



ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

**Integration of Rice-Husk Filler on Physico-Mechanical Characteristics of Hybrid
Sisal and Glass Fiber Reinforced Epoxy Composites for neck brace.**

A Master Thesis Submitted to Graduate School of Addis Ababa University In partial fulfillment of the requirements for the award of the degree of Masters of Science (M.Sc.) in Mechanical Engineering (Manufacturing Engineering).

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Addis Ababa, Ethiopia

Declaration

I, [the undersigned], declare that I have completed this thesis under the supervision of Dr. Desalegn Wogaso and that it is entirely my own work, except for the sources cited in the references. I have given due credit to all sources of data used in the thesis. I further declare that this thesis has not been submitted to any other higher education institution for the purpose of obtaining a degree or professional qualification. This is to certify that the above declaration made by the candidate is correct to the best of our knowledge and belief. It has been submitted for examination with our approval.

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Dr. Desalegn Wogaso

Advisor

Signature

Date

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Submitted in accordance with the requirements for degree
of Masters of Science

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Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

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Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

Abstract

Despite the fact that composites have better corrosion resistance, light weight, good consolidation, and are available in large sheet sizes and wide range of thicknesses, physical and mechanical properties still need to be examined and improved to meet the needs of a wide range of applications. At the time of operation of composites some mechanical properties are significantly influenced by the presence of voids. The voids are the locations where stress is concentrated which accelerates the failure process leading to early and catastrophic failure of the composite. Different investigation also described important properties, including water resistance, weathering, surface smoothness, stiffness, dimensional stability, machinability, shrinkage, voids and temperature resistance, can all be improved through the proper use of fillers. The objective of this research work is to develop and characterize the physico-mechanical properties of hybrid sisal and glass fiber with rice husk filler epoxy composite. Hand lay-up fabrication technique will be used to prepare the specimen with 20% fiber and 0%, 2%, 4%, 6% and 8% rice husk filler which are then compressed using a compression molding machine. compressive strength (ASTM D3039), flexural strength (ASTM D790), impact energy tests (ASTM D256) and physical properties such as density (ASTM D792) and water absorption (ASTM D570) was conducted using ASTM standard. From the experiment executed, it is observed the flexural strength, water absorption and void content improved with addition of filler. However, compression and impact strengths slightly reduced. The design of composite structures was then evaluated using Ansys ACP analysis in order to utilize it for the required application. In compared to the others, the hybrid sisal and glass fiber reinforced epoxy composites with 2% and 4% rice husk filler exhibit outstanding performance.

Key words: physic- mechanical properties, ASTM, sisal, glass fiber, rice husk filler.

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LIST OF ABBREVIATIONS AND ACRONYMS

CM	Composite material
FEM	Finite element method
NaOH	Sodium hydroxide
NF	Natural fibers
GFRPs	Glass-Fiber Reinforced Polymers
RH	Rice husk
RHF	Rice husk fiber
BVW	Bauhinia-vahlia-weight
BVWS	Bauhinia vahlia-weight/sisal
PP	Polypropylene
MAPP	Maleic anhydride modified PP
MMCs	metal matrix composites
Mm	Millimeter
Ly556	brand name of epoxy resin used
Ly951	brand name of hardener
MPA	Mega Pascal
GPA	Giga Pascal
Km ²	Kilometer square
GPS	Glycidoxy propyltrimethoxy silane
CS	Coconut shell
ASTM	America Society for Testing and Material
Kg	Kilogram
Qty.	Quantity
SG-R0	Sisal, Glass And Rice Husk With 0%
ρ_c	density of composite

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ρ_f	density of fiber
ρ_m	density of matrix
W_c	weight of composite
W_f	weight of fiber
W_m	weight of matrix
M_f	mass of fiber
M_m	mass of matrix
m_f	mass fraction of fiber
m_m	mass fraction of matrix
SP	sugar palm

Chapter one

1. Introduction

1.1. Background

New material with better characteristics is developed when two or more distinct materials with dissimilar properties are mixed. Composite materials are used in many industries, including aerospace, automotive, construction, and marine. Research on composite materials is essential in order to develop new composite materials with improved properties, to improve the production methods for composite materials, and to develop new applications for composite materials, such as medical devices. Composite materials are used in components because they are strong and stiff, but also lightweight. It is an exciting field to work in since new materials, methods, and applications are always being created in the composites industry. Examples include the use of hybrid virgin and recycled fibers and quicker and more automated manufacturing.

In composite, the continuous component is referred to as the matrix, and the discrete or discontinuous component is referred to as the fibers. The fibers and the matrix both combine to form the composite material, which functions as a single entity [1]. The composites' load-bearing component is the fiber, which can be either natural or synthetic. The matrix, which holds the fillers together, serves as the material for reinforcement. Natural fibers are ones that were developed by nature, not by humans. Environmentally friendly materials have come into consideration on account of rising environmental awareness and public interest, new environmental rules, and unsustainable petroleum consumption. In comparison to synthetic fiber, natural fiber is one of the more environmentally friendly materials and has better qualities [2].

The fiber reinforced composites manufacturing industries have made filler synergy a well-liked study topic. As a result, adding fillers significantly alters the mechanical and tribological characteristics of the final materials. The use of agro-filler as a reinforcing component in polymer composites produced successful results, particularly in mechanical performance [3]. composites made of polymer and glass fiber are widely employed in a number of industrial applications due to their low weight, simplicity of manufacture, affordability, and noise-isolating

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properties. Particulate filler can be added to the composites to further enhance their performance. The "filler" has a significant impact on how well polymer composites work. In general, filler materials are used to lower material costs, improve mechanical qualities to some extent, and in some situations, increase the material's processability. The impact of mustard cake filler on the mechanical features of glass fiber-based hybrid composites has been studied and Results indicate that, while wear rate decreases with increasing fiber loading, mechanical features of glass fiber composites containing mustard cake as a particulate are improved when compared to unfilled composites [4].

Hybrid polymer composites that use vinyl ester as a binder and coir and rice husk as reinforcement. They found that flexural strength increases with increasing weight percentages of fiber loading and reaches its peak at 20 weight percentages of coir, however tensile strength decreases at the same weight percentage. Hybridization with rice husk (3wt%) increases flexural strength by 10.74% [5]. The ultimate strength and swelling measurement clearly showed that the bagasse filler ash had more compatibility for addition with silica and carbon black particulate, according to research on the mechanical behavior of natural rubber compounds using bagasse fiber ash as a secondary particulate in silica or carbon black [6]. it has been clearly seen that with increasing filler content, there is an increasing in density, consequently reduction in water absorption and improvement mechanical property. However, more addition of filler may create more voids [7].

1.2. Problem statement

Hybrid fibers as reinforcements in composite materials have been increasingly popular in recent years due to their benefits over synthetic fibers and natural fiber only. Thus, Rice husk and Sisal, which are readily available in Ethiopia and includes high tensile fiber from their leaves, are combined. However most composite materials are developed entirely of synthetic fibers (glass fiber), which makes them pricey due to their importation. As a result, including widely available natural fibers makes the material more cost-effective and has better qualities of both synthetic and natural fibers. Beyond its several benefits of plant fiber-based composites, there are also some drawbacks like; high water absorption and voids due to presence of hydroxyl group in cellulosic fibers and lower mechanical potency rather than synthetic fibers (carbon, Kevlar and

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glass). These inherent limitations of plant fiber reinforced composites can be successfully diminished by hybridization with synthetic fibers and using fillers [8]. Additionally, flexural constraints of composites made of naturally based and synthetic materials can be enhanced. It is required to improve and reduce natural fibers shortcomings. Despite the fact that composites have better corrosion resistance, light weight, good consolidation, and are available in large sheet sizes and wide range of thicknesses, to fulfil the demands of a variety of applications, physical and mechanical parameters such void fraction, water absorption, tensile strength, flexural strength, hardness, and impact energy still need to be researched and improved. At the moment of operation of composites some mechanical properties are significantly influenced by the presence of voids. The voids are the locations where stress is concentrated which accelerates the failure process leading to early and catastrophic failure of the composite. The cost of composite materials with desired mechanical and thermal characteristics, such as fire retardancy, water resistance, surface smoothness, voids, machinability, and reproducibility, could be decreased by the use of fillers. The increase in filler (biochar) concentration recorded reduced weight with lower moisture absorptivity, improved surface adhesion, advanced impact properties, and higher tensile and flexural strength [9]. Fillers can be used effectively to enhance a variety of crucial characteristics, including water resistance, weathering, surface smoothness, stiffness, dimensional stability, shrinkage, and temperature resistance [10]. Foam, plastic, and metal are the materials now utilized to make cervical collars. Foam collars that are easy and lightweight but don't offer much support. They are inappropriate for people with serious neck injuries. While plastic collars might be bulkier and difficult to wear for extended periods of time, they are more supportive than foam collars. The most supporting cervical collars are made of metal, but they are also the heaviest and most unpleasant. composite materials combine low weight, high strength, and stiffness, they have the potential to replace the materials now utilized to make hard cervical collars. This would enable the creation of cervical collars that are more supportive and comfortable than conventional collars.

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1.3. Objective

1.3.1. General objectives

The general objective of this research work was to investigate the integration effect of rice husk fillers on physic-mechanical properties of hybrid sisal-glass fibers reinforced epoxy composite.

1.3.2. Specific objective

- To develop hybrid sisal – glass fiber (20% volume composition of fibers) reinforced epoxy composite with 0%, 2%, 4%, 6% and 8% of rice husk fillers.
- To determine physic-mechanical properties (compression, flexural, impact strengths, water absorption and void fraction) using standard ASTM testing.
- To examine the impact of rice husk inclusion on the hybrid composite's physic-mechanical performance.
- To identify appropriate composition of the hybrid composite.
- To test the material's appropriateness for the Cervical collar application using FEM analysis

1.4. Scope of the study

The material made from sisal, glass fiber, and rice husk filler combined with epoxy as a matrix is anticipated to have special properties (high strength, high elastic modulus, light weight, and corrosion resistance) and be used in construction decoration, automotive inner body construction, water tank construction, home furnishings, and advertising displays. It is predicted that this material will become the darling of the material industry's demands.

However, the primary goal of this investigation is to manufacture the cervical collar which support the cervical spine while the patient is comfortable with a lightweight, pre-shaped foam neck brace with strong composite reinforcement. Patients who have had surgery on the cervical spine frequently utilize cervical/neck collars to immobilize the neck. Additionally, neck pain is treated with it.

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It was determined that using a hybrid sisal and glass fiber and rice husk filler epoxy composite material reduced material costs and allowed to save and create hard cash, as well as allowing local Ethiopian farmers to readily grow sisal plants and reuse rice husk and earn money. The scope of this study will provide the development of the hybrid epoxy composites the mechanical properties (tensile, flexural and impact strengths) and physical properties (density, water absorption) with filler material.

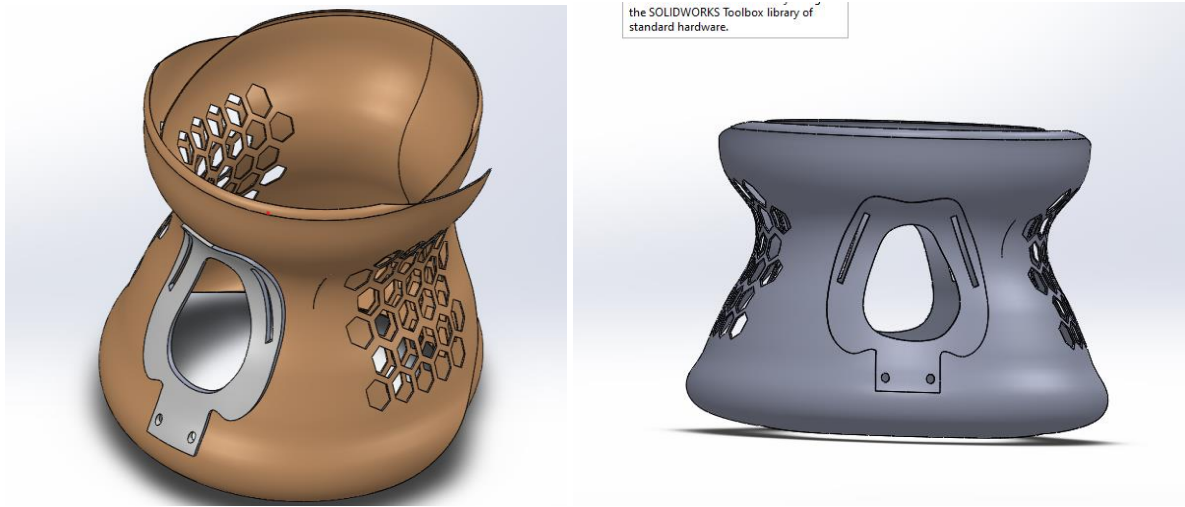


Figure 1.1: Cervical collar immobilization (immobilizing neck brace) [11]

1.5. Significance of the study

The implication of this research could be that it can be used as a starting point for further research into the physico-mechanical properties of hybrid composites with filler materials in order to improve performance for various engineering applications in the construction, automotive, furnishing and bio medical equipment industries. In addition, it encourages further research into natural fibers, which are readily available and inexpensive.

This thesis was beneficial since it may be used as a reference for scholars as well as teaching material, it replaces expensive components like metals with light weight, high-performance composite materials produced from sisal fiber, and rice husk can be employed in composite creation.

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1.6. Motivational statement

To begin with, plant-based fibers are widely available in many regions of Ethiopia, and farmers use them to create rope, fences, and other local necessities. It serves no other purpose. To generate lightweight composites with good mechanical qualities, however, researchers are presently researching hybrid glass fiber, sisal plant, and rice husk filler.

1.7. Research questions

Q1. Is it possible to develop and characterize hybrid sisal-glass fiber epoxy composite with rice husk filler?

Q2. was it possible synergy of rice husk to improve the compression, flexural and impact strength of sisal-glass fiber reinforced composite?

Q3. What was the effect of filler material on the physic-mechanical properties of the composite?

Q4. What was the better composition with the better physic-mechanical properties?

Q5. Was the developed composite appropriate for cervical collar application?

Chapter two

2. Literatures review

2.1. Composite material

Composite materials are typically formed through the engineering process from two or more constituents with distinct physical or chemical properties that continue to exist inside the final structure. The composite should also have properties which surpass the properties of the individual constituents that make up the composites [12], [13]. In general, the composite materials consist of a matrix reinforced with particles or fibers. Natural fibers were used for reinforcing the matrix until early in to the mid-20th century. However, since 1950, there has been a rise in the need for composite materials that are stiffer, stronger, and lighter while still being used in the building, transportation, and aerospace industries. As consequence, high-performance fibers were added as reinforcement. Comparing these more recent composites to conventional engineering materials like metals, they have lower specific gravities, greater strengths, and higher modulus. These materials are results of combining two or more elements so that certain improved or desired properties are achieved. In a composite, the dispersed phase is distributed in a continuous medium called matrix. This definition of composite material includes natural composites. Hybrid composites are made with two or more types of reinforcements. Commonly they are made with glass/carbon, glass/aramid, and aramid/ carbon fibers. A recent development is glass/natural fiber hybrid composites. Hybrid composites benefit from the properties or features of each reinforcement type. For example, in the glass/carbon hybrid composite, the low cost of glass fiber and high modules of carbon fiber are taken into consideration to form the low cost and high modules composite [13].

Composite material usage is still growing quickly. It is challenging to quantify the current global market worth, but it is undoubtedly higher than \$ hundred billion. Second only to steel in terms of economic significance and the variety of uses, composites are currently one of the largest and most significant classes of engineering materials [14]. This is due to a number of factors. One of them is the fact that they frequently provide attractive mixes of stiffness, strength, toughness,

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lightweight, and corrosion resistance. A second is that there is a lot of room for customization of their structure to fit service conditions. Biological materials like wood, bone, teeth, and hide, which are all composites with intricate internal structures developed (through evolutionary processes) to provide mechanical qualities well-suited to the performance needs, are excellent examples of this notion. Naturally, this adaptability is appealing for many industrial applications, but it also contributes to the complexity that must be thoroughly understood if they're to be employed efficiently. In fact, input from multiple scientific fields is necessary for the adaption of manufactured composite structures for various engineering objectives [15]. Generally composite can be classified as in Figure 2.1.

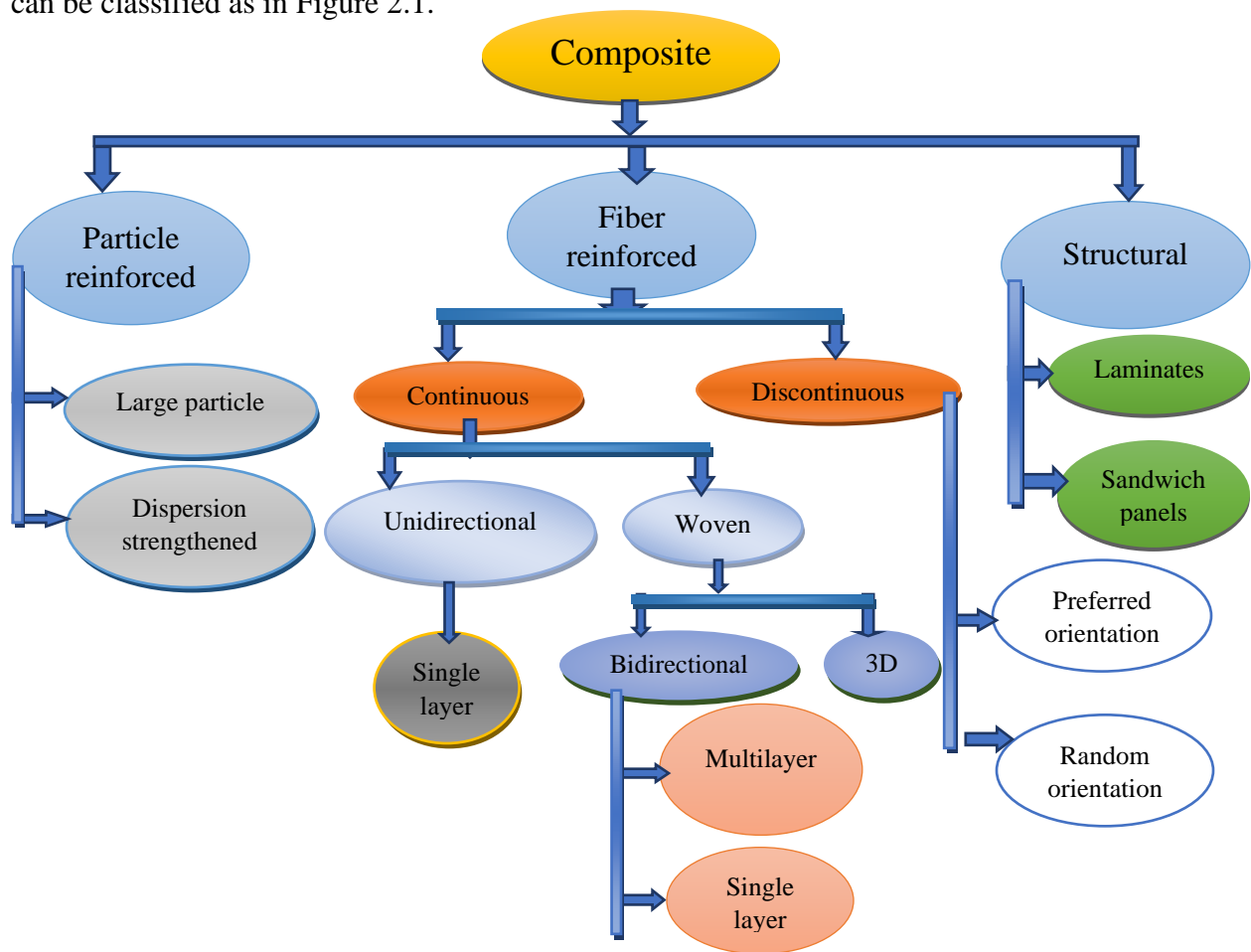


Figure 2. 1: Composite materials classification [15]

In the fields of energy and medicine, nano/micro composite and bio-nanocomposite polymer materials/membranes have captured significant interest. Their composites make them suitable

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options for a range of applications in the industrial, biomedical, and energy industries. The polymer industry is interested in composite materials. To enhance the quality of the finished product, many fillers have been introduced into polymers, including cellulose-based fillers, carbon black, clay nanoparticles, glass fibers, ceramic nanomaterials, carbon quantum dots, talc, and many more [16].

Because of their strong specific strength and modulus, fiber-reinforced polymer composites have long dominated a wide range of applications. In reinforced plastics, the fiber that acts as reinforcement might be synthetic or natural. Only synthetic fibers, such as glass, carbon, and others, have been utilized in fiber-reinforced plastics, according to earlier studies. Glass and other synthetic fiber-reinforced polymers have high specific strengths, but their usage is relatively restricted due to their higher production costs [17].

2.1.1. Hybrid composite

Hybridization is a process that involves the use of two or more fibers in a single-base matrix. The term "hybridization" is also used to describe the addition of fillers to a fiber polymer composite. To utilize the benefits of both synthetic and natural fibers are put in hybrid form, a process known as hybridization in composites. This hybridization emphasizes numerous desirable qualities of together synthetic and natural fibers, which led to the final composite's exceptional mechanical and tribological capabilities. However, this is not the only reason for the composite's different properties. To achieve promising results in the composite properties, it is essential to consider the fiber type, fiber size, proportion of fiber, the polymer utilized, processing methods, and chemical treatment [18]. Because natural fibers absorb moisture, composite materials reinforced with them cannot be used in outdoor applications. The mechanical qualities of natural fibers are inferior to those of synthetic fibers. Hybridization is a technique for enhancing the mechanical qualities of composites reinforced with natural fibers. Moisture absorption is one of the natural fibers' biggest drawbacks. As the proportion of natural fibers rises, so does their potential to absorb moisture. Chemical therapy can diminish it using substances like silane, NaOH, and occasionally even water [19].

In comparison to traditional monolithic composites, hybrid composites offer superior and

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integrated properties. The many hybrid combinations, at least two reinforcement phases included in multiple matrices or more reinforcement phases combined in multiple matrices, or a single reinforcement phase entrenched with two or more matrices like what figure 2.2 indicates. When designing and creating hybrid composites, the issue of choosing the kind of suitable fibers and the degree of their qualities is crucial [20]. Due to its unique properties, hybrid composites can be used in a numerous of structures and/or structural elements without losing their quality and life expectancy. However, the construction is more affordable and healthier for the environment when natural fibers are used in composites. they offer a number of improved features and numerous advantages over traditional composite materials. These materials are being used more and more in a variety of engineering applications. The positioning of the fibers, the amount and length of the fibers, the layering patterns formed by the two fibers, the range to which they can intermix, the fiber-to-matrix contact, and the failure strain of individual fibers can all affect the attributes of a hybrid composite. The parameters of the hybrid system fabricated of two components were predicted using the rule of mixtures [21], [22].

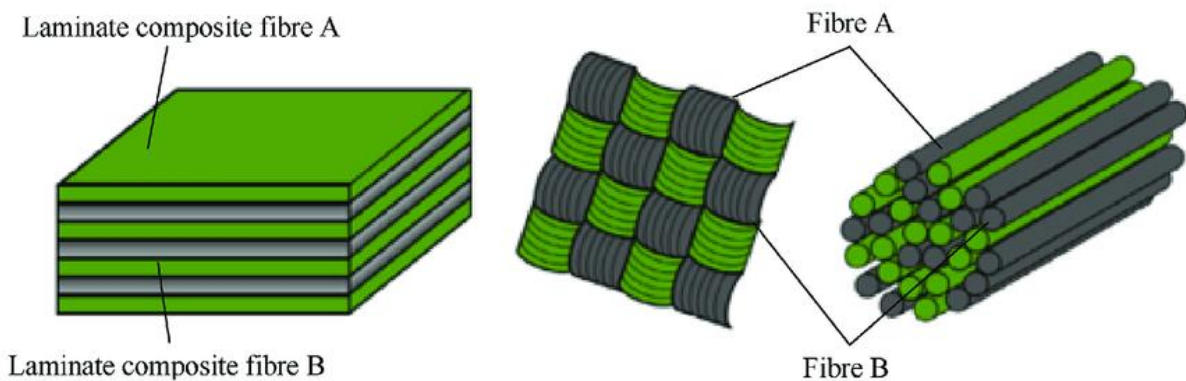


Figure 2. 2: hybrid composite interlayer or layer-by-layer, hybrid composite interlayer or yarn-by-yarn, and hybrid composite intrayarn or fiber-by-fiber [23]

2.1.2. Natural Fibers

Natural fibers, as the name suggests and indicate in Figure 2.1, a particular substance that exist naturally and are not man-made. Being renewable, natural fibers are assumed as a good substitute for traditional materials. Because of their higher aspect ratio and high strength, natural fibers are gaining greater attention in the automotive sectors for structural applications [24]. In

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addition, natural fibers are also gaining interest in the field of textile, medical implantation, building structures, aviation, etc. Because synthetic fibers are so expensive, it has really taken on greater significance and the health risks associated with artificial fibers [25]. Synthetic fibers' appropriateness in polymer composites is dwindling (losing) due to their higher cost, non-biodegradability, and dumping issues. These issues can be easily handled by utilizing natural fibers in the area of polymer composites [26]. There are two kinds of fibers available which is natural fiber and synthetic fiber. Natural fiber, being nontoxic and harmless, is made of minerals, animals, and plants; the plant materials used for this project are bamboo, hemp, sugarcane bagasse, flax, curana, rice husks, and banana. The animal materials used for this project include wool, skin, and hair. Various natural fibers have been used as fibers that give strength and rigidity to the composite [27].



