VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JNANA SANGAMA", BELGAVI - 590018.

A Project Report On

"BIO-DESIGN AND FABRICATION OF BIO-COMPOSITE HELMET (SISAL, BANANA, JUTE AND COCONUT COIR)"

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF VIII SEMESTER FOR THE AWARD OF

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

SUBMITTED BY

BHARATH B	[1AH13ME404]
CHETHAN KUMAR G	[1AH13ME406]
SHIVANNA G	[1AH13ME417]
SYED SAJJAD HUSSAIN	[1AH13ME418]

UNDER THE GUIDANCE OF

SUNIL RAJ B A

&

CHANDRASHEKAR B

ASSOCIATE PROFESSORS

DEPARTMENT OF MECHANICAL ENGINEERING,

DEPARTMENT OF MECHANICAL ENGINEERING

ACS COLLEGE OF ENGINEERING

#74, KAMBIPURA, MYSORE ROAD, BENGALURU 560074

2015 - 2016

DEPARTMENT OF MECHANICAL ENGINEERING

CERTIFICATE

Certified that the Project Work entitled "**BIO-DESIGN AND FABRICATION OF BIO-COMPOSITE HELMET (SISAL, BANANA, JUTE AND COCONUT COIR)**" has been successfully carried out by **Mr.Bharath B (1AH13ME404), Mr.Chethan Kumar G (1AH13ME406), Mr.Shivanna G (1AH13ME417), Mr.Syed Sajjad Hussain (1AH13ME418) Bonafide Students of ACS College of Engineering, Bengaluru** in partial fulfillment for the award of Bachelor of Engineering in **Mechanical Engineering** of the **Visvesvaraya Technological University, Belgavi** for the year 2015-2016. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**
Sunil Raj B A &	Dr.M.Eswaramoorthy	Dr. Murli M
Chandrashekhar B	Department of Mechanical	Principal
Associate Professors	Engineering	ACSCE

SL No.	**Name of Examiners**	**Signature with date**
1.		
2.		

DECLARATION

We, the students of final semester of Mechanical Engineering, ACS College Of Engineering, Bengaluru-560074 declare that the work entitled "**BIO-DESIGN AND FABRICATION OF BIO-COMPOSITE HELMET (SISAL, BANANA, JUTE AND COCONUT COIR**" has been successfully completed under the guidance of **Sunil Raj B A** , Associate Professor and **Chandrashekhar B**, Associate Professor, Department of Mechanical Engineering, ACS College Of Engineering, Bengaluru. This dissertation work is submitted to Visvesvaraya Technological University in partial fulfillment of the requirements for the award of Degree of Bachelor of Engineering in Mechanical Engineering during the academic year 2015 - 2016. Further the matter embodied in the project report has not been submitted previously by anybody for the award of any degree or diploma to any university.

Place: Bangalore

Date:

By:

BHARATH B	**[1AH13ME404]**
CHETHAN KUMAR G	**[1AH13ME406]**
SHIVANNA G	**[1AH13ME417]**
SYED SAJJAD HUSSAIN	**[1AH13ME418]**

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Karnataka State Council for Science and Technology
Indian Institute of Science Campus, Bangalore - 560 012
Telephone: 080-23341652, 23348848, 23348849 ♦ **Telefax**: 080-23348840
Email: office@kscst.iisc.ernet.in, office@kscst.org.in ♦ **Website**: www.kscst.iisc.ernet.in, www.kscst.org.in
KSCST

Dr. S. G. Sreekanteswara Swamy
Executive Secretary

23rd March 2016

Ref: 7.1.03/SPP/ 1148

The Principal
ACS College of Engineering
207, Kambipura,Mysuru Road, Kengeri Hobli,
Bengaluru - 560 074

Dear Sir,

Sub : Sanction of Student Project - 39th Series: Year 2015-2016
Your Project Proposal Reference No. : 39S_BE_2249

Ref : Your Project Proposal entitled: **BIO-DESIGN AND FABRICATION OF BIO-COMPOSITE HELMET**

I am happy to inform that your project proposal referred above, has been approved by the Secretary, KSCST for "Student Project Programme - 39th Series" and has been sanctioned with a budgetary break-up as detailed below:

Student / s	Mr. Bharath B and others		**Budget**	**Amount (Rs)**
			Materials/Consumables	3,000.00
Guide/s	Mr. Sunil Raj B.A		Labor	-
			Travel	-
Department	Mechanical Engineering		Miscellaneous	1,000.00
			Report	500.00
			TOTAL	4,500.00
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The following are the guidelines to carryout the project work :

a) The project should be performed based on the objectives of the proposal sent by you.

b) The project should be completed in all respects and one copy of the hardbound report along with softcopy of the full report (including coverpages, abstract and preliminary pages) and in a CD (.pdf format) should be submitted to KSCST.

c) Any change in the project title and objectives, etc., or students is liable to rejection of the project and the amount sanctioned needs to be returned to KSCST.

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e) **Important:** After completing the project, 2 to 3 page write-up (synopsis) needs to be sent by e-mail [spp@kscst.iisc.ernet.in] and should include following :

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2) Name of the College & Department
3) Name of the students & Guide(s)
4) Keywords

5) Introduction / background **39S_BE_2249**

(with specific reference to the project, work done earlier, etc) - about 20 lines

6) Objectives (about 10 lines)

7) Methodology (about 20 lines)

(materials, methods, details of work carried out, including drawings, diagrams etc)

8) Results and Conclusions

(about 20 lines with specific reference to work carried out)

9) Scope for future work (about 20 lines).

(Note: The write-up (Synopsis) should be sent with the approval of project guide. The softcopy of the write-up, in MS Word format, should be sent by e-mail (spp@kscst.iisc.ernet.in). In your e-mail, please also include project proposal reference number and title of the project.)

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Thanking you and with best regards,

Yours sincerely,

(SGS Swamy)

Copy to:

1) The Head of the Department of
Mechanical Engineering
Acs College Of Engineering
207, Kambipura,Mysuru Road, Kengeri Hobli,
Bengaluru - 560 074

2) Mr. Sunil Raj B.A
Department of Mechanical Engineering
Acs College Of Engineering
207, Kambipura,Mysuru Road, Kengeri Hobli,
Bengaluru - 560 074

3) The Finance Officer, KSCST, Bangalore

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ABSTRACT

Recently, bio composite materials are synthesized using natural cellulose fibers as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, availability, renewability, degradable and being environmental-friendly. The present work attempts to make an improvement in the current existing helmet manufacturing methodology and materials used to have better mechanical properties as well as to enhance the compatibility between fibers and the matrix. The bio-composite are prepared with the unsaturated polyester matrix and fibers such as jute, sisal, coconut, areca and banana using hand lay-up method with appropriate proportions to result in helmet shell structure. The fabricated helmet are planned to evaluate its mechanical properties such as tensile strength, impact strength and compression strength .

CHAPTER - 1

INTRODUCTION

1.1. Overview of composites

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armouring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects.

A composite material consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases, with an interface separating them. It has characteristics that are not depicted by any of the components in isolation. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger. The function of individual components has been described as:

- ### Matrix phase

The primary phase, having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it.

- ### Dispersed (reinforcing) phase

The second phase (or phases) is embedded in the matrix in a discontinuous form. This secondary phase is called dispersed phase. Dispersed phase is usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

Many of common materials(metal alloys, doped Ceramics and Polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical properties of steel are similar to those of pure iron). There are two classification systems of composite materials. One of them is based on the matrix material (metal, ceramic, polymer) and the second is based on the material structure.

