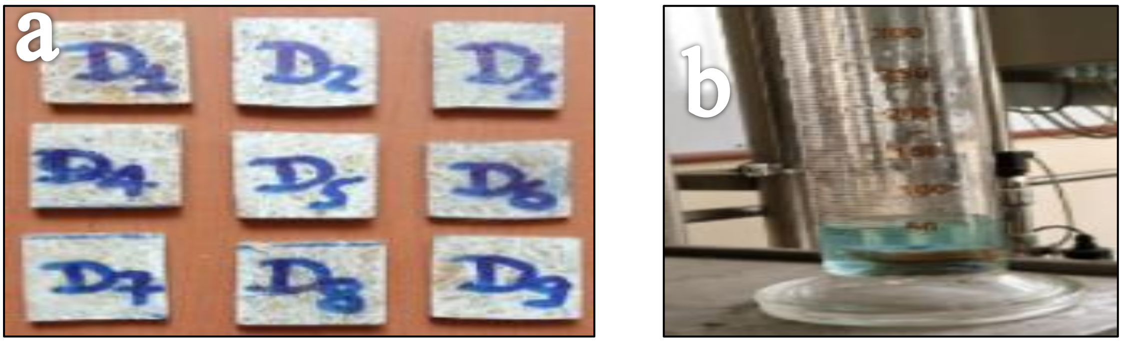


Figure3.23. Density and porosity specimens (a) specimens (b) biker.

3.7. SEM Morphological Analysis

SEM Morphological analysis under SEM was carried out, for S1 and S9. The reason to select these specimens show good mechanical properties (flexural and tensile respectively) when compared to the other specimens.

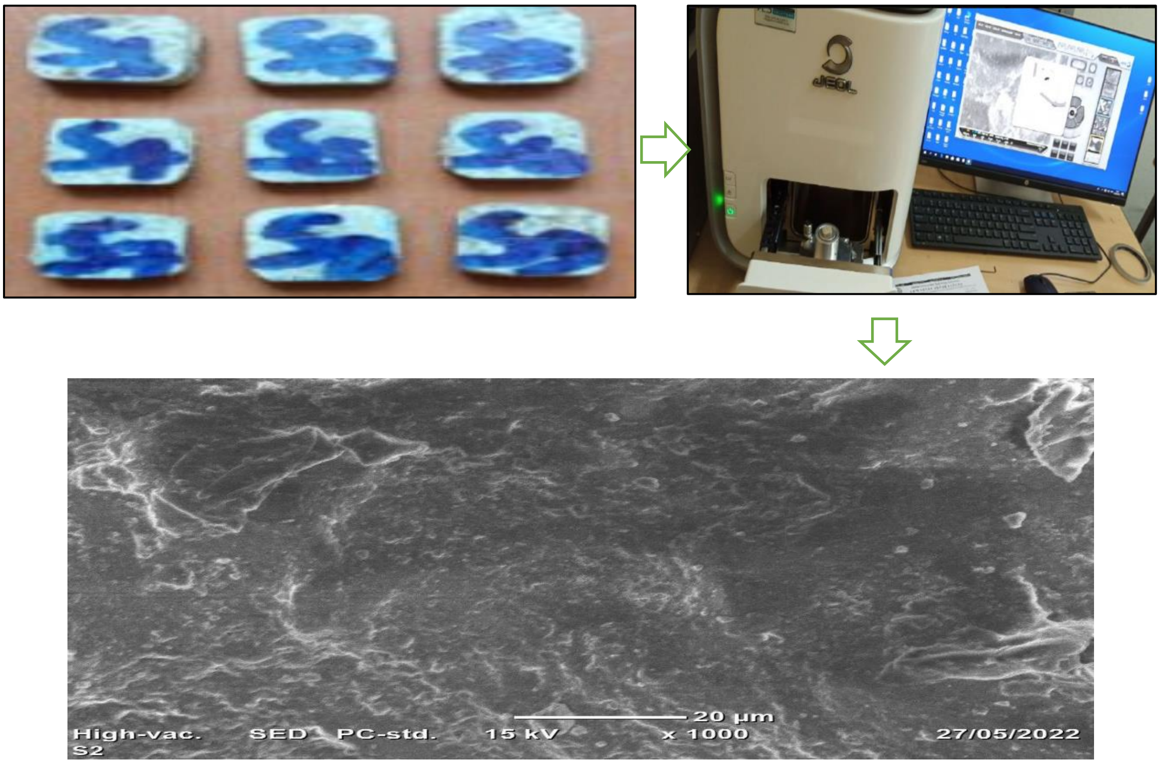


Figure 3.24. Specimens prepared for the SEM.

CHAPTER -4

RESULTS AND DISCUSSIONS

4.1. Introduction

In this chapter, the experimental work results of all tests have been discussed in detail. The tests performed in this study are tensile strength, flexural strength, compression strength, hardness, impact strength, water absorption, density and porosity, machinability and morphological analysis of hybrid composite made from Chopped bamboo, glass and elephant grass reinforced fibers and polyester. Taguchi experimental design with signal-to-noise (S/N) ratio and analysis of variance was used to prepare and for analysis of hybrid composite made from Chopped bamboo, glass and elephant grass reinforced fibers and polyester material.

4.2. Tensile Strength Test

From experimental work result for the tensile strength of hybrid composite made from Chopped bamboo, glass and elephant grass reinforced fibers and polyester material was obtained as follows.

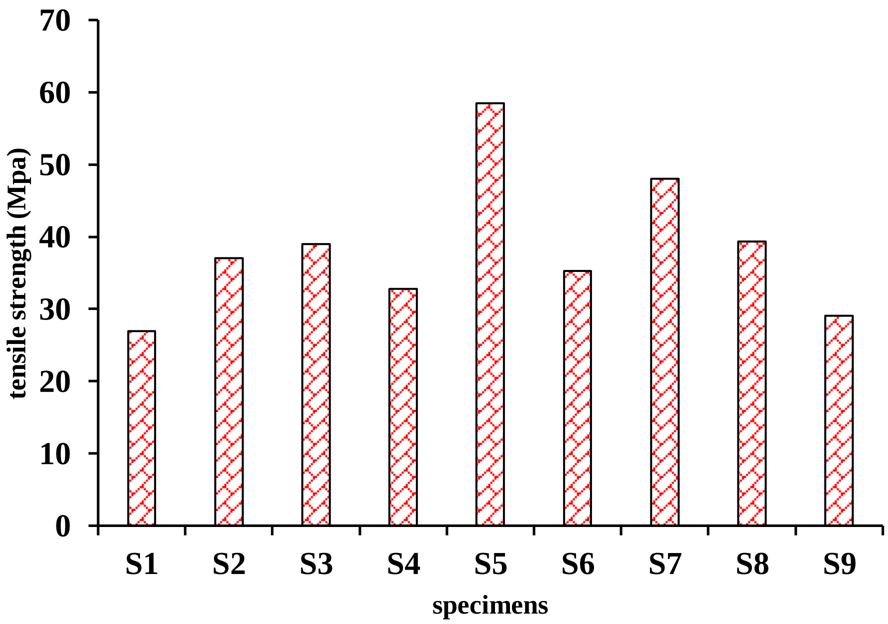


Figure 4.1. Tensile strength test results.

Figure: 4.1 shows the tensile strength test results for all specimens. Specimen 1 has a tensile strength result of 26.9 Mpa. This specimen was fabricated from 5wt. % of elephant grass fiber, 5wt. % of bamboo fiber, and 5wt. % of glass fiber. Specimen 2 has a tensile strength result of 37 Mpa. This specimen was fabricated from 5wt. % of elephant grass fiber, 10wt. % of bamboo fiber, and 10wt. % of glass fiber. Specimen 3 has a tensile strength of 39.1 Mpa. This specimen was fabricated from 5wt. % of elephant grass fiber, 15wt. % of bamboo fiber, and 15wt. % of glass fiber. Specimen 4 has a tensile strength of 32.8 Mpa. This specimen was fabricated from 10wt. % of elephant grass fiber, 5wt. % of bamboo fiber, and 10wt. % of glass fiber. Specimen 5 has a tensile strength of 58.5 Mpa. This specimen was fabricated from 10wt. % of elephant grass fiber, 10wt. % of bamboo fiber, and 15wt. % of glass fiber. Specimen 6 has a tensile strength of 35.3 Mpa. This specimen was fabricated from 10wt. % of elephant grass fiber, 15wt. % of bamboo fiber, and 5wt. % of glass fiber. Specimen 7 has a tensile strength of 48 Mpa. This specimen was fabricated from 15wt. % of elephant grass fiber, 5wt. % of bamboo fiber, and 15wt. % of glass fiber. Specimen 8 has a tensile strength of 39.3 Mpa. This specimen was fabricated from 15wt. % of elephant grass fiber, 10wt. % of bamboo fiber, and 5wt. % of glass fiber. Specimen 9 has a tensile strength of 29.1 Mpa. This specimen was fabricated from 15wt. % of elephant grass fiber, 15wt. % of bamboo fiber, and 10wt. % of glass fiber. From this, the specimen 5 shows maximum tensile strength.

Stress versus strain diagram for tensile strength given as below.

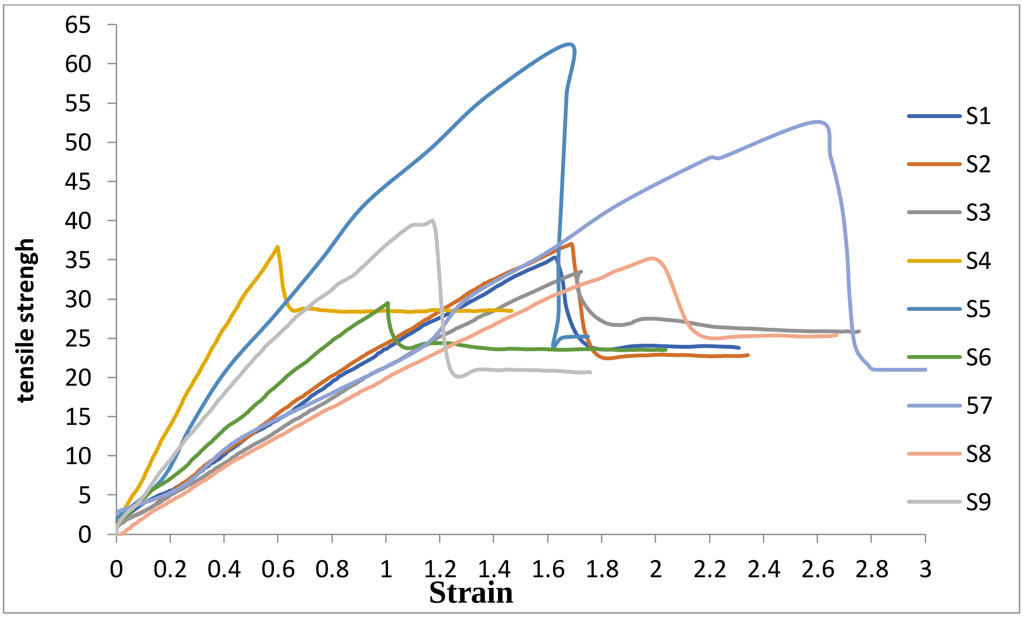


Figure 4.2. Stress vs strain for tensile test.

4.2.1. Taguchi Analysis using S/N ratios for Tensile Strength

Table 4.1. Response Table for Signal to Noise Ratios

Level	Elephant grass Fiber content	Bamboo fiber content	Glass fiber content
1	30.59	30.85	30.48
2	32.21	32.87	30.32
3	31.60	30.68	33.60
Delta	1.61	2.18	3.28
Rank	3	2	1

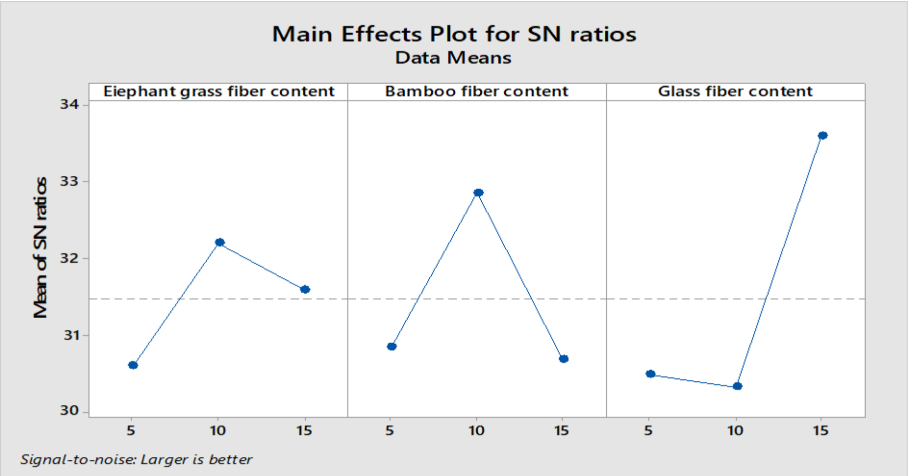


Figure 4.3. Tensile strength main effects plot for S/N ratio.

Looking at the response table 4.1 for the signal-to-noise (S/N) ratios shows that glass fiber Weight Percentage has the highest contribution in increasing the tensile strength of the composite with a delta number of 3.28. While bamboo fiber Weight Percentage is the second contributing factor in increasing the tensile strength of the composite with a delta number of 2.18 and third ranker contributing factor is elephant grass fiber Weight Percentage with a delta number of 1.61. The optimal parameter combination on larger is the better quality character is A2B2C3 are the possible parameter combinations for increasing the tensile strength of hybrid composite made from elephant grass, bamboo, glass fiber and polyester matrix material specimens. Figure 4.2 above shows the main effect plot for SN ratios shows that the optimum condition for the tensile test is A2B2C3 which contains 10% elephant grass fiber, 10% bamboo fiber, and 15% glass fiber.

4.2.2. Analysis of variance for S/N ratios for Tensile Strength

Table 4.2. Analysis of Variance for S/N ratios of tensile strength.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Elephant grass fiber content	2	94.22	12.41%	94.22	47.110	6.53	0.133
Bamboo fiber content	2	193.21	25.46%	193.21	96.603	13.39	0.069
Glass fiber content	2	457.15	60.23%	457.15	228.573	31.69	0.031
Error	2	14.43	1.90%	14.43	7.213		
Total	8	759.00	100.00%				

The last column of the ANOVA table shown in table 4.2 indicates the percentage of Contribution (Pc) in which Glass fiber weight percentage has the highest level of contribution (60.23%) followed by Bamboo fiber weight percentage (25.46%) and Elephant grass fiber fiber (12.41%).

4.3. Flexural Strength Test

From experimental work result for the flexural strength of hybrid composite made from elephant grass, bamboo and glass fiber and polyester material was obtained as below.

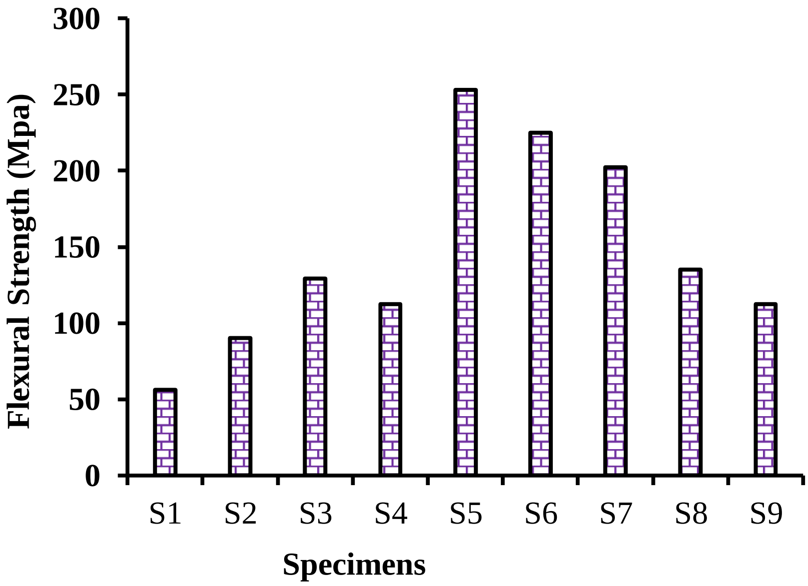


Figure 4.4. Flexural strength test result.

Figure: 4.4show the flexural strength for all specimens. Specimens (1, 2, and 3) were (56.25, 90, and 129.38) Mpa respectively. Specimens (4, 5, and 6) were (112.5, 253.13, and 225) Mpa respectively. Specimens (7, 8, and 9) were (202.5, 135, and 112.5) Mpa respectively. From this, specimen 5 shows maximum flexural strength.