Figure 2.3: Sisal fiber and rice husk (powder and sheathe) respectively from alibaba.com
Classification of plant fiber is depicted in figure 2.4. The minerals like ceramic and asbestos are required for manufacturing natural fiber. The second form, synthetic fiber is manufactured by human being while it is a combination of glass fiber, carbon fiber, and aramid [28]. There is a huge market and demand for the fiber reinforced polymeric composition specifically for the synthetic fiber as it is utilized in making pipes, in tanks, sports goods, and construction of bridges, boat hulls, automotive industry and aircraft secondary structure while thermoset matrices and thermoplastic require natural fiber [29].

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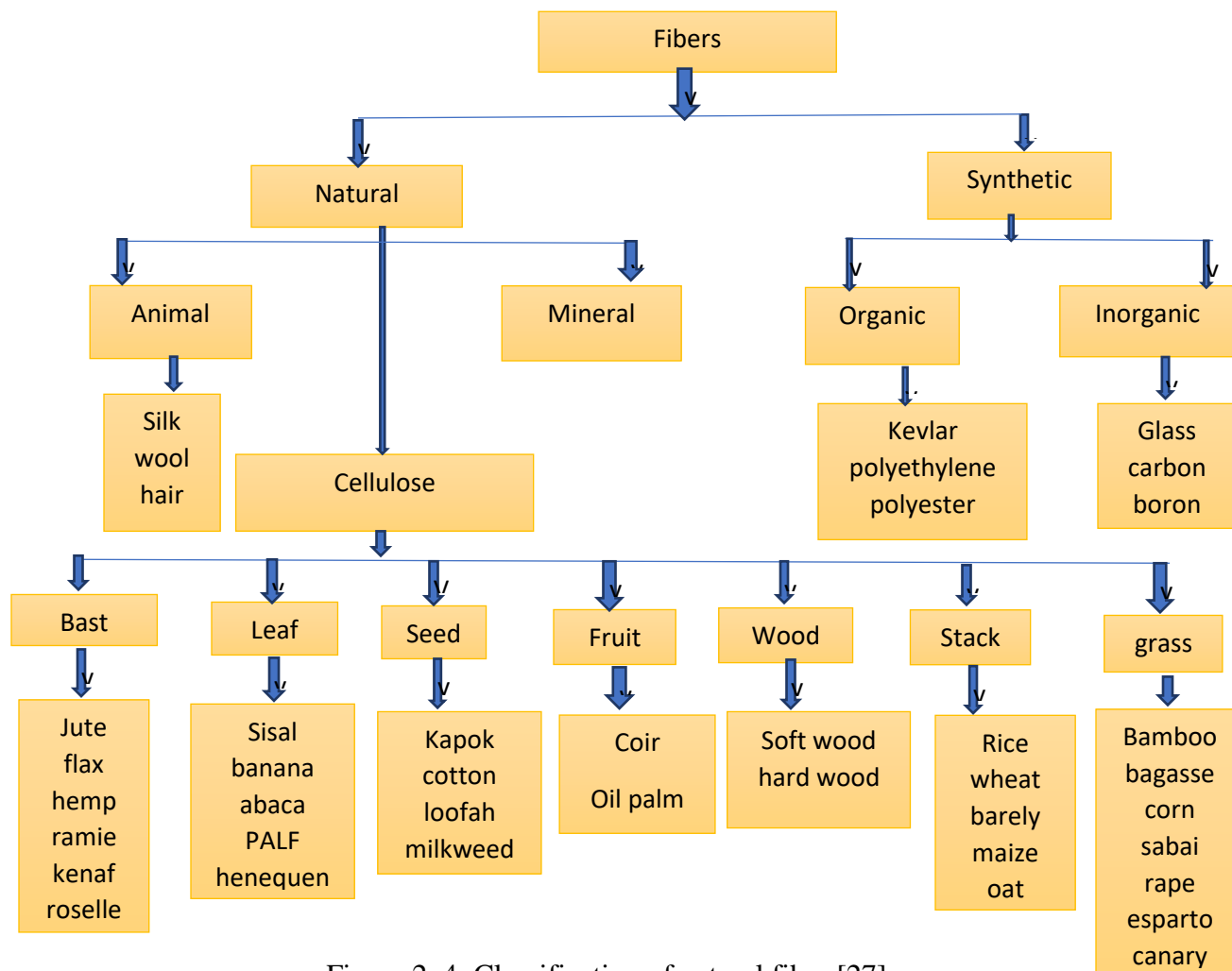


Figure 2. 4: Classification of natural fiber [27].

Natural fibers (NF) are being studied as a suitable synthetic fiber alternative in fiber/polymer composites. Natural fibers provide a number of advantages over synthetic fibers, including a favorable environmental effect, low cost, low density, and biodegradability. Natural fibers are numerous, renewable, and safe for the environment. As a result, they're increasingly being used as reinforcement in composite materials made from polymers and plastics, for both industrial and research purposes. They are plentiful, regenerative, and eco-friendly. They are consequently being utilized more frequently as reinforcement with polymers and plastics to create composite materials for both research and industry uses. Sisal fiber, a natural fiber, is being progressively used in natural fiber composite applications [30].

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

2.1.3. Sisal fiber

Sisal is one of the most popular natural fibers, sisal is also one of the easiest to grow. It comes from the sisal plant. *Agave sisalana* is the official name of the plant. These plants generate sword-shaped rosettes of leaves that are initially toothed but eventually lose them as they mature. Every leaf has many long, straight fibers that can be removed by a procedure called decortication. The rough fibers are left behind after the leaves are thrashed to remove the pulp and plant matter. The fibers can be pulped to create paper goods or spun into thread for twine and textile manufacturing. Sisal is a leaf fiber that is made from agave plant leaves and is used as a strengthening agent [31].

Sisal fiber has potential uses outside of its customary range (ropes, carpets, mats, etc.). These include the aerospace and automotive industries and in different engineering departments. Sisal fiber's physical and mechanical behaviors are influenced by its source, age, and location as well as its gauge length, experimental temperature, and strain rate [32]. The interfacial adhesion between the hydrophilic sisal fiber and the hydrophobic polymer matrix is improved by fiber surface modification or treatment. As a result, moisture absorption is decreased and the mechanical characteristics are improved, and its effectiveness and performance of composite materials are thought to be improved by the hybridization of reinforcements. In order to advance the characteristics and applications of composites, industry, and academics are focusing their research on the surface treatment of natural fibers and the inclusion of tiny fillers (either natural or synthetic) [33]. It is completely biodegradable, and green composites were created using gelatin-modified soy protein resin. It is not suggested for moist locations and is not appropriate for a smooth wall finish. sisal has a lifetime of 7 to 10 years and normally yields 200 to 250 leaves that are suitable for commercial use. On average, there are about 1000 fibers per leaf. It is taken out using a procedure called decortications [34].

2.1.4. Synthetic fibers

Synthetic fibers are chemically synthesized fibers made by humans as opposed to naturally occurring fibers made from living things like plants (like cotton) or animal fur. They are the product of years of research by experts to improve on natural Plant and animal fibers. Synthetic

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fibers are made by extruding fiber-forming ingredients via spinnerets and generating a different fiber in the process. Synthetic or artificial fibers are what they're termed. Synthetic fibers are incredibly strong, absorb very little water, and dry rapidly. They are also more durable than natural fibers, wrinkle resistant, exceedingly light, and fire resistant. High mechanical properties, longevity, stability, and long-life span are all characteristics of synthetic fibers. There are numerous varieties of synthetic fibers, but the composites business mostly uses Kevlar (aramid), glass, and carbon fibers on a big scale [35].

2.1.5. Contrasting between natural and synthetic fibers

Natural and synthetic fibers each have their own unique properties and advantages as shown in table: 2.1. The best type of fiber for a particular application will depend on the specific requirements of that application.

Table 2.1: The basic comparison between natural and synthetic fibers [24]

Properties	Natural fibers	Synthetic fibers
Density	Low	Twice that of natural fibers
Cost	Low	High, compared to natural fiber (NF)
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	Wide
CO2 neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegradable	Not biodegradable

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2.1.6. Glass fiber

Glass fibers are a material that is highly sought-after in high-performance composite applications. As indicated in table: 2.2, due to its appealing physical and mechanical qualities, simplicity of production, and comparably low cost to carbon fibers [36]. They are advantageous due to their large surface area to weight ratio and exceptional mechanical characteristics, including low fragility, high strength, low stiffness, and light weight. It is a lightweight, strong, and robust material used in different industries due to their excellent properties. Although it is less stiff and has slightly lower strength than carbon fiber, the material is often much less brittle, and the cost of the raw materials is significantly lower [37].

Glass fibers are composed of oxides of silica. Its exceptional mechanical qualities include low fragility, high strength, low stiffness, and lightweight. Glass fiber-reinforcing polymers are a vast family of distinct types of glass fibers that are used to improve the mechanical and tribological properties of polymer composites. These types of glass fibers include longitudinal, chopped strand fiber, woven mat, and chopped strand mat. By varying the proportion of raw ingredients such sand for silica, clay for alumina, calcite for calcium oxide, and colemanite for boron oxide, glass fibers can be produced in a variety of compositions. As a result, different types of glass fiber that include varying amounts of silica or other sources have a variety of attributes, such as excellent mechanical capabilities or alkali resistance [38].

Glass fibers are used primarily to reinforce polymers. The leading types of glass fibers for mechanical engineering applications are E-glass and S-glass fibers. E-glass fibers are the most prevalent among all fibrous reinforcements, because of their low cost and relatively low elastic moduli compared to other reinforcements [39]. S-glass fibers are stronger, stiffer, and more resistant to fatigue and creep than E-glass ones. Natural fiber composites composed of sisal and jute are becoming more and more popular because to their high specific strength, low weight, and biodegradability, and the applications for fusing natural fiber with glass-fiber reinforced polymers (GFRPs) are growing. Additionally, sisal-jute fiber can be used as an alternative material for glass fiber-reinforced polymer composites and can enhance the qualities of GFRP [40].

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Table 2.2: Properties of glass fiber [41]

Property	Unit	Glass fiber
Density	gr/cm ³	2.56-2.62
Tensile strength	MPa	3445
Poisson's ratio		0.19-0.25
Thermal heat conductivity	W/m.k	1.38
Modulus of elasticity	GPa	76
Tensile elongation	%	2.75
Fiber diameter	µm	13
Chopped length	mm	3
Moisture content	%	Max. 0.1

2.2. Improvement of composite properties

The content (volume fraction), chemical treatments, fiber shape and orientation, filler materials, matrix variables, thickness, additives, and interfaces between the components are just a few of the approaches for increasing composite attributes that are covered in various research studies. Although concrete is a well-known composite material, it can be strengthened under tension by the addition of metal rods, wires, mesh, or cables[42].

2.2.1. Filler materials in composite

The filler material has an effect on the mechanical characteristics, tribological characteristics, and interfacial bonding of composites[43]. Filler addition to polymers is mainly to modify and improve the mechanical properties at a reasonable cost. The plastics industry has long used these mineral fillers to alter the performance of thermoplastics' properties. Excellent stiffness and temperature resistance are provided by them[44]. These mineral fillers are expensive, though, and frequently have rough surfaces that damage processing equipment. Additionally, the composites created with these kinds of fillers are not biodegradable.

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Rice husk natural filler is a readily available raw material for the construction of polymer composites. Despite the fact that synthetic fibres use into polymer composites improves composite qualities, the high cost and environmental impact has moved attention to naturally reinforced polymer composites. Low cost, low density, non-abrasive, reduced health risk, minimum energy consumption, renewability, and biodegradability are some of the reasons for natural materials getting attention[45]. Recently, numerous researches on the preparation of novel materials based on the bio-resourced materials have received significant of attention. It has been widely used as a reinforcing filler in composite applications because to rice husk's low density, great deformability, minimal abrasion, biodegradability, and inexpensive cost[46]. Rice husk (RH) is a natural covering that develops around rice grains as they grow. RH can be utilized as filler in composite materials in a variety of polymer matrices because it is a form of natural fiber made from agricultural industry waste[47].

Fibers that have absorbed water are prone to become less stiff and to develop shear stress at the interface, which leads to debonding between the fiber and matrix. Also, the rate of reduction in tensile strength was depends on duration of immersion, quantity of fiber and percentage of filler material. The addition of filler materials may fill the small void spaces resulted on minimizing the penetration of water. This may enhance the bonding between matrix and fibers. The findings of the samples with nanofiller material addition are better than those with micro filler material addition, possibly because the nanofiller material occupies the tiny nanoscale voids[48].

By enhancing the qualities of these hybrid materials, filler additions such nanotubes, whiskers, fibers, and nanoclusters may improve the overall performance of dental composite resin materials when employed carefully[49]. The nature, type, size distribution, and surface changes of the filler have contributed significantly to the practically implemented improvement in composites during the past few decades[50]. The impact of rice husk fillers was examined on the physical, mechanical, and sliding wear characteristics of hybrid composites reinforced with Bauhinia vahlii weight (BVW) and Bauhinia vahlii weight/sisal (BVWS) fibers. By varying the loading amounts of BVW and combination BVW-Sisal fiber reinforced epoxy composites, the rice husk content was hybridized. In this study, it was observed that the amount of rice husk had a significant impact on the physical and mechanical parameters such void fraction, water

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absorption, tensile strength, flexural strength, hardness, and impact energy[51].

When mixed with various thermoplastics, the use of natural fibers as particle fillers is known to have a variety of benefits, and in most situations, improves the impact strength, stiffness, thermal distortion temperature, and cost reduction. Use of rice husk in the manufacture of polymer composites is attracting much attention. It is one of the most widely available agricultural wastes in many rice producing countries of the world. They are the hard-protecting coverings of grains of rice and removed from rice seed as a by-product during the milling process[52].

The introduction of rice hulls into the polypropylene matrix resulted in a reduction in peak stress as well as an increase in the tensile and flexural modulus of the composites made of rice hulls and polypropylene[53]. Rice husk was milled and dried for using as filler in polypropylene (PP) composites. It was verified that it is feasible to use this by-product of the rice milling process as a low-cost filler, in view of the properties of the obtained products. The composite stiffness was seen to increase with increasing filler loading. The tensile strengths slightly decreased; however, they were improved in the presence of the coupling agent Maleic anhydride modified PP (MAPP). It was verified that MAPP/RHF ratio of 0.03 produced the best results. Density determinations showed that PP/RHF composites are very light materials since its density did not increase too much with respect to pure PP. It is also discovered in the study of impact of fiber surface treatments on physic-mechanical behavior of jute/epoxy composites impregnated with aluminum oxide filler) that the addition of Al₂O₃ particulates (at different volume fraction) into the composite results in improvement of tensile strength. The maximum value was found in in the higher volume fraction particulate filled composites with benzoyl chloride treated composite [54].

2.2.2. Filler size

Adding nanoscale and micrometer sized fillers to composites has been proposed as a way to enhance their mechanical qualities in recent years. Due to their low specific wear rate, high specific resistance modulus, and low water absorption, filler-based hybrid polymer composites are replacing metallic components [55]. The development of many items in the contemporary

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world has been significantly impacted by the use of nano/micro materials. One idea for the development of nanomaterials is the use of nanofillers in composite materials. The production of diverse composite mixtures, followed by a thorough discussion of the various nanofillers, is briefly covered in this review along with the different forms of nanofillers. The addition of these nanofillers as reinforcement or matrix drastically alters the mechanical features of composites. The nanofiller's dispersion has received special consideration because it enhances the mechanical qualities of the material [56].

The incorporation of nanoparticles into polymeric materials improved architectural performance, physiological connectivity, and ecological aspects compared to similar composites without them. The mechanical properties of the epoxy hybrid composite have been significantly improved through the use of nano and micro fillers. Comparing composites including and excluding the addition of microfilters, composites with the addition of nanofillers showed better performance [57].

2.3. Polymer (epoxy resin)

For its heat resistance, insulation, thermal stability, chemical resistance, and mechanical qualities, epoxy resin is widely employed in the aviation and composites industries. The increased market demand has driven epoxy to further enhance its performance.

Epoxy resins are the thermoset resins that, when mixed with glass, carbon, or aramid fibers, generate composite materials with the best qualities of most thermosets because of their reactivity, which enables them to connect to fibers, and their toughness. Epoxy resins often have greater mechanical qualities than thermosetting polyesters and, when properly hardened, also have better heat resistance and chemical resistance, especially resistance to alkalis[58].

Many traditional metals and materials have been replaced by polymers in a variety of applications. This is achievable due to the advantages of polymers over traditional materials, such as simplicity of processing, productivity, and cost savings. For the majority of these applications, fibers are used to modify the characteristics of polymers in order to meet the demands for high strength and high modulus[59]. epoxy resins have established themselves as unique building blocks for high-performance coatings, adhesives, and reinforced plastics. The family of epoxy resins includes monomeric and oligomeric materials that can be further reacted

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to create thermoset polymers with excellent adhesion to a variety of substrates, low order shrinkage upon cure, impact resistance, flexibility, and good electrical properties[60].

2.4. Fabrication techniques of composite materials

Many techniques such as compression molding, vacuum molding, hand lay-up and others are available for manufacturing of composites. In this study, the desired composite sample was produced using hand lay-up, which are then compressed using a compression molding machine. The production technique, fibers, fiber phase, matrix material, and filler components are the primary considerations for any composite. The characteristics of the composite can be improved by optimizing these elements.[61].

The tensile strength and causes of damage of GF/PP composite materials with a fiber content between 10% and 30% were examined. Tensile strength and breaking strength increased with increasing fiber volume fraction in the tested area. However, when the fiber volume fraction was exceeded, there was an increase in fiber elongation and delamination in this composite[62]. The mechanical as well as physical properties of thermoplastic polyurethane hybrid composites reinforced with sugar palm (SP) and glass (GF) fibers at (SP/GF) ratios of 30/10, 20/20, 10/30, and 40/0 by % weight fractions. According to the testing findings, the addition of SP/GF 10/30 resulted in a higher density, less thickness swelling, and less water absorption. It was also noted that due to the superior hybrid performance of the two fibers, the tensile and impact properties of the SP/GF composites were improved with an increase in sugar palm fiber content (30/10 SP/GF) in comparison to glass fiber reinforced composites (0/40 SP/GF)[63].

2.4.1. Treatment of natural fibers

As stated above the composites reinforced with natural fibers can't be used in outdoor applications because of moisture absorption behavior of natural fibers. One of the main disadvantages of natural fibers is moisture absorption. The capacity of moisture absorption increases with increase in natural fiber content. It can be diminished through chemical treatment using substances like silane, NaOH, and occasionally water as well. Natural fiber reinforced composites are less desirable to work with because they have weak interfacial adhesion and poor resistance to moisture absorption. The structural alignments of materials like cellulose,

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hemicelluloses, lignin, pectin, and waxy components, which permit moisture absorption from the environment, cause poor bonding with the matrix materials. Different chemical techniques are employed to improve the compatibility between the fiber and matrix, which is ultimately accountable for the improvement in the mechanical properties of the composites. Alkali treatment is a widespread, effective, and economically more affordable procedure for the treatment of fiber surfaces[64].

A plant fiber is subjected to an action of a fairly concentrated aqueous solution of a strong base to create significant swelling, with subsequent changes in the fine structure, size, morphology, and mechanical characteristics. This process is known as alkaline treatment or mercerization. The most popular chemical for bleaching and/or cleaning the surface of plant fibers is sodium hydroxide (NaOH). Sisal is treated with alkali by submerging the fiber for a predetermined amount of time at room temperature or at a higher temperature in a solution with a particular concentration of NaOH or another alkali. The loss of some of the hydrogen bonds in the network structure as a result of alkali treatment is anticipated to increase the content of amorphous material. Mercerization facilitates chemical bonding, enhances resin uptake, and eliminates cuticle layers and waxy materials [65].

Natural fibers were often subjected to the alkali treatment, which produced composite materials with good fiber matrix adhesion, thermal conductivity, and mechanical strength. Under diverse circumstances, the effects of alkali treatment on kenaf fiber physical qualities were investigated. Kenaf bast fiber physical qualities are influenced by the alkali treatment conditions setting. It was discovered that kenaf fiber density increased slightly following alkali treatment compared to untreated kenaf fiber. The density of kenaf fiber also marginally increased as each alkali treatment parameter was raised[66].

2.5. Factors influencing the mechanical properties

The following factors influence mechanical properties of composites[67]:

1. **Fiber content:** The weight or volume percentage of fibers in the composite is known as the fiber content. Mechanical qualities like tensile strength, flexural strength, and hardness also improve as the amount of fiber in the composite increases. At 30 to 50 percent of the fiber weight, the greatest values of the characteristics were discovered.

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2. **Chemical treatment:** The tensile strength and flexural strength of the composites are enhanced by chemical or surface treatment of the fibers prior to composite manufacture. The qualities are improved by the surface treatment, which removes contaminants from fiber surfaces and strengthens the link between the fiber and matrix[68]. However, because the strength of the fiber after treatment drops, the impact strength of composites also falls. Alkalization, silane treatment, acylation, and benzolization are a few examples of several chemical treatment methods.
3. **Bonding between matrix and fiber:** The degree of bonding between the matrix and fiber greatly affects the characteristics of composites. Higher-quality composites with better matrix-to-fiber bonding have superior characteristics. And surface treatment can help you get there. The process of surface treatment leaves some empty spaces on the surface of the fiber, which are then filled with matrix, improving the bonding between the matrix and fiber.
4. **Fiber form:** Form of the fiber means long fibers, short fibers and fiber in powder form. With increase in length of fibers the impact strength increases because larger size fibers absorb more energy. There is no change in tensile and flexural strength with respect to the fiber length. Optimum size of fibers gives the better tensile and flexural strength.
5. **Water absorption:** The water absorption behavior of fibers reduces the bonding between the matrix and fibers. And it leads to decrease in the properties of composites. So, the fiber reinforced composites can be used in the areas where there is less interaction with water. This behavior of fibers can be reduced by chemical treatment.
6. **Stacking sequence:** In some composites more than one fiber are used. The arrangement of fibers also influences the properties. By choosing the best stacking sequence of fibers the properties of composites can be improved.

2.6. Properties of natural fibers:

The properties like density, tensile strength, modulus, percentage of elongation and moisture content are shown in Table 2.3:

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Table 2.3: Natural fiber's properties[67].

