AN EXPERIMENTAL STUDY ON THE MECHANICAL PROPERTIES OF ALTERNATE HELMET MATERIALS FABRICATED USING ARECA AND GLASS FIBER REINFORCED EPOXY HYBRID COMPOSITES

MUNAWWAR K K , E Vidhyasri

SHREE VENKATESHWARA HI-TECH ENGINEERING COLLEGE

ABSTRACT

A composite is a structural material that consists of two or more combined constituents at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the other in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes to name a few. The matrix phase materials are generally continuous. Hybrid composites have distinctive characteristics that can be utilized in various structures and/or structural components without compromising their structural performance and durability. However, use of natural fibers in composites makes the structure more economical as well as eco-friendly. Glass Fiber Reinforced Polymers are mixed with natural fibers to increase Engineering and Technology applications. Using a hybrid composite that contains two or more types of different fibers, the advantages of one type of fiber could complement what are lacking in the other. As a consequence, a balance in performance and cost could be achieved through proper material selection, design, fabrication etc. This project aims to fabricate Areca fiber/glass fiber reinforced epoxy hybrid composites in five different compositions and investigate the mechanical characterization of the developed hybrid composites. Finally the mechanical properties are compared with commonly used plastic material to ensure the possibility to replace the plastic material with the developed hybrid composite material for industrial applications such as helmet for workers in industries.

CHAPTER I

INTRODUCTION

1.1 General Background

A composite material is a combination of two or more chemically different materials with a distinct interface between them. The constituent materials maintain their separate identities in the composite, yet of the constituents. One of the constituents forms a continuous phase and is called the matrix. Then their combination produces properties and characteristics that are superior to other major constituents is reinforcement in the form of fibers that is in general added to the matrix to enhance matrix properties. In most of the cases, reinforcement is harder, stronger and stiffer than the matrix. Reinforcements are strong materials with a particular morphology that is incorporated into the matrix to improve a composite's physical properties. The different reinforcements used in composites have different properties and so affect the properties of the composite in different ways. Consequently, the properties of composites are a function of the properties of this dispersed phase, its relative amounts, and its morphology, which mean that the composites can be classified according to their types of reinforcement. The matrix material in a composite may be a polymer, a metal, or a ceramic, depending on which composite materials are classified as polymer matrix composite (PMCs), metal matrix composite (MMCs), or ceramic matrix composite (CMCs). Polymers are classified as thermosets (epoxies, polyesters, phenolics, polyamide etc) and thermoplastics (polyethylene, polystyrene, polyether-ether-ketone (PEEK) etc). Examples of metal matrices are aluminium, magnesium and titanium and examples of ceramic matrices are alumina, calcium alumino silicate.

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. 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. In the case of metal matrix composites the working temperature is much higher. Hence both chemical and mechanical harmonies are major issues. Metal matrix composites generally comprise high strength and high modules.

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.

Constituents the polymer composites the most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the often show excellent specific properties.

A range of composites is available which consist of a fibrous carbon in a carbonaceous matrix. All the carbon fibers have been employed in carbon-carbon composites in a number of forms, e.g. Chopped fibers and fiber mats.

1.2 Classification of Fiber

Fibers are a class of hair-like materials that are in the form of continuous filaments or are in discontinuous short fibers. They can be made into filaments, thread or rope. They can be used as composite materials. They can also be matted into sheets to make products such as paper of felt.

1.2.1 Natural Fibers

Natural fibers are made from plant, animal and mineral sources. Natural fibers classified according to their origin.

Table 1.1 Types of Natural fibers

Type of fiber	**Sub Class**	**Name**
Natural Fiber	Animal	Alpaca,Angora,Bison,Down,Hair,Cashmere, catgut,chiengora,Guanaco,Liama, Mohair, Pashmina,Rabbit,Silk,Wool,Vicura,Yak
	Plant or Vegetable	Abaca,Bamboo,coir,Cotton,Hemp,Palm Kenaf,Pina,Sisal,Wood
	Mineral	Asbestos,Basalt,Mineral Wool,Glass

1.2.2 Hybrid Fiber

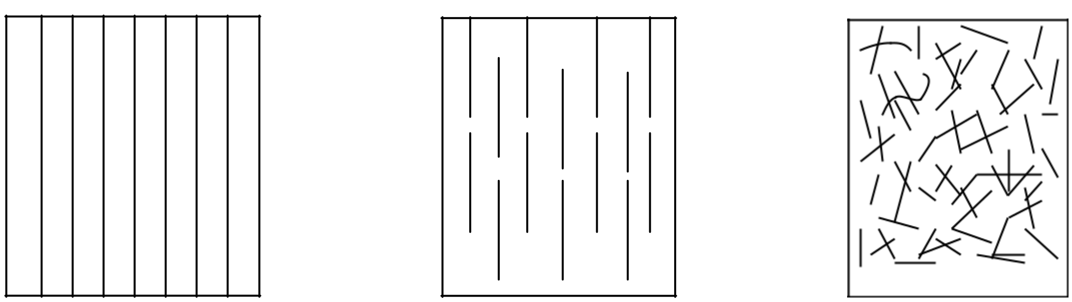
In a laminate when more than one type of resin or fiber is used, then the laminates are called as hybrid.