1.2. Definition of Composite

The most widely used meaning is the following one, which has been stated by **Jartiz** “Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form”. The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures.

Kelly very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Beghezan defines as “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings”, in order to obtain improved materials.

Van Suchetclan explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

1.3. Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers

(a) Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminium oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(b) Polymer Matrix Composites (PMC)

Most commonly used matrix materials are polymeric. The reasons for this are two-fold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and does not require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. For this reason polymer composites developed rapidly and soon became popular for structural applications. Polymer composites are used because overall properties of the composites are superior to those of the individual polymers. They have a greater elastic modulus than the neat polymer but are not as brittle as ceramics. Polymeric matrix composites are composed of a matrix from thermoset (unsaturated polyester, epoxy or thermoplastic polycarbonate, polyvinylchloride, nylon, polystyrene and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

The potential applications of polymer composites include consumer goods (sewing machines, doors, bathtubs, tables, chairs, computers, printers, etc), sporting goods industry (golf shafts, tennis rackets, snow skis, fishing rods, etc.), aerospace industry (doors, horizontal and vertical stabilizers, wing skins, fin boxes, flaps, and various other structural components), marine applications (passenger ferries, power boats, buoys, etc.), automotive industry (bumper beam, seat/load floor, hood radiator support, roof panel and land transport systems like cars, trucks and bus bodies, railway coach components, containers and two and three wheelers), construction and civil structures (bridges, columns doors, windows and partitions and for translucent roofing sheets, prefabricated modular houses and buildings etc.), industrial applications

Two main kinds of polymers are **thermosets** and **thermoplastics**. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the **chopped fiber composites** form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of **conventional compress techniques** to mould the compounds.

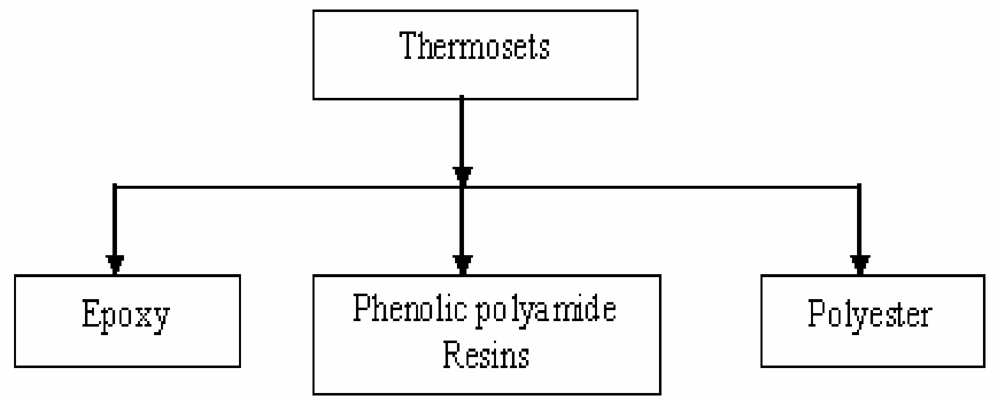

Fig 1.3(a): Thermoset resin

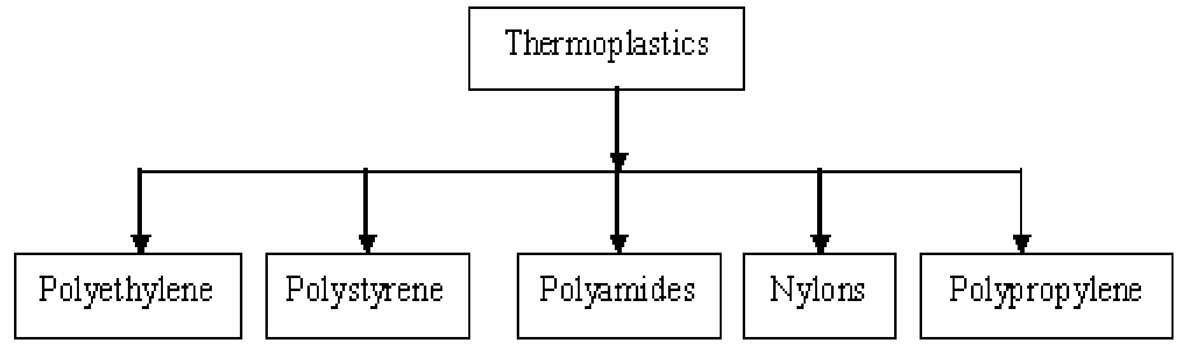

Fig1.3(a):Thermoplastic resin

1.3.1 Based on reinforcing material structure

Classification of composites: three main categories

- ❖ particle-reinforced (large-particle and dispersion-strengthened)
- ❖ fiber-reinforced (continuous (aligned) and short fibers (aligned or random)
- ❖ structural (laminates and sandwich panels)

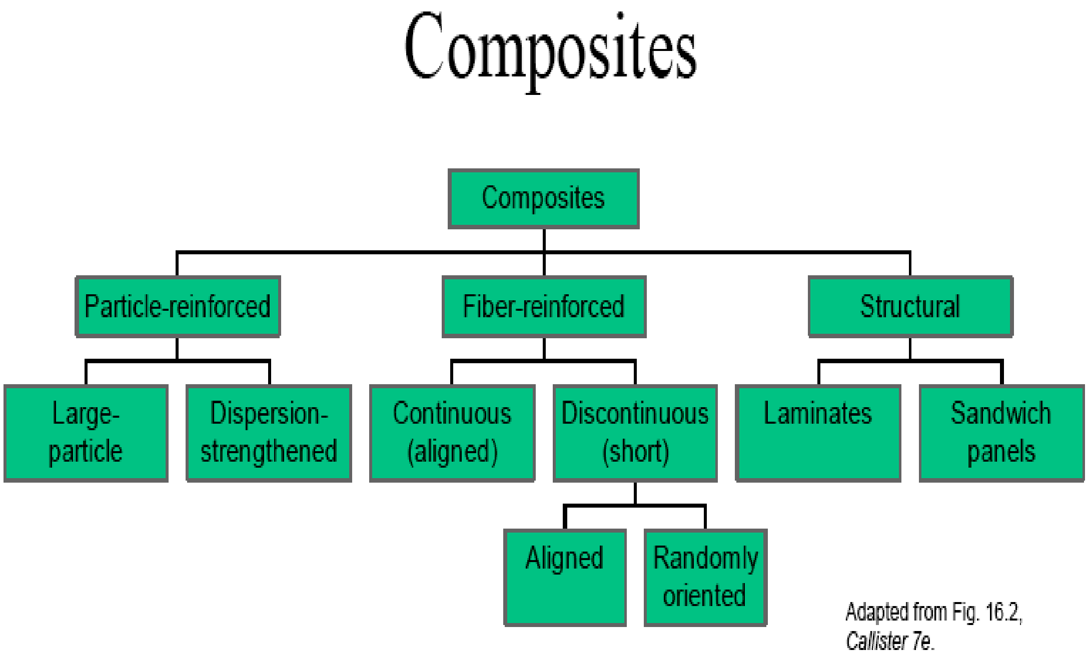

Fig1.3.1: Reinforced based composites

❖ **Particulate Composites**

Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles. These are the cheapest and most widely used. They fall in two categories depending on the size of the particles

- ➢ Composites with random orientation of particles.
- ➢ Composites with preferred orientation of particles.

Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.