Fiber	Density (g/cm³)	Tensile strength (Mpa)	young's modulus (Gpa)	Elongation at break (%)	Moisture content (wt. %)
Sisal	1.4	468-640	9.4-22.0	3.0-7.0	11
Cotton	1.5-1.6	287-800	5.5-12.6	7.0-8.0	-
Flax	1.5	345-1100	27.6	2.7-3.2	10
Hemp	1.47	690	30- 60	1.6	10.8
Jute	1.3-1.4	393-773	13.0-26.5	1.2-1.5	12.6
Kenaf	1.3	930	53	1.6	-
Ramie	1.5	400-938	61.4-128	1.2-3.8	-
Abaca	1.5	400	12	3.0-10.0	15
Pineapple	1.3	413-1627	34.5-82.7	1.6	11.8
Coir	1.1	131-175	4.0-6.0	15-40	8

2.7. Applications of composite materials

2.7.1. Applications of natural fiber reinforced composite

Natural fibers have been used to reinforce garments for about 3,000 years. In recent years, they have been employed in combination with polymers. The potential for using these materials in polymers includes flax, hemp, jute, straw, wood fiber, rice husks, wheat, barley, oats, rye, cane (sugar and bamboo), grass reeds, ramie, oil palm empty fruit bundle, sisal, coir, water hyacinth, pennywort, kapok, paper-mulberry, banana fiber, pineapple leaf fiber, and papyrus[69]. Natural fiber composites are attracting a lot of interest in study and development because of their improved formability, abundance, renewable nature, economic effectiveness, and environmental friendliness. Growing environmental consciousness has led to its application as an effective reinforcing substance in polymer matrix composites. The biggest problem is the incompatibility of the fibers, despite the fact that they are effective materials that can be used in place of synthetic

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fibers, materials made from plants and animals also have low moisture resistance. The use of natural fiber reinforced polymer composites (NFRPCs) is widespread in a variety of technical applications, and this area of study is expanding constantly[70]. Natural fibers have a wide range of industrial and commercial uses due to their low cost and wide availability. Some examples include the interior of passenger cars, partition and false ceiling panels, partition boards, roof tiles, furniture applications, coir fibers in packaging, geo-textiles for soil protection and erosion control, improving barrier properties, and composites[71].

2.7.2. Applications of composite materials in biomedical

Composite materials are recognized as an essential part of our daily lives because of their excellent properties and diverse range of applications. Polymer composites, a popular class of composites, are inexpensive, have straightforward manufacturing methods, and have a broad range of applications, from simple structural problems to exceedingly complicated electronics and cutting-edge medical combinations[72]. In comparison to the contemporary development of biomaterials for implantable metals, biomedical polymers, and bio ceramics, the development of biomedical composites is quite new. Numerous medical specialties, including orthopaedics, dentistry, medication delivery, and others, have benefited from the significant research and development of biomedical composites. innovative technology, such cancer theranostics. This is because employing composites for implants and other medical equipment has unmatched advantages[73]. In hybrid polymer composites, the microscale interactions of the ingredients result in a more homogeneous material with properties somewhere in between or better than the two initial phases. Simple polymer materials are difficult to meet all needs due to a number of limitations, especially in the biomedical field. To overcome the biological performance limitations of inorganic structures and to improve the mechanical capabilities of organic structures, hybrid polymers have recently attracted much attention. Research on the application of hybrid polymers in the field of biomedicine has mainly focused on activities such as mechanically demanding tissue engineering, biological/injectable scaffolds, implants, biosensors, drug delivery, and bone regeneration[74].

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2.8. Neck braces

There are soft and hard neck (cervical spine) braces. Cotton is used to cover a soft cervical collar constructed of thick foam rubber. The cervical region is supported by it, and the discomfort from an accident like whiplash is controlled by it. Rigid braces are constructed of molded composite with a front and rear piece that has Velcro-sealed detachable cushioned liners.

According to recent research in the journal "Surgical Technology International," your head weighs 10 to 12 lbs. (4.535-5.44kg) on average whether you are standing or sitting upright. However, the head weight increases to more than 27 lbs. (12.247kg) if you tilt 15 degrees forward. At a 30 and 45-degree angle, it appears to weigh 40 lbs. (18.1437 kg) and 49 lbs. (22.23 kg) respectively. And that is increasing compression on the discs in the neck and spine, which can result in persistent discomfort in the neck, shoulders, and head as well as severe headaches



Figure 2.5: adjustable neck brace[75]

2.9. Diversity of Sisal and rice husk plant In Ethiopia

There isn't much *Agave sisalana* production in Ethiopia. Nevertheless, the majority of the nation is semi-arid, making about 71% of its 1.115 km² total land area (approximately 46% of which is covered with *agave americana*)[76], [77]. Since most of the areas are dry land, there is fertile ground and great potential for producing *Agave sisalana* both on a small-scale (by farmers) and on a large-scale (by industry). Given how labor-intensive the crop is, it may provide a big

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number of employment opportunities for the significant rural population. Ethiopia is one of the continent's rice-growing nations, with an economy that is heavily dependent on agriculture. In Ethiopia, where the by-product or rice husk is currently used as traditional animal fodder and the remainder is disposed as waste, there is an estimated 20 million hectares of potential land for rice production, according to a report by the Ministry of Agriculture and Rural Development (2009)[78].

2.10. Summary of Literature Review

The use of filler materials in composites is a well-established practice that can be used to improve a variety of properties, including strength, stiffness, toughness, wear resistance, and flame retardance. Fillers can also be used to reduce the cost of composites. Rice husk is a sustainable and renewable waste product from the rice milling process that can be used as a low-cost filler for composite materials. Adding rice husk filler to composites can improve their mechanical, physical, and tribological properties. This is because rice husk filler acts as a reinforcement material, providing additional strength and stiffness to the composite, and reducing its porosity.

Table 2.4: Summary of some of the related literatures

Citation	Title of the work	objective	findings
[37]	Mechanical property evaluation of sisal–jute–glass fiber reinforced polyester composites	Evaluating the Mechanical property of GFRP mixing with natural fibers (sisal–jute)	The incorporation of sisal–jute fiber with GFRP can improve the properties and used as an alternate material for glass fiber reinforced polymer composites.
[44]	improving the mechanical properties of polypropylene composites with coconut shell particles.	The effect of the filler particle (coconut shell) size on the mechanical properties was investigated	The decrease in the size of filler (CS) was found to improve the yield strength, tensile strength, tensile modulus, flexural strength, flexural modulus, and hardness

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[46]	Properties of Rice Husk/Epoxy Composites Under Different Interfacial Treatments	The comparison on the NaOH and 3 – glycidoxy propyl- trimethoxy silane (GPS) modifications on the rice husk/ epoxy composites	An optimum concentration of NaOH at 6 wt% or GPS at 10 wt% was found based on the highest performance of mechanical properties at 70 wt% rice husk content. As for the effect of rice husk content, the maximum reinforcing effect was found at 50 wt% and 70 wt% of rice husk with NaOH and GPS treatment respectively.
[48]	Tensile properties of reinforced plastic material composites with natural fiber and filler material	Studying the tensile properties of woven bamboo bidirectional natural fiber with coconut shell powder in micro and nano size reinforced polymer composite with an angle of 0°/90° orientation.	It is analyzed and proved that bamboo fiber absorbs less water when compared to all other natural fibers. The inclusion of fillers increases the bonding strength between the natural woven bamboo fiber and polyester resin.
[53]	Polypropylene-based Eco-composites Filled with Agricultural Rice Hulls Waste	The properties of rice-hull-filled polypropylene (PP) composites were investigated with the purpose of enhancing adhesion between the polymer and the filler.	12 % improvement in the composite tensile strength, Modulus in flexure improvement of 52 % when compared to pure polypropylene. Thermal stability of PP was slightly improved by adding rice hulls.
[64]	Influence of fiber surface treatments on physico-mechanical behavior of jute/epoxy composites impregnated with aluminum oxide filler.	The effect of ceramic filler inclusion on physico-mechanical and water absorption behavior of untreated and chemically treated (alkali and benzoyl chloride treated) bi-directional jute natural-fiber-reinforced epoxy composites.	Chemically treated composites considerably improved the mechanical properties of the composite (water absorption resistance and strength properties).
[79]	Synergy of rice-husk filler on physico-mechanical and tribological properties of hybrid Bauhinia-vahlii /sisal fiber reinforced epoxy composites	influence by rice-husk on the physical and mechanical properties	the addition of rice husk fillers with optimum variation reflects the improvement in mechanical and wear performance of natural fiber based epoxy composites

2.11. Gaps Identified

Most studies have investigated hybrid composites with sisal, jute, hemp, and flax, and glass fibers. However, it could also be used in hybrid composites with rice husk filler. More research is needed to investigate the effects of using different natural fibers in hybrid composites filled

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with rice husk filler. rice husk filler can improve its adhesion with the epoxy matrix and lead to improved composite properties.

Hybrid sisal-glass fiber composites without filler have lower mechanical and physical properties, such as tensile strength, flexural strength, impact strength, water resistance, and porosity, than hybrid sisal-glass fiber composites with filler. They are also more susceptible to the effects of environmental factors, such as moisture. This is because sisal fibers are hygroscopic and can absorb water. This research focused at the influence of rice-husk filler on the physic-mechanical properties of hybrid sisal and glass fiber reinforced epoxy composites. The investigation of mechanical characteristics employing sisal, glass fiber, and rice husk fiber individually as a reinforcement has been the subject of several studies and investigations. There have been additional investigations employing rice husk as a filler, but with other reinforcing fibers. However, this investigation was conducted fabricating hybrid sisal-glass fiber epoxy composite using rice husk as a filler material as we have enough availability of both the natural fibers and testing the physic-mechanical characteristic of the composites.

Chapter Three

3. Materials and methods

The following are the main procedures used to accomplish the goals of this thesis:

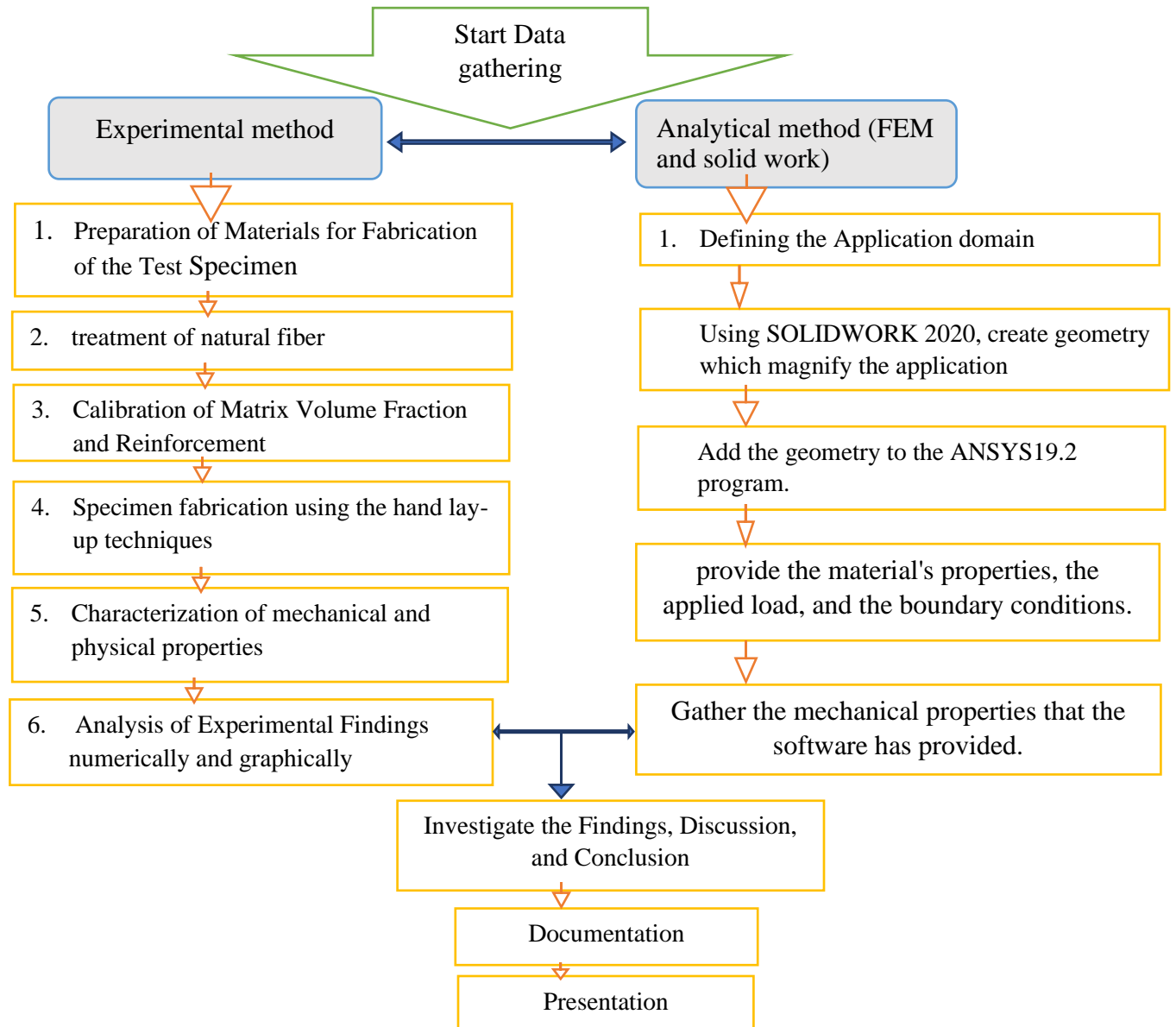


Figure 3.1: methodologies

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

3.1. Materials used

a. Epoxy resin and hardener

This investigation employed Epoxy Resin with the brand name (LY556), which was collected from the Indian market which is shown in figure 3.1. In advanced composites, epoxy resins are the most commonly used polymer. Their ubiquitous use arises from their superior mechanical properties, great adhesion, and capacity to use addition-type techniques, as well as their low cost and minimum cure shrinkage[80].



Figure 3.1: HERENBA waterborne epoxy resin (LY556) 1kg & hardener (hy951) 100 grams
Epoxy resin LY556 is a medium-viscosity, unmodified epoxy resin based on bisphenol-A. It is a clear liquid that has a pale-yellow color. LY556 has excellent mechanical properties, strong chemical resistance, and low electrical conductivity. It is also quite simple to handle and cure. Some of the key properties of epoxy resin LY556 are included in the table 3.1.

Table 3.1: standard properties of epoxy (LY556) [80], [81]

Product type	Epoxies-bisphenol-A based	
Chemical composition	Bisphenol-A-based epoxy resin	
Aspect(visual)	clear	
Viscosity at 25 ⁰	10000-12000 kg·m ⁻¹ ·s ⁻¹	
Density at 25 ⁰	1.15-1.20g/cm ³	
Compressive strength	51.3 Mpa	
Bond	<i>Standard</i>	2.1 Mpa

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

strength	<i>Cyclic heat temperature</i>	1.5 Mpa
Water permeability		2 g
Water absorption coefficient		0.11 kg/m ² .h ^{0.5}
Hardening time		24-36 hr.

In order to cure epoxy resin, it is required to combine it with a catalyst that starts a chemical reaction without changing the resin's composition. The chemical reaction that turns the epoxy resin and monomer component from a liquid to a solid is started by the catalyst. Because the epoxy-hardener ratio changes between formulations, the manufacturer needs to make this vital information public. The resin/hardener volume ratio may vary depending on the objects' place of origin. The weight ratio for mixing hardener and epoxy is 10:1. The manufacturer also sold 1000g of LY556 epoxy and 100g of hardener, which supports the above-stated weight ratio[82]. For about a minute, a stirrer is continuously thrown into the mixer.

b. Fiber preparation

Plant leaves are used to produce sisal fibers. The process of mechanical debarking, in which the sheet was shredded between rollers, was typically used to get the fiber. The resulting pulp was scraped off of the fiber, which was then mechanically or naturally dried after being cleaned. It can also be prepared manually with a knife and peel off. Sisal and glass fiber are collected here from Addis Ababa(world fiber), Rice husk is gathered from *Fogera* (South Gonder, Ethiopia).

c. Rice husk filler

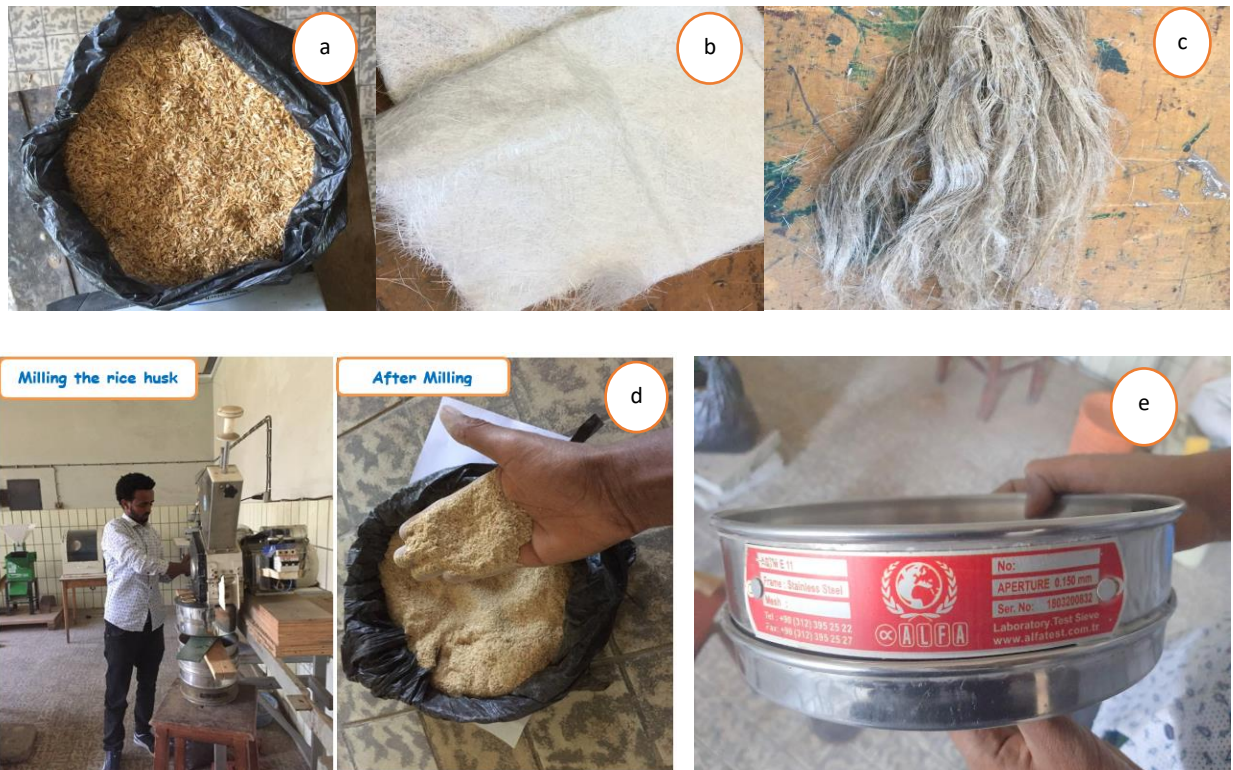
The rice husk, which is formed of hard materials like lignin and silica, is the covering that goes over a rice seed or grain to protect it during the growing season. It was milled to a micron size to fit into the teeny voids in the composite. The development of polymeric composites with excellent potential applications in the building and construction, automotive, aerospace, and packaging industries is made possible by polymeric matrix materials with appropriate and proper filler, better filler/matrix interaction, and cutting-edge and novel methods or approaches. By utilizing the synergy between natural fibers in a nano-reinforced bio-based polymer, hybrid bio-based composites can improve features while still being environmentally friendly[83]. By adding

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

organic or inorganic nanofiller, plant fiber-reinforced composites' mechanical, tribological, and thermal properties can be enhanced[84].

Researchers noted that adding filler materials fundamentally boosts the mechanical characteristics and in turn minimizes the organic contents in the composite laminates, thus enhancing the performance of a composite.

After the fibers and filler material was gathered, the rice husk was milled to a micro level and sieved, as indicated in the figure 3.2.



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Figure 3.2: a) Unmilled Rice husk, b) glass fiber and c) sisal fiber d)milling Rice husk e).150mm sieve f)seived 150µm filler respectively:

3.1.2. Alkali Treatment of sisal fiber

Sisal fibres were given an alkali treatment to increase their thermal stability and lessen their propensity to absorb water. Alkali-treated fibres also showed improved tensile characteristics and a stronger connection with the matrix. Additionally, when exposed to alkaline hostile circumstances, fibres became more stable[85]. Low sodium hydroxide concentrations during alkali treatment are preferred. A noticeable loss in strength was seen at greater sodium hydroxide concentrations[86]. 10% NaOH was added to one-liter distilled water and stirred at 60 C for 15 minutes to treat sisal fiber with NaOH. After that, 50 g of sisal fiber was added to the mixture. After being soaked in NaOH solution for one hour, the fiber was washed and dried as figure 3.3.



Figure 3.3: a) sodium hydroxide b) treated and washed sisal fiber

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

3.2 Composite Designation

The composite was produced in five different variations, with filler amounts ranging from 0% to 8% rice husk filler. Fillers can make composite materials more difficult to mix and place, especially if they are present in high concentrations. Using a small amount of filler helps to keep the composite material workable, making it easier to place it accurately and efficiently. Using a small amount of filler helps to reduce polymerization shrinkage, which can improve the longevity of the restoration [79]. The Designation and composition of the composites on this paper is like what table 3.2 indicates as:

Table 3.2: the composites' category and composition

Category/ Designation	Nomenclature
SG-R0	Sisal and glass fiber epoxy composite with 0% filler
SG-R2	Sisal and glass fiber epoxy composite with 2% filler
SG-R4	Sisal and glass fiber epoxy composite with 4% filler
SG-R6	Sisal and glass fiber with epoxy composite 6% filler
SG-R8	Sisal and glass fiber epoxy composite with 8% filler

3.2.1 Density of rice husk filler using pycnometer

The powder sample is put into the pycnometer, which is then weighed to determine its weight. The powder is then totally insoluble in a known density liquid that is then added to the pycnometer. The density of the powder can then be calculated from the weight of the liquid that was displaced.

W_1 = weight of empty bottle

$$= 28.4591\text{g}$$

W_2 = weight of bottle filled with water

$$= 72.1796\text{ g}$$

W_3 = weight of bottle filled with the rice husk filler

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

$$= 31.6852\text{g}$$

W_4 = weight of bottle, rice husk filler and filled water

$$= 71.0224\text{g}$$

Then,

- Weight of filler (W_f)

$$W_f = W_3 - W_1 \dots\dots\dots \text{eq. (3.1)}$$

$$= 31.6852\text{g} - 28.4591 = 3.2261\text{g}$$

- Weight of pycnometer and water present with filler (W_5)

$$W_5 = W_4 - W_f \dots\dots\dots \text{eq. (3.2)}$$

$$= 71.0224 - 3.2261 = 67.7963\text{g}$$

- Weight of displaced water by filler

$$= W_2 - W_5$$

$$= 72.1796\text{g} - 67.7963\text{g} = 4.3833\text{g} = 4.3833\text{ml of water, as density of water is } 1\text{g/cm}^3.$$

Therefore,

$$\text{density of filler} = x = \frac{3.2261\text{g}}{4.3833\text{cm}^3} = 0.736\text{g/cm}^3$$

Repeating it three times.

$$\text{Trial 2} = 0.719\text{g/cm}^3$$

$$\text{Trial 3} = 0.738\text{g/cm}^3$$

Then, the average value,

$$\text{➤ Density of filler} = \frac{0.736\text{g/cm}^3 + 0.719\text{g/cm}^3 + 0.738\text{g/cm}^3}{3} = \mathbf{0.731\text{g/cm}^3}$$

3.2.2 Density of the composite at different composition

$$\text{Density of composite} = \rho_c = \frac{\text{mass of composite}}{\text{volume of composite}} = \frac{M_c}{V_c}$$

$$= \frac{M_f}{V_f} + \frac{M_m}{V_m} = \frac{V_f * \rho_f}{V_c} + \frac{V_m * \rho_m}{V_c}$$

$$= V_f * \rho_f + V_m * \rho_m, \dots\dots\dots \text{eq. (3.3)}$$

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

Where, V_f and V_m are volume fraction of fiber and matrix.

Or

$$\begin{aligned} \frac{V_c}{M_c} &= \frac{1}{\rho_c} = \frac{V_f}{M_f} + \frac{V_m}{M_m} = \frac{V_f * \rho_f}{V_c} + \frac{V_m * \rho_m}{V_c} \\ &= \frac{M_f / \rho_f}{M_c} + \frac{M_m / \rho_m}{M_c} \\ &= m_f / \rho_f + m_m / \rho_m, \dots\dots\dots \text{eq. (3.4)} \end{aligned}$$

Where, m_f and m_m are mass fraction of fiber and matrix.