1.2.3 Fiber Reinforced Composites

Fiber Reinforced Composites is a type of advanced composite group, which makes use of rice hush, rice hull, and plastic as ingredients. This technology involves a method of refining, blending, and compounding natural fibers from cellulosic waste streams to form a high-strength fiber composite material in a polymer matrix.

A fiber-reinforced composites (FRC) consists of three components:

a) Particulate composites
b) The matrix as the discontinuous phase
c) The matrix as the continuous phase



Continues and aligned fibers

Figure 1.1 Fiber orientations in Fiber Reinforced Composites.

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The composites are heterogeneous materials, which is an important feature compared for instance to the metal homogeneous plastics. There are many kinds of failure and damage modes in the composite structures. One of them is the interlaminar fracture known as delamination, which is, at the same time one of the most important failure mode. Delamination growth remains a critical failure mode in laminated composite structures. The interlaminar fraction of composite material has been very intensively investigated. The delamination means degradation between adjacent plies of material. Many ways have been found to resist delamination, for example weaving the fibers increases the toughness, but introduces micro-buckling modes, which is detrimental to the compressive strength; toughening the resin suppresses delamination but often decreases the modulus, an inherent trade-off in increasing toughness in the resins. Toughened resins are commonly used in aerospace pre impregnated materials, to resist delamination. However, the cost of using prepreg materials in wind turbine manufacture can be high. Hence, low cost composite materials are sought for building wind turbine blades, such as fiberglass, where delamination has not been studied in detail.

Composite materials offer several advantages over conventional monolithic metals such as light weight, high specific strength, high specific modulus, corrosion resistance, fatigue and impact resistance, high temperature resistance etc. Because of these advantages, composite materials find wide applications in various industrial sectors, particularly where light weight structures are of utmost importance. To quote some applications, in aerospace sector, composite materials are used for wings, fuselage, helicopter blades, landing gears, antennas etc.; in automotive sector, composite materials are used for body panels, drive shafts, leaf springs, gears, instrument panels etc.; in chemical industry, composite materials are used for pipes, tanks, pressure vessels, hoppers, valves etc.; in electric sector, they are used for panels, housings, switch gears, insulators, and in domestic applications, composite materials are used for interior and exterior panels, chairs, tables, baths, ladders, shower units etc.

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1.3 Natural Fiber Reinforcement

Natural fibers can be subdivided into vegetable, animal, and mineral fibers. Mineral fibers are no longer or only in very small amounts applied in new technical developments because of their carcinogenic effect. Fibers of animal origin consist of proteins (e.g. hair, silk, wool etc).