4.3.1. Taguchi Analysis Using S/N ratios for Flexural Strength

Table 4. 3. Response Table for Signal to Noise Ratios

Level	Elephant grass fiber content	Bamboo fiber content	Glass fiber content
1	40.44	40.72	43.22
2	45.38	44.92	40.38
3	44.92	45.10	47.14
Delta	4.94	4.38	6.77
Rank	2	3	1

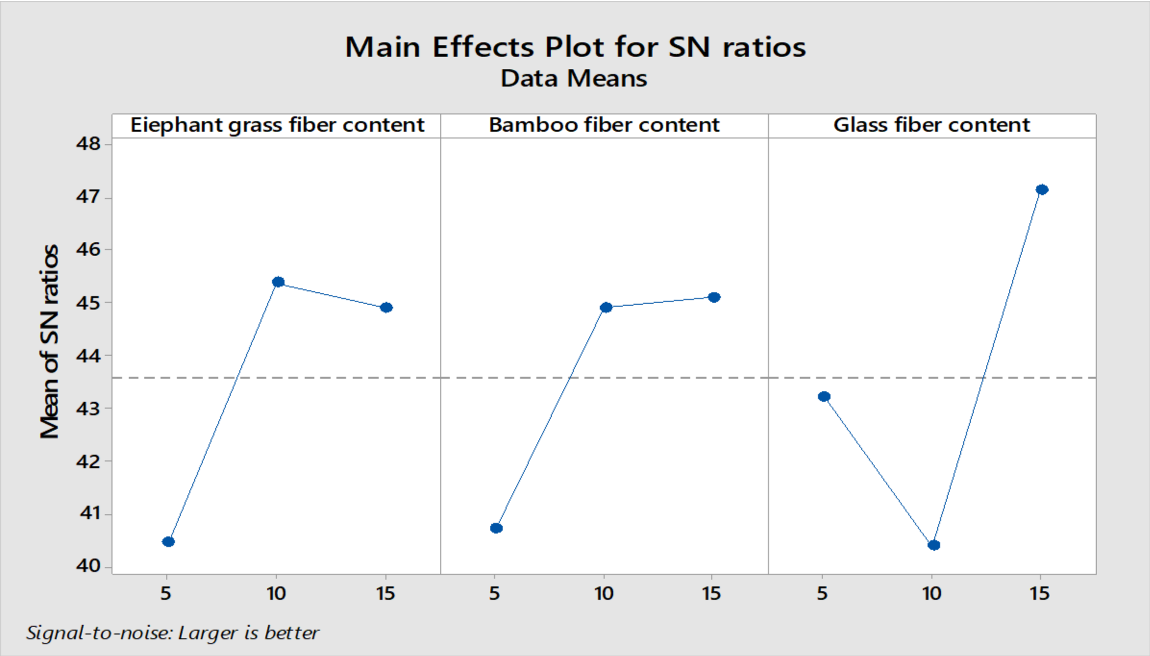


Figure 4.5. Flexural strength main effects plot for S/N ratio.

Figure 4.5 shows the signal-to-noise (S/N) ratios of flexural strength. This glass fiber Weight Percentage has the highest contribution in increasing the flexural strength of the composite with a delta number of 6.77. While elephant grass fiber Weight Percentage is the second contributing factor in increasing the flexural strength of the composite with a delta number of 4.94 and the third ranker contributing factor is bamboo fiber Weight Percentage with a delta number of 4.38. The optimal parameter combination on larger is the better quality character is A2B3C3 are the possible parameter combinations for increasing the flexural strength of hybrid composite made from elephant grass, bamboo, glass fiber and polyester matrix material specimens. Figure 4.6 above shows the main effect plot for SN ratios shows that the optimum condition for the flexural test is A2B3C3 which contains 10% elephant grass fiber, 15% bamboo fiber, and 15% glass fiber. This analysis leads to the conclusion that the process parameter combination of A2B3C3 gives the maximum flexural strength.

4.3.2. Analysis of Variance for S/N ratios of Flexural Strength

Table 4.4. Analysis of Variance for S/N ratios of Flexural Strength.

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Elephant grass fiber content	2	8798	19.36%	8798	4399	2.02	0.331
Bamboo fiber content	2	9295	20.46%	9295	4647	2.14	0.319
Glass fiber content	2	22992	50.60%	22992	11496	5.28	0.159
Error	2	4352	9.58%	4352	2176		
Total	8	45436	100.00%				

From Analysis of Variance shown in table 4.4 indicates the percentage of contribution (Pc) of process parameter for flexural strength. Glass fiber fiber weight percentage has the highest level of contribution (50.60%) followed by Bamboo fiber weight percentage (20.46%) and Elephant grass fiber (19.36%).

4.4. Impact Strength Test

Toughness refers to a material's ability to endure a rapidly imposed stress or the amount of energy absorbed or accepted by a material prior to failure. Matrix fracture, fiber/matrix deboning, and fiber pull-out are all examples of composite impact failure. In fiber reinforced composites, fiber pull–out is revealed to be an essential energy dissipation mechanism. When the applied load transferred to fibers via shear exceeds the fiber/matrix interfacial bond strength, fiber-matrix deboning occurs. Fiber fracture happens when the stress level surpasses the fiber strength. The shattered fibers may be yanked out of the matrix, causing energy to be wasted.

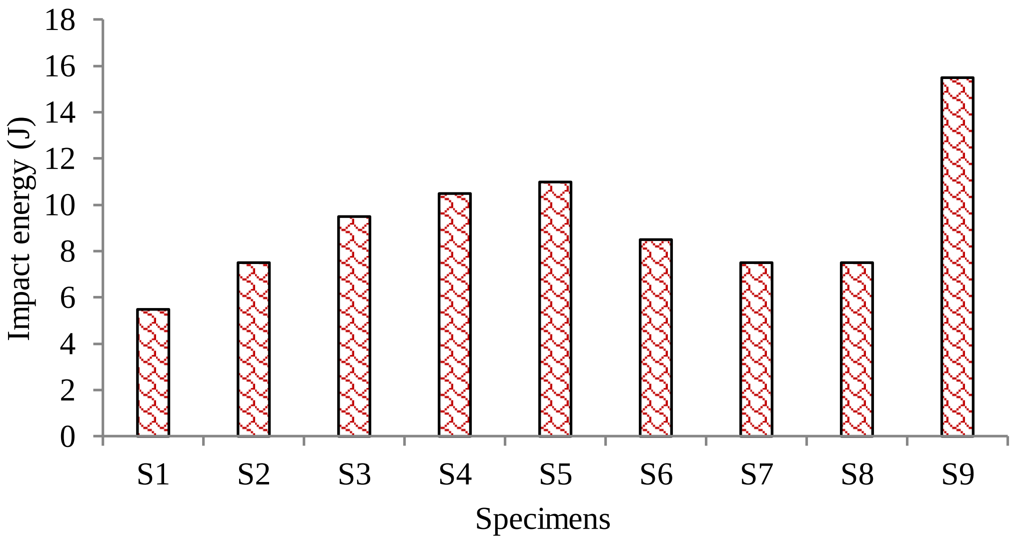


Figure 4.6. Impact test result.

Figure: 4.6 shows the impact test results. From this, the specimens (1, 2, and 3) have impact values (5.5, 7.5 & 9.5) J. Specimens (4, 5 and 6) have impact values (10.5, 11 and 8.5) J. Specimen (7, 8 and 9) have impact values (7.5, 7.5 and 15.5) J. The maximum impact strength was obtained at specimen 9 with 15.5J.

4.4.1. Taguchi analysis Using S/N Ratio for Impact

Table 4.5. Response Table for Signal to Noise Ratios.

Level	Elephant grass fiber content	Bamboo fiber content	Glass fiber content
1	17.29	17.58	16.97
2	19.95	18.61	20.58
3	19.60	20.65	19.29
Delta	2.66	3.07	3.61
Rank	3	2	1

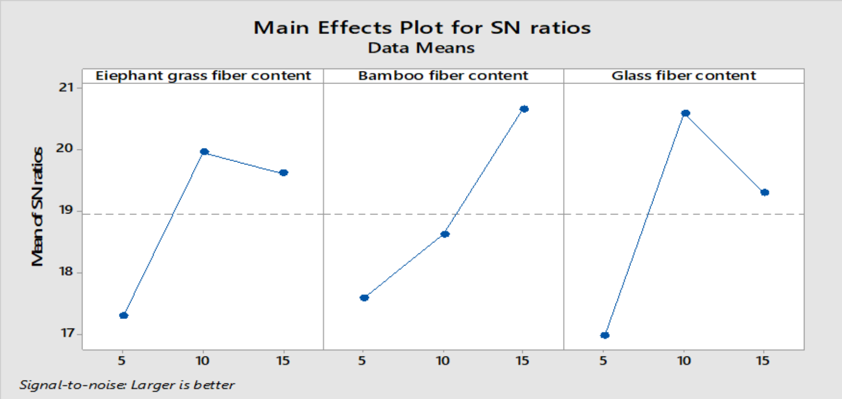


Figure 4.7. Impact main effects plot for S/N ratio for impact strength.

Table 4.5 shows the Response Table for Signal to Noise Ratios for the impact test. From this glass fiber content has the first ranker in the contribution of increasing the impact strength with a delta value of 3.61. Bamboo Fiber content has the second ranker in the contribution of increasing the impact strength with a delta value of 3.07. Elephant grass content has the third ranker in the contribution of increasing the impact strength with a delta value of 2.66. Figure: 4.7 Impact main effects plot for S/N ratio for impact strength demonstrate that mean S/N ratio maximum at level 2 for elephant grass fiber content of 10wt. %. Mean S/N ratio maximum at level 3 for the bamboo fiber content of 15wt. % and Mean S/N ratio maximum at level 2 for glass fiber content of 10 wt. %. This analysis leads to the conclusion that the process parameter combination of A2B3C2 gives the maximum impact strength.

4.4.2. Analysis of Variance for S/N ratios for Impact strength

Table 4.6 Analysis of Variance for S/N ratios for impact strength

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Elephant grass fiber content	2	13.39	19.82%	13.39	6.694	1.11	0.474
Bamboo fiber content	2	18.06	26.73%	18.06	9.028	1.50	0.400
Glass fiber content	2	24.06	35.61%	24.06	12.028	2.00	0.334
Error	2	12.06	17.85%	12.06	6.028		
Total	8	67.56	100.00%				

From Analysis of Variance shown in table: 4.6 indicate the percentage of contribution (Pc) of process parameter for impact strength. Glass fiber weight percentage has the highest level of contribution 35.61% followed by Bamboo fiber weight percentage 26.73% and Elephant grass fiber 19.82%.

4.5. Compressive Strength

Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. The formula for calculating compressive strength is: CS = F / A.

From the samples, the highest compressive strength recorded was 69.33MPa and the lowest recorded value was 17.33MPa. The maximum compressive strength value indicated that, the composite bears the maximum compressive load on its cross section before the material reached the fracture point.

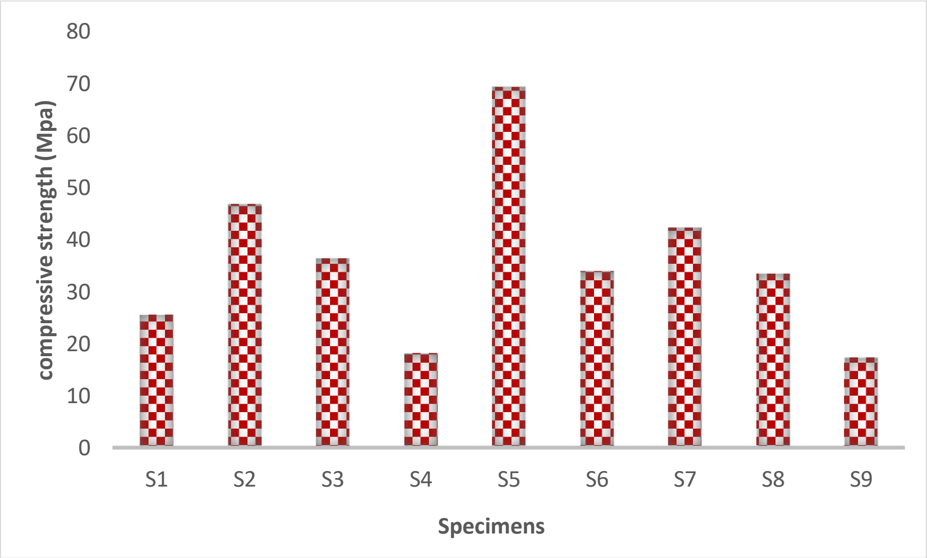


Figure 4.8. Compressive test result.

4.5.1. Taguchi analysis Using S/N Ratio for compressive strength

Table 4.7. Response Table for Signal to Noise Ratios

Level	Elephant grass Fiber content	Bamboo fiber content	Glass fiber content
1	30.93	28.63	29.76
2	30.89	33.58	27.80
3	29.26	28.88	33.53
Delta	1.67	4.94	5.72
Rank	3	2	1

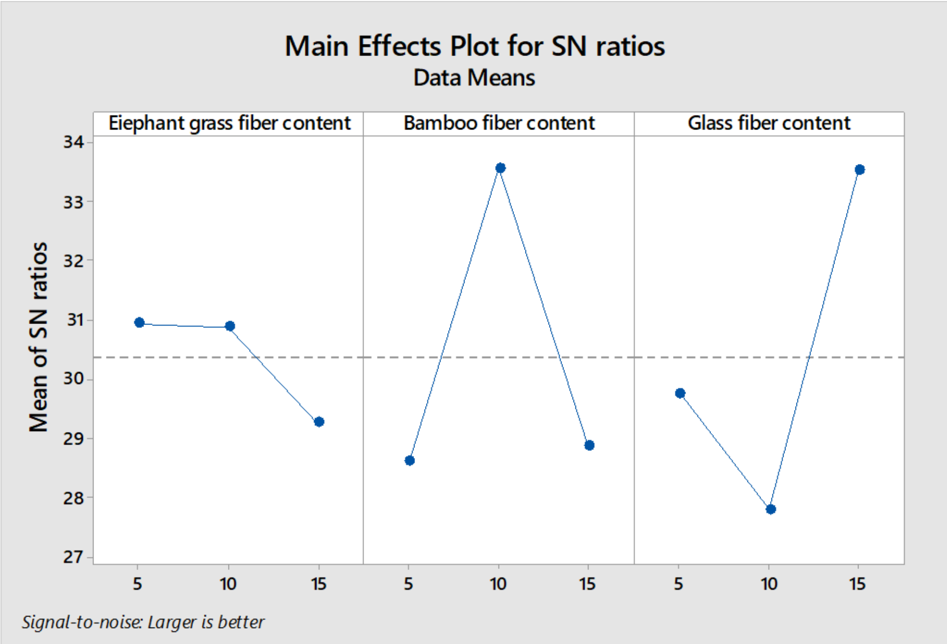


Figure 4.9. Compressive main effects plot for S/N ratio for compressive strength.

Figure 4.9 shows the Response Table for Signal to Noise Ratios for the compressive test. From this glass fiber content has the first ranker in the contribution of increasing the compressive strength with a delta value of 5.72. Bamboo Fiber content has the second ranker in the contribution of increasing the compressive strength with a delta value of 4.94. Elephant grass content has the third ranker in the contribution of increasing the compression strength with a delta value of 1.67. Figure: 4.9 compressive main effects plot for S/N ratio for compressive strength demonstrate that mean S/N ratio maximum at level 1 for elephant grass fiber content of 5wt. %. Mean S/N ratio maximum at level 2 for the bamboo fiber content of 10wt. % and Mean S/N ratio maximum at level 3 for glass fiber content of 15 wt. %. This analysis leads to the conclusion that the process parameter combination of A1B2C3 gives the maximum impact strength.

4.5.2. Analysis of Variance for S/N ratios for compressive strength

Table 4.8. Analysis of Variance for S/N ratios for impact strength

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Elephant grass fiber content	2	135.4	6.59%	135.4	67.72	0.63	0.614
Bamboo fiber content	2	874.6	42.58%	874.6	437.32	4.07	0.197
Glass fiber content	2	828.8	40.35%	828.8	414.38	3.85	0.206
Error	2	215.1	10.47%	215.1	107.57		
Total	8	2054.0	100.00%				

From Analysis of Variance shown in table 4.8 indicates the percentage of contribution (Pc) of process parameter for hardness. Bamboo weight percentage has the highest level of contribution 42.58% followed by glass fiber fiber weight percentage 40.35% and Elephant grass fiber 6.59%.

4.6. Hardness Test

Hardness is the confrontation of a material to deform, indentation or scratching the basic goal of hardness is to enumerate the resistance of a material to plastic deformation. Load during hardness test is 10 kg (99.1 N) on two trials on the specimens. For each test, two reputations are followed and an average value was taken.