Thus,

$$\begin{aligned} \text{At 0\% filler, } \frac{1}{\rho_c} &= m_f / \rho_f + m_m / \rho_m = 0.1/2.54 + 0.1/1.45 + 0.8/1.20 \\ &= 0.775 \text{ cm}^3/\text{g} \\ \rho_c &= 1.2903 \text{ g/cm}^3 \end{aligned}$$

Therefore, the table 3.3 serves as a summary of the aforementioned experimental findings and computations.

Table 3.3: density, weight of the composite designation

Designation	Density (g/ cm ³)	Weight (gm)	Weight of fiber (gm)	Weight of matrix (gm)
	$= \frac{\rho_f * m_f}{m_f * \rho_f + m_m * \rho_m}$	$W_c = \rho_c * V_c$	$W_f = \%m_f * W_c$	$W_m = \%m_m * W_c$
SG-R0	1.2903	198.7062	39.74124	158.96496
SG-R2	1.2738	196.1652	39.23304	156.93216
SG-R4	1.2562	193.4548	38.69096	154.76384
SG-R6	1.2391	190.8214	38.16428	152.65712
SG-R8	1.2229	188.3266	37.66532	150.66128

3.3 Experimental Procedures and Workflows

The next step was the manufacturing of the hybrid sisal and glass reinforced composite at varied rice husk filler compositions was followed as per ASTM standard after gathering the necessary

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

components stated above. The methods used to process the experimental analysis was discussed in this section.

3.3.1 Mold Material for a Hand Lay-Up

As in figure 3.4, cast-iron metal was used to prepare the mold. The stirred epoxy and rice husk filler was progressively poured into a metal mold that measured (275mm*175mm*5mm) while being stirred by hand. The air bubbles in the mold were removed by a hand roller. When the composite was disassembled, polyethylene plastic was used to prevent the epoxy from sticking to the mold.

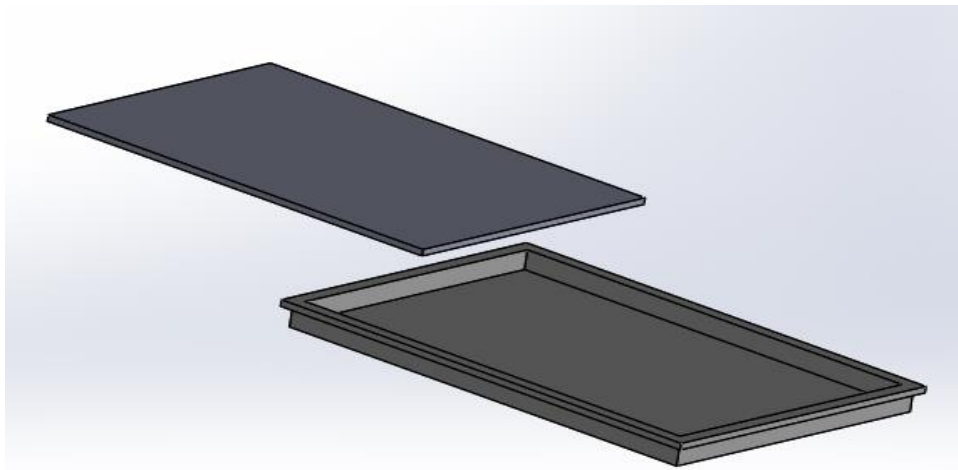


Figure 3.4: mold (275mm*175mm*5mm)

3.3.2 Steps how the composite was manufactured

- firstly, metal mold was welded to the required dimension and the rice husk filler finely grinded to micro level.
- To avoid polymer from adhering to the surface, a polyethylene plastic was first applied to the surface of the metal mold.
- Sisal fiber and woven glass reinforcing layers were cut to the appropriate shapes and placed on the mold's surface.
- The surface of the reinforcement was infused with epoxy resin mixed with rice husk filler and hardener already positioned in the mold, spreading it evenly with a brush.

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- And then the other reinforcement layers were placed on the preceding polymer layer, rolled under pressure to remove any trapped air bubbles and extra polymer.
- After the mold was closed and pressure released to create a single mat and kept at room temperature for 24 hours, it was opened, and the composite was removed from the mold surface.

3.3.3 composite specimen preparation

The manufactured fiber reinforced polymer composites were shaped to the required dimensions using a saw cutter, and the edges were prepared for compressive testing using an abrasive sheet. The ASTM standard was followed in the creation of the test specimen as in figure 3.5.

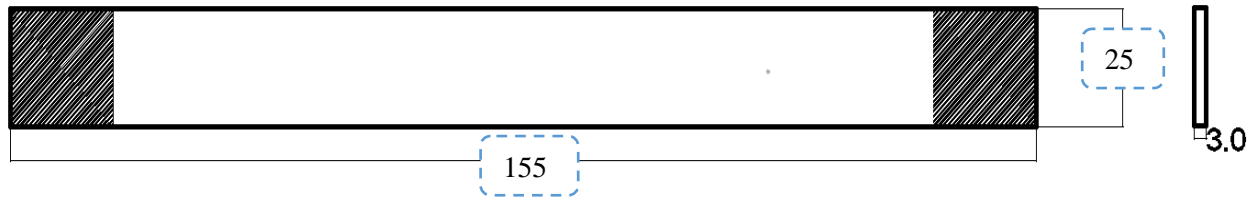


Figure 3.5: compressive specimen dimensions (mm) in accordance with ASTM D3410 (6" length *1"width)

Flexural strength testing was performed to determine a material's capacity to withstand deformation caused by a load. A three-point flexural test was frequently performed on fiber composites. Flexural tests on manufactured specimens in figure 3.6 were carried out in accordance with ASTM standards (ASTM D790).

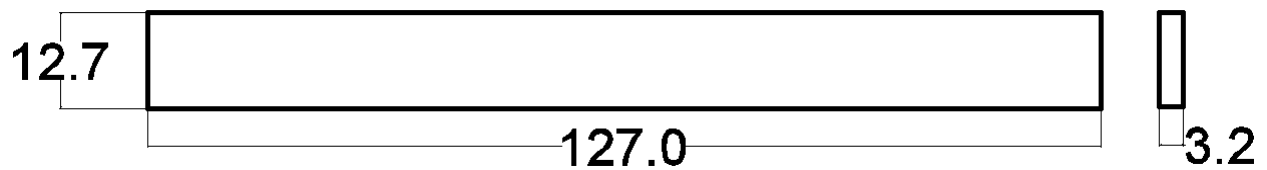


Figure 3.6: flexural specimen according to ASTM standard D790 (5" * 0.5" * 0.125").

The impact test samples were prepared in accordance with ASTM guidelines (ASTM D256). The prepared sample in figure 3.7 was fed into the machine. The pendulum permitted the specimens put in the tester to be stuck. The function of energy, which is necessary to shatter the specimen, is the notable finding. It's a tool for determining the yield qualities of fiber-reinforced polymer composites.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

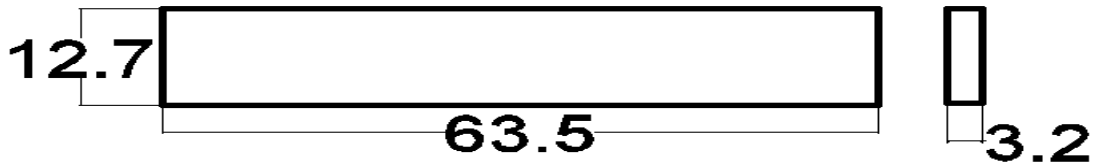


Figure 3.7: Impact test specimen dimensions as defined by ASTM D256 (2.5" * 0.5" * 0.125"). The percentage of moisture absorption was calculated by the difference of mass (before and after immersion) divide by the initial mass of the samples. It was tested according to the ASTM standard (ASTM D570) after preparing the specimen abased on figure 3.8. The rate of water absorption is greatly affected by the composite's density and void content[87].

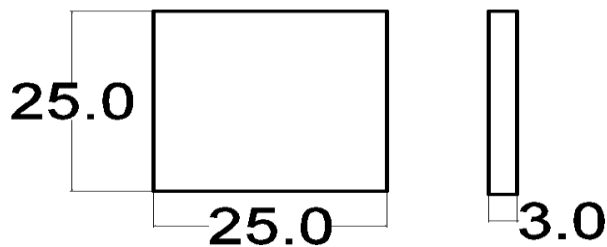


Figure 3.8: moisture absorption specimen ASTM D570-99

Based on the ASTM dimensions given cutting and shaping the testing specimens followed as shown in figure 3.9. After the specimens were cut and shaped, they required polishing to make them smooth. This have been performed using sandpaper and ready to be tested for their mechanical and physical properties.



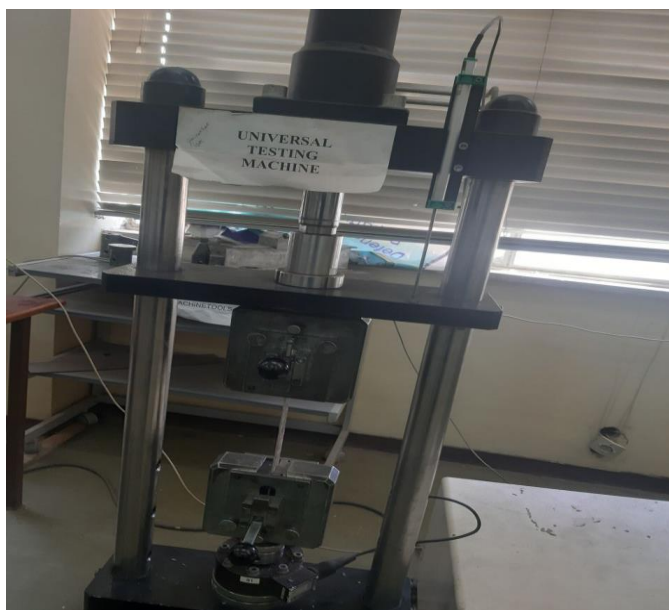
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Figure 3.9: testing specimens' preparation

3.4 Testing machineries

UTMs (universal testing machines) are machines that are used to test a variety of mechanical qualities, including tensile, flexural, compressive, and shear. The UTM is a fantastic multifunctional tool for a quality control or R&D department. Materials compressive, flexural and impact strengths were examined using a universal testing apparatus shown figure 3.10.



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Figure 3.10: Universal testing machines from Defense University (Bishoftu)

In the experiment, compression and flexural testing were conducted at constant strain rates and at a constant room temperature. The next task entailed putting prepared test parts under various stresses from dynamometer load cells on a UTM. After each test, displacements at varied load responses were produced in a data collection system as an output. For each test, three samples were collected in order to reduce possible errors and demonstrate the repeatability of the results.

3.4.1 Mechanical property characterization

The test specimens were set up and put through several mechanical tests, including compression, flexural, and impact tests as per the ASTM standards[88]

1. Compressive Strength Testing

In material characterization, it is essential to quantify a material's ability to endure stresses and how far it can stretch and compress before breaking. The saw cutter were used to shape the manufactured fiber reinforced polymer composites to the desired dimensions, and an abrasive sheet was used to prepare the edges for compression testing. The test specimens were created in accordance with the ASTM standard. The ASTM standard (ASTM D3410) was used to determine the parameters. The specimen was centered in the wedge grips using a fixture, after which the grips were tightened. The specimens were squeezed till it breaks. The compression test yielded highly precise results, and the method was done three times with the identical test samples. Finally, the average value is accounted for.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

The compressive characteristics of polymer matrix composite materials reinforced by high-modulus fibers were tested according to ASTM test procedure, data on the compressive properties of hybrid sisal and glass fiber reinforced materials were produced. The medical sector mostly uses polymers for structural design and analysis, research and development, and material requirements. When a high strength and stiffness (rigidity) are necessary, such as in automotive, sports equipment, shock-absorbing, medical, as well as in civil engineering, glass fiber-reinforced polymers are the ideal material. In addition, more consumer and technical applications are using hybrid composites[89].

Shear loading using wedge grip faces within a loading fixture were used to apply the compressive force. The ultimate compressive strength, compressive and ultimate compressive strain, compressive chord modulus of elasticity, compressive Poisson's ratio by chord modulus, and the transition strain are significant findings from this test.

The compression test was performed on the prepared specimens (rectangular cross-section 155mm length x 25mm width) using the universal testing machine. The figure 3.11 illustrates the experimental apparatus and samples for the compression test, respectively. This apparatus examined three samples.

$$\sigma = \frac{P}{A} = \frac{P}{a*b} \dots\dots\dots \text{eq (3.5)}$$

Where, σ = compressive stress, P= applied load, a= average thickness and b= width of the test specimen.

The samples were held in UTM's grips throughout the test. The necessary information, including the sample's thickness, gage length, width, material type, and date, was added to the UTM computer program once it had been gripped. Once the machine had started, the load had been applied automatically up until the spacemen had run down their fuel. The values will be received from the program when the stress-strain measurements are captured during the test.

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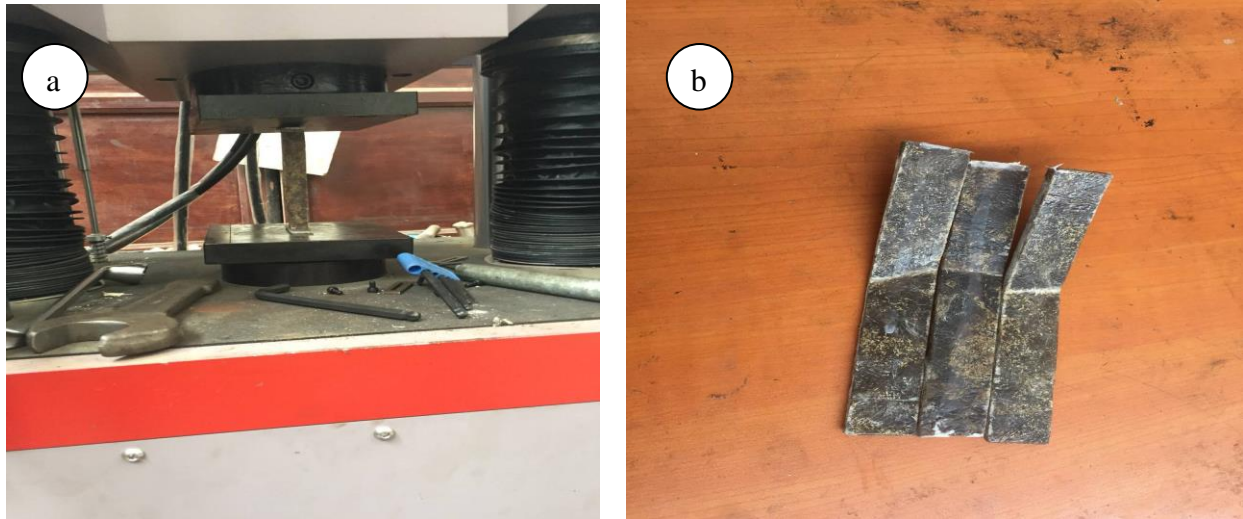


Figure 3.11: performing compression strength test: a) sample in compression testing b) after testing and brakes

2. Flexural Strength Testing

Flexural strength was carried out to find the ability of the material to resist the deformation under the load. On a fiber composite, a three-point flexural test is often used. The ASTM standards (ASTM D790) were now used to conduct flexural tests on created specimens. like what figure 3.12 indicates, The test specimen was placed between two supports and loaded in the middle until failure happens on the composite specimen. The flexural strength data were noted. The method was repeated three times before the mean value was provided.



Figure 3.12: performing flexural strength test

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The supporting roller was prepared to depend on the specimen's dimension as part of the test's fundamental process. The supporting roller was then adjusted to the piece's appropriate gauge length dimension in order to set the sample on it. Once the machine was running, the weight was applied by hand until all of the spacemen had failed. The software then displays the test-related data that was recorded.

3. Impact Strength Testing

The impact test samples were prepared in accordance with ASTM guidelines (ASTM D256). By estimating the energy absorbed during fracture, impact testing of metals is used to assess the impact resistance or toughness of materials. These services offer test findings that can be highly helpful for determining whether a material is suitable for a given application as well as for estimating its projected service life. It's a tool for determining the yield qualities of fiber-reinforced polymer composites. To avoid human error, at least three tests were performed and the average reading were calculated.

In the CHARPY V notch Impact Test in Figure 3.13, a notched impact specimen was struck with a swinging weight attached to a pendulum that was swinging. The pendulum's upward swing was used to calculate how much energy was absorbed (notch toughness) before the specimen broke at its notched cross-section under impact.

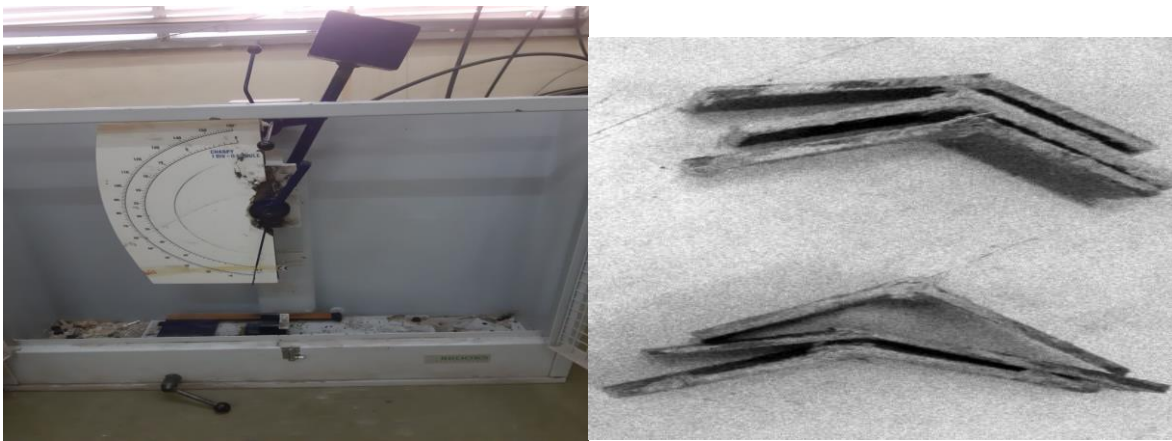


Figure 3.13: performing impact strength test

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

3.4.2 Physical property characterization of Composite Materials

The physical characterization of composites manufactured from natural fibers includes determining the density, water absorption, fiber to void volume ratio, thermal expansion coefficients, moisture expansion coefficients, and heat conduction coefficients.

Water absorption

Water absorption was used to determine the amount of water absorbed under specific conditions. Water absorption can be affected by the kind of plastic, the additives used, the temperature, and the length of exposure. The details make it clear how well the materials work in damp or humid environments. According to ASTM D570, the specimens were dried in an oven at a certain temperature and duration for the water absorption test, and then they are put in a dehydrator to cool. The specimens were weighed as soon as they have cooled. The substance was subsequently submerged in water at the predetermined temperature, typically 23 °C for 24 hours or until equilibrium. After being taken out, specimens were weighed after being dried with a lint-free towel. The specimen dimension is two-inch diameter disks, 0.125" thick.

Water absorption can be expressed in percent water absorption.

$$\text{Percent water absorption} = \frac{W_2 - W_1}{W_1} * 100 \dots\dots\dots \text{eq (3.7)}$$

Where, W2= wet weight

W1= dry weight

Void content

In accordance with ASTM D2734, void content was an additional physical characteristic that has to be examined in composites. The density of the composites, both theoretically and experimentally is used to calculate the void content through eq (3.8)

$$\text{Void content (\%)} = \frac{\text{theoretical density} - \text{experimental density}}{\text{theoretical density}} \dots\dots\dots \text{eq (3.8)}$$

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

Where,

$$\text{Theoretical density} = \frac{1}{\frac{W_f}{\rho_f} + \frac{w_m}{\rho_m}}$$

3.5 Load in Neck brace

In straight position, human being head apply in average $5\text{kg} \times 9.8\text{m/s}^2 = 49$ newton and at a 45-degree angle, it appears to weigh 22.23 kg and 217.85 newton amount of load is applied in the neck brace [90].

3.5.1. Sizes of Neck brace

It's crucial to know two measurements since an improperly fitted collar could exacerbate the neck problems. A tape measure, a pen, and paper are required. It should be taken an inch-by-inch measurement of neck circumference, then add 2 inches to account for the collar's curve. Second, gauge how deep the neck is. Measure from the base of the ear lobe straight down to the point where neck meets the body, keeping head in a neutral position. Now have the two dimensions needed to get the collar that fits you perfectly. But the common and standard sizes are listed table 3.4.

Table 3.4: standard neck brace sizes according to healthandcare.co.uk[91]

size	Length (centimeter or inch)	height(inch)
Extra small	38cm (15")	2.75"
small	43cm (17")	3"
Medium	46cm (18")	3.5"
large	51cm (20")	4"
Extra large	59cm (22")	4.5"
XX - large	61cm (24")	5"

Foam is cushioned around the jaw and neck for a pleasant, supportive fit for to its ergonomic design. For maximum comfort, the foam is shaped to tightly match the chin and jaw.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

3.7 Ansys modeling

Ansys modelling of composites involves creating a virtual model of the composite structure that can be used to predict how it will behave under different loading scenarios. Ansys offers a variety of tools to make modelling composite buildings easier. Ansys Composite Prep Post (ACP) is a pre- and post-processing tool that is specifically designed for composite materials. To assist users in defining composite materials, layups, and failure criteria, it offers a variety of features. Ansys modelling of composites is a potent tool that can be used to design and optimize composite structures for a variety of applications, including the prediction of a composite structure's strength and stiffness under different loading conditions and the identification of stress concentrations and potential failure zones .

The steps below are often needed to generate an Ansys model of a composite structure:

1. Define the properties of the material. Ansys must be used to specify the composite's properties. This covers the composite's layup as well as the characteristics of the fiber and matrix.
2. Create the model's geometry. Ansys must be used to generate the composite structure's geometry. You may accomplish this by importing a CAD model or by utilizing the Ansys Design Modeler.
3. The model is mesh. The model has to be broken up into components. Depending on the sort of analysis being done, different components will be employed. For instance, shell elements are often utilized for composite constructions with thin walls, whereas solid elements are employed for composite structures with larger walls.
4. Apply loads and boundary conditions. The model must incorporate the loads and boundary conditions that will be applied to the structure in practice.
5. Solve the model. The Ansys solver is then used to resolve the model. The model's stresses, strains, and displacements will be computed by the solver.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

1. the first step was updating the Ansys workbench with additional material characteristics (sisal, glass, rice husk and LY556 epoxy resin).