- **Fibrous Composites**

Short fiber reinforced composites:

Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter). They are classified as

- Composites with random orientation of fibers.
- Composites with preferred orientation of fibers.

Long-fiber reinforced composites:

Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.

- Unidirectional orientation of fibers.
- Bidirectional orientation of fibers (woven).

- **Laminate composite**

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer composite.

1.4 Introduction to Reinforcements

Reinforcements for the composites can be fibers, fabrics particles or **whiskers**. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure.2.3 shows types of reinforcements in composites

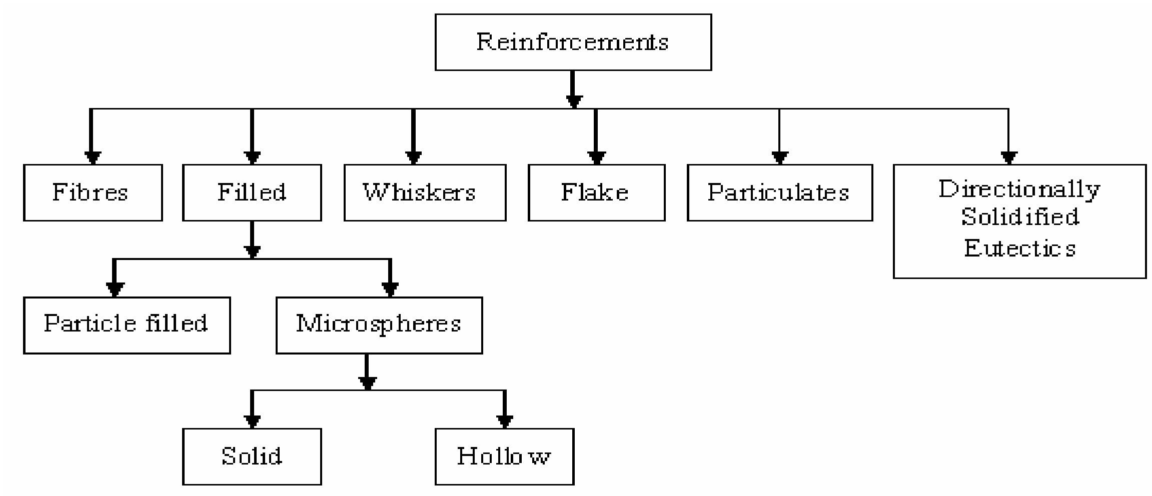

Fig1.4: Types of reinforcement

Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements

1.5 Natural Fiber Reinforced Composites

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The manufacture, use and removal of traditional fiber–reinforced plastic, usually made of glass, carbon or aramid fibers–reinforced thermoplastic and thermoset resins are considered critically because of environmental problems. By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example carbon or aramid fibers that have to be synthesized. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. The detailed classification is shown in Figure 1.1.

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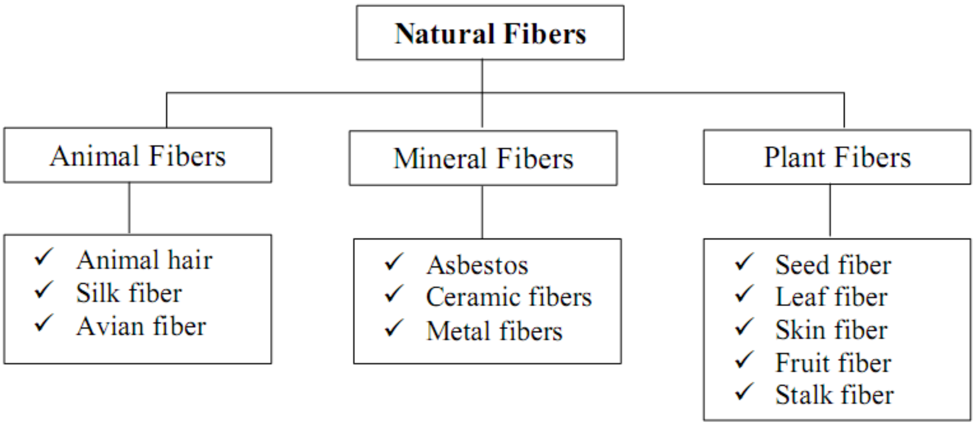

Figure 1.1 Classification of natural fibers

Fig 1.5: Classification of natural fiber

1.5.1 Animal Fiber

Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora. Animal hair (wool or hair) are the fibers taken from animals or hairy mammals. E.g. Sheep's wool, goat hair (cashmere, mohair),alpaca hair, horse hair, etc. Silk fiber are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms. Avian fiber are the fibers from birds, e.g. feathers and feather fiber.

1.5.2 Mineral fiber

Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized into the following categories: Asbestos is the only naturally occurring mineral fiber. Variations are serpentine and amphiboles, anthophyllite. Ceramic fibers includes glass fibers (Glass wood and Quartz), aluminium oxide, silicon carbide, and boron carbide. Metal fibers includes aluminium fibers.

1.5.3 Plant fiber

Plant fibers are generally comprised mainly of cellulose: examples include cotton, jute, flax, ramie, sisal and hemp. Cellulose fibers serve in the manufacture of paper and cloth. This fiber can be further categorizes into following as Seed fiber are the fibers collected from the seed and seed case e.g. cotton and kapok. Leaf fiber are the fibers collected from the leaves e.g. sisal and agave. Skin fiber are the fibers are collected from the skin or bast surrounding the stem of their respective plant. These fibers have higher tensile strength than other fibers. Therefore, these fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, banana, hemp, and soybean. Fruit fiber are the fibers are collected from the fruit of the plant, e.g. coconut (coir) fiber.

Stalk fiber are the fibers are actually the stalks of the plant. E.g. straws of wheat, rice, barley and other crops including bamboo and grass. Tree wood is also such a fiber. Natural fiber composites are by no means new to mankind. Already the ancient Egyptians used clay that was reinforced by straw to build walls. In the beginning of the 20th century wood- or cotton fiber reinforced phenol- or melamine formaldehyde resins were fabricated and used in electrical applications for their non-conductive and heat-resistant properties. At present day natural fiber composites are mainly found in automotive and building industry and then mostly in applications where load bearing capacity and dimensional stability under moist and high thermal conditions are of second order importance. For example, flax fiber reinforced polyolefins are extensively used today in the automotive industry, but the fiber acts mainly as filler material in non-structural interior panels. Natural fiber composites used for structural purposes do exist, but then usually with synthetic thermoset matrices which of course limit the environmental benefits.

The natural fiber composites can be very cost effective material for following applications:

- Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc.
- Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
- Furniture: chair, table, shower, bath units, etc.

- Electric devices: electrical appliances, pipes, etc.
- Everyday applications: lampshades, suitcases, helmets, etc.
- Transportation: Aerospace, automobile and railway coach interior, boat, etc.

Natural fibers are generally lignocellulosic in nature, consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicellulose. According to a Food and Agricultural Organization survey, Tanzania and Brazil produce the largest amount of sisal.Henequen is grown in Mexico. Abaca and hemp are grown in the Philippines. The largest producers of jute are India, China, and Bangladesh. Presently, the annual production of natural fibers in India is about 6 million tons as compared to worldwide production of about 25 million tons. The detail information of fibers and the countries of origin are given in Table 1.1.