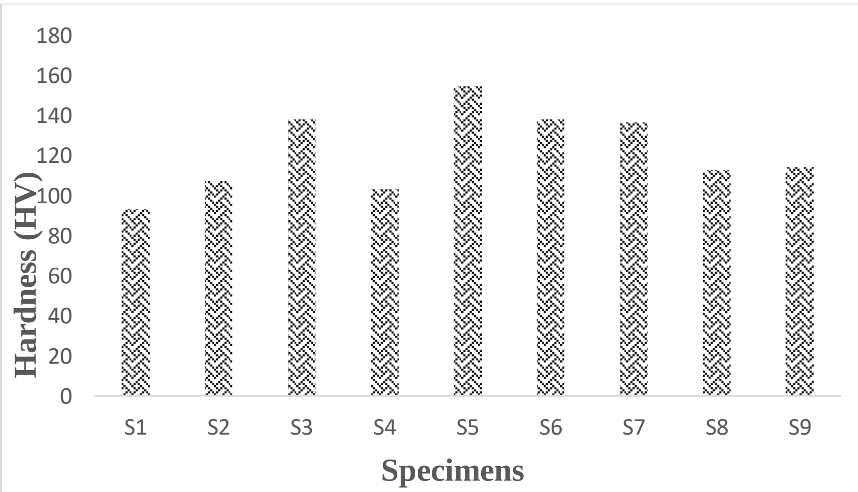


Figure 4.10. Hardness test result.

The Comparisons of hardness for all specimens. Specimens (1, 2, and 3) were (93.2, 107.1, and 138.3) HV respectively. Specimens (4, 5, and 6) were (103.3, 154.8, and 138.3) HV respectively. Specimens (7, 8, and 9) were (136.6, 112.6, and 114.2) HV respectively. From all specimens, the specimen 5 maximum hardness value.

4.6.1. Taguchi analysis Using S/N Ratios for Hardness

Table 4.9. Response Table for Signal to Noise Ratios.

Level	Elephant grass fiber content	Bamboo fiber content	Glass fiber content
1	40.93	40.79	41.08
2	42.30	41.81	40.68
3	41.63	42.26	43.11
Delta	1.36	1.47	2.43
Rank	3	2	1

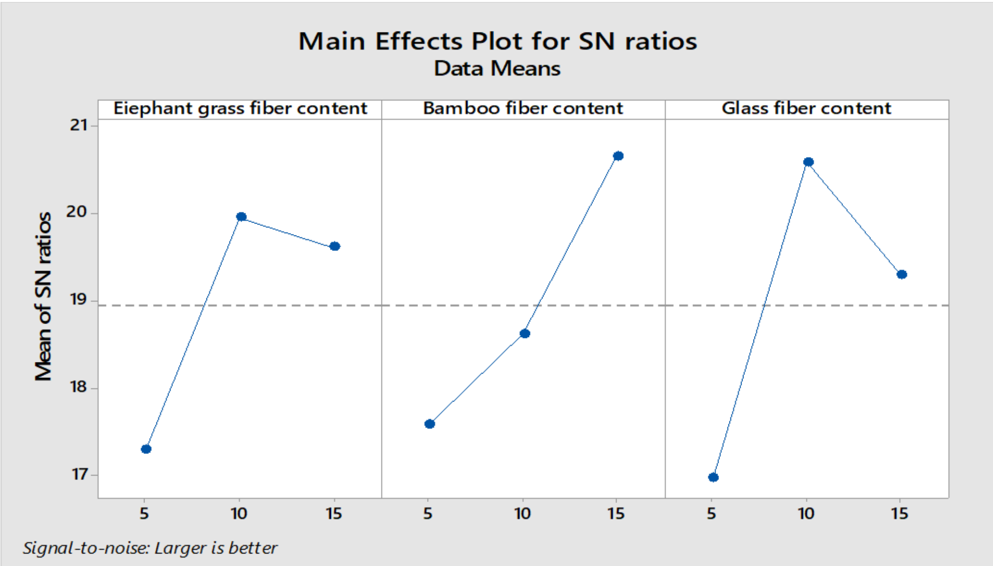


Figure 4.11. Hardness main effects plot for S/N ratio.

Table 4.9 and Figure: 4.11 show the influence of fabrication process parameters on the hardness. It was observed that the optimum fabrication process parameters on the hardness are identified as glass fiber content the first ranker at level 2 (10wt.%), Bamboo fiber content the second ranker at level 3 (15wt.%), and elephant grass fiber content the third ranker at level 2(10wt.%). This analysis leads to the conclusion that the process parameter combination of A2B3C2 gives the maximum hardness.

4.6.2. Analysis of Variance for S/N ratios for Hardness

Table 4.10 Analysis of Variance for S/N ratios for hardness

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Elephant grass fiber content	2	560.5	16.63%	560.5	280.27	4.11	0.196
Bamboo fiber content	2	589.9	17.50%	589.9	294.94	4.32	0.188
Glass fiber content	2	2083.7	61.82%	2083.7	1041.87	15.26	0.061
Error	2	136.5	4.05%	136.5	68.27		
Total	8	3370.7	100.00%				

From Analysis of Variance shown in table 4.10 indicates the percentage of contribution (Pc) of process parameter for hardness. Glass fiber weight percentage has the highest level of contribution 61.82% followed by Bamboo fiber weight percentage 17.50% and Elephant grass fiber 16.63%.

4.7. Water Absorption

Water absorption is the important aspect considering the usage of the natural fiber polymer composite material in various industry applications with different place conditions. Several factors affected water absorption percentages such as fiber/matrix bonding surface covered, and porosity of composites and structural of fiber interfacial bonding. The water absorption can results reduction of the mechanical properties and dimensional stability of composites due to water absorption can lead to swelling of the fiber, micro cracks and forming voids at the fiber-matrix interface region. The water absorption was carried out for 8 days. The result of the water absorption test was given as below.

Table 4.11. Water absorption test result.

Specimen	**Mass (g)**	**Measuring duration of water absorption test**								**Average WA (%)**
		24hrs	48hrs	72hrs	96hrs	120hrs	144hrs	168hrs	192hrs	
S1	4.429	4.473	4.491	4.506	4.544	4.551	4.561	4.569	4.574	0.0206
WA (%)		0.064	0.018	0.015	0.038	0.007	0.010	0.008	0.005	
S2	5.049	5.091	5.121	5.140	5.156	5.168	5.179	5.183	5.184	0.01662
WA (%)		0.042	0.030	0.019	0.016	0.012	0.011	0.002	0.001	
S3	5.117	5.168	5.197	5.214	5.230	5.242	5.254	5.261	5.266	0.0186
WA (%)		0.051	0.029	0.019	0.014	0.012	0.012	0.007	0.005	
S4	4.586	4.640	4.663	4.682	4.706	4.720	4.722	4.733	4.741	0.0194
WA (%)		0.054	0.023	0.019	0.024	0.014	0.002	0.011	0.008	
S5	4.925	4.964	4.989	5.011	5.043	5.049	5.055	5.062	5.065	0.01625
WA (%)		0.039	0.025	0.022	0.022	0.006	0.006	0.007	0.003	
S6	5.037	5.131	5.142	5.151	5.190	5.203	5.207	5.220	5.229	0.024
WA (%)		0.094	0.011	0.009	0.039	0.013	0.004	0.013	0.009	
S7	4.758	4.801	4.831	4.854	4.889	4.899	4.908	4.919	4.927	0.0211
WA (%)		0.043	0.030	0.023	0.035	0.010	0.009	0.011	0.008	
S8	4.792	4.856	4.864	4.869	4.905	4.914	4.919	4.930	4.938	0.0182
WA (%)		0.064	0.008	0.005	0.036	0.009	0.005	0.011	0.008	
S9	5.709	5.801	5.814	5.825	5.881	5.894	5.902	5.911	5.917	0.026
WA (%)		0.092	0.013	0.011	0.056	0.013	0.008	0.009	0.006	

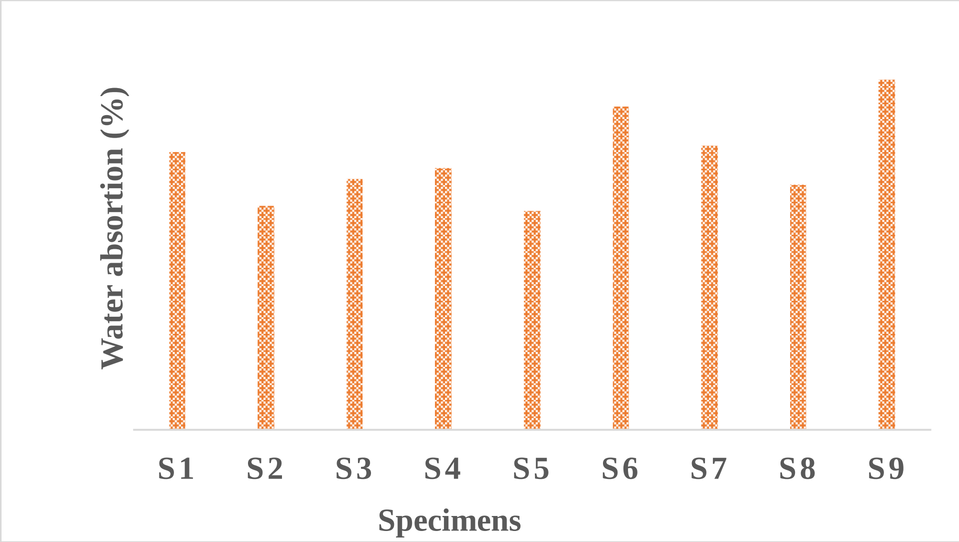


Figure 4.12. Water absorption test results for 8 days.

Table 4.11 and figure: 4.12 shows water absorption test performed for eight days. From this observation amount of water absorption of specimen 5 and specimen 2 were (0.01625 and 0.0166) % respectively. These two specimens absorb a small amount of water. Specimen 5 was fabricated from 10wt. % of Elephant grass fiber, 10wt. % bamboo fiber and 15wt. % of glass fiber. Specimen 2 was fabricated from 5wt. % of Elephant grass fiber, 10wt. % of bamboo fiber and 10wt. % of glass fiber. From two specimens specimen 5 absorbs the smallest amount of in 8 days. This shows that the bonding between the matrix and reinforcement was best.

4.8. Density and porosity of composites

Density of a composite material depends on the relative proportion of reinforcing and matrix materials and it is one of the key factors in determining the properties of the composites. The theoretical and experimental densities of the composites along with the corresponding porosity are obtainable in Table 4.12. It is observed that the composite densities values are calculated theoretically from weight fractions are not equal to the experimentally measured values. This difference is due to the presence of voids and pores in the composites. The porosity considerably affects some of the mechanical properties and even the performance of composites in the workplace. It is understandable that a good composite should have less porosity. Presence of porosity is unavoidable in composite making particularly through hand-lay-up methods.

Table 4.12. Actual and theoretical density composites.

Specimens	S1	S2	S3	S4	S5	S6	S7	S8	S9
Actual density (g/cm^3)	1.226	1.150	1.148	1.094	1.166	0.956	1.000	1.086	1.214
Theoretical density (g/cm^3)	1.262	1.186	1.218	1.165	1.196	1.127	1.163	1.118	1.332
Porosity (%)	0.036	0.036	0.07	0.071	0.030	0.171	0.173	0.032	0.118

Table: 4.12 show the result of actual density and porosity of composites specimens. Specimen 8 has lowest porosity percentage value 0.030%. From this as the fiber content increases from 5 wt.% to 10wt.% , 10 wt.% to 15wt.%, porosity is found to be increasing.

4.9. SEM Morphology Analysis

SEM Morphology is used to check the bonding and filler material distribution in the matrix. SEM images were taken for the specimens to observe the microstructure. The images were taken for the hybrid composite made from elephant grass fiber, bamboo fiber, glass fiber and polyester and the images were analyzed in the scanning electron microscope. The Scanning electron microscope image shows the dispersion of the elephant grass fiber, bamboo fiber, glass fiber with the polyester matrix.

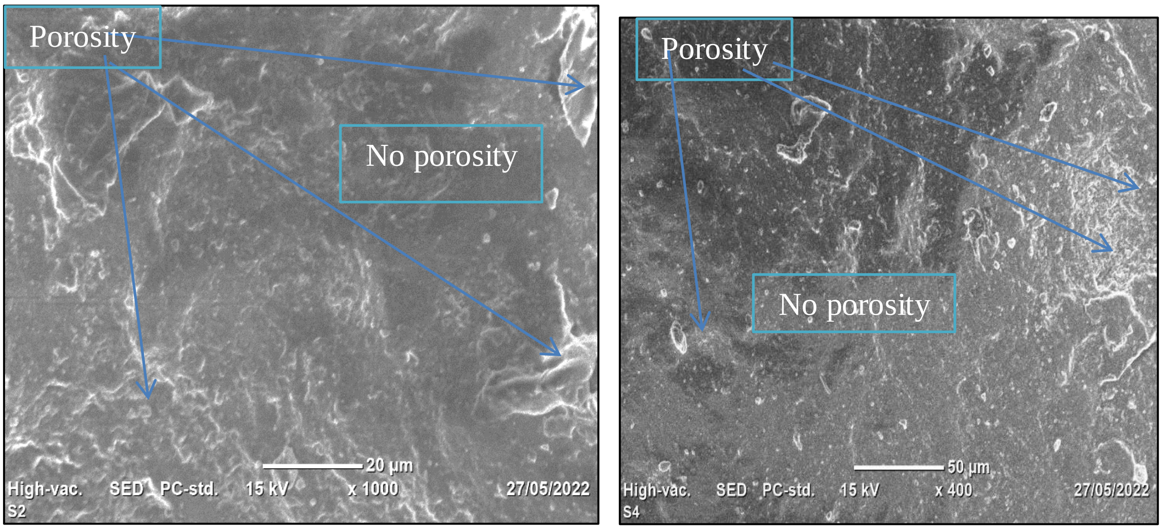


Figure 4.13 SEM Image of specimen

4.10 Analysis of grey relational analysis of mechanical and Physical tests

The data obtained from signal to noise ratio of tensile, compressive, flexural, impact Hardness, water absorption and void content tests were compiled in to one to predict the optimal parameter combination for best mechanical and physical property of the composite. The obtained S/N ratio was normalized and then the normalizing sequence value deviation was calculated from it. The grey relational coefficient for all parameters was calculated using the deviation sequence values.at the end the grey relational grade was developed from grey relational coefficient.by analyzing the main effect of the grey relational grade value in Minitab 18 software, the optimal parameter was predicted for the best value of mechanical and physical property.

Table 0.13 Response of mechanical and physical tests

Exp no	Tensile (Mpa)	Compression (Mpa)	Flexural (Mpa)	Impact (J)	Hardness (HV)	Distilled water absorption (%)	Void content (%)
1	26.9	25.56	56.25	5.5	93.2	0.0206	0.036
2	37	46.89	90	7.5	107.1	0.01662	0.036
3	39.1	36.44	129.38	9.5	138.3	0.0186	0.07
4	32.8	18.22	112.5	10.5	103.3	0.0194	0.071
5	58.5	69.33	253.13	11	154.8	0.01625	0.030
6	35.3	34	225	8.5	138.3	0.024	0.171
7	48	42.33	202.5	7.5	136.6	0.0211	0.173
8	39.3	33.44	135	7.5	112.6	0.0182	0.032
9	29.1	17.33	112.5	15.5	114.2	0.026	0.118

Table 0.14 S/N ratio values of all responses.