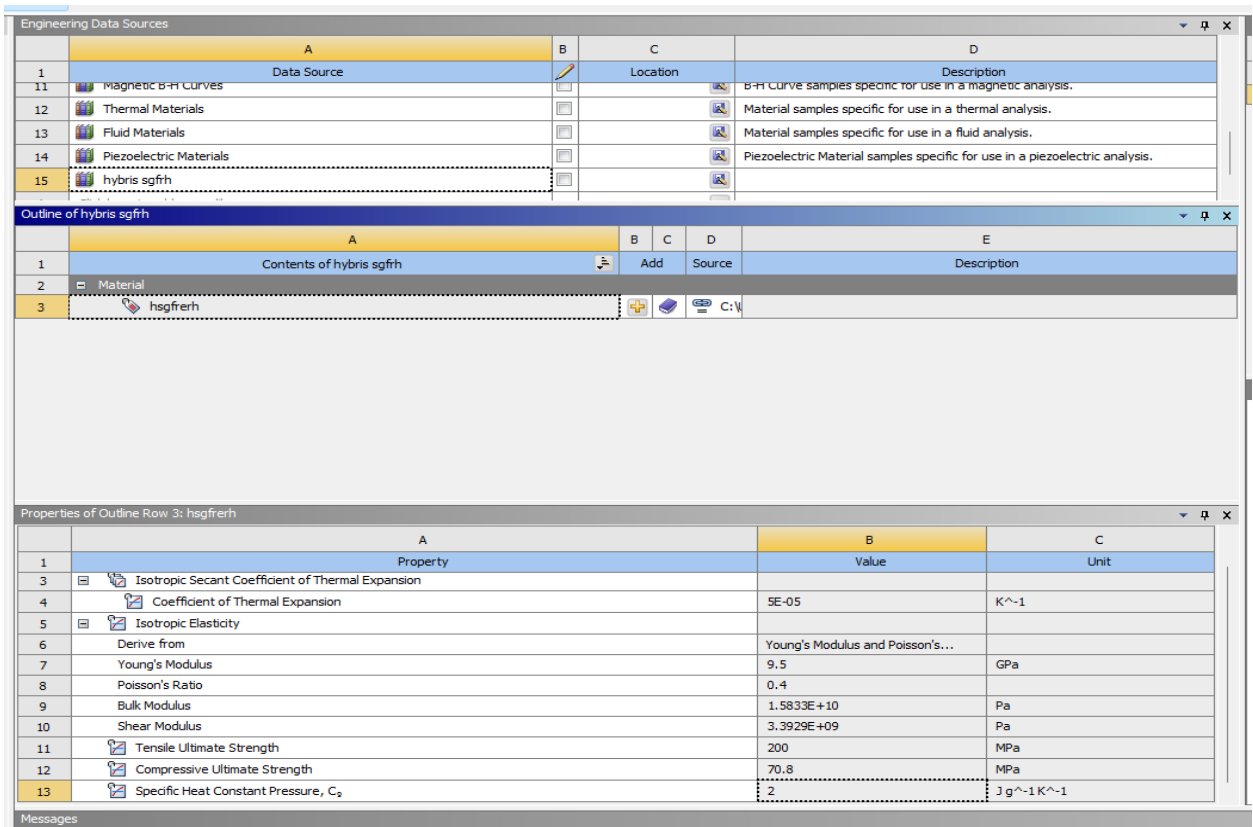
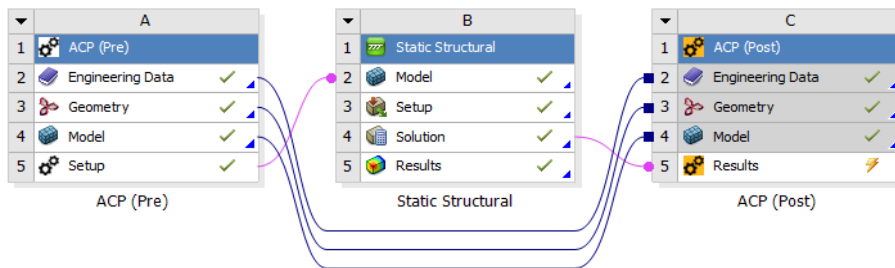


Figure 3.14: adding the new materials to Ansys workbench

2. Ansys ACP, which was preferred for composite analysis, was linked with static structural and the material properties of all materials.



Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

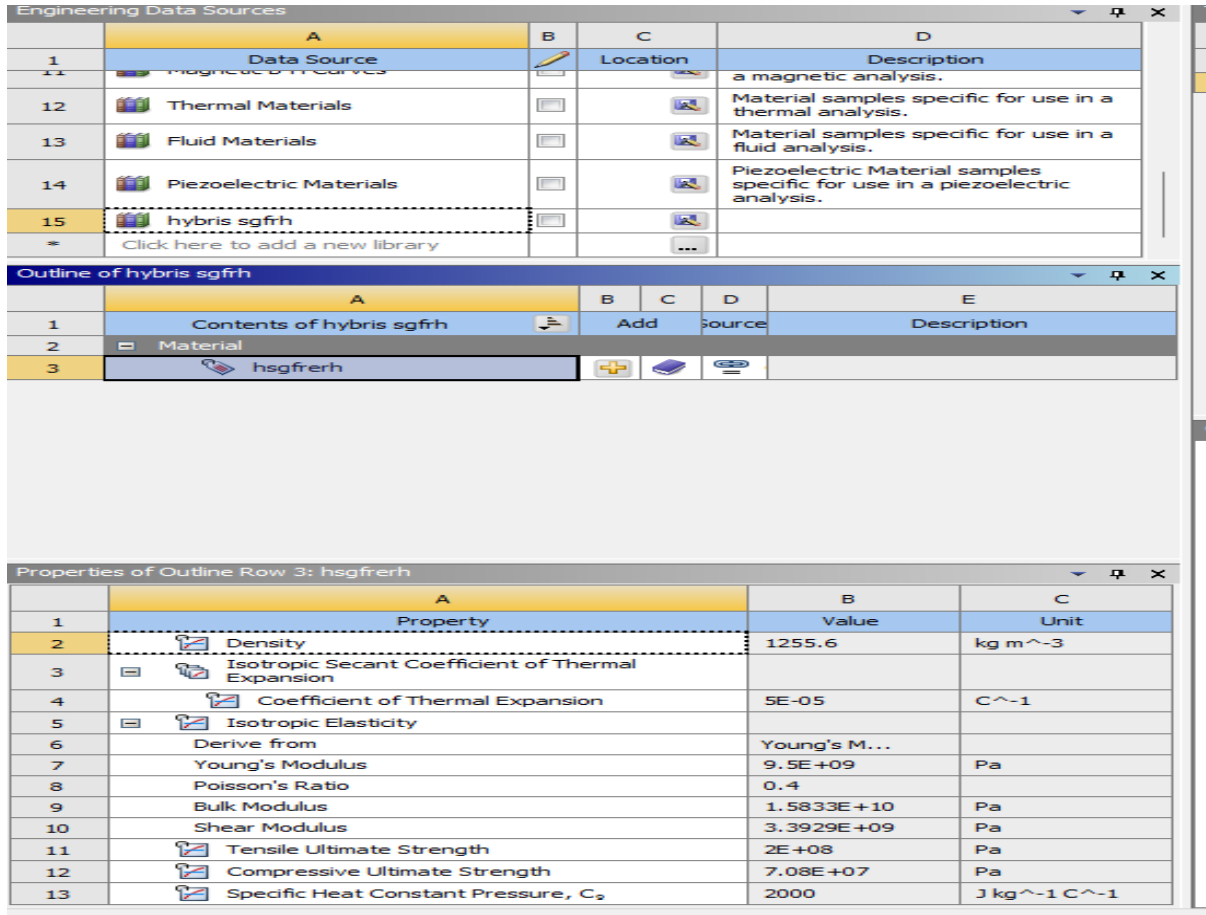


Figure 3.15: linkage of Ansys ACP with Ansys static structural to generate solutions

3. Meshing in Ansys modelling importing the geometry from Cad, and giving material thickness and material properties.

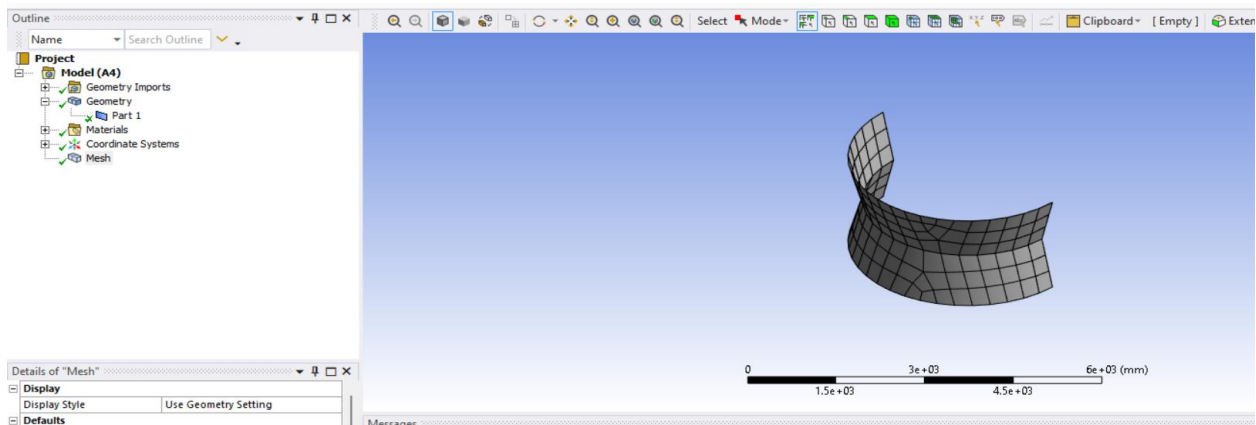
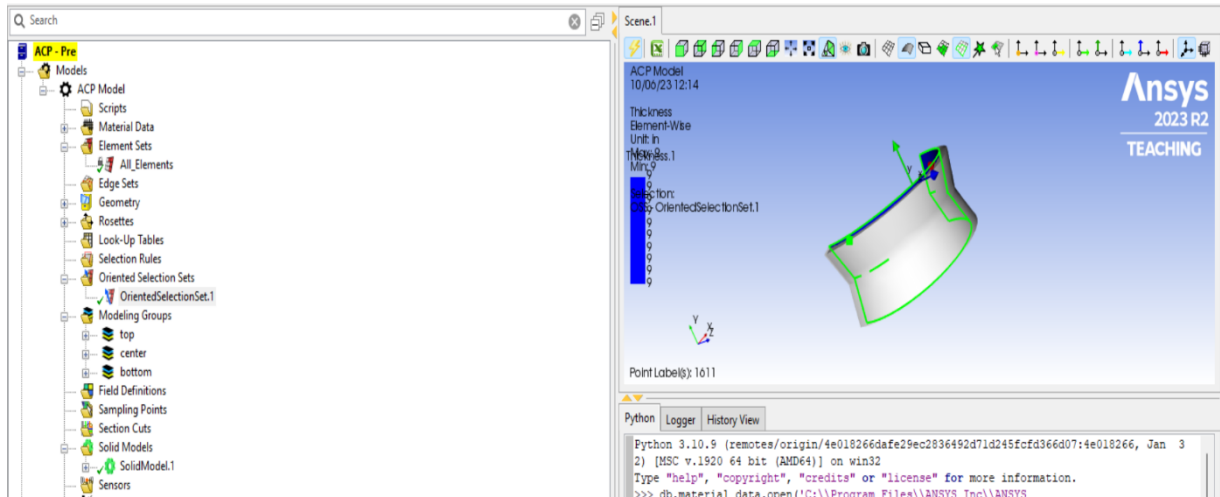


Figure 3.16: generate meshing on the geometry

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

4. ACP-Pre: Set up



5. Boundary condition and load applied.

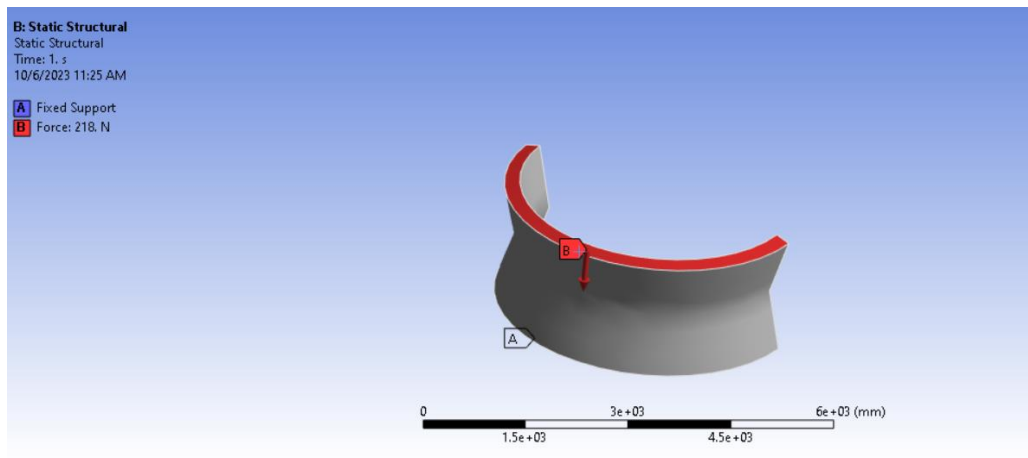


Figure 3.17: Boundary condition and giving load to the geometry

Chapter four

4. Results and Discussions

Results

4.1. Compressive Strength of the composite

Three specimens were utilized for each designation or category of the composite when evaluating the compressive strength. The compression strength of the three samples, which had identical amounts of reinforcement, matrix, and filler, showed a slight variation according to the results generated. The experiment analysis can be evaluated for each designation in Figure 4.1- Figure 4.5.

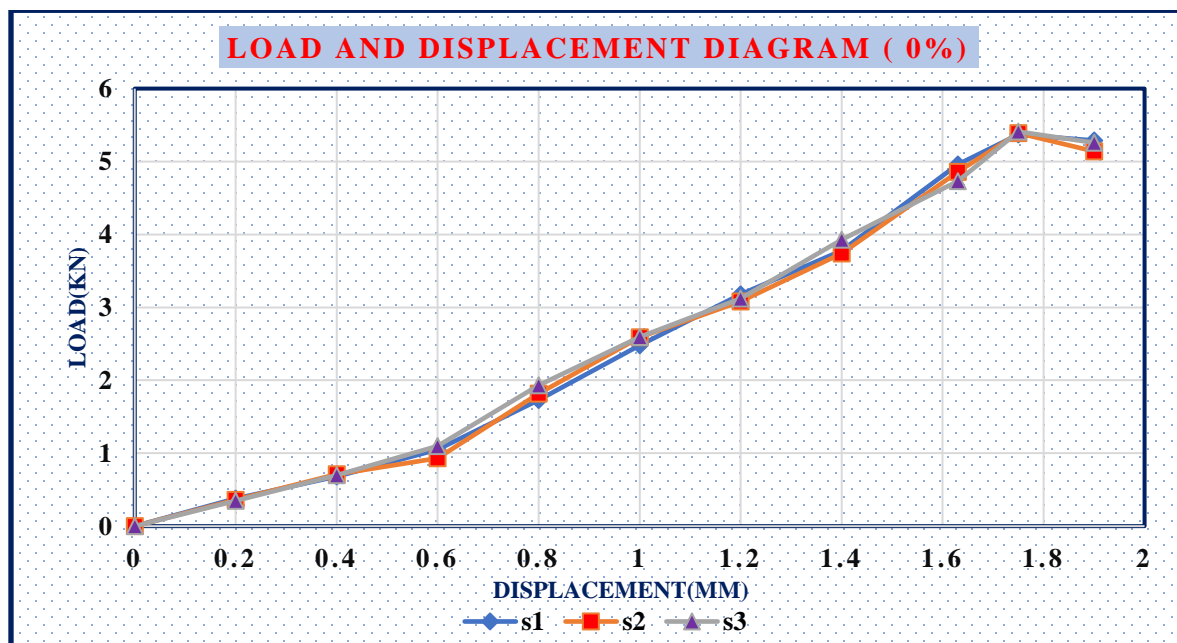


Figure 4.1: compression behavior of the three samples and their average value of 0% rice husk filler composites.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

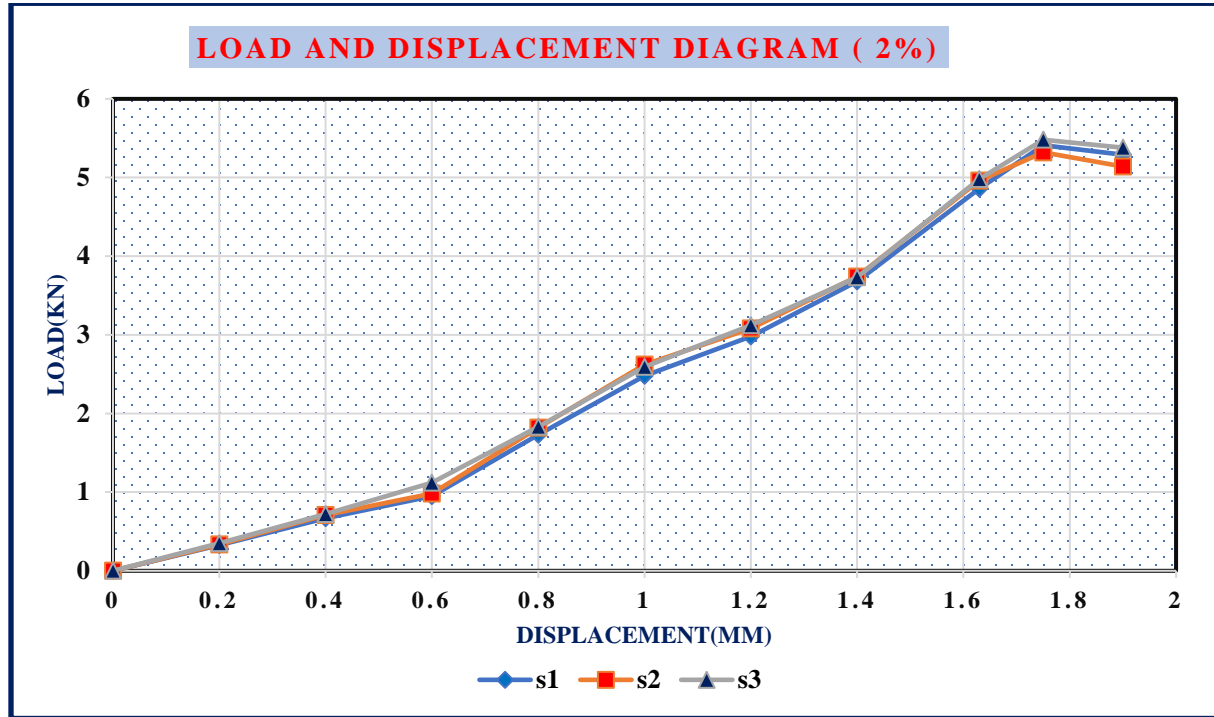


Figure 4.2: compression behavior of the three samples and their average value of 2% rice husk filler composites.

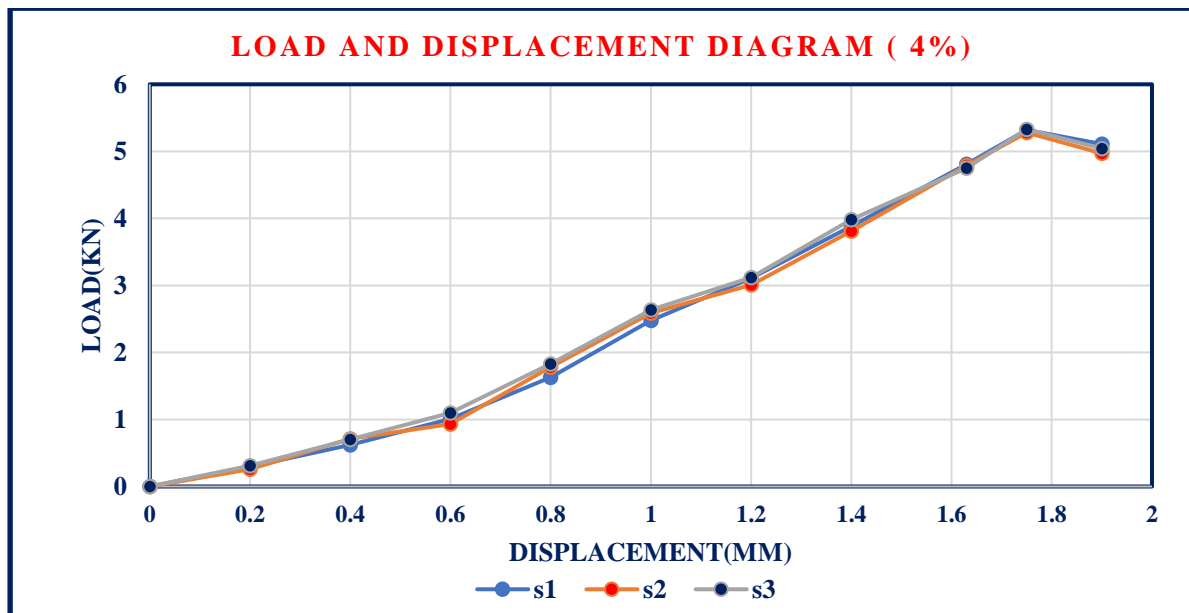


Figure 4.3: compression behavior of the three samples and their average value of 4% rice husk filler composites.

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

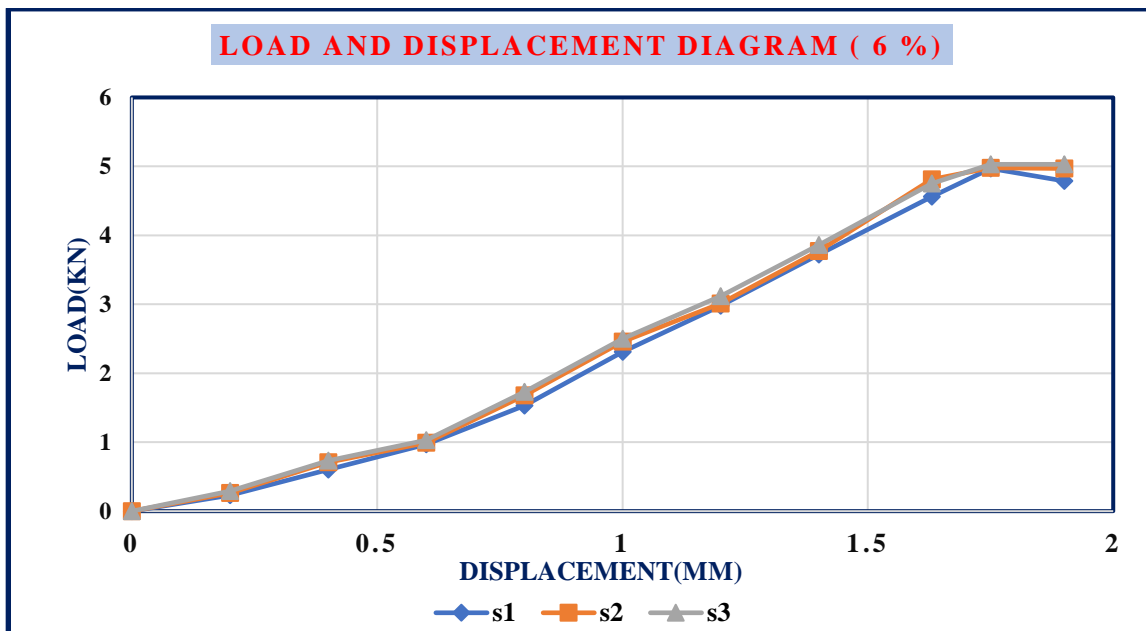


Figure 4.4: compression behavior of the three samples and their average value of 6% rice husk filler composites.

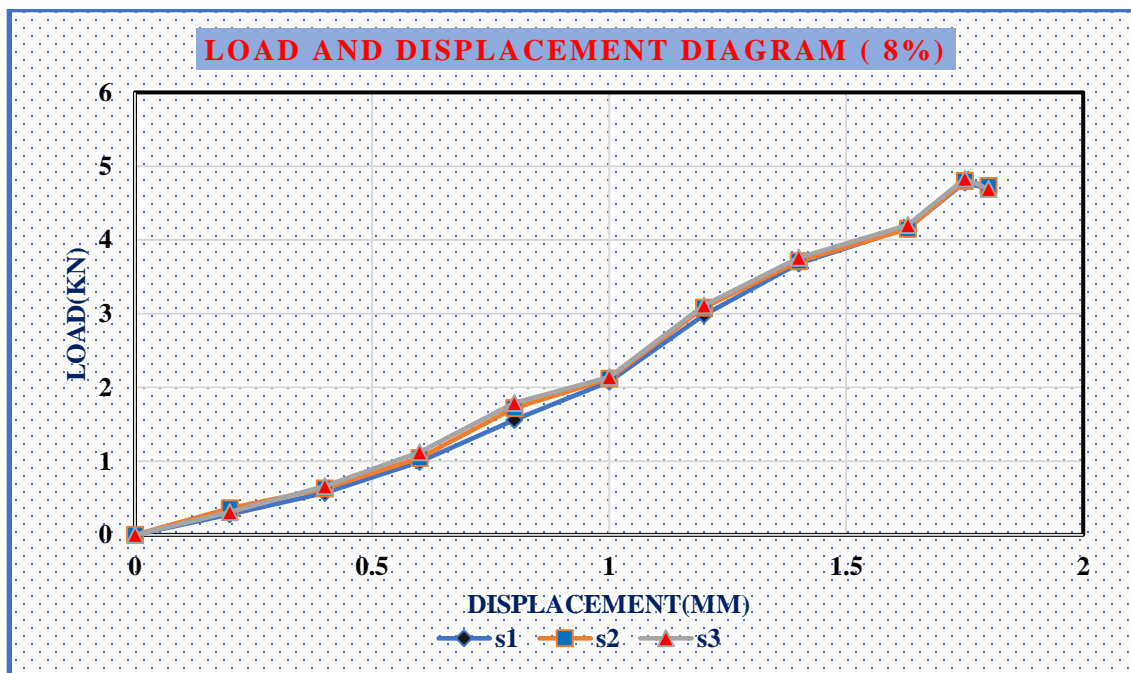


Figure 4.5: compression behavior of the three samples and their average value of 8% rice husk filler composites.