Table.1.1 Fibers and countries of origin [7]

Flax	Borneo
Hemp	Yugoslavia, china
Sun Hemp	Nigeria, Guyana, Siera Leone, India
Ramie	Hondurus, Mauritius
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania
Kenaf	Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo
Roselle	Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, Tanzania
Sisal	East Africa, Bahamas, Antiqua, Kenya, Tanzania, India
Abaca	Malaysia, Uganda, Philippines, Bolivia
Coir	India, Sri Lanka, Philippines, Malaysia

Natural fibers such as jute, sisal, pineapple, abaca and coir have been studied as a reinforcement and filler in composites. Growing attention is nowadays being paid to coconut fiber due to its availability. The coconut husk is available in large quantities as residue from coconut production in many areas, which is yielding the coarse coir fiber. Coir is a lingo-cellulosic natural fiber. It is a seed-hair fiber obtained from the outer shell, or husk, of the coconut. It is resistant to abrasion and can be dyed. Total world coir fiber production is 250,000 tonnes. The coir fiber industry is particularly important in some areas of the developing world. Over 50% of the coir fiber produced annually throughout the world is consumed in the countries of origin, mainly India. Because of its hard-wearing quality, durability and other advantages, it is used for making a wide variety of floor furnishing materials, yarn, rope etc. However, these traditional coir products consume only a small percentage of the potential total world production of coconut husk. Hence, research and development efforts have been underway to find new use areas for coir, including utilization of coir as reinforcement in polymer composites.

1.6 Surface treatment of fibers

The influence of fiber treatment on the properties of biocomposites derived from grass fiber and soy based bioplastic has been investigated with environmental scanning electron microscopy, thermal and mechanical properties measurements. Grass fibers were treated with alkali solution that reduced the inter-fibrillar region of the fiber by removing hemicellulose and lignin, which reduce the cementing force between fibrils. This led to a more homogenous dispersion of the biofiber in the matrix as well as increase in the aspect ratio of the fiber in the composite, resulting in an improvement in fiber reinforcement efficiency. This led to enhancement in mechanical properties including tensile and flexural properties as well as impact strength. Additionally, the alkali solution treatment increased the concentration of hydroxyl groups on the surface, which led to a better interaction between the fibers and the matrix.

Against this background, the present research work has been undertaken, with an objective to explore the potential of coir fiber as a reinforcing material in polymer composites and to investigate its effect on the mechanical behavior of the resulting composites. The present work thus aims to develop this new class of natural fiber based polymer composites with different fiber lengths and to analyze their mechanical behavior by experimentation.

1.7 Manufacturing Processes of Composite Material

Manufacturing of a composite material is to combine the polymeric resin system with the fiber reinforcement. Since the orientation of the fibers is critical to the end properties of the composite, manufacturing process is utmost important to align the fibers in desired direction. A good manufacturing process will produce a higher, uniform fiber volume fraction along with a higher production of a large volume of parts economically and have repeatable dimensional tolerances.

The composite manufacturing techniques can be classified into two categories:

A. Open mould process

a) Hand lay-up process

b) Spray up process

c) Vacuum-bag auto clave process

d) Filament winding process

B. Closed mould process

a) Compression moulding

b) Injection moulding

c) Sheet moulding compound (SMC) process

d) Continuous pultrusion process

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CHAPTER - 2

LITERATURE SURVEY

This chapter outlines some of the recent reports published in literature on mechanical behavior of special emphasis on natural fiber reinforced polymer composites. Persistence of plastics in the environment, the shortage of landfill space, the depletion of petroleum resources, concerns over emissions during incineration, and entrapment by and ingestion of pack-aging plastics by fish, fowl and animals have spurred efforts to develop biodegradable/bio based plastics. This new generation of biobased polymeric products is based on renewable bio based plant and agricultural stock and form the basis for a portfolio of sustainable, eco-efficient products that can compete in markets currently dominated by products based on petroleum feedstock in applications such as packaging, automotives, building products, furniture and consumer goods. It is not necessary to produce 100%biobased materials as substitutes for petroleum-based materials immediately. Available solution is to combine petroleum and bioresources to produce a useful product having the requisite cost-performance properties for real-world applications. Biopolymers or synthetic polymers reinforced with natural/biofiber frequently termed 'biocomposites' can be viable alternatives to glass fiber reinforced composites. The combination of biofibers like kenaf, industrial hemp, flax, jute, henequen, pineapple leaf fiber, sisal, wood and various grasses with polymer matrices from both non-renewable (petroleum-based) and renewable resources to produce composite materials that are competitive with synthetic composites such as glass-polypropylene, glass-epoxies, etc., is gaining attention over the last decade.

The use of natural fibers for the reinforcement of the composites has received increasing attention both by the academic sector and the industries. Natural fibers have many significant advantages over synthetic fibers currently, many types of natural fibers have been investigated for use in plastics including flax, hemp, jute straw, wood, rice husk, wheat, barley, sisal, coir, bamboo etc.The chemical composition of natural fibers varies depending upon the type of fibers. The chemical composition as well as the structure of the plant fibers is fairly complicated. Plant fibers are a composite material designed by nature. The fibers are basically a rigid, crystalline cellulose microfibril-reinforced amorphous lignin and/or with hemicellulosic matrix. Most plant fibers, except for cotton, are composed of cellulose, hemicellulose, lignin, waxes, and some water-soluble compounds, where cellulose, hemicelluloses, and lignin are the major constituents. The properties of the constituents contribute to the overall properties of the fiber. Hemicellulose is responsible for the biodegradation, microabsorption and thermal degradation of the fiber as it shows least resistance, whereas lignin is thermally stable but prone to UV degradation. The percentage composition of each of these components varies for different fibers. Generally, the fiber contains 60-80 % cellulose, 5-20 % lignin and up to 20 % moisture. The cell wall of the fibers undergoes pyrolysis with increasing processing temperature and contributes to char formation. These charred layers help to insulate the ligno-cellulose from further thermal degradation.

The global demand for wood as a building material is steadily growing, while the availability of this natural resource is diminishing. This situation has led to the development of alternative materials. Of the various synthetic materials that have been explored and advocated, polymer composites claim a major participation as building materials. There has been a growing interest in utilizing natural fibers as reinforcement in polymer composite for making low cost construction materials in recent years. Natural fibers are prospective reinforcing materials and their use until now has been more traditional than technical. They have long served many useful purposes but the application of the material technology for the utilization of natural fibers as reinforcement in polymer matrix took place in comparatively recent years. Economic and other related factors in many developing countries where natural fibers are abundant, demand that scientists and engineers apply appropriate technology to utilize these natural fibers as effectively and economically as possible to produce good quality fiber reinforced polymer composites for housing and other needs. Among the various natural fibers, sisal is of particular interest in that its composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibers. The present paper surveys the research work published in the field of sisal fiber reinforced polymer composites with special reference to the structure and properties of sisal fiber, processing techniques, and the physical and mechanical properties of the composites.

The worldwide trend toward using cheap, atoxic and durable materials from renewable resources contributes to sustainable development. Thus, the investigation of the potential use of vegetal fibers as reinforcing agent in polymeric composites has gained new significance. Sisal fiber has emerged as a reinforcing material for polymers used in automobile, footwear and civil industries. In this work, properties such as hardness, tensile strength and tear strength of polymer composites composed by block copolymer styrene-butadiene-styrene (SBS) and 5, 10 and 20% by weight of sisal fiber were evaluated. The influence of conventional polymer processing techniques such as single-screw and double-screw extrusion, as well as the addition of coupling agent on the composite mechanical performance was investigated. Also, the morphology and thermal stability of the composites were analyzed. The addition of 2 wt. (%) maleic anhydride as coupling agent between sisal fiber and SBS has improved the composite mechanical performance and the processing in a double-screw extruder has favored the sisal fiber distribution in the SBS matrix.