Exp no	**Tensile (MPa)**	**Compression (MPa)**	**Flexural (MPa)**	**Impact (J)**	**Hardness (HV)**	**Distilled water absorption**	**Void content**
1	28.5950	28.1512	35.0025	14.8073	39.3883	-33.7227	-28.8739
2	31.3640	33.4216	39.0849	17.5012	40.5958	-35.5874	-28.8739
3	31.8435	31.2316	42.2373	19.5545	42.8164	-34.6097	-23.0980
4	30.3175	25.2110	41.0231	20.4238	40.1246	-34.2440	-22.9748
5	35.3431	36.8184	48.0669	20.8279	43.7954	-35.7829	-30.4576
6	30.9555	30.6296	47.0437	18.5884	42.8164	-32.3958	-15.3401
7	32.5330	32.5330	46.1285	17.5012	42.7090	-33.5144	-15.2391
8	30.4853	30.4853	42.6067	17.5012	41.0308	-34.7986	-29.8970
9	29.2779	24.7760	41.0231	23.8066	41.1533	-31.7005	-18.5624

Table 0.15 Normalization of all responses

Exp no	**Tensile**	**Compration**	**Flexural**	**Impact**	**Hardness**	**Distilled water absorption**	**Void content**
1	0.000	0.280	0.000	0.000	0.000	0.495	0.895
2	0.403	0.717	0.312	0.299	0.273	0.952	0.895
3	0.481	0.536	0.553	0.527	0.777	0.712	0.516
4	0.255	0.036	0.460	0.624	0.167	0.626	0.508
5	1.000	1.000	1.000	0.668	1.000	1.000	1.000
6	0.349	0.486	0.921	0.420	0.777	0.170	0.006
7	0.583	0.644	0.851	0.312	0.742	0.742	0.000
8	0.280	0.474	0.582	0.312	0.372	0.761	0.963
9	0.101	0.000	0.460	1.000	0.400	0.000	0.218

Table 4.16 Deviation sequence of all responses

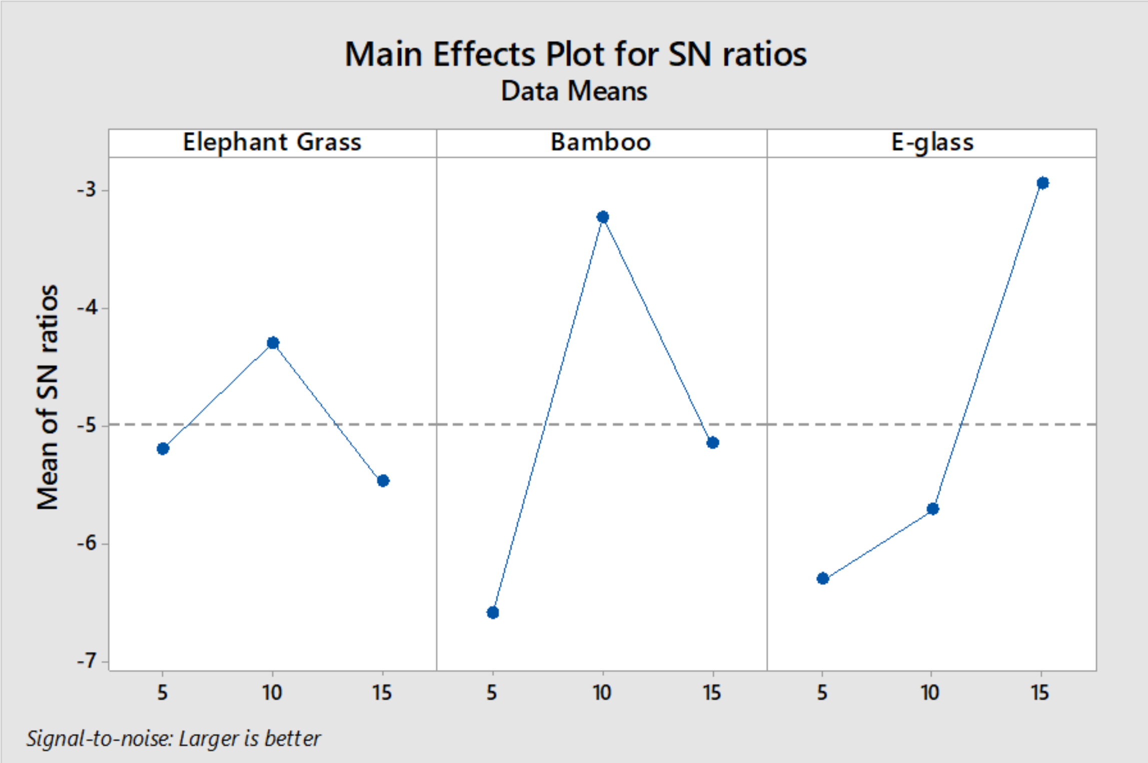
Exp no	Tensile	Comp	Flexural	Impact	Hardness	Distilled water absorption	Void content
1	1.000	0.72	1.000	1.000	1.000	0.505	0.105
2	0.597	0.283	0.688	0.701	0.727	0.048	0.105
3	0.519	0.464	0.447	0.527	0.223	0.288	0.484
4	0.745	0.964	0.54	0.376	0.833	0.374	0.492
5	0.000	0.000	0.000	0.335	0.000	0.000	0.000
6	0.651	0.514	0.079	0.580	0.223	0.83	0.994
7	0.417	0.356	0.149	0.688	0.258	0.258	1.000
8	0.72	0.526	0.418	0.688	0.672	0.239	0.037
9	0.899	1.000	0.54	0.000	0.600	1.000	0.782

Table 4.17 Grey relational coefficient and Grey relational grade of all responses

	Gray relational grade (GRD)							
Exp no	Tensile	Comp	flexural	Impact	Hardness	Distilled water absorption	Void content	Gray relational grade (GRD)
1	0.333	0.409	0.333	0.333	0.333	0.497	0.826	0.390
2	0.772	0.638	0.420	0.416	0.407	0.912	0.826	0.627
3	0.490	0.518	0.527	0.486	0.691	0.634	0.508	0.679
4	0.400	0.341	0.480	0.570	0.375	0.572	0.504	0.463
5	1.000	1.000	1.000	0.598	1.000	1.000	1.000	0.942
6	0.434	0.493	0.863	0.462	0.691	0.375	0.334	0.521
7	0.545	0.584	0.770	0.420	0.659	0.659	0.333	0.568
8	0.409	0.487	0.544	0.420	0.426	0.676	0.931	0.556
9	0.357	0.333	0.480	1.000	0.454	0.333	0.39	0.478

4.10.1 Analysis of GRG of mechanical and physical tests

From main effect plot of signal to noise ratio of tensile, compressive, flexural, impact strength, hardness, water absorption and void content of the composite, the optimal parametric combination was predicted to be 10%Elephant grass fiber, 10% Bamboo fiber and 15% E- glass fiber (A2B2C3).



4.10.2 Response table for means of GRG of mechanical and physical tests

The response table analysis of tensile compressive flexural, impact strength, hardness, water absorption and void content of the composite indicated that the type of E- glass fiber content has the first ranker parameter with delta number 3.379. Bamboo fiber content has the second ranker parameter with delta number of 3.366. Elephant grass fiber content has the third ranker in the contribution of increasing the mechanical and physical strength with a delta value of 1.181.

Table 4.18 Response table of signal to noise ratio of all responses

Larger is better

Level	Elephant Grass	Bamboo	E-glass
1	-5.199	-6.593	-6.313
2	-4.293	-3.227	-5.718
3	-5.474	-5.146	-2.935
Delta	1.181	3.366	3.379
Rank	3	2	1

4.11 Confirmation experiment

After obtaining the optimal process parameters and levels the next step was to verify that the predicted result was against experimental results. If the combination of optimal process parameters level coincides with that of any experimental trial in the orthogonal array their will not be need of confirmation test.in this studies the optimal process parameter combination for tensile compressive flexural, impact strength, hardness, water absorption and void content of the composite coincided with sample number 5.

4.12 Comparison of fabricated composite with current automotive dashboards

After the analysis of different mechanical strength tests the composite is compared with the current available dashboards used in different type of composite in table 4.19

Table 4.19 Comparison of dashboards strength with the fabricated composite

materials	sisal epoxy composite	sisal-epoxy-Aluminum powder composite	jute/banana hybrid composite	poly (vinyl) alcohol (PVA) for fabrication of composites	novel hybrid composite
Tensile strength (Mpa)	13.323	15.807	33.36	55.92	19.8
Flexural strength (Mpa)	71.3	79.7	82.58	98.49	28.79
Impact strength (J)	2.033	2.7116	11.726	13.43	2.00
Hardness	29Hv	28Hv	-	-	30.02
	Partha Haldar, (2017)	Partha Haldar, (2017)	M. Boopalan, 2013	Nayak et al (2022)	Mk.Marichelvam et al (2021)

CHAPTRE -5

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The fabrication of hybrid chopped composite made from elephant grass, bamboo, glass reinforced fiber and polyester at three levels and three weight percentages were successfully produced via the hand lay-up method. The following conclusions were drawn:-

- The composites containing elephant grass, bamboo and glass fiber (5, 10, and 15) wt. % were fabricated.
- Tensile strength for specimen 5 was 58.5 Mpa. The tensile strength maximum at 10wt. % elephant grass, 10wt. % bamboo fiber, and 15wt. % glass fiber. The results indicate that increasing the glass fiber wt. % increased the tensile strength and after (elephant grass and bamboo fiber) wt. % reached optimum values the tensile strength decreased.
- Flexural strength for specimen 5 was 253.13Mpa. The flexural strength is maximum at elephant grass, 10wt. % bamboo fiber, and 15wt. % glass fiber. Increasing (elephant grass, bamboo and glass fiber) wt. %, increases flexural strength.
- Impact strength for specimen 9 was 15.5 J. Impact strength maximum at 10wt. % elephant grass fiber, 15wt. % bamboo fiber, and 10wt. % glass fiber. Increasing (elephant grass and glass fiber fiber) wt. % after the optimum values decrease the impact strength and, increasing glass fiber wt. % increase impact strength.
- Water absorption was minimum at specimen 5 with 0.0162 %. Water absorption minimum at 10wt. % Elephant grass fiber, 10wt. % bamboo fiber, and 15wt. % E-glass fiber. As (Elephant grass and Bamboo fiber) wt. % increases the percentage of water absorption of composite was increased.
- The hardness for specimen 5was 154.8 HV. Hardness maximum at 10 wt. % elephant grass fiber, 10wt. % bamboo fiber, and 15wt. % E-glass fiber. Increasing bamboo fiber wt. % increases the hardness of composite, and increasing (elephant grass and E-glass fiber) wt. % increases the hardness, then after reaches optimum values the hardness was decreased.

- Actual density and porosity of composite material was minimum at specimen 5 with 0.030%. From this as glass fiber weight percentage increase the actual density and porosity of composite material increased.

5.2. Recommendations

Considering the fabrication and material characterization of hybrid composite made from elephant grass, bamboo and glass fiber reinforced chopped polyester the following recommendations were forwarded.

- The result of this thesis is recommends higher institutes, automotive companies
- The result of this thesis is recommended to replace heavy metals by low density, biodegradable, renewable, environmental friendly and green composite.
- To control the variation of thickness and presence of porosity in hand layup technique, different fabrication methods should be applied. mechanism to control the variation of thickness and presence of porosity in hand layup technique
- Longer natural fiber as a reinforcement may result with higher mechanical property.

5.3. Future Work

- This study was carried out using a simple hand layup technique. However, the work can be extended further by considering other methods of fabrication, like vacuum bag molding and compression molding for enhancement of mechanical characterization and batter surface finish.
- This study can be extended using different optimization techniques, (multi response optimization and response surface methodology) with different processing parameters.
- Further extension of this study through can be done on machinability and wear properties.

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APPENDICES

APPENDIX A: Tensile test result

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Ethiopian Conformity Assessment Enterprise

ቁጥር (NO) 2/8/16-2/39261

ቀን (Date) ሚያዚያ 12 2014

ለሀብታሙ አባተ

<u>አዳማ</u>

ሚያዚያ 6 ቀን 2014 ዓ.ም በአገልግሎት መጠየቂያ ቁጥር 7/2-1-3/7ጠ80/9339 የComposite ናሙና እንዲፈተሽላችሁ መጠየቃችሁ ይታወሳል።

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<u>አባሪ</u>፡ 9 ገጽ የፍተሻ ውጤት MTR/2216-2224/14

<u>ግልባጭ</u>፣

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ወደ ላቀ ብቃት የሚያደርስዎ!

Moving you forward!

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት **Ethiopian Conformity Assessment Enterprise**	Document No. TLD/F7.08-1	
		Copy No: -	Rev No: 2
Title:	**TEST REPORT** **የፍተሻ ሪፖርት**	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2216/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S1	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222032	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	26.9	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

ISO/IEC 17025:2017 Accredited Testing Laboratory

✉ 11145 ☎ 011 6 51-64-68, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com

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		Document No. TLD/F7.08-1	
ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Copy No: -	Rev No: 2
Title:	TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client: Habtamu Abate, Adama
Tel: +251-923-15-16-87
Fax: --
E-mail: --
Date sample Received: 20/04/2022

Client Sample code: S2
Type of sample: Composite
Laboratory Designation Number: 14222033

Test Report No: MTR/2217/14
Test Order No: 7/2-1-3/7mjo/9339/14
Reported date: 20/04/2022
Date of sampling Not Specified
Place of sampling Not Specified
Sampled and submitted by Client
Date tested: 20/04/2022
Method Specification Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	37.0	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign. For

ISO/IEC 17025:2017 Accredited Testing Laboratory

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ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት **Ethiopian Conformity Assessment Enterprise**	Document No. TLD/F7.08-1	
		Copy No: -	Rev No: 2
Title:	**TEST REPORT** **የፍተሻ ሪፖርት**	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2218/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S3	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222034	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	39.1	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

ISO/IEC 17025:2017 Accredited Testing Laboratory

✉ 11145 ☎ 011 6 51-64-68, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com

BOLE SUBCITY, WOREDA 6, ADDIS ABABA, ETHIOPIA

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F7.08-1 Copy No: - Rev No: 2
Title:	TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1 Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2219/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
		Sampled and submitted by	Client
Client Sample code:	S4	Date tested:	20/04/2022
Type of sample:	Composite	Method Specification	Not Specified
Laboratory Designation Number:	14222035		

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	32.8	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

ISO/IEC 17025:2017 Accredited Testing Laboratory

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ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F7.08-1	
		Copy No: -	Rev No: 2
Title:	TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2220/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S5	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222036	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	58.5	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

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Title:	**TEST REPORT** የፍተሻ ሪፖርት	Page No: 1 of 1 Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2221/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S6	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222037	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	35.3	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

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		Copy No: -	Rev No: 2
Title:	TEST REPORT የፍተሻ ሪፖርት	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2222/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S7	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222038	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	48.0	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

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ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት **Ethiopian Conformity Assessment Enterprise**	Document No. TLD/F7.08-1	
		Copy No: -	Rev No: 2
Title:	**TEST REPORT** **የፍተሻ ሪፖርት**	Page No: 1 of 1	Effective Date: 07 Apr 22

Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2223/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	--	Reported date:	20/04/2022
E-mail:	--	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S8	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222039	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	39.3	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign.

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Name and address of client:	Habtamu Abate, Adama	Test Report No:	MTR/2224/14
Tel:	+251-923-15-16-87	Test Order No:	7/2-1-3/7mjo/9339/14
Fax:	–	Reported date:	20/04/2022
E-mail:	–	Date of sampling	Not Specified
Date sample Received:	20/04/2022	Place of sampling	Not Specified
Client Sample code:	S9	Sampled and submitted by	Client
Type of sample:	Composite	Date tested:	20/04/2022
Laboratory Designation Number:	14222040	Method Specification	Not Specified

S/N	Characteristics tested	Test Method/Specification	Standard Requirements			Test result	Comment
			Min	Nom	Max		
1.	Tensile Strength (Mpa)	As per client agreement/-	-	-	-	29.1	-

Remark

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

Test report authorized by, Name Ayalew Gashaw, Position Analyst II, Sign

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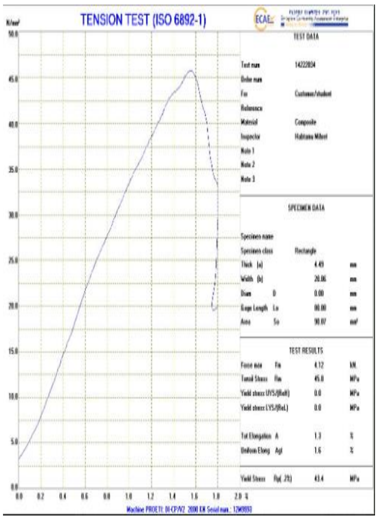
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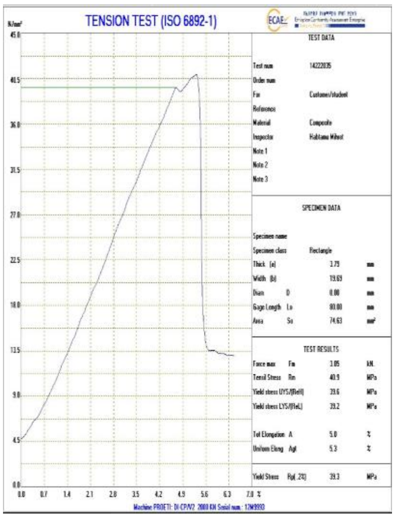
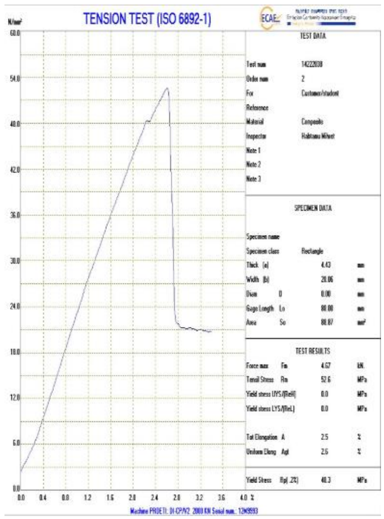

TENSION TEST (ISO 6892-1)