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Compressive strength is the capacity of a material to withstand axially applied pressing stresses. In this case, the specimens were supported by the testing apparatus' two platforms as a load was applied along a 25-mm span length at a constant 10 mm/min overhead speed. Three distinct specimens were subjected to compression testing. Compression strength measurements exhibit significant variations depending on the rice husk filler concentration of the material. An interesting tendency have been seen in the data. Compressive strength slightly increases in the 2% filler only, however, decreased with increased filler loading due to insufficient interfacial bonding in the other composite designation. As filler loading increases, the it decreases due to the weak link between the hydrophilic filler and the hydrophobic matrix polymer, which prevents stress from spreading. Adding more filler can decrease the compression strength of the composite as the matrix adheres poorly to the fibers and the fibers tear. Due to the fiber's limited ability to carry additional loads, this poor adhesion minimizes contact between the fiber and the matrix, which reduces compression strength[92]. The compressive strength of hybrid sisal and glass fiber reinforced epoxy composite with 4 % rice husk filler (HSGRF/RHE) is typically lower than that of hybrid sisal and glass fiber reinforced epoxy composite without rice husk filler (HSGRF/0). This is because rice husk filler is a weaker material than the epoxy resin and the fibers. Additionally, rice husk filler can create voids and defects in the composite, which can act as stress concentrators and weaken the composite under compressive loading[93].

However, all produced composites had compressive strengths that were greater than those of other composites that are often used to make lightweight natural fiber-based composites.

4.2. Flexural Strength of the composite

Flexural strength testing was carried out when test specimens were cut from molded or extruded shapes, or molded to the appropriate finishing dimensions. Bending test with D790 done under three-point bending with the force F_{max} applied at mid-span of a rectangular specimen with dimensions of L, B, and H between two rollers, with the maximum flexural strength (σ_f) measured by:

$$\sigma_f = \frac{Mb \max}{Wb} = \frac{F_{max} * L / 4}{BH^2 / 6} = \frac{3 * F_{max} * L}{2 * BH^2} \dots\dots\dots \text{eq (4.1)}$$

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where, M_b = bending, W_b = section modulus, F_{max} = Load at fracture, L = support span of the specimen, B = width of the specimen, and H = height of the specimen.

And the flexural strength results are shown graphically in the Figure 4.6.

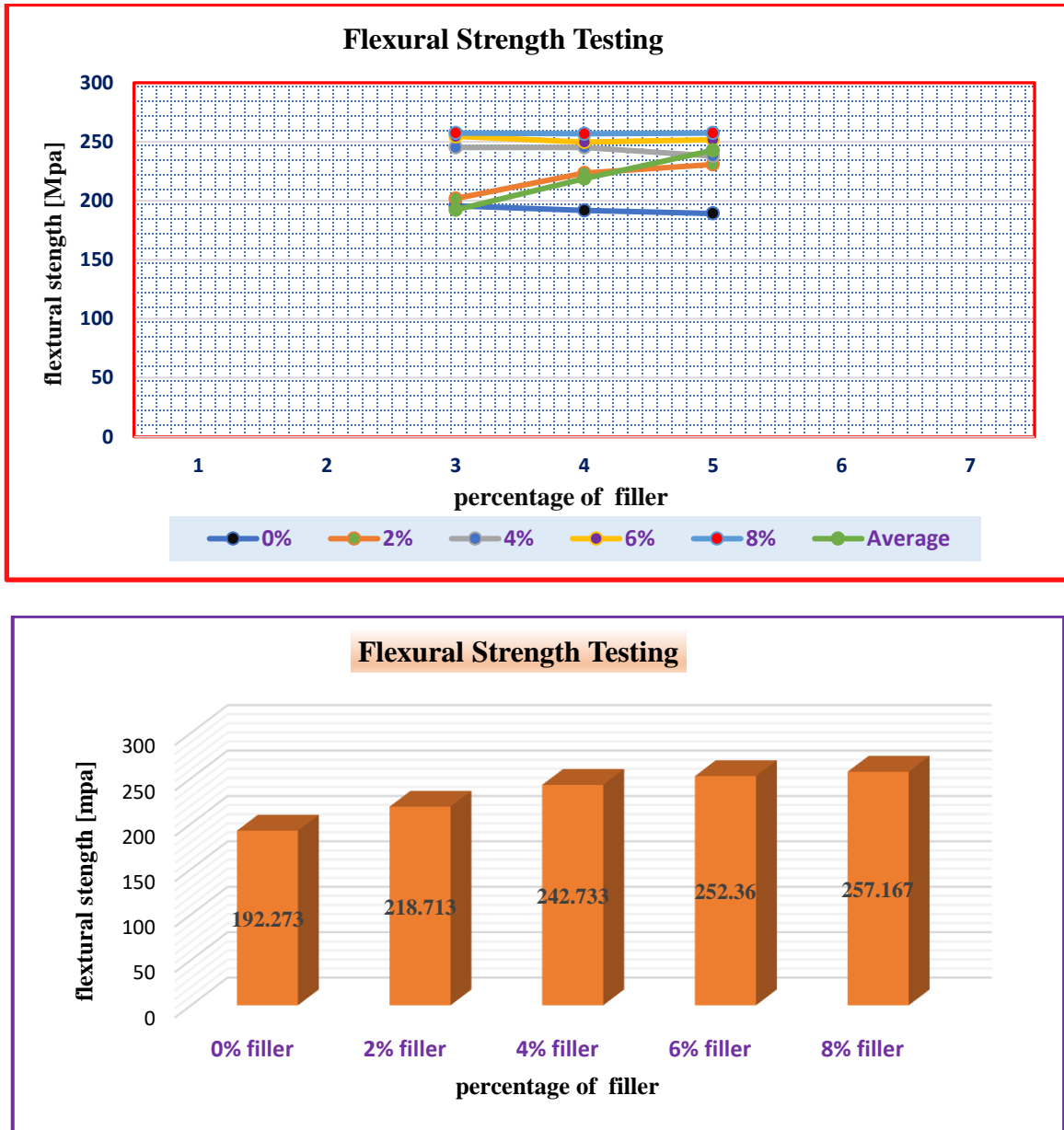


Figure 4.6: Flexural Strength of SG-R at 0%, 2%, 4%, 6%, 8% filler

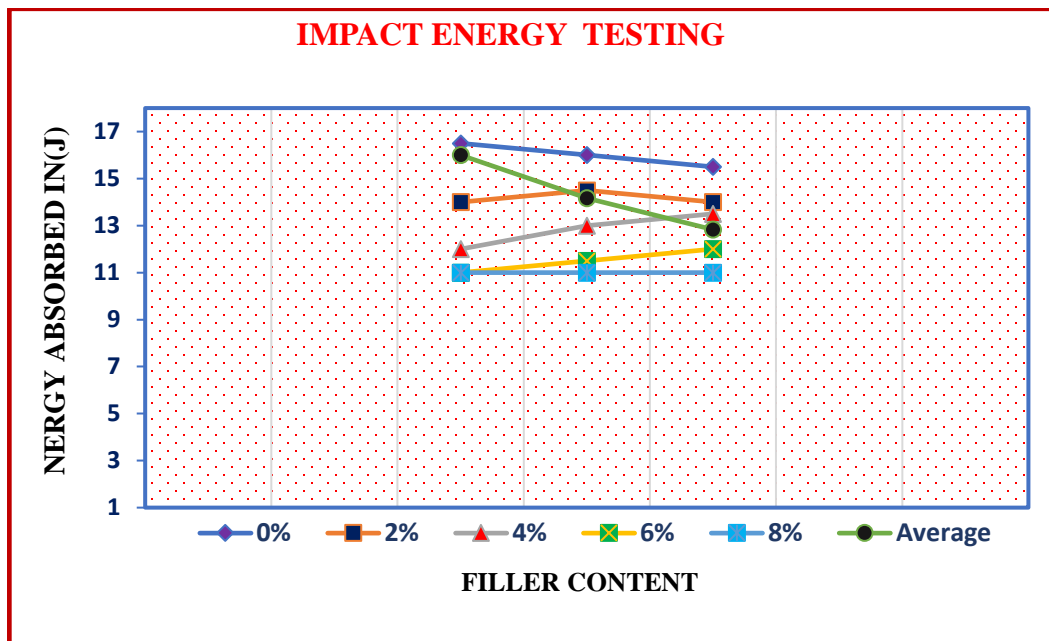
The graph above demonstrates how increasing filler content increased the flexural strength of S/G epoxy composites. Consequently, it has been found that the addition of RH to SG fills SG

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more than unfilled ones, improving the flexural strength of composites. The main reasons for the observed increase in flexural strength could be the increased interaction of the filler with the matrix and the increased dispersion of fine filler particles at high filler loading. It is important to note that the relationship between filler content and flexural strength is complex and depends on a number of factors, including the type of filler, the size of the filler particles, and the dispersion of the filler particles in the matrix. However, in general, increasing filler content will increase the flexural strength of a composite material[94].

4.3. Impact energy of the composite

In the Charpy crash test, a pendulum or "trampling" weight coupled to a swinging pendulum strikes a notched impact specimen. The upward movement of the pendulum before the specimen breaks on impact in the notched cross-section is used to calculate the energy absorbed (notch toughness). The results were indicated in figure 4.7.



Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

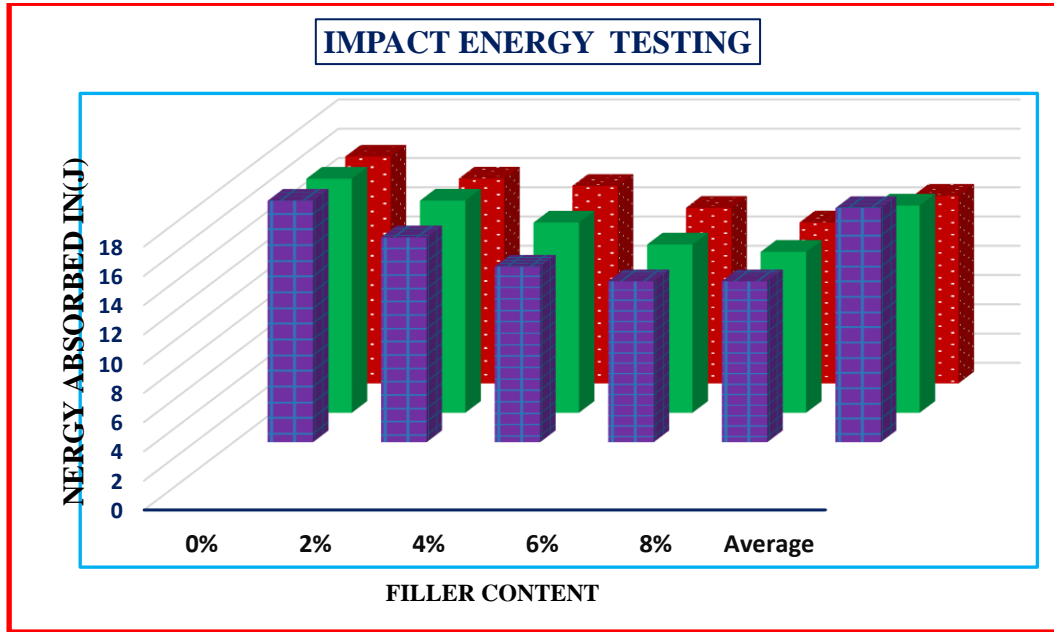


Figure 4.7: Impact Strength of SG-R at 0%, 2%, 4%, 6%, 8% filler.

The figure above makes it obvious that the impact strength declines with the addition of filler. This is primarily caused by the material's decreased elasticity as a result of the addition of filler, which also lessens the matrix's capacity to deform. Impact strength shrinks when filler concentration rises because it affects the matrix's capacity to absorb energy and, consequently, its toughness. The use of rice husk fillers, which limited the deform-ability behavior of the resin constituent, may be the reason for the slight drop in impact energy of the manufactured materials[79].

4.4. Water absorption capability of the composite

According to ASTM 570 methodology, the water absorption test for SGF/RH hybrid composites was performed by soaking in distilled water at room temperature. Prior to the experiment, hybrid composites were weighed using a precision balance after being dried at 60 °C for 24 hours to remove any last bits of moisture. The composites were weighed and then immediately submerged in water. The composite specimens were regularly removed from the water bath after every 24 hours, and tissue paper was used to clean the specimen surface. The mass of the water

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the composite specimens absorbed was then measured by weighing them and the water absorption was like what figure 4.8 indicates.

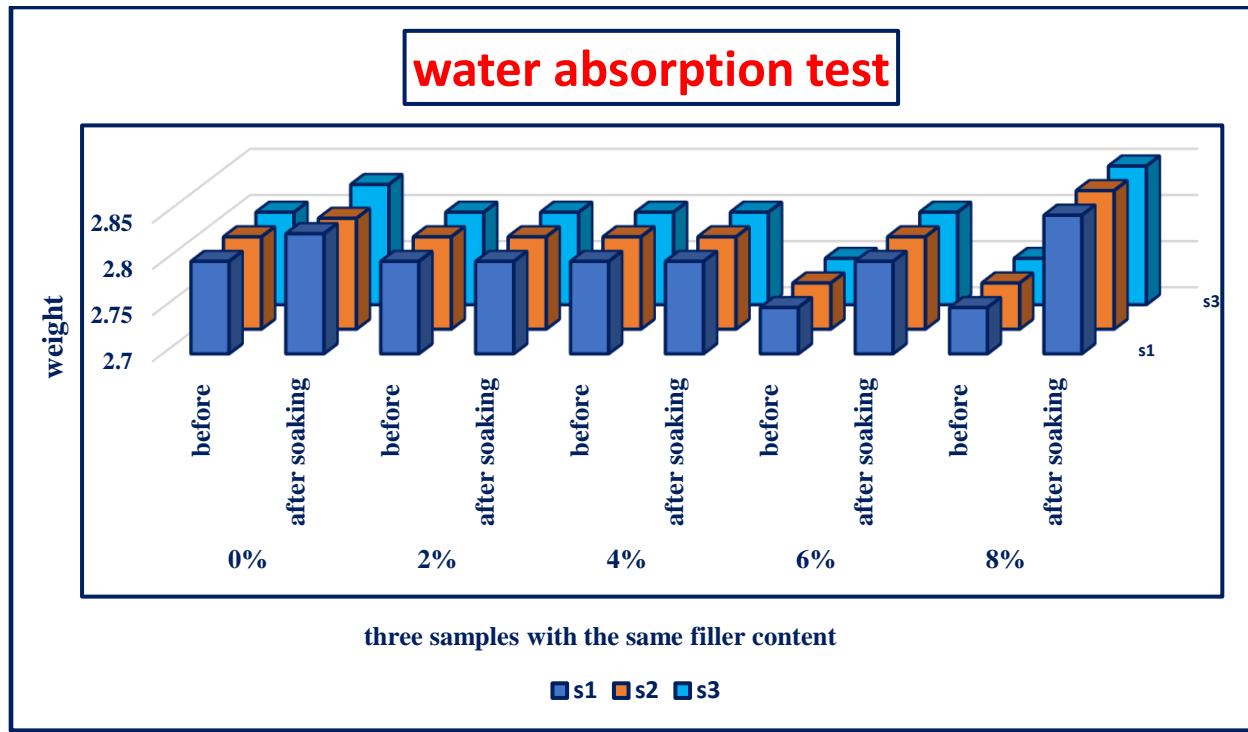


Figure 4.8: water absorption

It is observed 0.95% weight variation before and after soaking in water on the hybrid composite with no filler. However, there is no change in weight between the two specimens before and after being soaked in distilled water at room temperature for filler concentrations of 2% and 4%. The 6% filler's weight, which went from 2.75 to 2.80 grammes, however, showed a 1.81% water absorption. The 8% filler's water absorption also increased to 3.6%. This is because natural filler polymer composites have gaps in them. Insufficient interaction between the matrix and the filler causes these voids to develop.

4.5. Void fraction of the composite

From Table 3.3 Theoretical density is calculated, and experimental density was found using ASTM standard D792-86. and the void fraction of the composite is indicated in figure 4.9.

Table 4.1: Theoretical density and experimental density found

specimen's) filler percentage	its theoretical density	its experimental density	void
0	1.2903	1.2887	0.00124
2	1.2738	1.2732	0.000471
4	1.2562	1.2554	0.000637
6	1.2391	1.2374	0.001372
8	1.2229	1..2208	0.001717

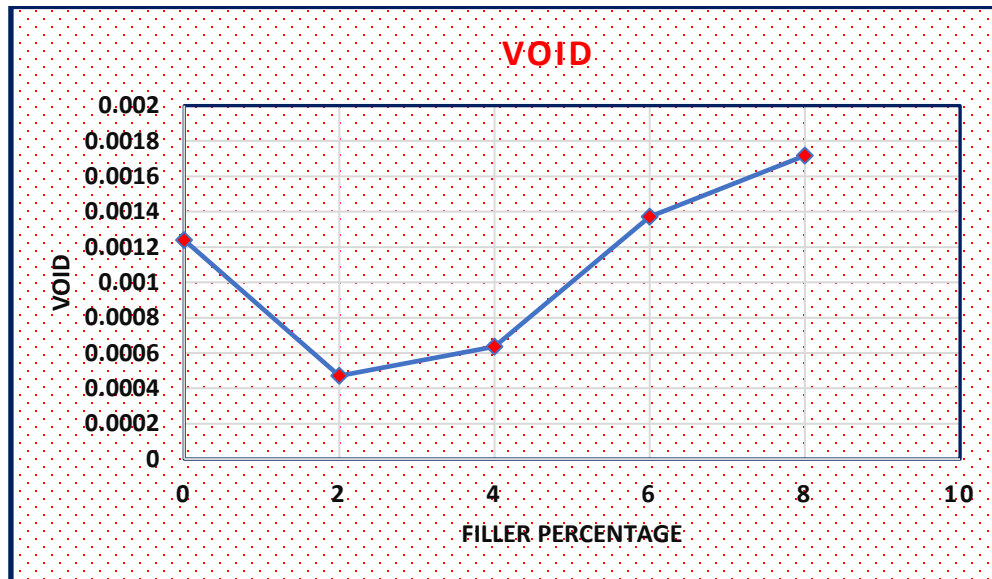


Figure 4.9: void percentage of different filler compositions

Since filler material has a lower density (0.731g/cc) than polymer, the density of composites decreases as filler content does. Because less hydrophilic filler material has been supplied, the empty content has decreased despite the increased filler quantity of up to 8wt%. Due of an

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imbalance in the weight percentages of the filler and matrix, the void content slightly increases beyond 8 weight percent.

4.6. Ansys ACP/Structural analysis results

The findings of the Ansys ACP/Structural study can provide a range of details regarding how a composite structure behaves while under load. Among the most typical outcomes shown in figure 4.10 - figure 4.13. The normal stress of a composite material is the average force per unit area acting perpendicular to a cross-section of the material. The normal stress of a composite material is an important parameter to consider when designing engineering components. It is used to determine the strength and stiffness of the component, as well as the potential for failure. As figure 4.10 indicates, the maximum normal stress of HSGF/RHF composite was 489.59 pa which is below the yielding strength of the composite which is 70.8Mpa which is safe.

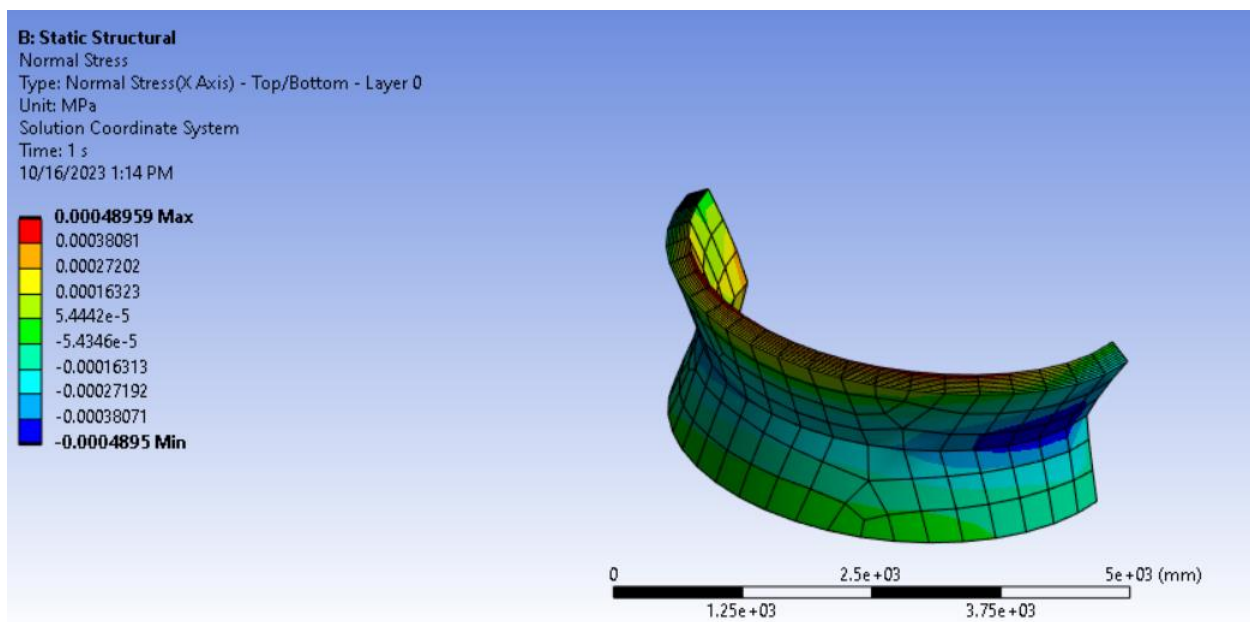


Figure 4.10: Normal stress of the composite

4.6.1. Total deformation

The total deformation of a composite in ANSYS ACP indicates the amount of displacement of the composite structure under the applied loads. It is calculated by taking into account the elastic

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and plastic deformations of the constituent materials, as well as the effects of geometric nonlinearity. Total deformation is an important parameter to consider when designing composite structures, as it can be used to assess the structural integrity of the component, The likelihood of component failure, The performance of the component under service conditions. Thus, the maximum deformation is 0.000334mm applying the maximum load. However, the material can withstand up to 1.75mm before failure during the experiment. The total deformation values of hybrid Sisal and Glass fiber reinforced epoxy composites with rice husk filler was as shown in Figure 4.11:

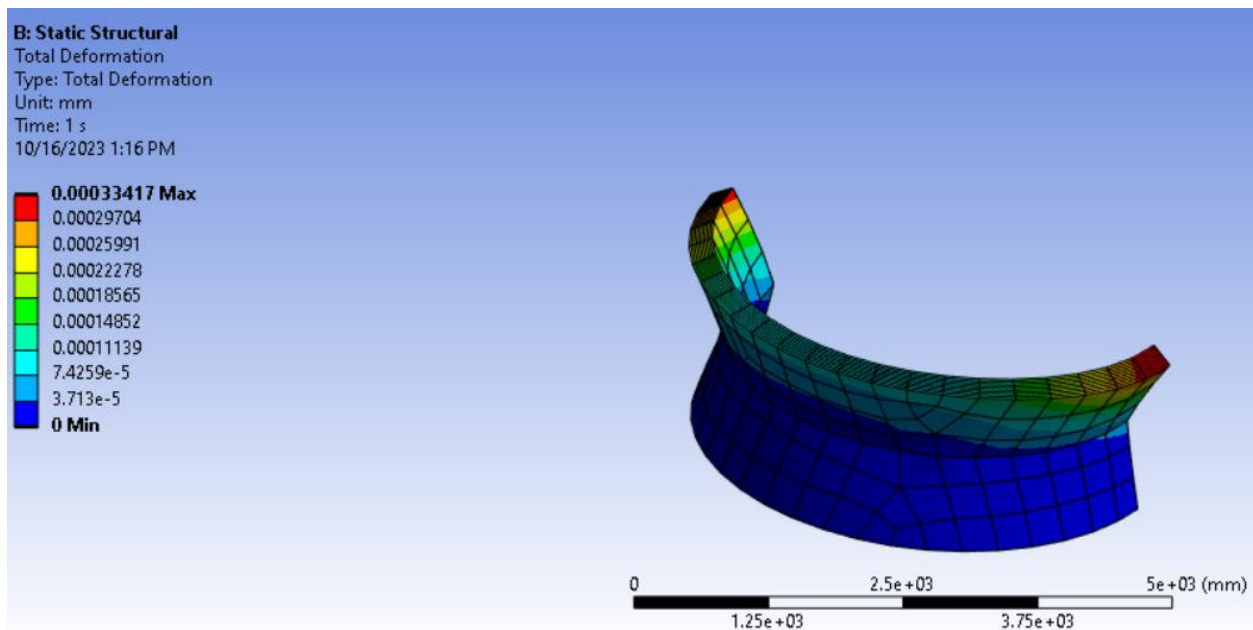


Figure 4.11: Total deformation of the composite

4.6.2. Von misses stress

The von Mises stress is used to predict the yielding of materials under complex loads based on the results of uniaxial tensile and compression tests. The equivalent (Von Misses) stress values of the hybrid epoxy composite were as shown in Figure 4.12 was 679.09 pa which is safe.