The Tensile properties and scanning electron Microscope analysis of Bamboo/glass fibers Reinforced epoxy Hybrid composites were studied. The effect of alkali treatment of the bamboo fibers on these properties was also studied. It was observed that tensile properties of the hybrid composite increase with glass fiber content. These properties found to be higher when alkali treated bamboo fibers were used in the hybrid composites. The elimination of amorphous hemi-cellulose with alkali treatment leading to higher crystallinity of the bamboo fibers with alkali treatment may be responsible for these observations. The author investigated the interfacial bonding between Glass / Bamboo reinforced epoxy composites. The effect of alkali treatment on the bonding between Glass / Bamboo composites was also studied.

In recent years, there has been a marked increase in interest in biodegradable materials for use in packaging, agriculture, medicine, and other areas. In particular, biodegradable polymer materials (known as biocomposites) are of interest. Polymers form the backbones of plastic materials, and are continually being employed in an expanding range of areas. As a result, many researchers are investing time into modifying traditional materials to make them more user-friendly, and into designing novel polymer composites out of naturally occurring materials. A number of biological materials may be incorporated into biodegradable polymer materials, with the most common being starch and fiber extracted from various types of plants. The belief is that biodegradable polymer materials will reduce the need for synthetic polymer production (thus reducing pollution) at a low cost, thereby producing a positive effect both environmentally and economically. This paper is intended to provide a brief outline of work that is under way in the area of biodegradable polymer research and development, the scientific theory behind these materials, areas in which this research is being applied, and future work that awaits.

Yan Le at all presents a summary of recent developments of sisal fiber and its composites. The properties of sisal fiber itself interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites have been reviewed. Suggestions for future work are also given. In the review they describe in detail about the properties of sisal fiber, Interface properties between sisal fiber and matrix; Properties of sisal-fiber-reinforced composites; Sisal/glass-fiber-reinforced hybrid composites; Price; Interface modifications; Treatment of sisal fiber; Alkali treatment; Isocyanate treatment; Peroxide treatment; Permanganate treatment; surface Treatment of fiber/matrix interfaces; Sisal/polyester composites; Sisal/epoxy composites; Sisal/phenol formaldehyde composites; Sisal/polyethylene composites; Sisal-fiber-reinforced thermo set matrices; Sisal-fiber-reinforced thermoplastics matrices; Processing methods; Properties of sisal fiber reinforced polyethylene; Properties of sisal fiber-reinforced polystyrene matrices; Properties of sisal-fiber-reinforced PVC composite; Sisal-fiber-reinforced rubber matrix; Sisal-fiber-reinforced gypsum and cement matrices; Sisal and synthetic hybrid-fiber composites; and they evaluate the Dynamic mechanical properties.

Electrical properties and Ageing properties. Finally they conclude that different matrix systems have different properties. The mechanical and physical properties of sisal-fiber-reinforced composites are very sensitive to processing methods, fiber length, fiber orientation and fiber-volume fraction. Sisal and glass fiber can be combined to produce hybrid composites which take full advantage of the best properties of the constituents; almost all the mechanical properties have show positive hybrid effects.

K. Murali Mohan Rao., at all aims at introducing new natural fibers used as fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures. An investigation of the extraction procedures of vakka (Roystonea regia), date and bamboo fibers has been undertaken. The cross-sectional shape, the density and tensile properties of these fibers, along with established fibers like sisal, banana, coconut and palm are determined experimentally under similar conditions and compared. The fibers introduced in the present study could be used as an effective reinforcement for making composites, which have an added advantage of being lightweight.

K. Murali Mohan Rao., at all have carried out a study to investigate the tensile, flexural and dielectric properties of composites made by reinforcing vakka as a new natural fiber into a polyester resin matrix. The fibers extracted by retting and manual processes have been used to fabricate the composites. These composites are tested for tensile, flexural and dielectric properties and compared with those of established composites like sisal, bamboo and banana made under the same laboratory conditions.

The composites are fabricated up to a maximum volume fraction of fiber of 0.37 in the case of tensile testing and 0.39 for flexural and dielectric testing. It has been observed that the tensile properties increase with respect to volume fraction of fiber for vakka fiber composite and are also more than those of sisal and banana composites and comparable to those of bamboo composites.The flexural strength of vakka fiber composite is more than that of banana composite and is closer to sisal fiber composite with respect to the volume fraction of fiber, where as the flexural modulus is much higher than those of banana and sisal fiber composites and also very much closer to bamboo fiber composites.

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CHAPTER - 3

MATERIALS AND METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are

3.1. MATERIALS USED

- **Epoxy resin (LY-556)**
- **Hardener(HY-951)**
- **Natural Fibers (Sisal,banana, Areca , Coconut Coir and Jute mat)**
- **NaoH Solution**

3.1.1 Epoxy resin (LY-556)

Features of Epoxy

- Light weight
- Resists most alkalis and acids
- Resists stress cracking
- Retains stiffness and flexibility
- Low moisture absorption
- Non-staining
- Easily fabricated

Applications of Epoxy

- Structural applications
- Industrial tooling and composites
- Electrical system and electronics

3.1.2. Hardener (HY-951)

Hardener is a curing agent for epoxy or fiberglass. Epoxy resin requires a hardener to initiate curing; it is also called as catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determines the final characteristics and suitability of the epoxy coating for given environment.

3.1.3 Natural fibers such as Sisal/Banana/Coconut coir/Areca nut/ Jute mat

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The manufacture, use and removal of traditional fiber–reinforced plastic, usually made of glass, carbon or aramid fibers–reinforced thermoplastic and thermoset resins are considered critically because of environmental problems. By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example carbon or aramide fibers that have to be synthesized

3.1.4 Advantages of Natural Fibers

Comparing to conventional reinforcing fibers like glass, carbon and Kevlar, natural fibers have the following advantages:

- Environmentally friendly
- Fully biodegradable
- Non toxic
- Easy to handle

- Non abrasive during processing and use
- Low density/light weight
- Source of income for rural/agricultural community
- Renewable, abundant and continuous supply of raw materials
- Low cost
- Free from health hazard (cause no skin irritations)
- High toughness
- Good thermal properties

3.1.5 Properties Of Natural Fiber:

Plant Fibers	Density (Kg/m^3)	Tensile Strength (MPa)	Young'sModulus (GPa)
Jute Fiber	1300-1500	200-450	20-55
Sisal Fiber	1300-1500	80-840	9-22
Coconut Coir	1150-1250	106-175	6-8
Areca Nut	1050-1150	300-530	30-60

Table3.1.5: Properties of natural fiber

3.1.6. NaOH Solution

Sodium Hydroxide(NaOH) is a alkaline solution used to enhance the surface morphology of natural fibers

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3.2 METHODOLOGY

3.2.1 Step 1: Selection of matrix material

Epoxy LY-556 resin belonging to the Epoxide family was taken as the matrix.
HY 951 was used as the hardener.

3.2.2 Step 2: Selection of reinforcement and Natural fibers

Natural fibers such as Sisal, Coconut coir, Arecanut, Ridge gourd and Tamarind were taken to fill as reinforcements in the Polymer composite.

3.2.3 Step 3: Extraction of fibers

Sisal Fiber:

- Sisal is Commercially available.
- Sisal is a natural fiber (Scientific name is Agave sisalana) of Agavaceae (Agave) family yields a stiff fiber traditionally used in making twine and rope.
- Sisal is fully biodegradable and highly renewable resource.
- Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear.