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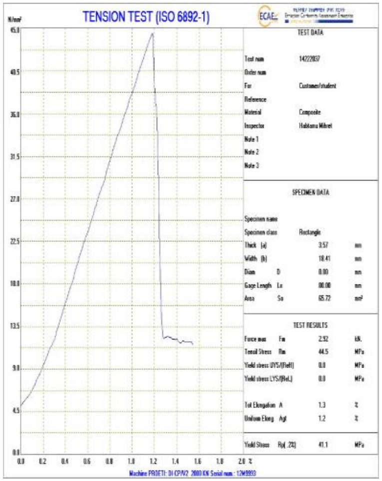
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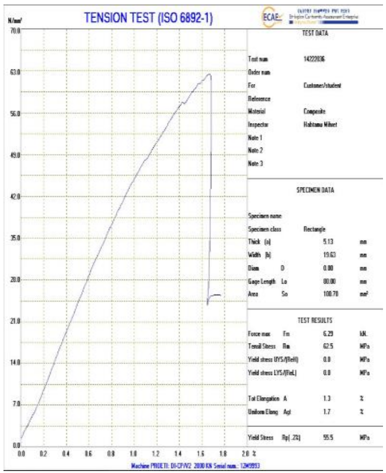
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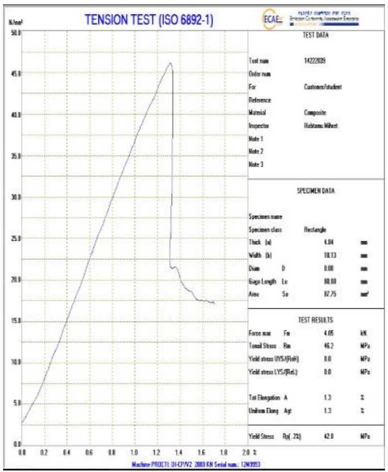
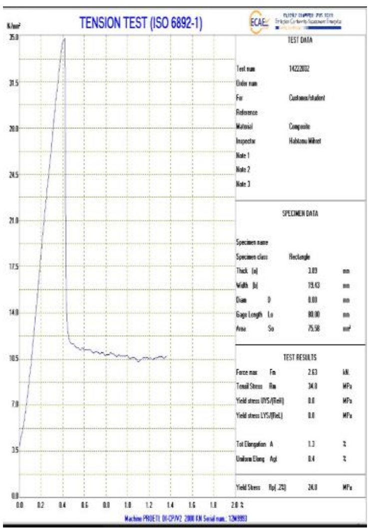
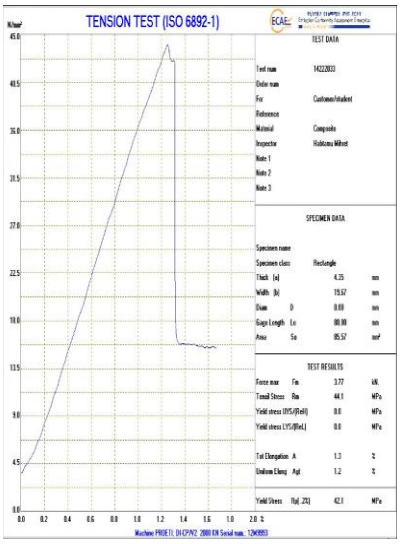
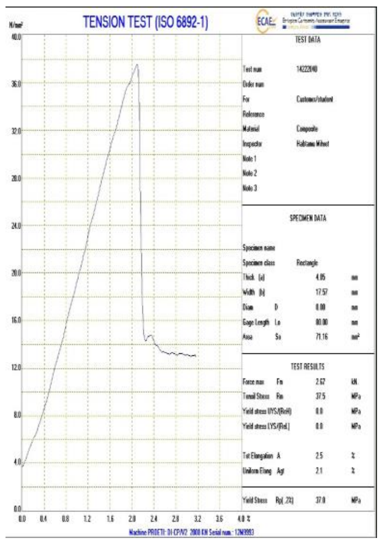

TENSION TEST (ISO 6892-1)

TENSION TEST (ISO 6892-1)

TENSION TEST (ISO 6892-1)

TENSION TEST (ISO 6892-1)

APPENDIX B: Impact test result

የኢ.ፌ.ዲ.ሪ መከላከያ ሚኒስቴር
በመከላከያ ዩኒቨርሲቲ የኢንጂነሪንግ ኮሌጅ
F.D.R.E Ministry of Defense
Defense University, College of Engineering

ቀን Date: may 16/2022
ቁጥር Ref. No. m/6.4/ST20/H/979/22

To: - Adama Science and Technology University

Adama

Subject :- Regarding composite Testing

Upon your request dated on May.13/2022 to perform flexural, compression, and Impact Test of Composite for your post graduate student (**Habtamu Abate**), the respective test is conducted in our Mechanical testing laboratory.

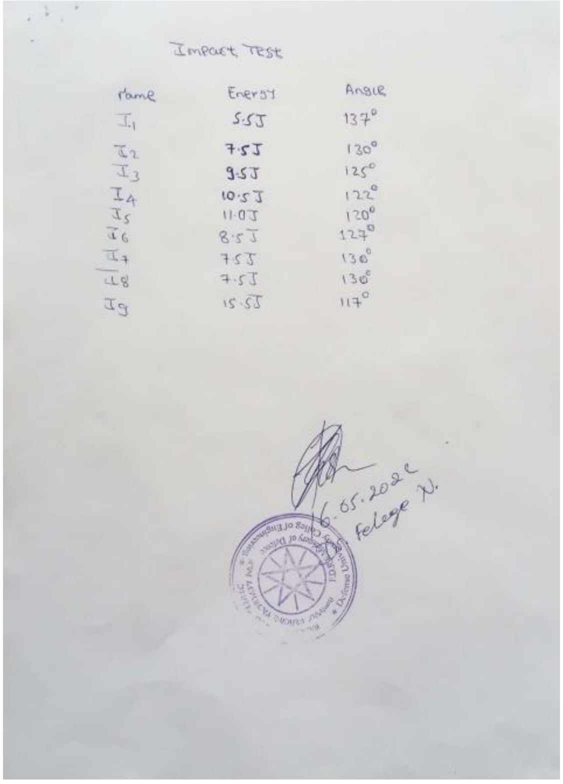
Accordingly the analysis is completed as per request and hence, you find the report attached here.

Attached : - 7

With Regards

Lt.Col Bisrat Yosef (Dr.)
Defense University College of Engineering
Academic Dean (Acting)

Tel. 251-11433-27-11 P.O.Box. 1041 Fax 251-11433-86-08 E-mail: dec_cs@dec.edu.et Website: www.dec.edu.et Bishoftu -Ethiopia



Impact Test

Name	Energy	Angle
I_1	5.5J	137°
I_2	7.5J	130°
I_3	9.5J	125°
I_4	10.5J	122°
I_5	11.0J	120°
I_6	8.5J	127°
I_7	7.5J	130°
I_8	7.5J	130°
I_9	15.5J	117°

16.05.2022
Felege N.






APPENDIX C: Flexural test result

Saturday, May 14, 2022
2:55 PM

Test report

Kind of test:	Bending test DIN 50110
Material of specimen:	S2
Kind of specimen	Bending specimen 25 DIN 50110
Temperature:	20°C
max.test force:	160 N
flectional strength	90.00 N/mm²
Ductile yield	
Description of the fracture area:	
Distance between supports:	150 mm
Date:	14.05.2022
Name of tester:	Manwesnot T
Signature:	

16.05.2022
Dr. Felego N.

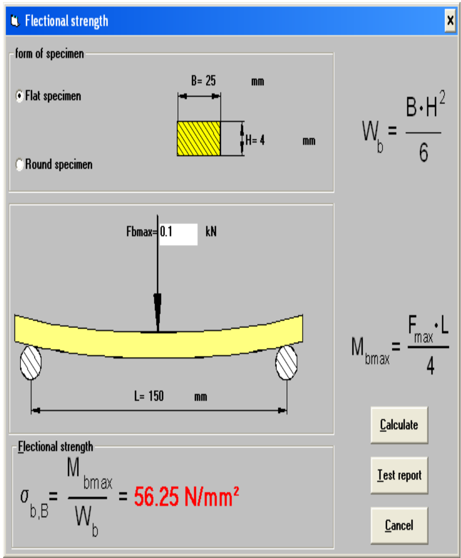
Test report

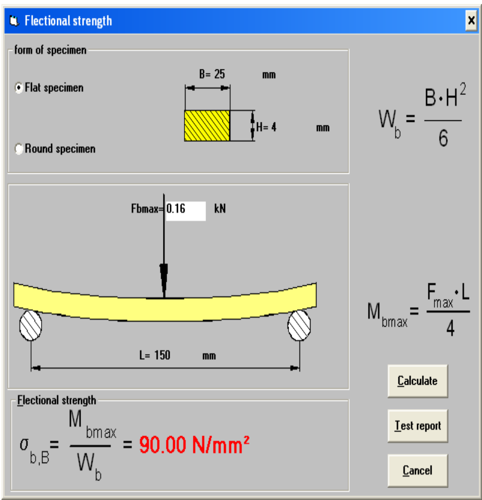
Kind of test:	Bending test DIN 50110
Material of specimen:	S5
Kind of specimen:	Bending specimen 25 DIN 50110
Temperature:	20°C
max.test force:	450 N
flectional strength:	[illegible]
Ductile yield	
Description of the fracture area:	
Distance between supports:	150 mm
Date:	14.05.2022
Name of tester:	Manwesnot T
Signature:	

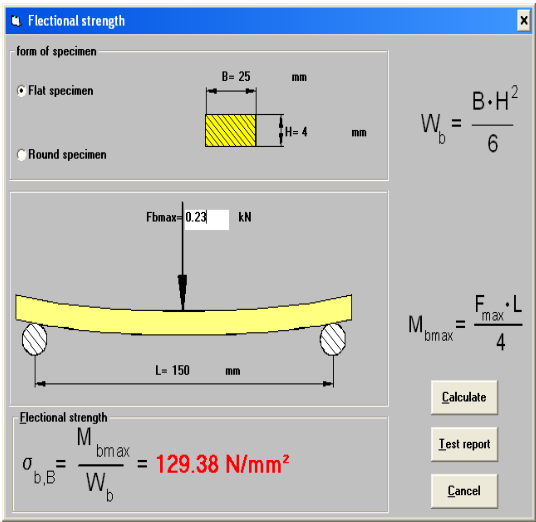
16.05.2022
Dr. Felego N.

Test report

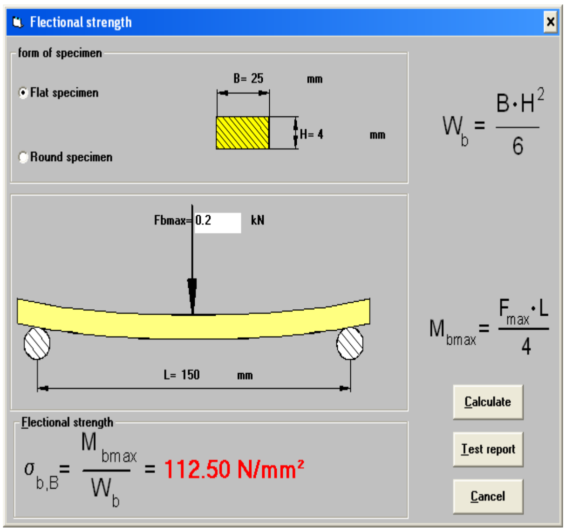
16.05.2022
Dr. Felego N.

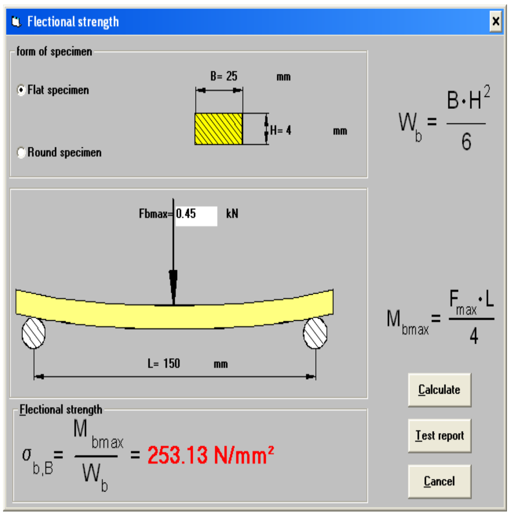


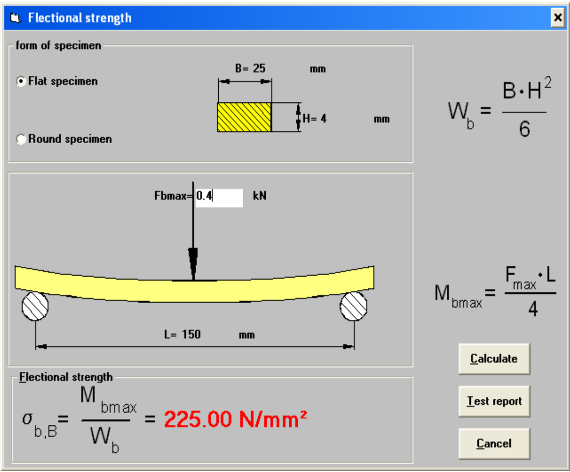


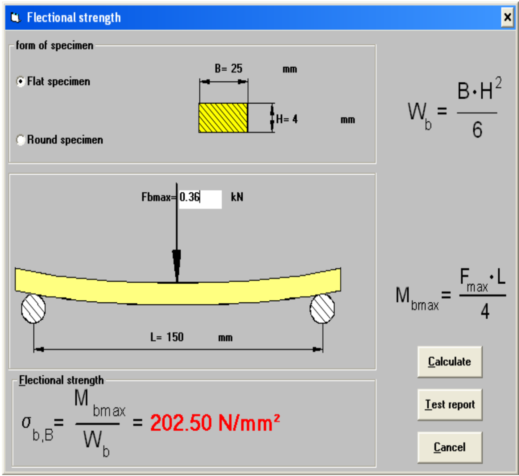


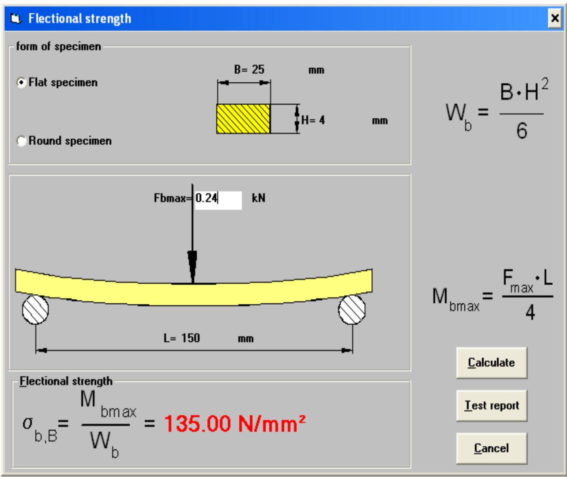
$$W_b = \frac{B \cdot H^2}{6} \qquad M_{bmax} = \frac{F_{max} \cdot L}{4} \qquad \sigma_{b,B} = \frac{M_{bmax}}{W_b}$$

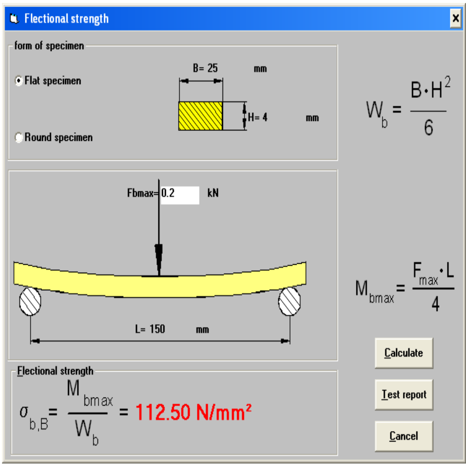

Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.2 kN
L= 150 mm
Flectional strength
= 112.50 N/mm²
Calculate
Test report
Cancel


Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.45 kN
L= 150 mm
Flectional strength
= 253.13 N/mm²
Calculate
Test report
Cancel

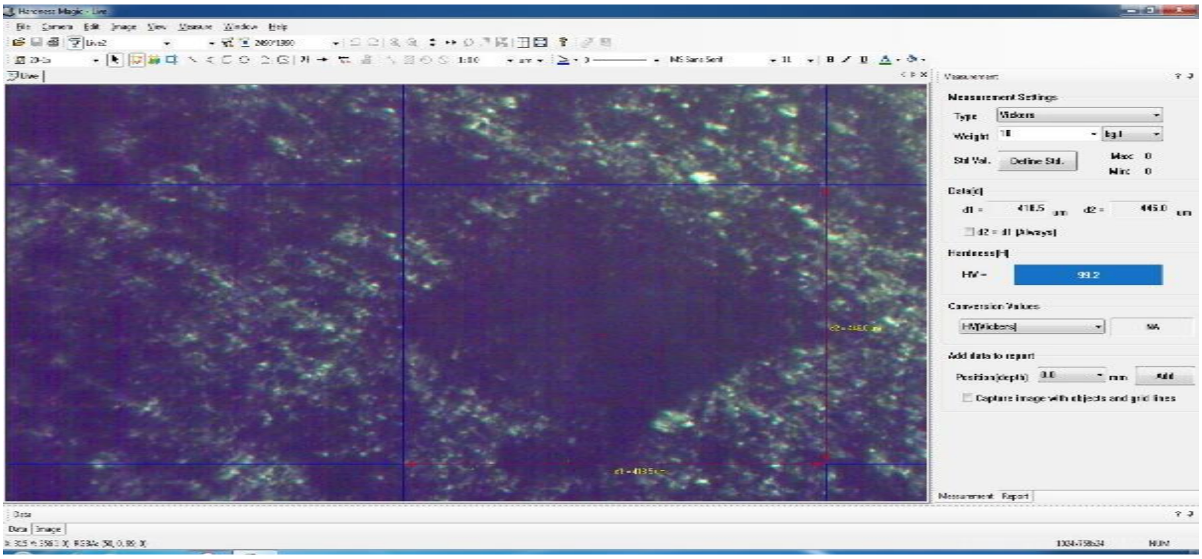

Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.4 kN
L= 150 mm
Flectional strength
= 225.00 N/mm²
Calculate
Test report
Cancel