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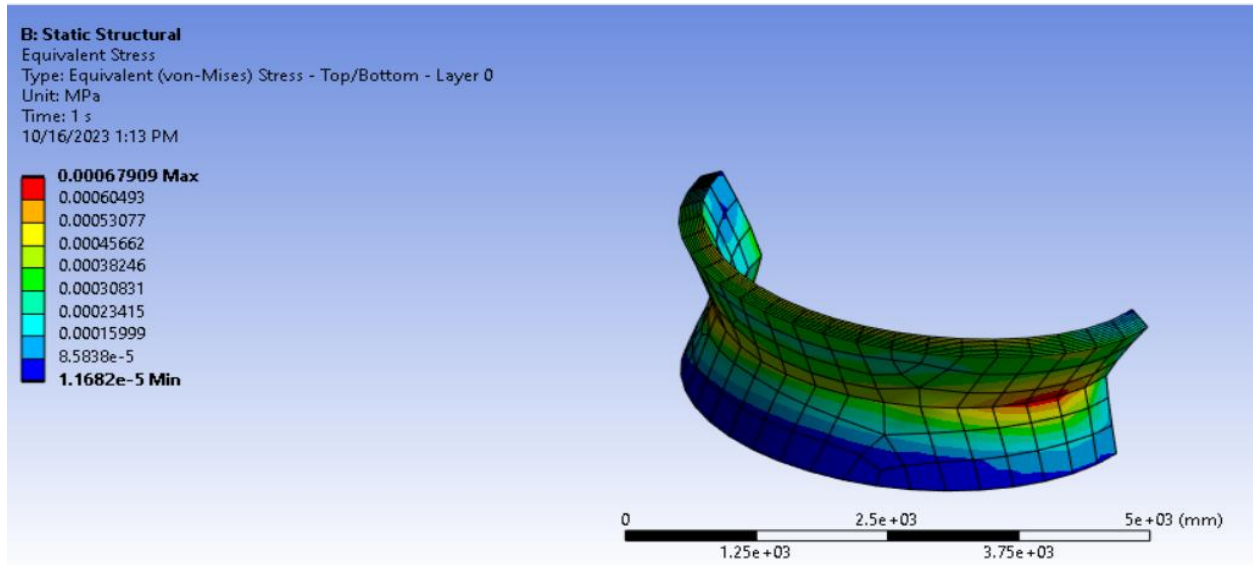


Figure 4.12: Equivalent stress of the composite

4.6.3. Maximum stress

The maximum stress of a composite is the highest stress that the composite is facing before failure. It is a function of the constituent materials and the applied loads. The maximum stress values of hybrid Sisal and Glass fiber reinforced epoxy composites with rice husk filler as shown in Figure 4.13 was 500.22 pa which indicates the material used can fit with required application area and perform its function without failure.

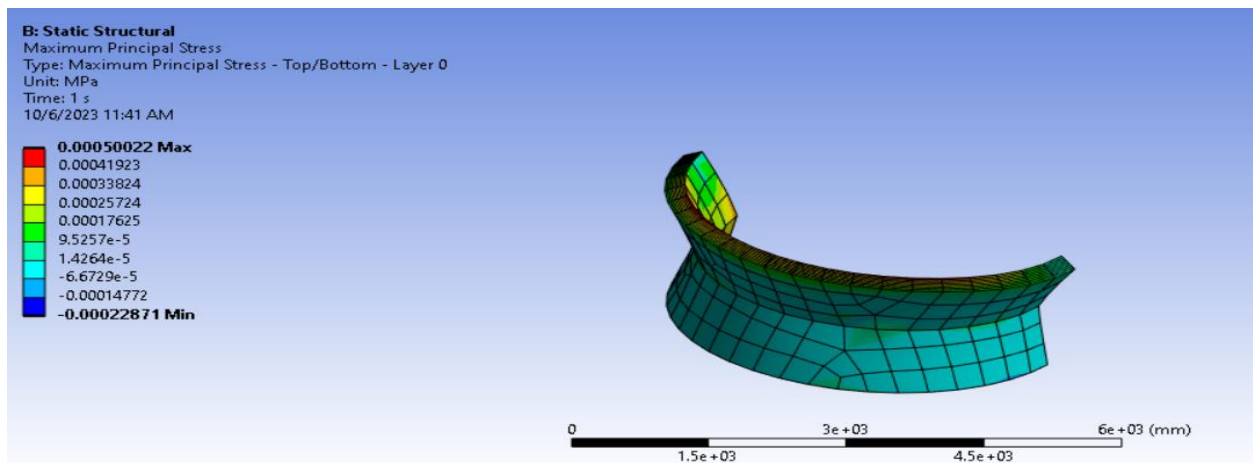


Figure 4.13: Maximum principal stress of the composite

Chapter 5

5. Conclusion, recommendation and future work areas

5.1. Conclusion

In this study, an experimental investigation was conducted to assess the mechanical and physical characteristics of a hybrid sisal and glass fiber-reinforced epoxy composite packed with rice husks. The findings demonstrate that multi-component hybrid composites with three separate elements may be effectively fabricated for use in the medical field. It is evident that the rice husk filler affects the hybrid sisal and glass fiber composite's strength. The high concentration of cellulose in rice husks, however, makes it simpler for water to leak into the interface through microcracks caused by filler swelling as the quantity of filler material increases. Stress from this leads to the composite's eventual breakdown. Lower filler content typically improves the mechanical properties of composites reinforced with lignocellulosic materials.

The hybrid sisal and glass fiber reinforced epoxy composites with rice-husk filler were made using the hand layup technique. Its mechanical performance, including compression, flexural strength, and impact energy, as well as its physical characteristics, including water absorption and void fraction, were studied. The composition of hybrid sisal and glass fiber reinforced epoxy composites with 2% and 4% rice-husk filler then produced better results by its flexural strength, compression strength performance, and physical properties than the other compositions with 6% and 8% filler, according to the results of the tests that were conducted. Based on the outcomes of the investigation, the composite was chosen for use in neck braces.

The 2% filler's compressive strength noticeably rises by 0.45% as a result of the filler particles' ability to strengthen the matrix and prevent crack propagation. however, Due to inadequate interfacial bonding, compressive strength declined with increasing filler loading from 4% to 8%. The hybrid reinforced epoxy composites with 4% volume fractions of rice-husk filler, however, have compression strength close to composites without filler and can sustain the loadings on the application area. This difference, which is just 1.84%, is negligible. However, it gets quite

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substantial over 6% volume fraction and values of compressive strength drop by around 7.7% & 11.21% in comparison to unfilled specimens. As the rice husk filler amount rises in the composite, it also disrupts this load transfer between the fiber and matrix, leading to a decrease in compressive strength

flexural strength which is the capacity of composites or materials to withstand bending deflection when energy is imparted to the structure also increased with the filler loading increased as well. This resulted from composite panels' increased volume proportion of high-modulus lignocellulosic material. hybrid reinforced epoxy composites with 2%, 4%, 6% and 8% volume fractions of rice-husk filler increased by 13.73%, 26.2%, 31.04% and 33.64% respectively as compared with the unfilled one. However, if the filler content is high, the rate of increment tends to slow down. According to [5] due to the settling process and improved interfacial adhesion, mechanical characteristics (tensile strength, flexural strength, and hardness) enhanced with increasing weight percentage loading of rice husk content. However, it has been shown that the impact energy has slightly decreased as a result of the resin constituent's decreased deformability.

As filler concentration increases, impact strength decreases due to decreasing elasticity brought on by filler addition. The composites with 2% volume fractions of rice-husk decreased its impact by 15.1% and for 4%, 6% and 8% filler decreased by 18.1%, 27.2%, 33.3% respectively. The impact resistance depends on complex energy dissipation mechanisms, which in turn depend on the properties of the interface, the complex stress concentration of the kind and size of particles, and the geometry of the fibers, regulate the composite fracture. The inclusion of fillers did not result in an improvement in the impact strength of the composite [95].

For filler concentrations of 2%, and 4%, there is no difference in weight between the two specimens before and after being soaked in distilled water at room temperature, its void fraction was also decreased comparing with 0% filler. According to [96] fillers improve the bond between the fiber and matrix and hence the composites' water resistance by limiting the entrance of water. However, in comparison to the 0% filled, the 6% and 8% filler weights had water absorption behavior of 1.81% and 3.6%, respectively. The 8% filler also results in a higher void

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fraction. This is because as the filler material is natural fiber and starts to swell water as its amount increases.

Finally, it can be concluded that the hybrid sisal and glass fiber reinforced epoxy composites with 2% and 4% rice husk filler have outstanding performance in comparison to the others.

5.2. Recommendation

several tests on the physic-mechanical characteristics of the hybrid composites should be investigated utilizing a range of characterization methods. Testing for tensile strength, hardness, wear and others may be included based on their application area. Utilize scanning electron microscopy (SEM) to examine how the amount of rice husk filler affects the microstructure of the hybrid composites. This will make it easier to understand how the filler particles are distributed throughout the matrix and how they impact the composites' mechanical characteristics. It is strongly encouraged to utilize this hybrid material in the aforementioned application area due to its superior characteristics.

5.3. Future work

The field of composite materials is continuously evolving, with researchers constantly seeing innovative solutions to enhance material properties and address environmental concern. While synthetic and meta fillers have traditionally dominated the industry due to their superior properties, there is a growing interest in exploring natura fillers as sustainable alternatives. This study delves into the potential of rice husk, an abundant agricultural byproduct, as a promising natura filler material.

Despite its advantages, rice husk also presents certain limitations. Its compressive strength, while adequate for many applications, falls short of the exceptional compressive strength exhibited by synthetic and metal fillers. This limitation calls for further research to develop innovative methods for enhancing the compressive strength of rice husk composites.

Future research directions should not only focus on improving the compressive strength of rice husk composites but also expand the exploration of other natural fillers at the nanoscale. By

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incorporating nanoscale natural fillers, researchers can tailor the properties of composite materials to achieve unprecedented levels of performance and sustainability.

Many avenues of research remain to be explored in this field, but this study has focused on using rice husk as a natural filler material due to its sustainability, good mechanical properties such as high stiffness and strength, low weight can reduce the overall weight of composite materials, low cost and abundance. While synthetic and metal fillers are widely encouraged due to their superior properties. Despite its advantages, rice husk also has some limitations, such as its lower compressive strength compared to synthetic and metal fillers. Future research should focus on developing alternative methods to improve the compressive strength of hybrid composites, as well as exploring the use of other natural fillers in composite materials in nano level.

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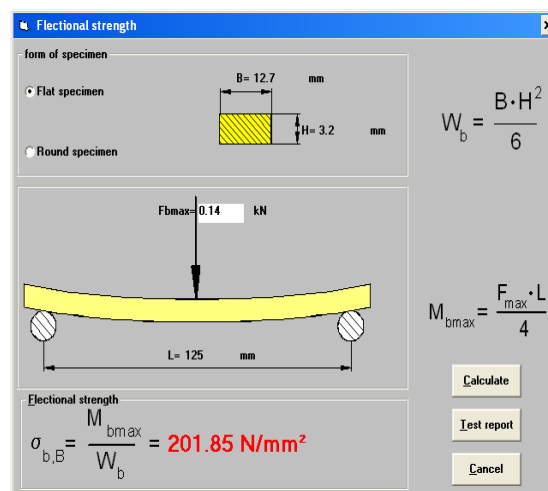
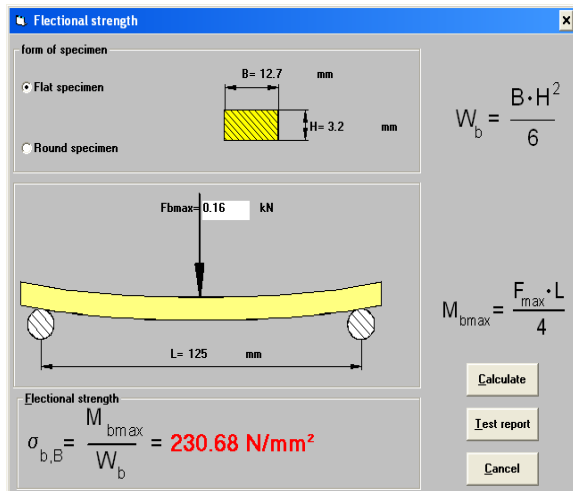
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7. APPENDIX

Table1: Flexural strength results

flexural testing				
Material: composite with 0% filler				
samples	s1	s2	s3	Average
load	160	140	100	
flexural	189.2	191.89	195.73	192.273
Material: composite with 2% filler				
samples	s1	s2	s3	
load	140	155	160	
flexural	201.89	223.52	230.73	218.713
Material: composite with 4% filler				
samples	s1	s2	s3	
load	170	170	165	
flexural	245.15	245.15	237.9	242.733
Material: composite with 6% filler				
samples	s1	s2	s3	
load	180	160	185	
flexural	249.73	254.57	251.78	252.027
Material: composite with 8% filler				
samples	s1	s2	s3	
load	175	185	175	
flexural	252.36	266.78	252.36	257.167



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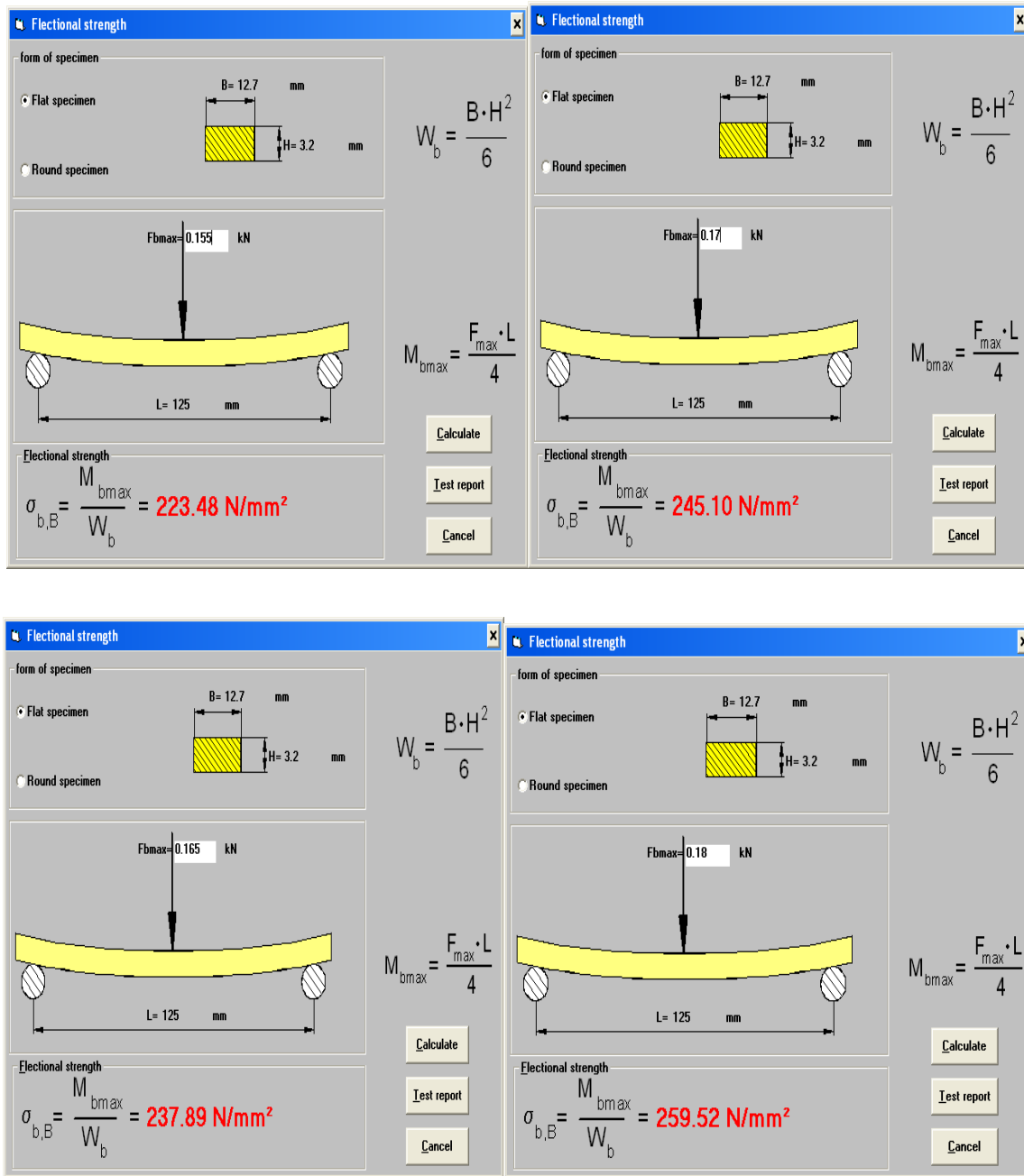
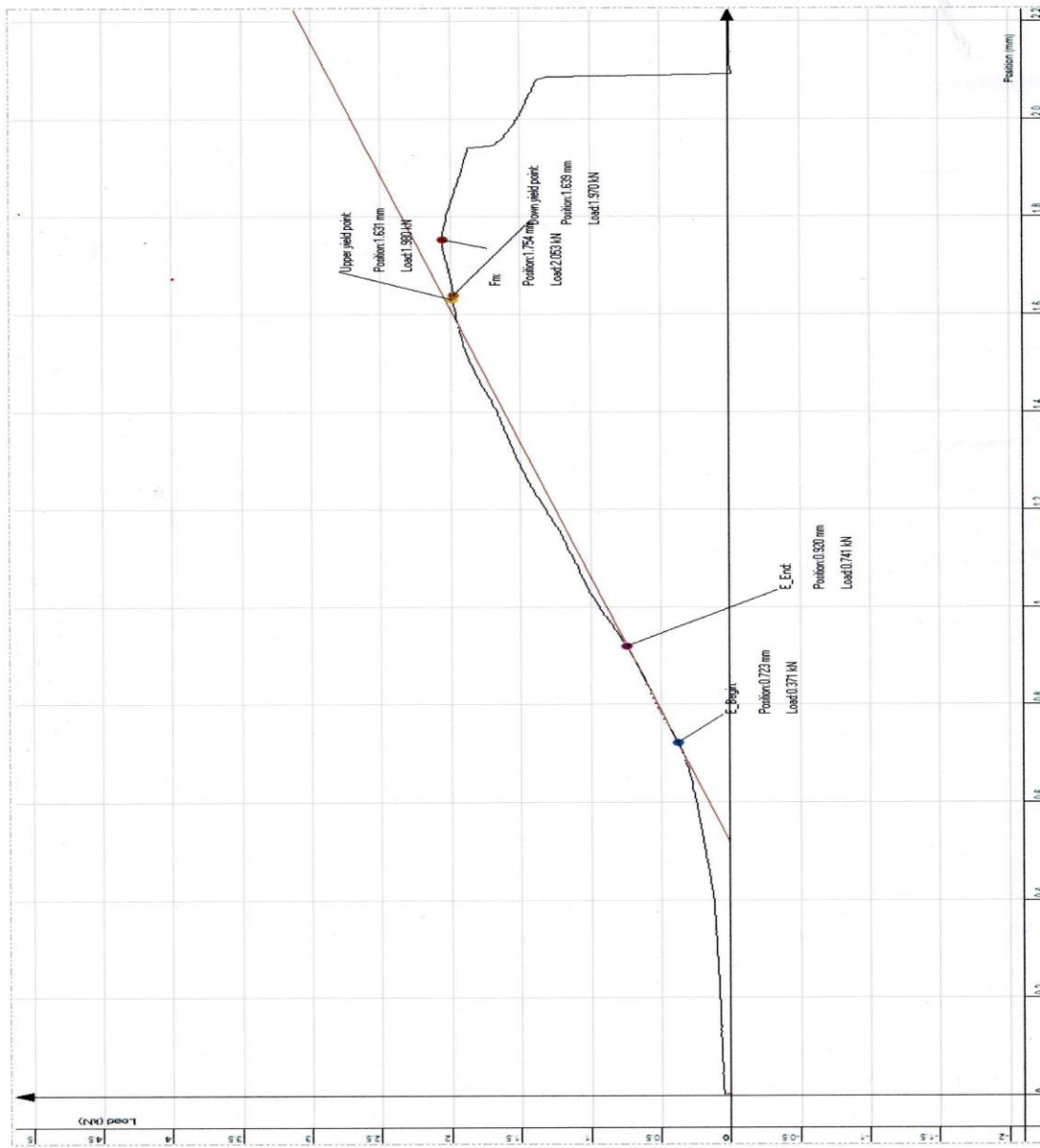
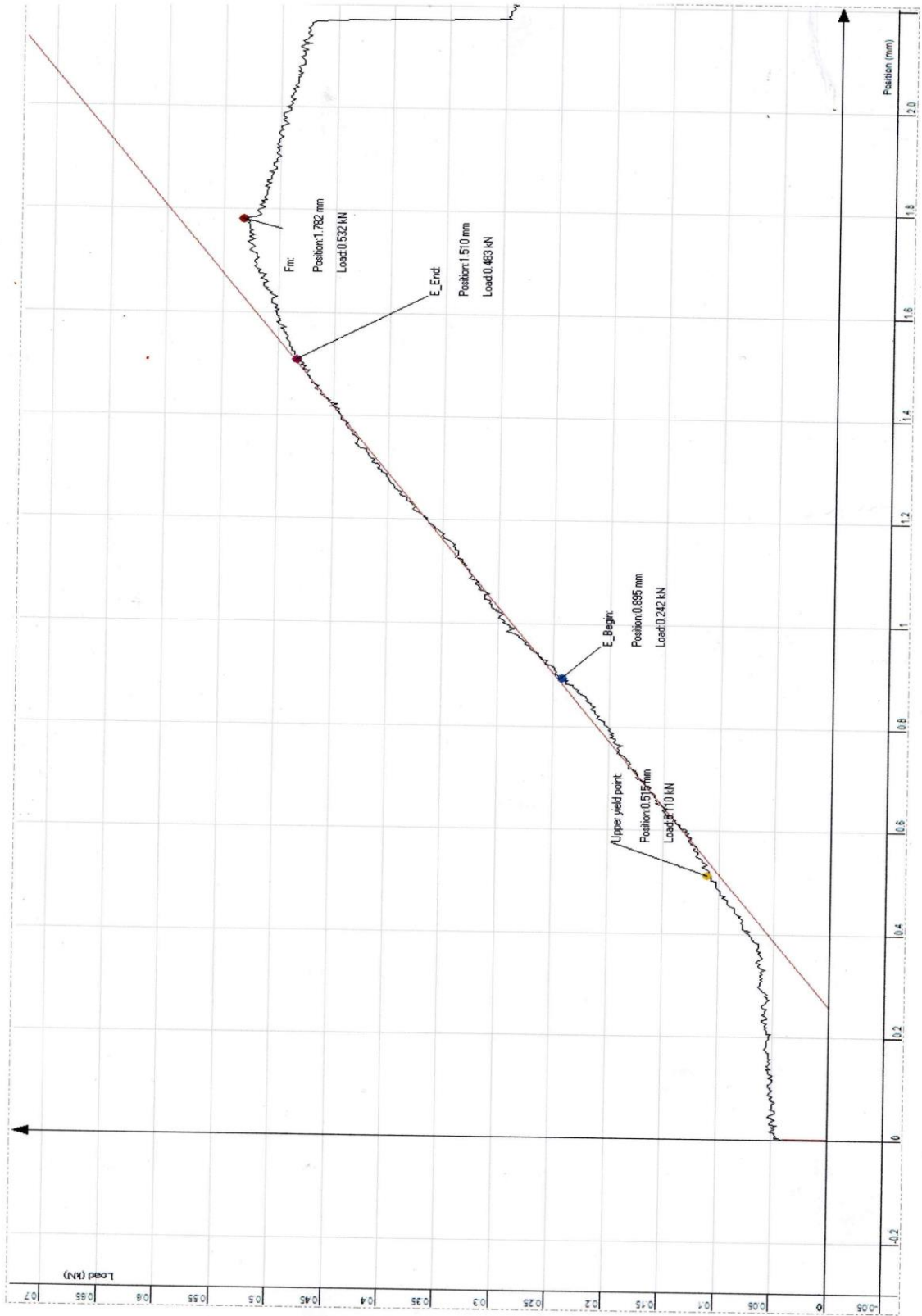