Fig3.2.3.1: Sisal Fiber

Areca Nut:

- Areca nut is also known as Betel nut.
- The areca nut husk fibers are predominantly composed of cellulose and varying proportions of hemicelluloses, lignin, pectin and proto-pectin.
- The fibers adjoining the inner layers are irregularly lignified group of cells called hard fibers, and the portions of the middle layer below the outermost layer are soft fibers.

Fig3.2.3.2: Areca Nut

Jute Mat Fiber:

- Jute is a long, soft, shiny plant fiber that can be spun into coarse, strong threads. It is produced from plants in the genus Corchorus.
- Jute is one of the cheapest natural fibers, and is second only to cotton in amount produced and variety of uses.
- Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute is a rainy season crop, growing best in warm, humid climates.
- It is 100% bio-degradable & recyclable and thus environment friendly.

Fig3.2.3.3: Jute mat Fiber

- **Banana fiber:** Banana Fiber contains cellulose, hemicelluloses and lignin. Available at reasonable prices, our Banana Fiber is widely appreciated for its characteristics such as high strength, strong moisture absorption, good luster, light weight, fast moisture absorption and release, small elongation, easy degradation and many more.

- **Coconut Coir Fiber:**
  Coconut coir- Coconut fruit peel were gathered and soaked in water. Later clean fibers were drawn manually from them.

Fig3.2.3.4: Coconut Coir

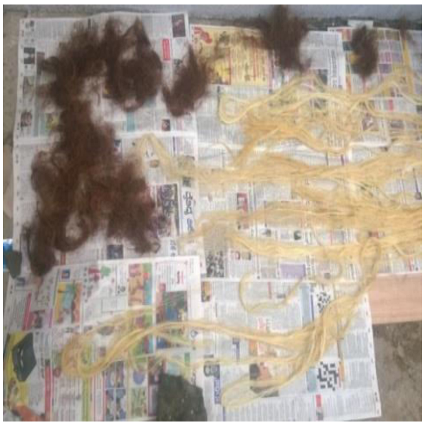
3.2.4 Step 4: Surface treatment of fibers

Freshly drawn fibers generally include lots of impurities that can adversely affect the fiber matrix bonding. Consequently the composite material made from such fibers may not possess satisfactory mechanical properties. Therefore it is desirable to eliminate the impurity content of the fibers and perhaps enhance the surface topography of the fibers to obtain a stronger fiber-matrix bonding. The fibers were left to treat with 5% NaOH for 3-4 hrs. Later they were drawn and dried under sunlight for 1-2 hours.

(a) 5% NaOH solution

(b) Fibers in NaOH solution

(c) Water Treatment



d) Drying at room temperature

Fig 3.2.4 : Surface Treatment With NaOH

3.2.5 Step 5: Wet Hand lay-up technique

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardner (curing agent) and poured onto the surface of mat already placed in the mold.

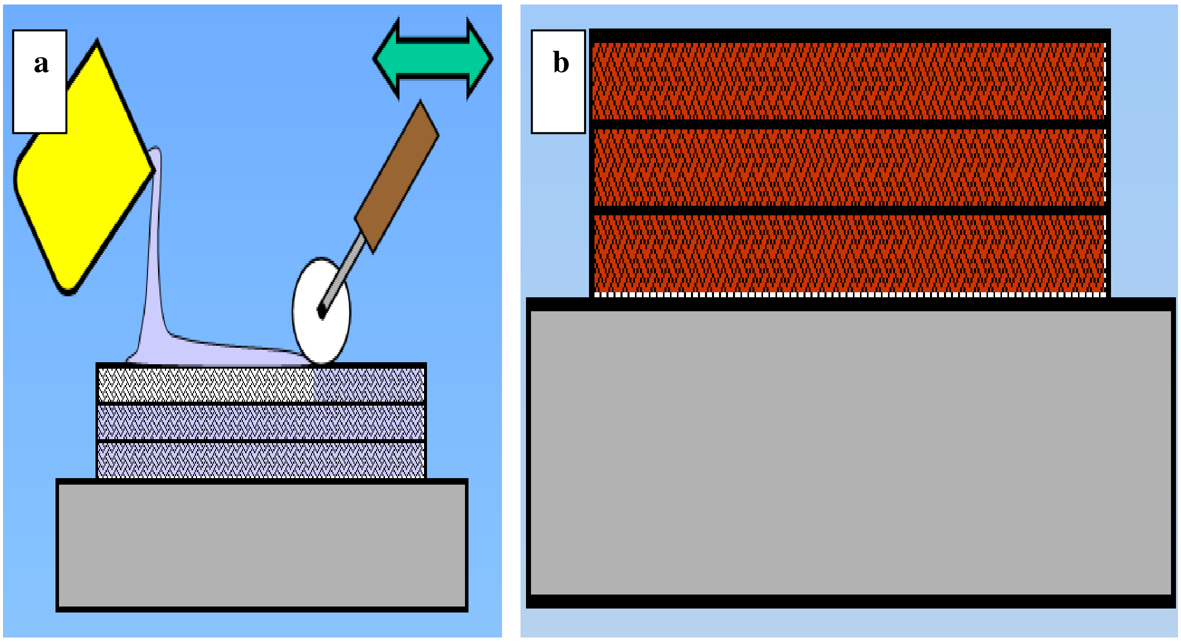


Fig 3.2.5: a) Schematic Diagram of hand lay-up process.
b) Orientation of fiber layers

The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in figure 1. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirements less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, diase board, deck etc.

Fig 3.2.6: Sample preparation by wet hand lay up process

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CHAPTER - 4

Samples Compositions

4.1 SAMPLE 1:

4.1: Sample 1

Composition:

JUTE FIBER
COCONUT COIR
SISAL FIBER
BANANA FIBER
ARECA FIBER
JUTE FIBER

Table 4.2: Composition of sample

4.3. Fabrication of a simple helmet using these bio-composites

Fabrication of the helmet was carried out by adopting the following hand lay process procedure. Initially a layer of epoxy – LY-556 and hardener HY-951 mixture is coated inside the glass fiber mould shown in Fig. 1 (a), which will act as an adhesive for a bottom layer of jute mat. Over the jute mat once again a layer of epoxy is applied, subsequently the natural fiber reinforcements such as chopped sisal fiber, banana fiber, areca fiber, coconut coir fibers are placed respectively. Finally, a layer jute mat is placed as a top layer. Now these fibers are compressed with help of inner mould as shown in Fig. 1 (b), to ensure the proper bonding between reinforcement and fibers. Subsequently, allowed for settling time of about 6 – 8 hours, then mould was released. The jute mat used prevents the de-bonding of the fibers. After releasing well cured and dried helmet from the mould (Fig. 1 (c)), the extra projections were cut, filed and smoothened with help of sand paper to achieve the desired shape Fig. 1 (d).

Fig. 1 Sequential Stages in Bio-Composite Helmet Fabrication.