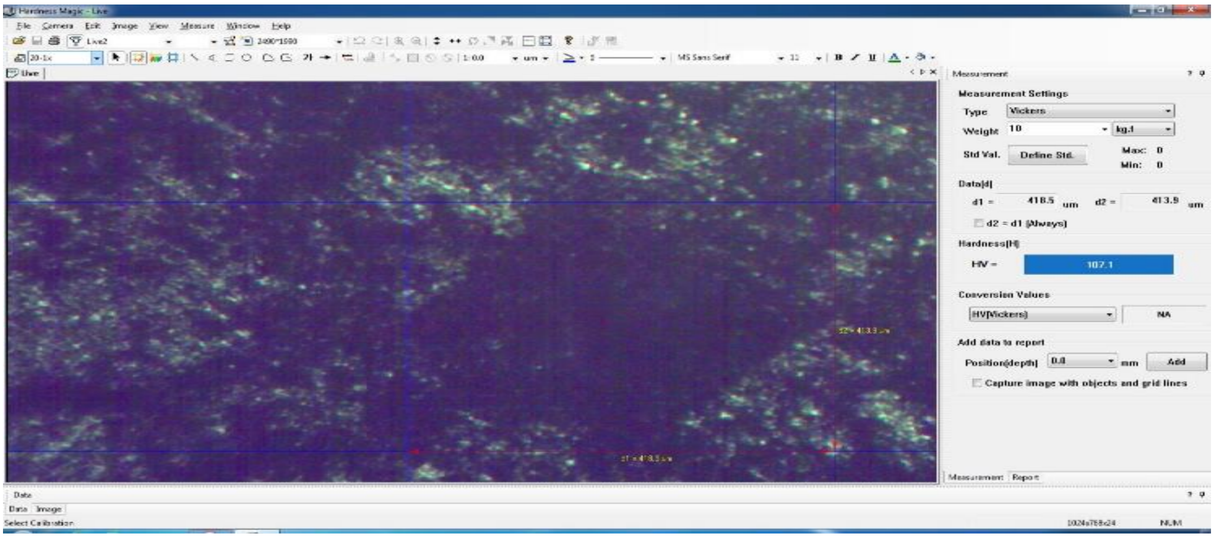

Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.36 kN
L= 150 mm
Flectional strength
= 202.50 N/mm²
Calculate
Test report
Cancel

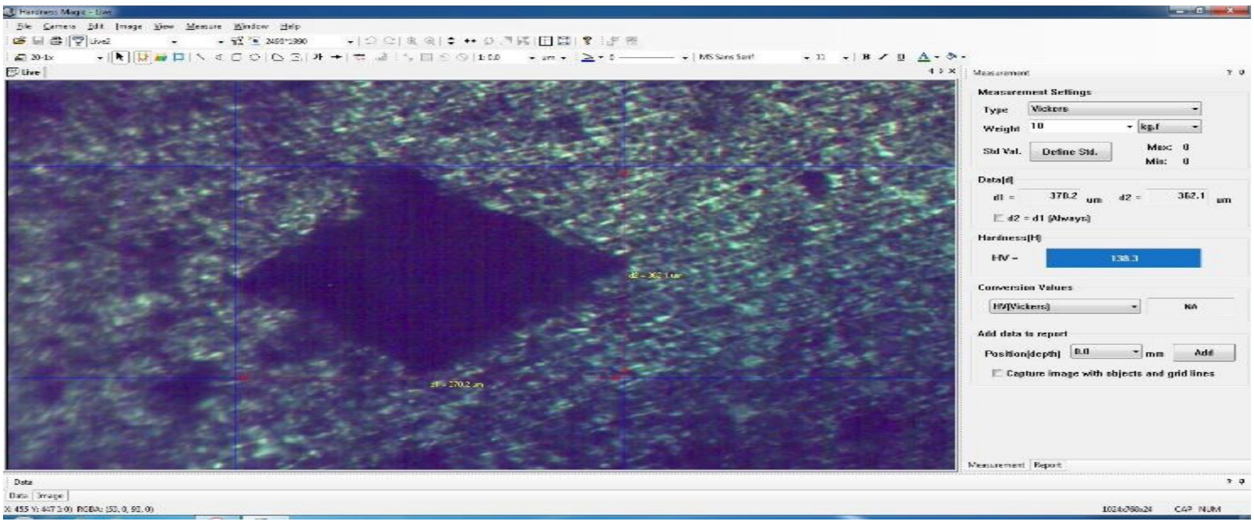

Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.24 kN
L= 150 mm
Flectional strength
= 135.00 N/mm²
Calculate
Test report
Cancel

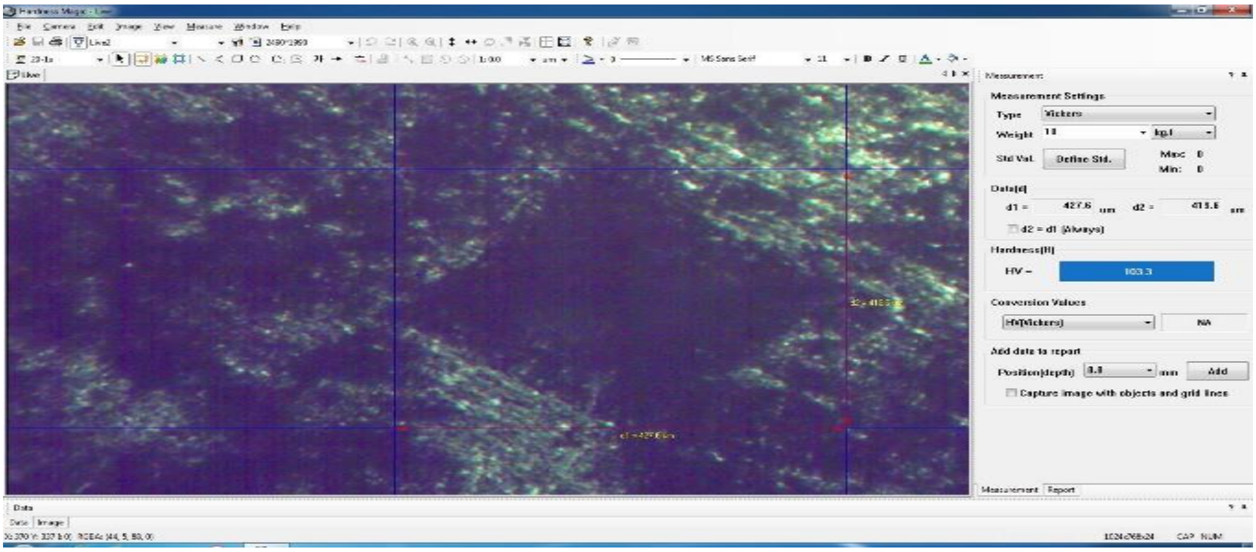

Flectional strength
form of specimen
Flat specimen
Round specimen
B= 25 mm
H= 4 mm
Fbmax= 0.2 kN
L= 150 mm
Flectional strength
= 112.50 N/mm²
Calculate
Test report
Cancel

APPENDIX D: Hardness Test Result

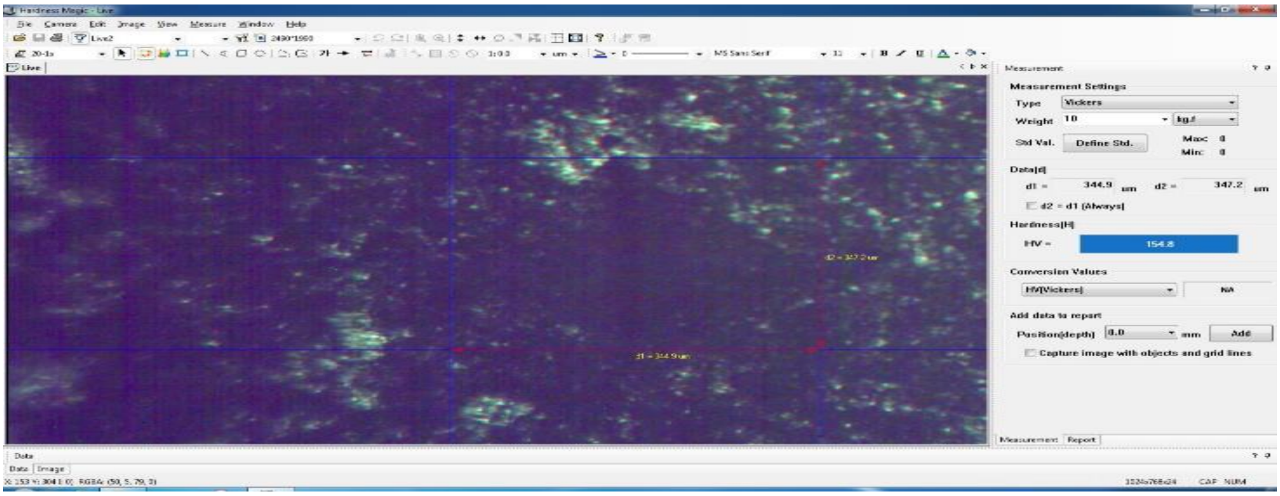




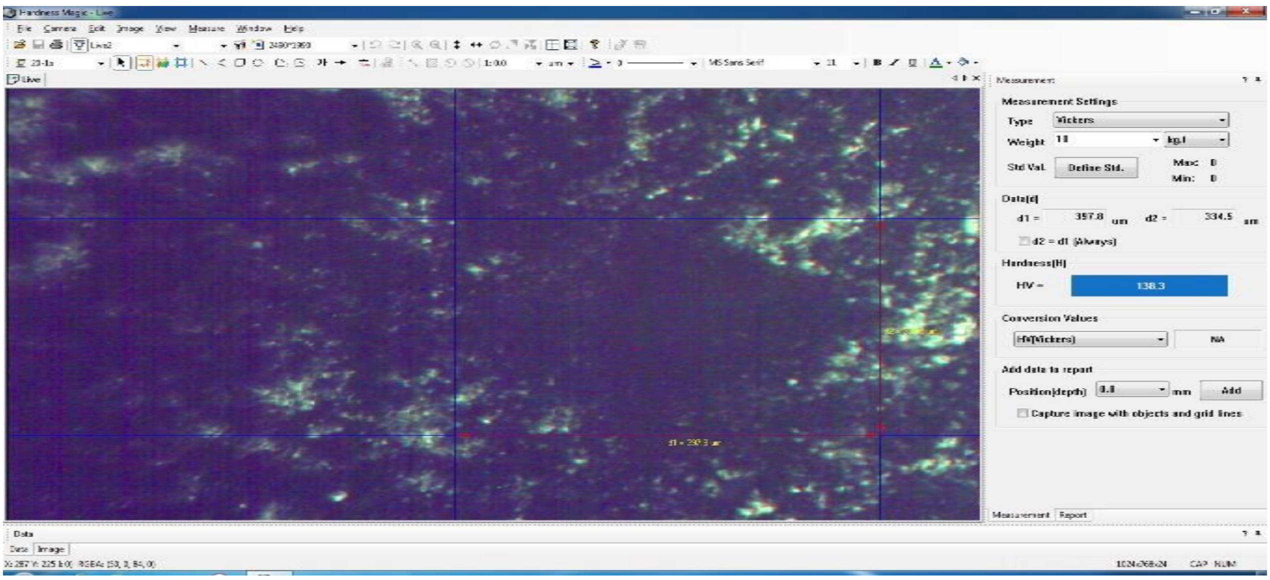




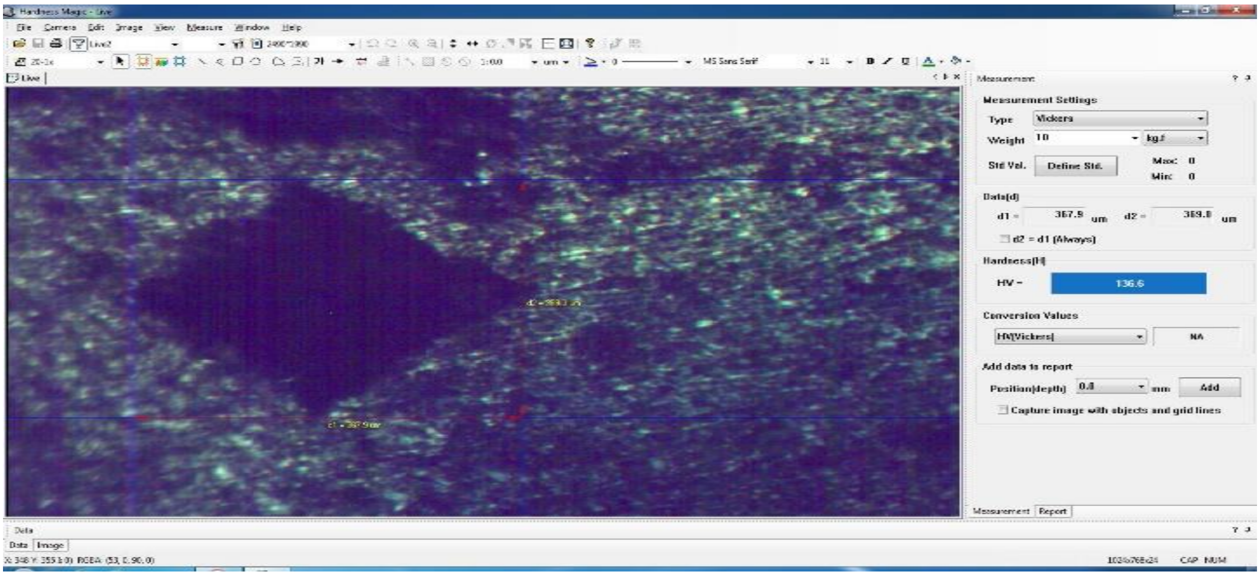
Measurement Settings
Type Vickers
Weight kg.f
Std Val. Define Std.
Data[d]
d1 = 427.6 um
Hardness[H]
HV =
103.3
Conversion Values
NA
Add data to report
Position(depth) mm Add
Capture image with objects and grid lines
Measurement Report



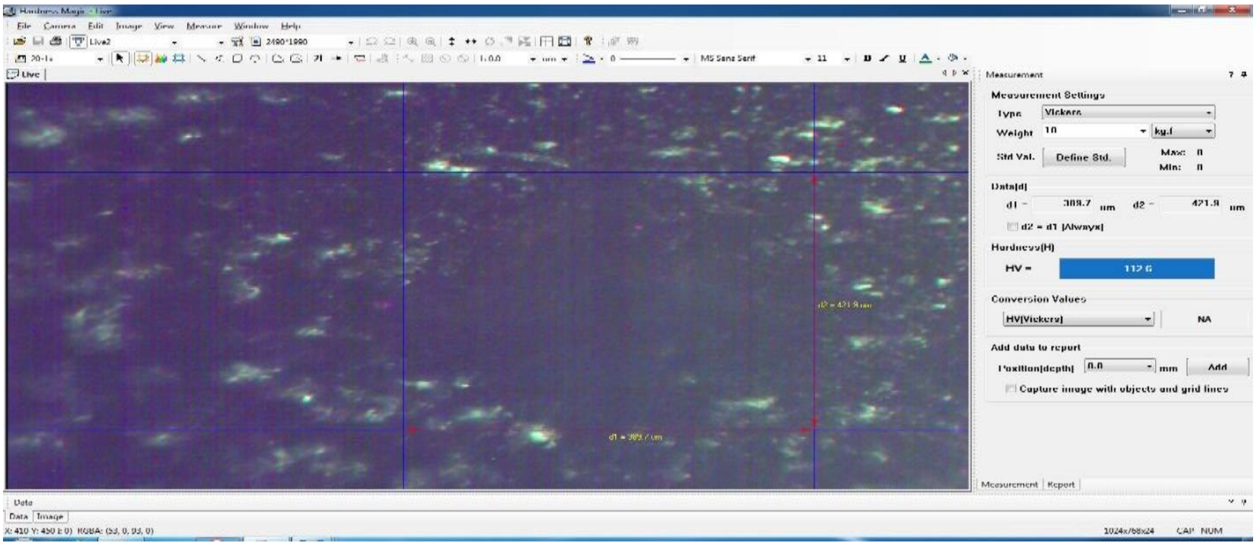
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 344.9 um d2 = 347.2 um
d2 = d1 (Always)
Hardness[H]
HV =
154.8
Conversion Values
HV(Vickers)
NA
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines
Measurement Report