Figure 1: flexural strength of the sample specimens

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Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites



Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

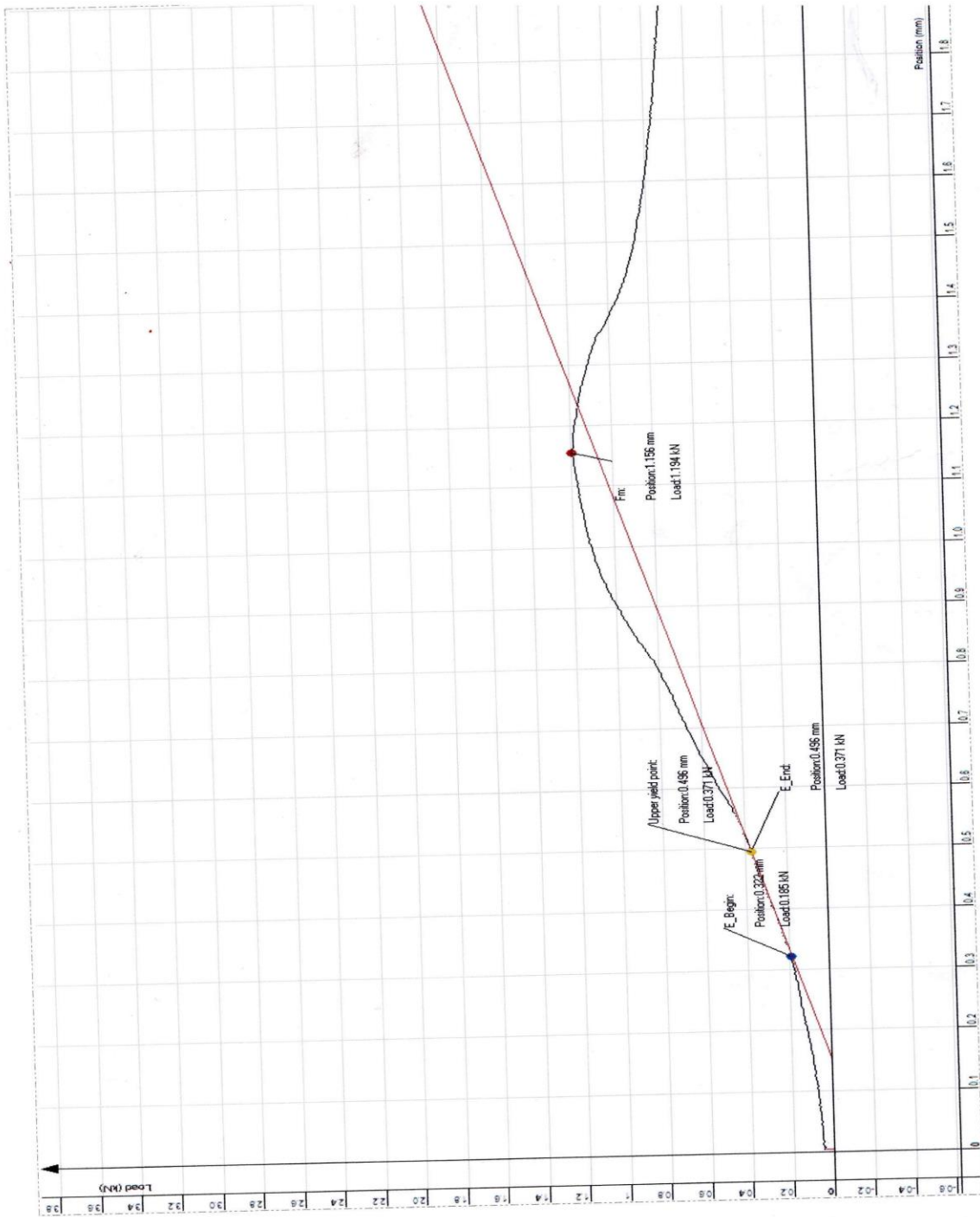


Figure 2: compressive strength of the sample specimens

Water absorption for each prepared specimens

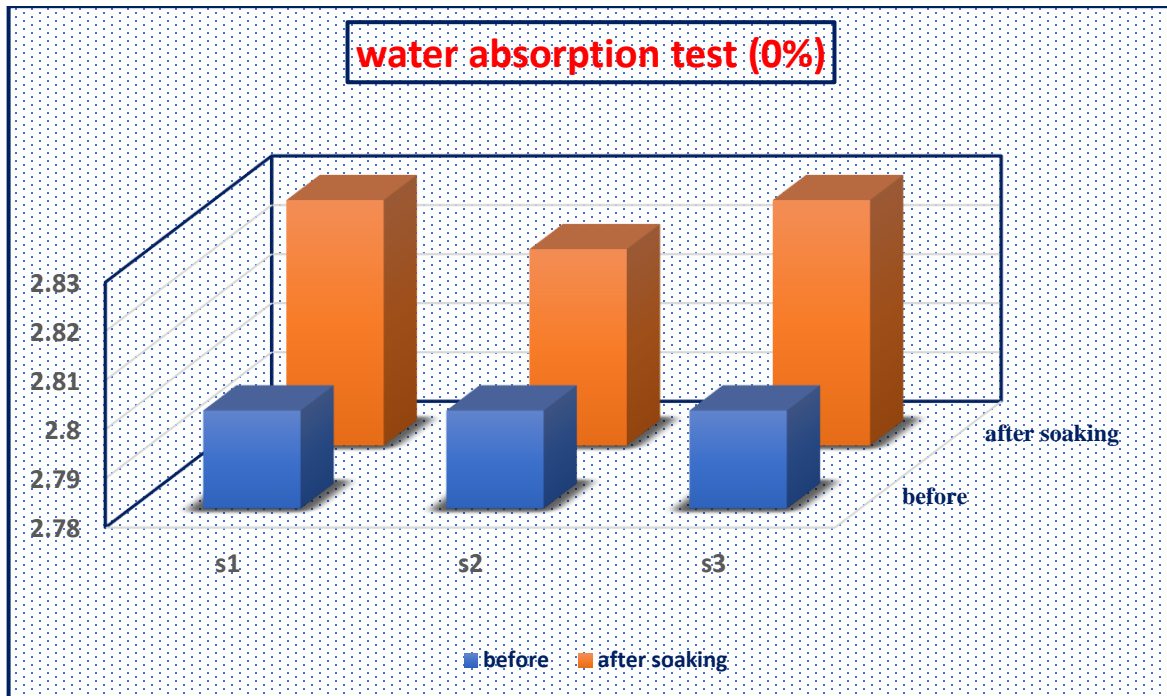


Figure 3: water absorption capability of 0% filler

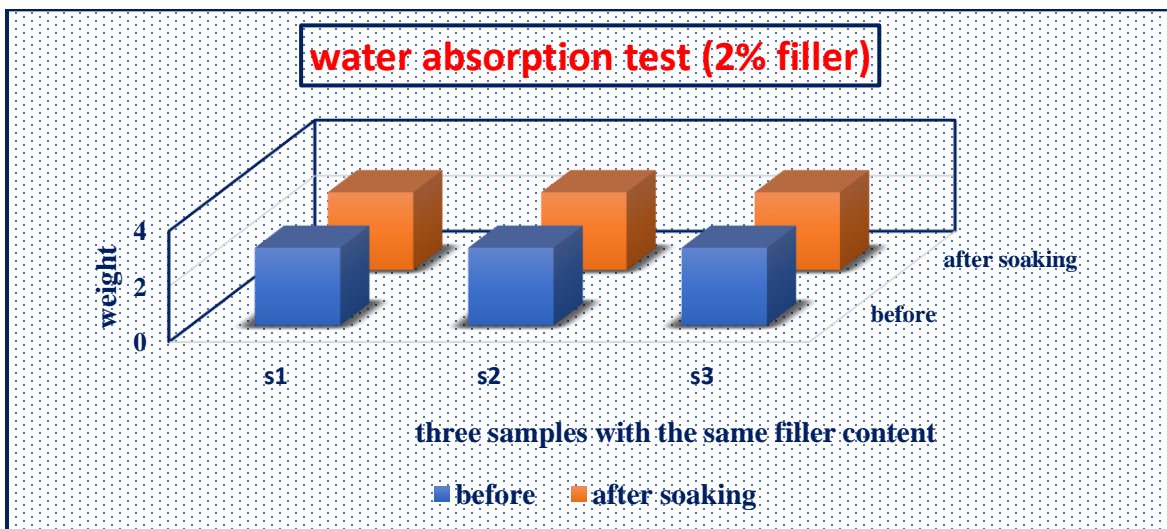


Figure 4: water absorption capability of 2% filler

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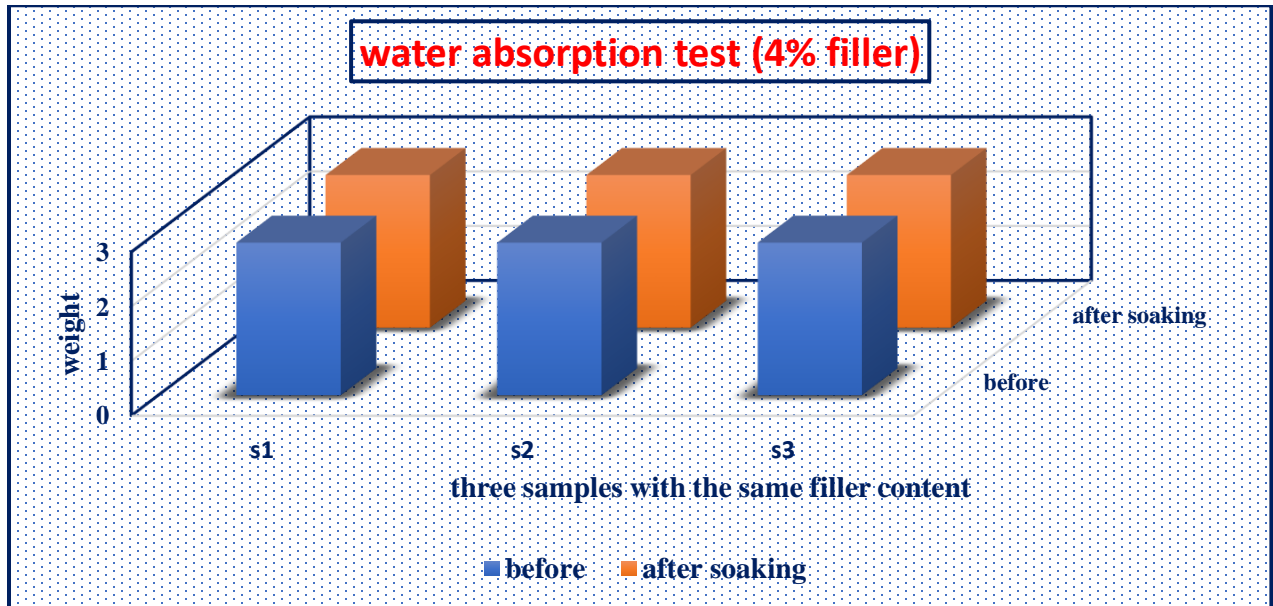


Figure 5: water absorption capability of 4% filler

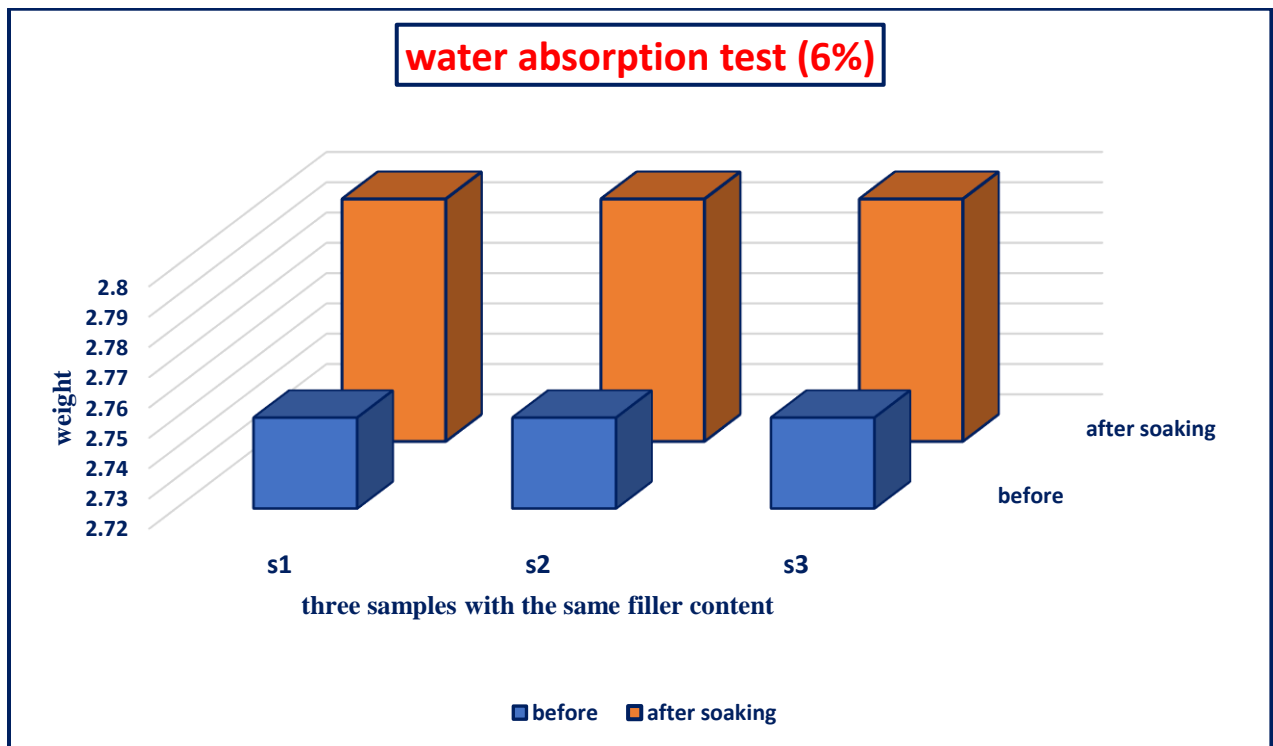


Figure 6: water absorption capability of 6% filler

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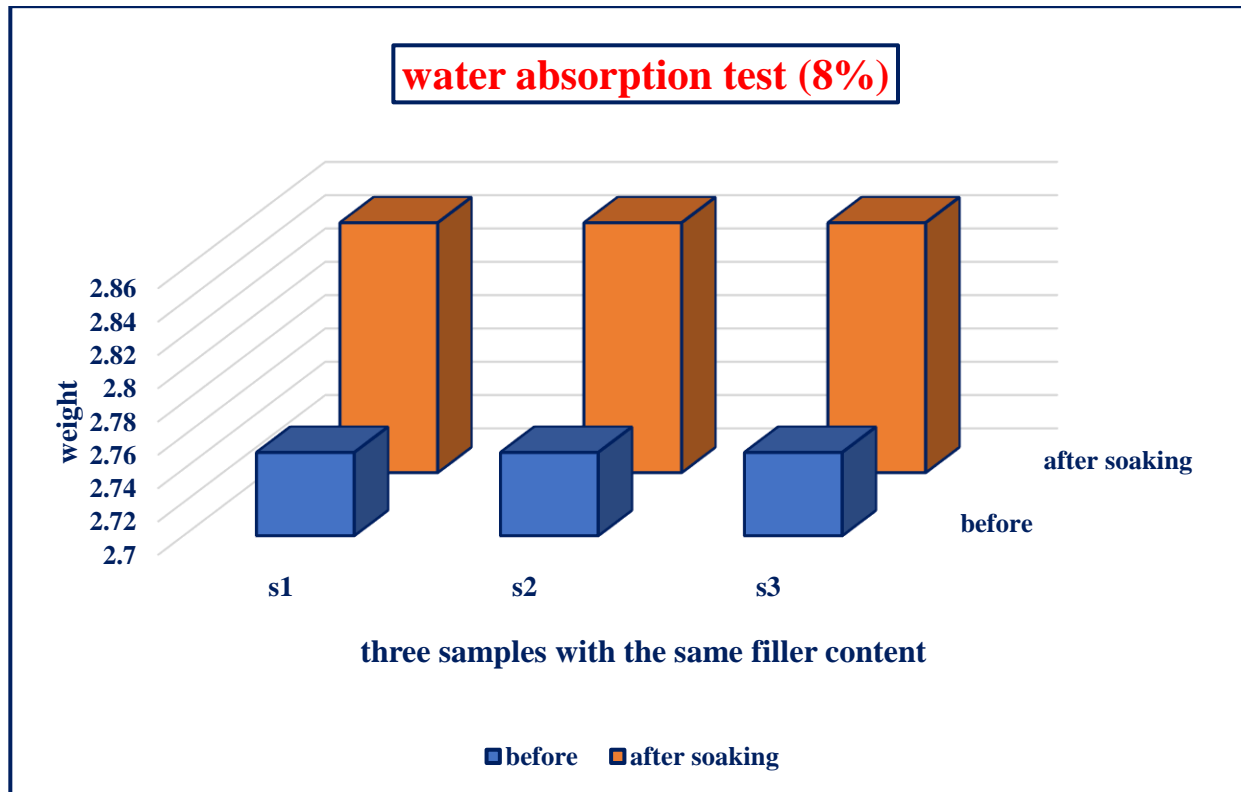


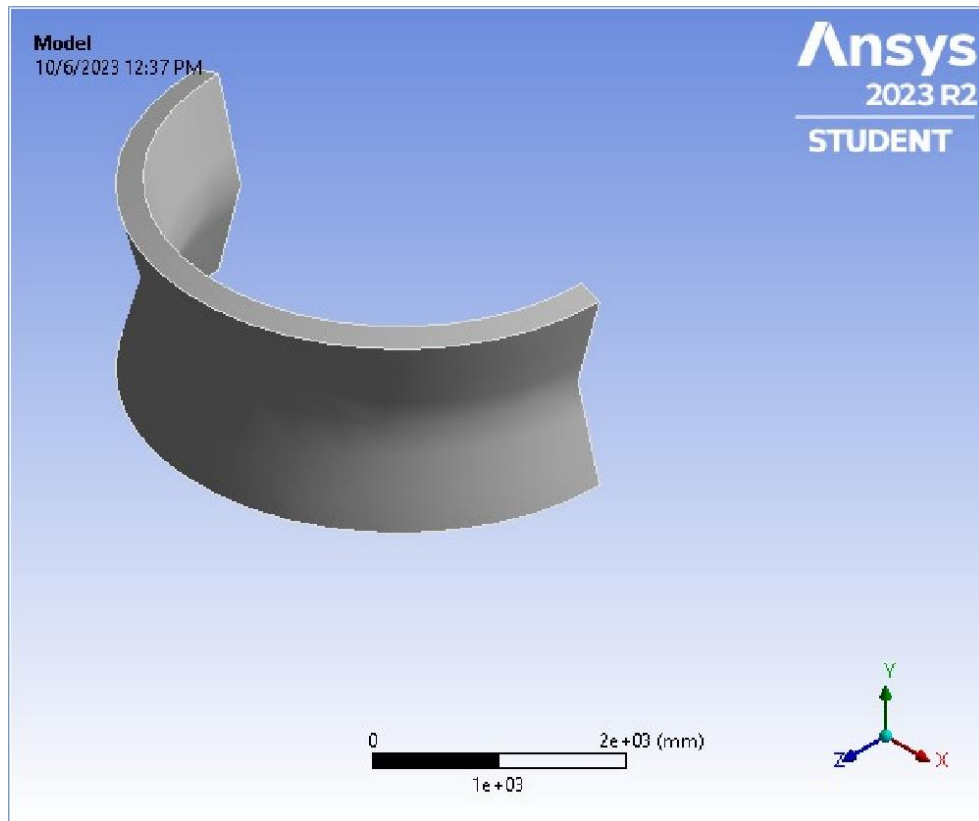
Figure 7: water absorption capabiities of 8% filler

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites



Project

First Saved	Friday, October 6, 2023
Last Saved	Friday, October 6, 2023
Product Version	2023 R2
Save Project Before Solution	No
Save Project After Solution	No



Geometry

TABLE 5
Model (B2) > Geometry

Object Name	<i>Geometry</i>
State	Fully Defined
Definition	
Source	C:\Users\BMC\AppData\Local\Temp\WB_BMC_16176_2\wbnew_files\dp0\global\MECH\SYS\AssembledModel\SYS.pmdb
Type	ACP

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Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	4504.5 mm
Length Y	1905. mm
Length Z	2247.5 mm
Properties	
Volume	2.7593e+009 mm ³
Mass	3464.6 kg
Statistics	
Bodies	1
Active Bodies	1
Nodes	1540
Elements	1143
Mesh Metric	None
Update Options	
Assign Default Material	No
Advanced Geometry Options	
Analysis Type	3-D

TABLE 6
Model (B2) > Geometry > Parts

Object Name	<i>SolidModel.1</i>
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Composite Material
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	4504.5 mm
Length Y	1905. mm
Length Z	2247.5 mm
Properties	
Volume	2.7593e+009 mm ³
Centroid X	-1295.9 mm
Centroid Y	-513.31 mm
Centroid Z	1288.7 mm
Statistics	
Nodes	1540
Elements	1143
Mesh Metric	None
Transfer Properties	
Source	A5::ACP (Pre)

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

Coordinate Systems

TABLE 8
Model (B2) > Coordinate Systems > Coordinate System

Object Name	<i>Global Coordinate System</i>
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Mesh

TABLE 10
Model (B2) > mesh

Object Name	<i>Mesh</i>
State	Solved
Display	
Display Style	Use Geometry Setting
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Mesh Metric	None
Statistics	
Nodes	1540
Elements	1143
Show Detailed Statistics	No
Model Assembly	
Read Only	Yes

Solution (B4)

TABLE 25
Model (B2) > Static Structural (B3) > Solution

Object Name	<i>Solution (B4)</i>
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	16. s
MAPDL Memory Used	91. MB
MAPDL Result File Size	1.375 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

Integration of rice husk filler on physico-mechanical characteristics of hybrid Sisal and Glass fiber reinforced epoxy composites

TABLE 27
Model (B2) > Static Structural (B3) > Solution (B4) > Results

Object Name	Total Deformation	Directional Deformation	Equivalent Stress	Maximum Principal Stress	Normal Stress
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Sub Scope By	Layer				
Layer	Entire Section				
Position	Top/Bottom				
Definition					
Type	Total Deformation	Directional Deformation	Equivalent (von-Mises) Stress	Maximum Principal Stress	Normal Stress
By	Time				
Display Time	Last				
Separate Data by Entity	No				
Calculate Time History	Yes				
Identifier					
Suppressed	No				
Orientation	X Axis				X Axis
Coordinate System	Global Coordinate System			Solution Coordinate System	
Results					
Minimum	0. mm	-3.0905e-004 mm	1.1682e-005 MPa	-2.2871e-004 MPa	-4.895e-004 MPa
Maximum	3.3417e-004 mm	3.1074e-004 mm	6.7909e-004 MPa	5.0022e-004 MPa	4.8959e-004 MPa
Average	5.4638e-005 mm	2.5859e-007 mm	2.0182e-004 MPa	5.5372e-005 MPa	-4.163e-005 MPa
Minimum Occurs On	SolidModel.1				
Maximum Occurs On	SolidModel.1				
Information					
Time	1. s				
Load Step	1				
Substep	1				
Iteration Number	1				
Integration Point Results					
Display Option	Averaged				
Average Across Bodies	No				