CHAPTER - 5

TESTING AND RESULTS

5.1 Specimen preparation as per ASTM standards

The samples are cut to the following dimensions as per ASTM standards for testing shown in **Table 5.1.**

Sl. No	ASTM Code	Mechanical Test	Sample Dimensions (mm)
1	ASTM-D790	Flexural	80 × 8 × 3
2	ASTM-D256	Impact	65 ×12.5× 3

Table 5.1: ASTM Standards for sample dimensions

5.2: Mechanical Testing of Composite Laminates

Mechanical properties such as Ultimate tensile strength (UTS), Young's modulus, Flexural strength (FS), Flexural modulus, Inter laminar shear strength (ILSS) of carbon and glass fiber reinforced vinyl ester composites are computed from the test conducted using universal testing machine (UTM) (**Fig 5.2**) in accordance to ASTM standards for specimen preparation. The 10 ton capacity UTM machine is supplied by Kalpak instruments and controls, Pune, India. UTM Specifications are shown in **Table 5.2**.

Table5.2: Specifications of Universal Testing Machine

Parameter	**Specifications**
Capacity	10 tones
Load frame	Mild steel C channel with double ball screw mechanism pre-loaded ball screw with zero backlash covered with bellow
Mounting	Free standing
Load range	1 kg-1000 kg using 1 ton load cell 1 kg-10000 kg using 10 ton load cell
Length measurements	Rotary encoder mounted on to the screw rod
Length resolution	0.01 mm
Cross head speed	0.1 to 100 mm/min
Controls	Emergency off, up and down key
Input power	220V±10% VAC,50 HZ,1500 VA
Net weight	225 kg
Grippers	Tensile, Compression, Three point Bending
Length accuracy	±0.1 mm

5.2.1 Flexural Testing of Composites

ASTM D 790: Standard Test Method for Flexural Properties of Polymer Composite. The samples are cut to the dimensions as per ASTM standards for flexural testing. The test specimen geometry as specified in the above standard for balanced symmetric carbon and glass fiber composites (0/90) are , width 12.7 mm, length 127 mm, thickness 6 mm.

The test is conducted at a strain rate of 0.5mm/minute. The Test Setup is shown in **Fig.5.3.1**and the details of test specimen are given in **Fig.5.3**. Flexural test is done using a three point bend setup. The distance between the two supports are maintained at 100mm. The ultimate load carrying capacity of the composite laminates is recorded.

Flexural strength, strain and flexural modulus of the composites are determined using the formula 5.3,5.4 and 5.5 respectively.

$$\sigma_f = \frac{3PL}{2bd^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5.3)$$

Strain $\boldsymbol{\varepsilon_f} = 6Dd/L^2$ ………………………………………………..…………… (5.4)

Flexural modulus X = $\boldsymbol{\sigma_f / \varepsilon_f}$……………………………………………………………………(5.5)

Where,

P = peak load in N,

L = span length in mm,

b = width of specimen in mm,

d = thickness of specimen in mm,

D = Deflection from no load condition in mm.

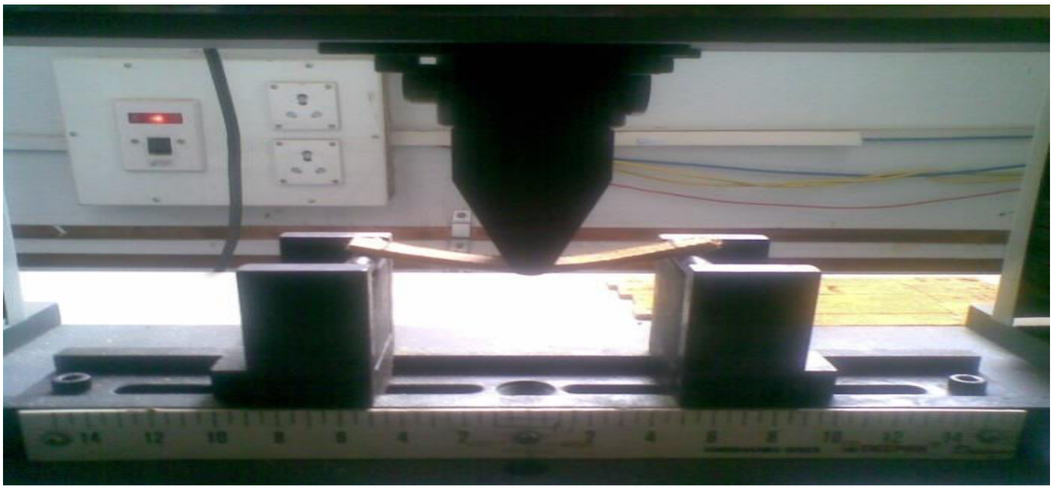

Fig. 5.3.1 Test set up for three point bending tests

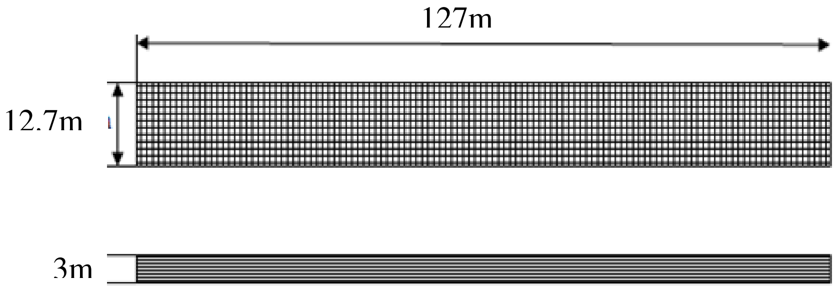

Fig. 5.3 Flexural test specimen

5.2.2 Impact Strength Testing of Composites

ASTM D 256: Standard test method for impact properties of polymer matrix composites. Izod impact strength of composite samples is evaluated as per ASTM D256, using Impact Testing Machine (**Fig5.5.1**) supplied by International Equipments, Mumbai, India.

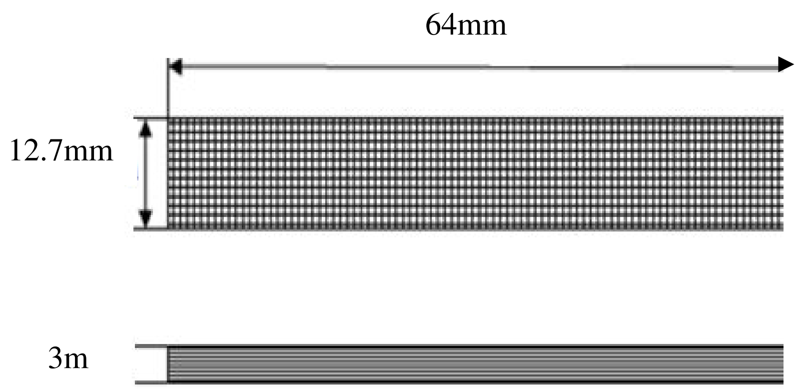

Fig. 5.5: Impact test specimen

The test specimen geometry as specified in the above standard for balance symmetric glass and carbon fiber (0/90) composites are 64 mm long × 12.7 mm wide × 3 mm thick (**Fig 5.5**). The Izod test specimens are clamped in an upright position so that the end of the specimen faced its striking edge and impact energy absorbed for breaking the specimen is directly obtained.Impact strength is calculated using the expression 5.7.Impact strength = Impact energy in joules / thickness of the specimen (mm)….. (5.7)

Fig5.5.1: Izod impact testing machine

5.2.3. Drop weight impact test experimental set up for Bio Composite Helmet

The fabricated bio composite helmet shell is tested with a drop weight impact test rig attached a with hammer of mass 43 Kgs at a drop height of 2 meters at the velocity of 6.24 m/s. Drop weight impact test experimental set up with helmet on loading platform to be tested is shown in Fig.

Fig. Pictorial View of Drop Weight Impact Test Rig with Helmet.