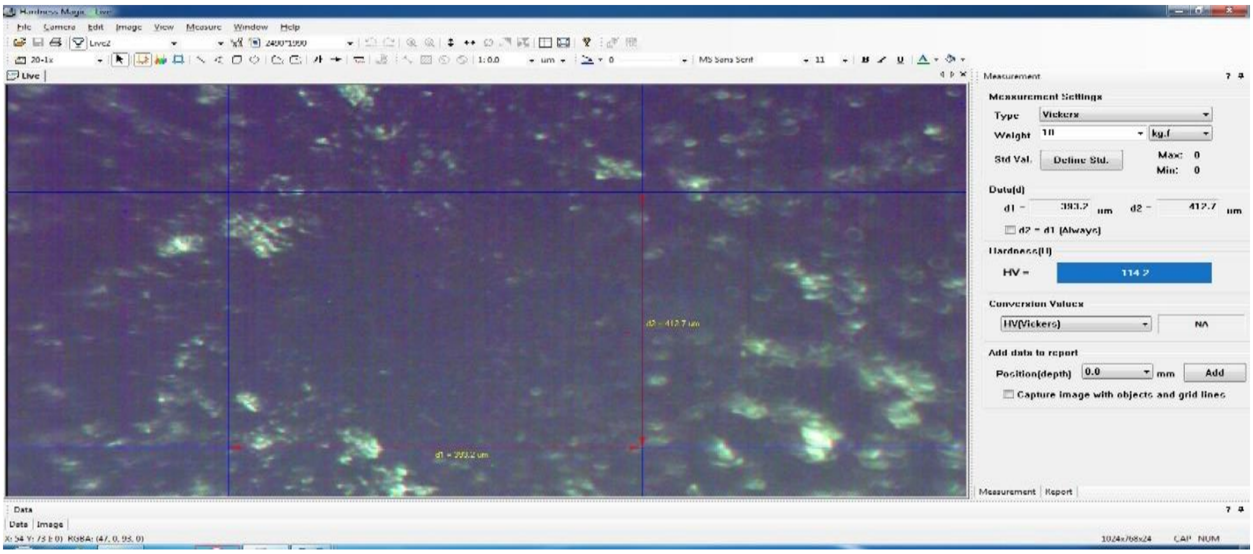
Measurement Settings
Type Vickers
Weight kg.f
Std Val. Define Std.
Data[d]
d1 = 357.8 um d2 = 334.5
Hardness[H]
HV =
138.3
Conversion Values
NA
Add data to report
Position(depth) mm Add
Capture image with objects and grid lines
Measurement Report



Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data(d)
d1 = 367.9 um d2 = 369.8 um
d2 = d1 (Always)
Hardness(H)
HV = 136.6
Conversion Values
HV(Vickers) NA
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines



Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data(d)
d1 = 388.7 um d2 = 421.8 um
d2 = d1 (Always)
Hardness(H)
HV = 112.6
Conversion Values
HV(Vickers) NA
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines



Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data(d)
d1 = 393.2 um d2 = 412.7 um
d2 = d1 (Always)
Hardness(H)
HV = 114.2
Conversion Values
HV(Vickers) NA
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines

APPENDIX E: Compressive Test Result

Friday, May 13, 2022
6:38 PM

Test report

Kind of test:	Compression test DIN 50106
Material of specimen:	composite
Dimensions of specimen:	press specimen123 x 250 DIN 50106
Kind of differential length-measurement:	between the compression plates
Lubrication of compression plates:	yes
Temperature:	20°C
Compression strength:	69.33 N/mm²
Values for changing of shape:	
Date:	13.05.2022
Name of tester:	
Signature:	

16.05.2022 Felege N.

4 Page 1

Test report

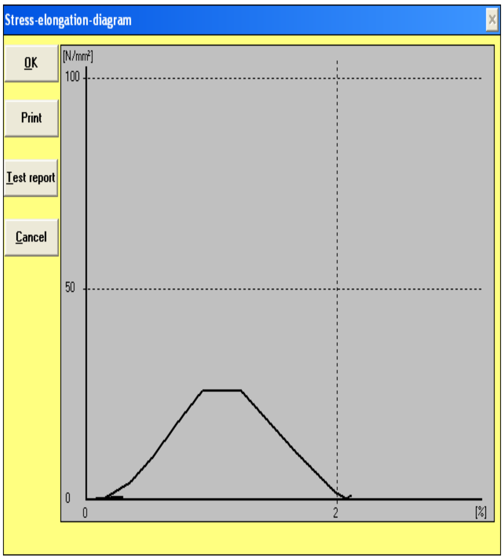
Kind of test:	Compression test DIN 50106
Material of specimen:	composite
Dimensions of specimen:	press specimen123 x 250 DIN 50106
Kind of differential length-measurement:	between the compression plates
Lubrication of compression plates:	yes
Temperature:	20°C
Compression strength:	33.46 N/mm²
Values for changing of shape:	
Date:	13.05.2022
Name of tester:	
Signature:	

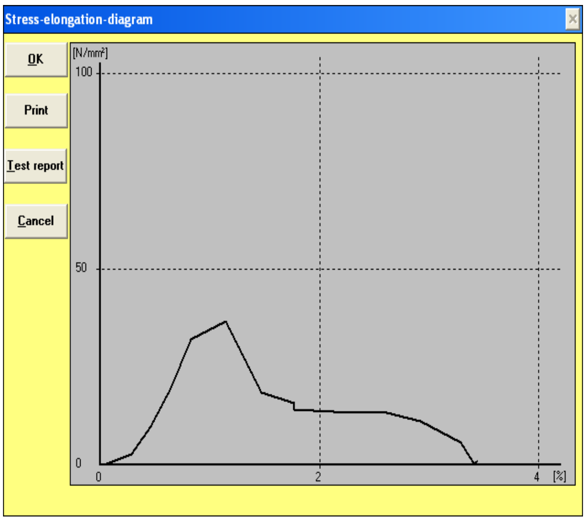
16.05.2022 Felege N.

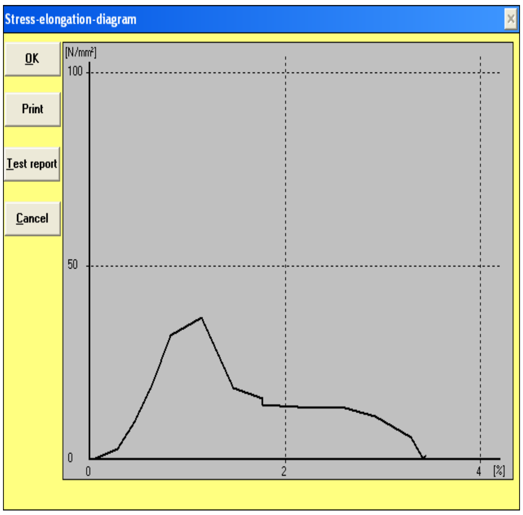
Test report

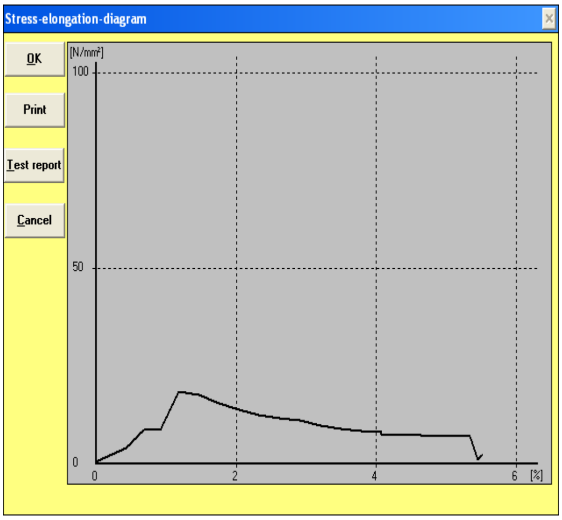
Kind of test:	Compression test DIN 50106
Material of specimen:	composite
Dimensions of specimen:	press specimen123 x 250 DIN 50106
Kind of differential length-measurement:	between the compression plates
Lubrication of compression plates:	yes
Temperature:	20°C
Compression strength:	33.46 N/mm²
Values for changing of shape:	
Date:	13.05.2022
Name of tester:	
Signature:	

16.05.2022 Felege N.

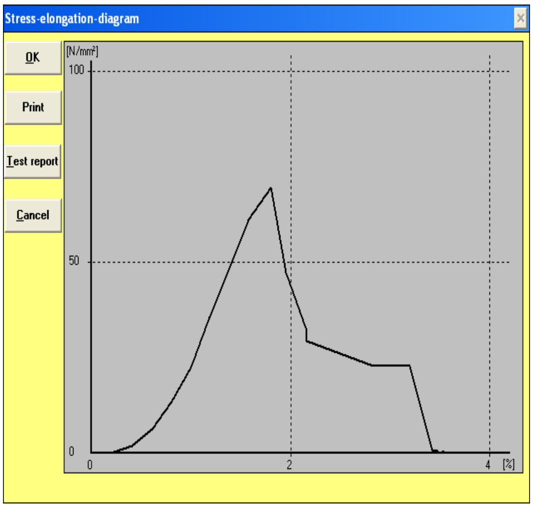




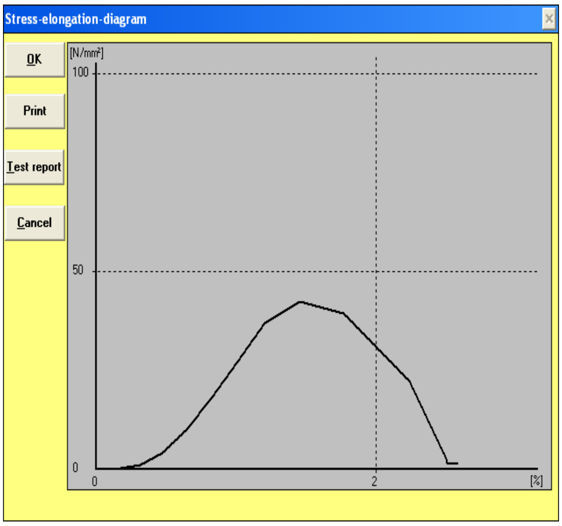




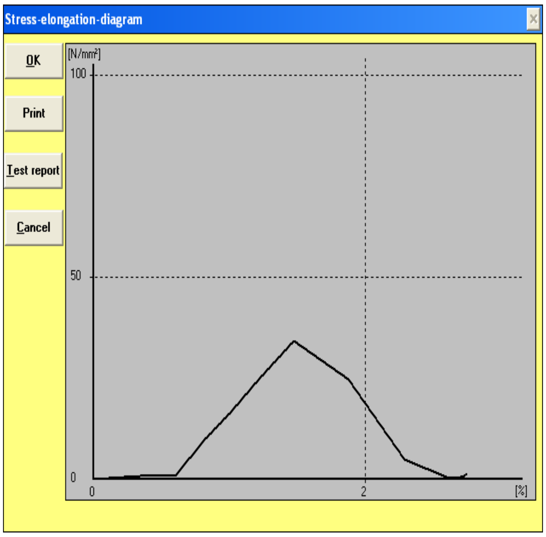
Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
4
6
[%]



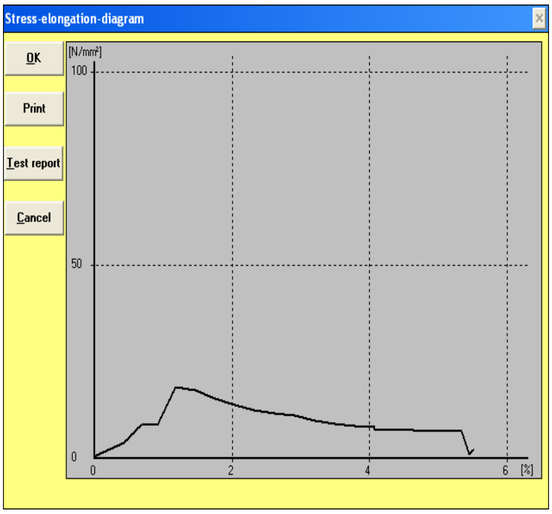
Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
4
[%]



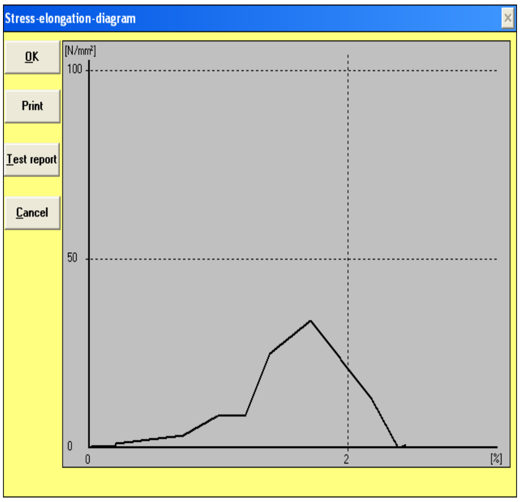
Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
[%]



Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
[%]



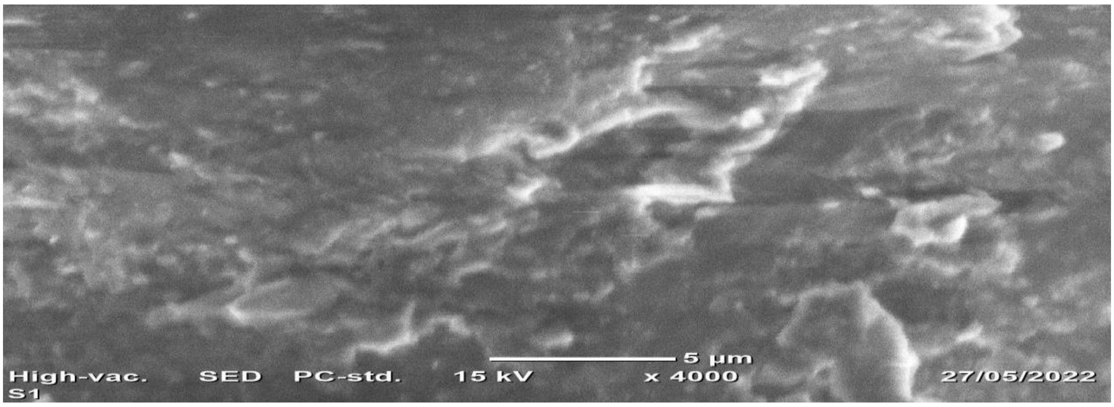
Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
4
6
[%]

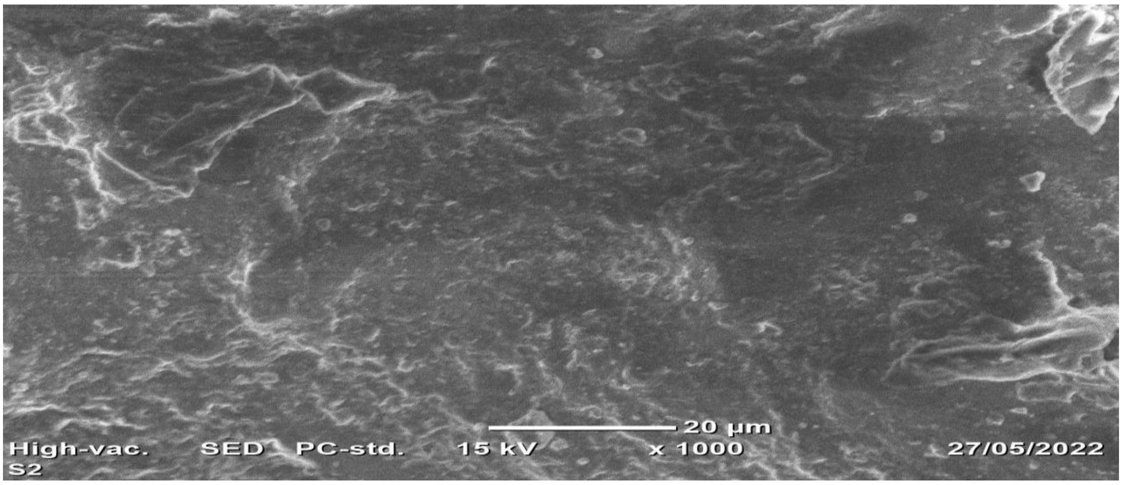


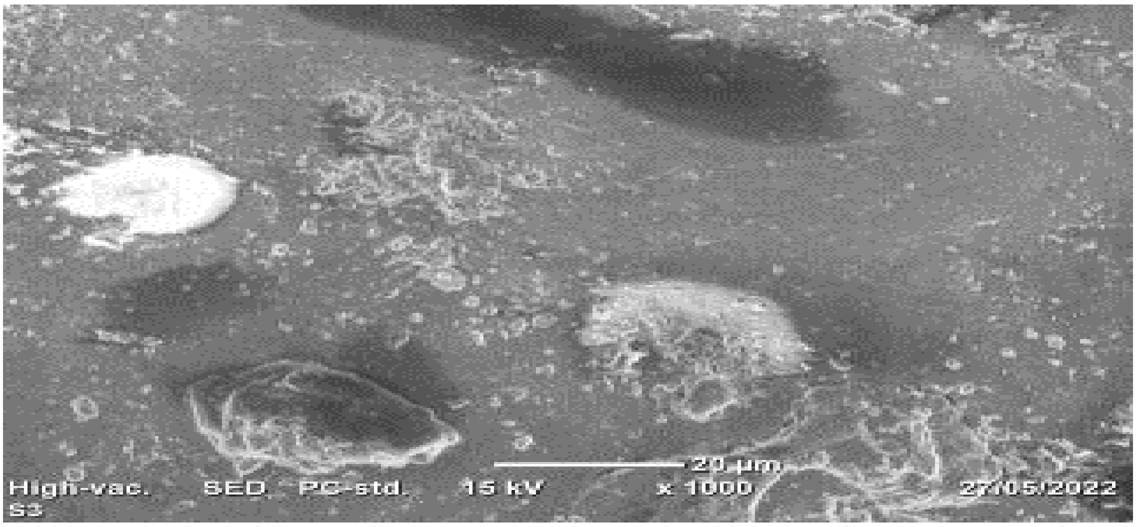
Stress-elongation-diagram
OK
Print
Test report
Cancel
[N/mm²]
100
50
0
0
2
[%]

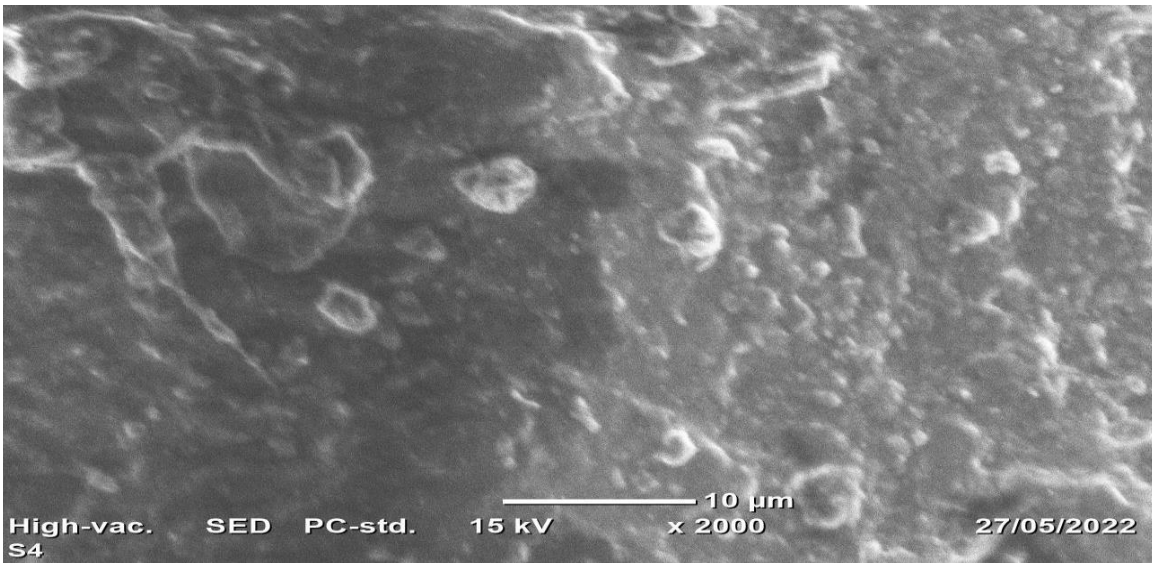
APPENDIX F: water absorption Test

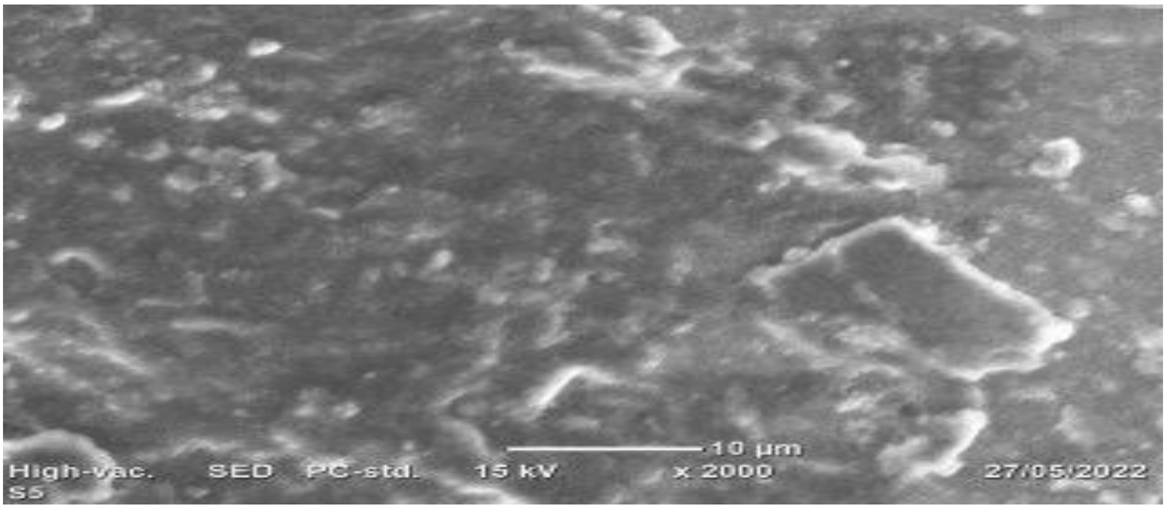
APPENDIX G: SEM morphology Test Result

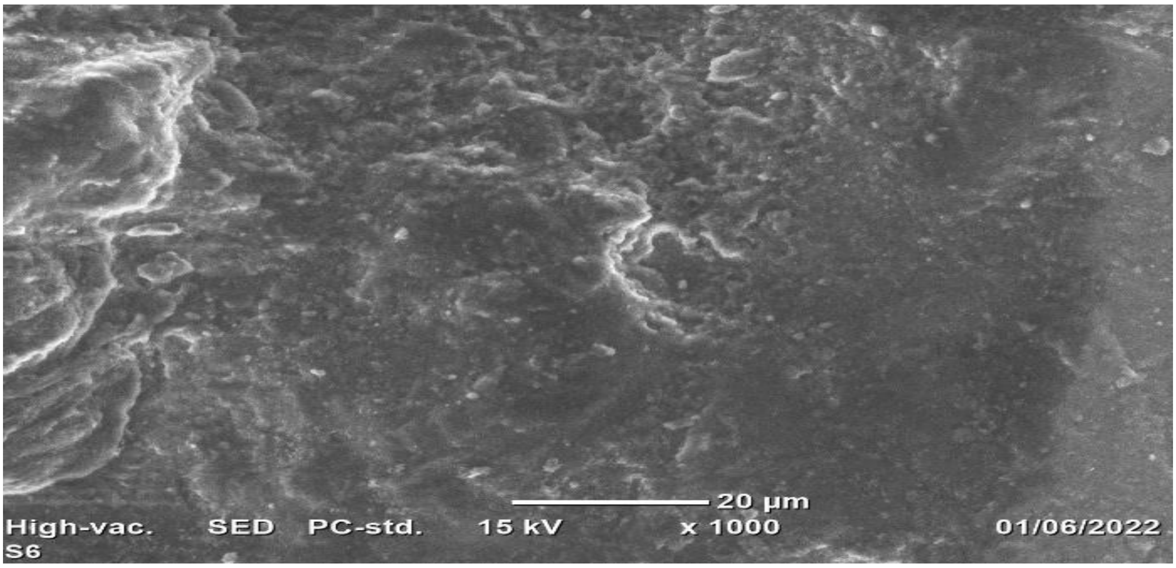


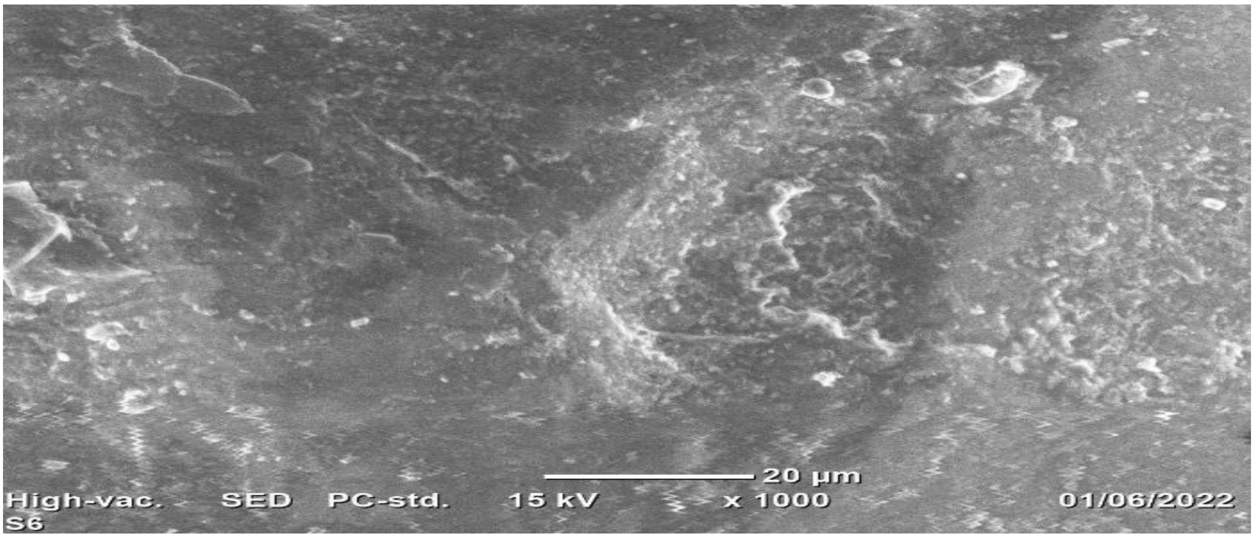


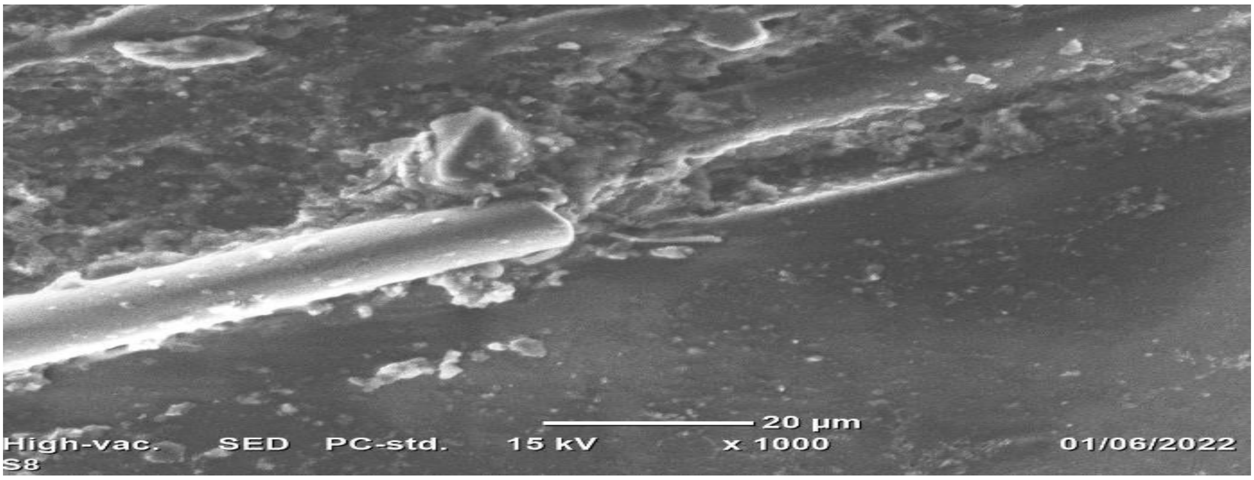


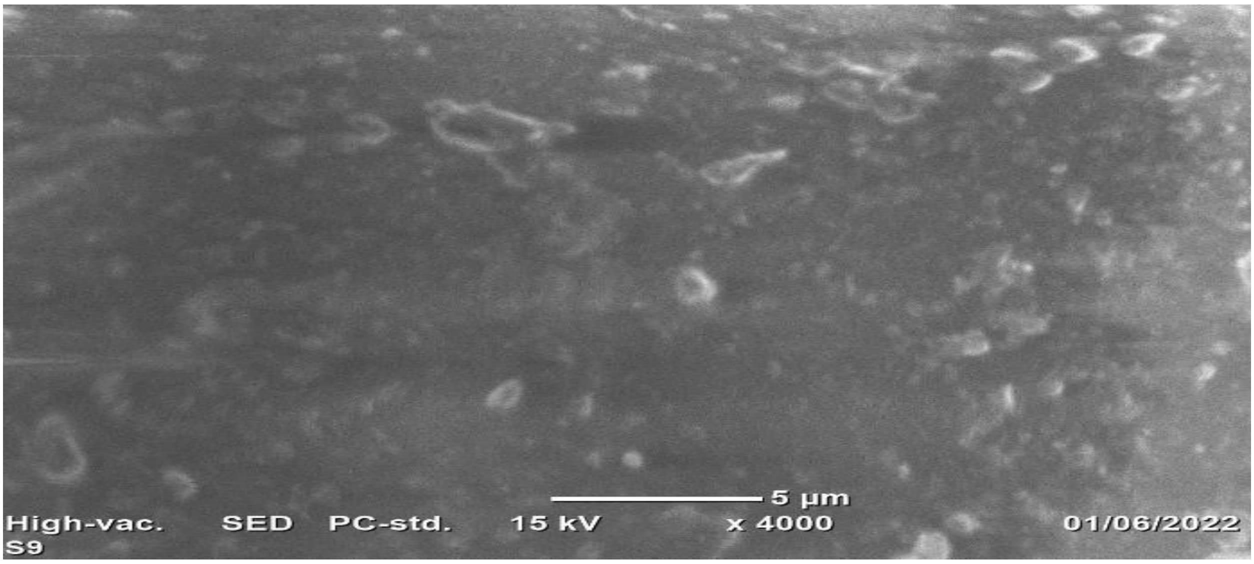

10 µm
High-vac. SED PC-std. 15 kV x 2000 27/05/2022
S4


10 µm
High-vac. SED PC-std. 15 kV x 2000 27/05/2022
S5

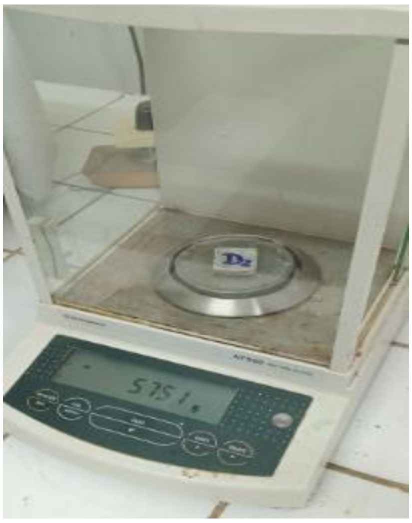
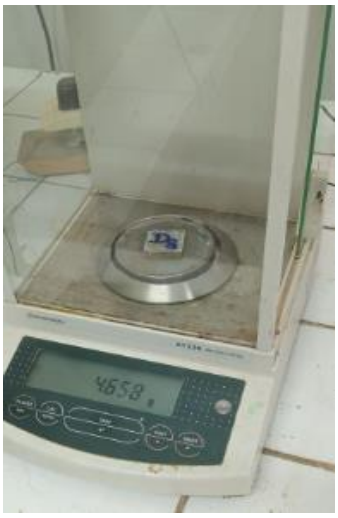

20 µm
High-vac. SED PC-std. 15 kV x 1000 01/06/2022
S6



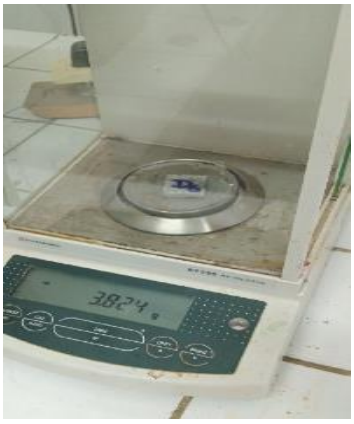


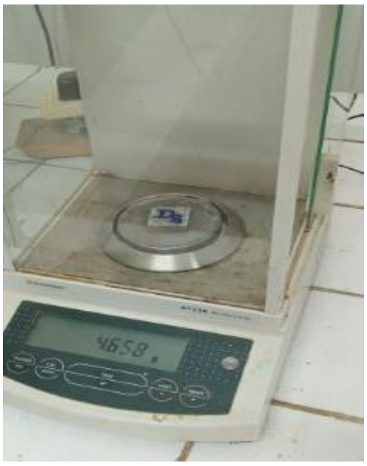


APPENDIX H: density measure


5.153 g

5.751 g

4.658 g

6.020 g

6.024 g

3.824 g

4.001 g

4.658 g

4.853 g