The test is conducted as per the following procedure. The drop mass is coupled with a piezoelectric accelerometer. The drop mass is lifted to desired a height by manually. After preparing the data acquisition system for the experiment, then drop mass is released using the load-releasing mechanism. The drop mass clamped to it was lifted up and supported on the safety rods provided in the machine. The crushed helmet is then removed. The acceleration-time data acquired by the data acquisition system was acquired by a personal computer for further processing was performed.

5.3 Results

5.3.1 Flexural test results

Sample 1:

Modulus	103.92 N/mm^2
Flexural strength	132.71 MPa
Peak load	297.47 N
3 Point Bend modulus	132.71 MPa

Table 5.3.1. (a): Sample 1 Flexural results

Modulus	192.65 N/mm^2
Flexural strength	160.93 MPa
Peak load	163.493 N
3 Point Bend modulus	115.5 MPa

Table 5.3.1. (b): Sample 2 Flexural results

Modulus	123.23 N/mm^2
Flexural strength	171.38 MPa
Peak load	257.55 N
3 Point Bend modulus	141.71MPa

Table 5.3.1. (c): Sample 3 Flexural results

5.3.2: Impact test results

The following tables provides the details of the Impact test results obtained for various combinations of Natural fibers reinforced bio-composites

Impact test result:

Specimen	***Impact Energy absorbed Joules***
Sample-1	***2.3***
Sample-2	***4.5***
Sample-3	***3.25***

Table 5.3.2: Impact test result

5.3.3. Test Result of Bio Composite Helmet:

The drop weight impact tests were performed on the fabricated bio-composite helmet. Although, the maximum permissible limit of 19.5 kN (as per BIS standard) impact load is required for drop weight impact analysis, due to limitation of test rig, we performed the test with drop mass of 430 N. Figure 3, shows the impact load against displacement for tested bio-composite helmet. It could be observed that maximum permissible load withstood by the helmet is 68.57 KN and the impact energy absorbed by the helmet was found to be 1397.913 KJ by post processing the experimentally acquired data.

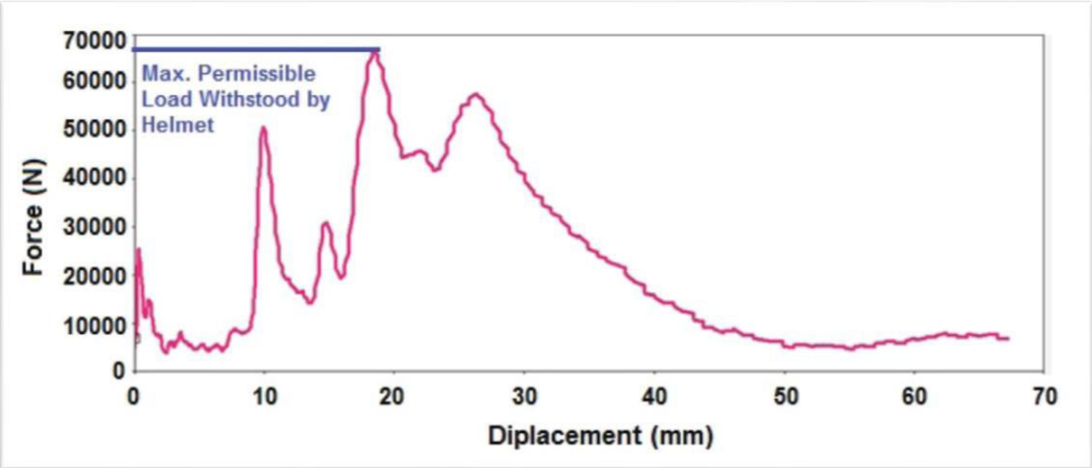

Fig. Experimental Load Displacement Curve of Tested Helmet

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Other Applications of Bio-Composites

- The bio-composite obtained can be used mainly for the fabrication of the interiors of the aircraft like

- floors
- ceilings,
- sidewalls and
- stowage bins.

- Composites, it is the fastest growing "materials" market segment. Sporting goods, Aircraft, automobile, shipbuilding, are just a few examples. Tennis rackets, golf clubs, bumpers, door panels, dashboard, even engine components of modern automobiles; look closely at a Boeing 777etc. Some applications are given below

- Paints and coatings
- Electrical systems and electronics
- Aircraft industry, Ex: Doors and elevators
- Consumer and marine applications
- Aerospace applications
- Chemical industry, Ex: Tanks, Pipes, Pressure vessels
- Automotive body frames, engine components

6. CONCLUSION

- The natural fibers have been successfully reinforced with the epoxy resin by simple wet hand lay-up technique. The aim of this project is to find the tensile, Bending, ILSS and impact strength of natural fiber reinforced bio-composites.
- The fibers like jute fibers, coconut coir, areca nut fibers, sisal fibers were successfully used to fabricate bio-composites with varying the fiber percentage.
- The new hybrid composite produced with natural fibers as reinforcements gives good mechanical properties as compared with pure matrix material. These hybrid-bio-composite can be used in Aerospace and automobile applications.

In the present work, bio-composite with multiple natural fibers such as jute fibers, Coconut coir, areca fibers, sisal fibers, banana fibers have been successfully reinforced with the epoxy resin by simple and inexpensive hand lay-up technique. The mechanical testing results of fabricated bio composite helmet indicate that, concept of using multiple natural fibers is viable for helmet application. However, there is a scope to optimize the volume fraction of natural fibers as reinforcements to achieve enhanced mechanical properties of helmet.

So, it is clearly indicates that reinforcement of natural fibers have good and comparable mechanical properties as conventional composite materials.

Bio composite helmet

7. SCOPE OF FUTURE IMPROVEMENT

Presently, the main markets for bio composites are in the construction and automotive sectors. With further developments and improvements in performance, however, new opportunities and applications will likely arise. Significant opportunities are likely to occur in the built environment as this sector is responsible for producing huge volumes of waste at a time when the environmental impact of industries is coming under close scrutiny. For example, new, 'environmentally friendly' materials are needed for off-site construction methods, improved quality and ease of installation and build. However, these opportunities may be hampered by regulations based on existing materials. A particular area that offers significant potential for growth is in the replacement of preservative treated wood. The introduction of tighter restrictions on the use of certain preservatives most notably those containing arsenic, presents an opportunity for bio-composites products in applications where there is a high risk of biological attack. In addition to this, improvements in the mechanical performance of existing biocomposites90 through, for example, the introduction of new fiber types, processing and additives may well result in an expansion in their use into more diverse, and technically demanding, application areas. An area of note in this respect is the ongoing research into solvent spinning of liquid crystalline cellulose, which looks promising for producing high-strength fibers. Biotechnology is being used to modify and/or increase the yield of specific triglycerides and oils in crops for producing resins. These resins will also be inexpensive compared with those available today and, if suitably modified, could be biodegradable. Research is also being conducted at various research laboratories to develop new pathways to synthesize inexpensive biodegradable resins with better mechanical properties. Once fully developed, these resins and high-strength fibers hold great promise for replacing many of the synthetic advanced composites currently in use. There are also opportunities for hybrid materials and products by, for example, using bio resins and bio plastics as adhesives in place of current fossil-based adhesives. There are also good prospects for using reclaimed fiber from products such as MDF (medium density fiberboard) or other waste streams from the pulp and paper industry to manufacture a range of cost-effective and environmentally effective materials and products. While there is ample opportunity for these products to enter new markets and find new application, it is essential that benefit in terms of cost saving be highlighted and a stronger commercial case for these materials be made.

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