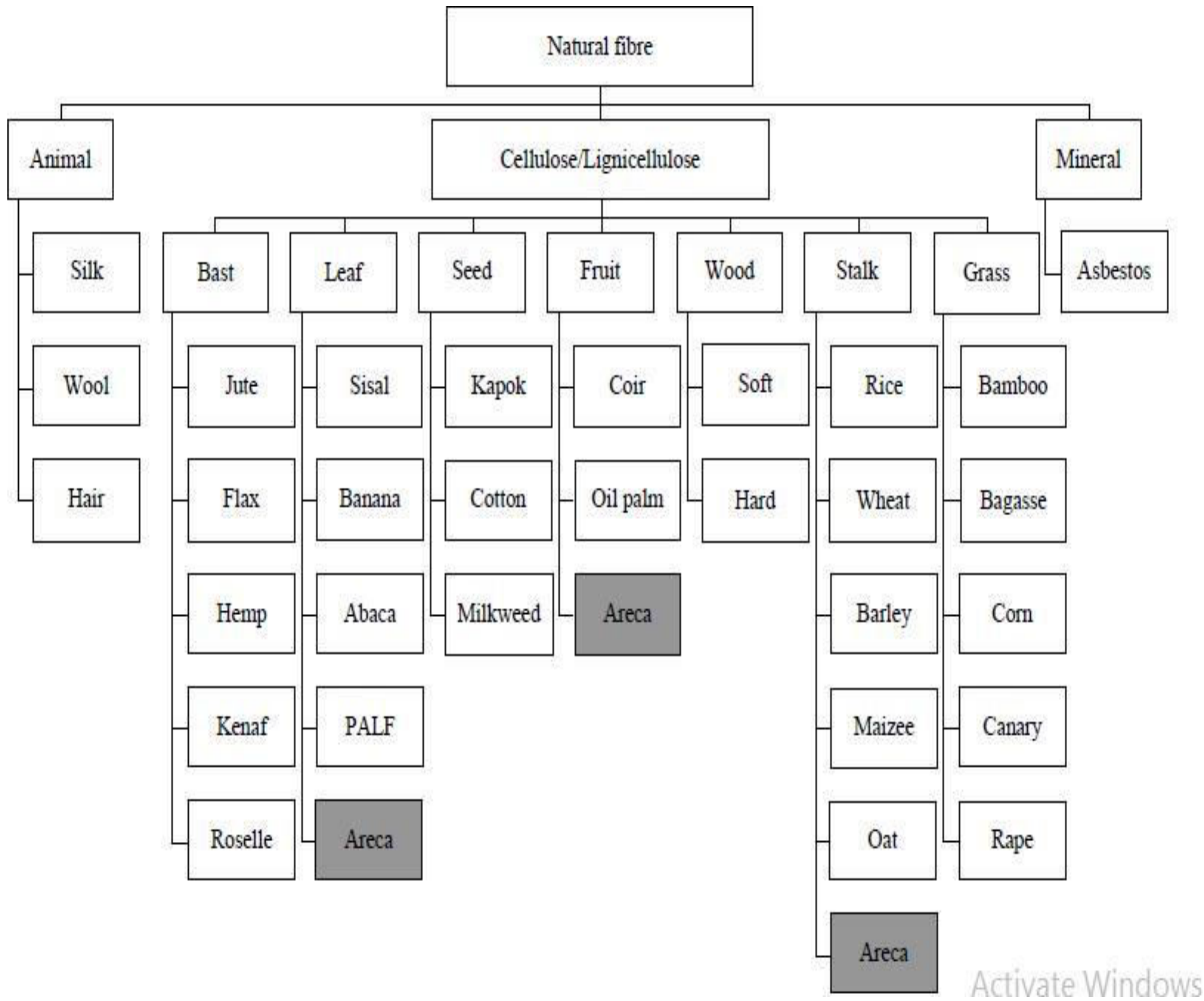

Fig 1.2 Different sources of natural fibers

Natural fibers of vegetable origin are constituted of cellulose (a natural polymeric substance made from glucose molecules), lignin and associated with varying amounts of other natural materials.

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Vegetable fibers (also known as cellulose or bast or plant fibers) are conveniently classified according to the part of the plant where they occur and from which they are extracted. Bast fibers are extracted from bast tissue or bark of the plant stem. They include flax, jute, hemp, ramie, kenaf, areca catechu, etc. Leaf fibers are extracted from leaves of the plants. They include sisal, pineapple, banana, areca sheath etc, and Seed or fruit fibers are extracted from seed or fruits. They include coir, cotton, oil palm etc. Bast fibers represent the vast majority of natural fibers with potential for composites usage.

1.3.1 Characteristics of Fiber Reinforced Composites

The following are the important characteristics of the Fiber Reinforced Plastics and are carefully taken into consideration while their application in composites.

- The strength and modulus of fiber reinforced polymers (FRP) are superior to the conventional metallic materials.
- The strength–weight ratios and modulus– weight ratios of composite materials are superior to those of metallic materials, because of their low density.
- Fatigue strength, fatigue damage tolerance of many composite laminates is excellent.
- Conventional structural metals, such as steel, aluminum alloys and copper alloys are considered isotropic, because they show equal properties in all the direction of measurement. The properties of a fiber-reinforced composite depend strongly on the direction of measurement, and hence they are considered as orthotropic materials.
- For example, the tensile strength and tensile modulus of a unidirectional oriented fiber-reinforced polymer are maximum when these properties are measured in the longitudinal direction of fibers. At any other angle of measurement, these properties are lower. Because the fibers will withstand the apply load only in the longitudinal direction. The minimum value is observed when they are measured in the transverse direction of fibers.
- The other mechanical and thermal property, impact strength, compressive strength, flexural strength, coefficient of thermal expansion (CTE), and thermal conductivity are also depends on the direction of measurements in FRPs.

- Multidirectional reinforcement and bi-directional reinforcements provides balanced set of properties, because the fibers are oriented in all directions.
- The composite materials possess the advantage of design flexibility. This design flexibility can be used,
  a) Increasing stiffness in the preferred directions
  b) Selective reinforcement is possible in the major stress areas
  c) Special curved shapes can be made
  d) Structures with least coefficients of thermal expansion can be made
- The metals in general exhibit yielding and plastic deformation whereas fiber reinforced composites are elastic in their tensile stress–strain characteristics.
- Depending on the type and nature of external loads, a composite laminate will gradually deteriorate in properties but usually would not fail in a poor manner.
- For many fiber-reinforced composites coefficient of thermal expansion is lesser than metals as a result, composite structures may provide a better dimensional stability over a wide temperature range applications than metals. But, the differences in thermal expansion between metals and composite materials may create unwanted thermal stresses when they are used in combination.
- Thermal conductivity influences the quick and effective heat dissipation in some applications (Ex. Electronic panels). In those applications, fiber-reinforced composites may be preferred than the metals.
- The electrical conductivity of fiber-reinforced polymers is lower than that of metals.
- The high internal damping is an important property, which absorbs the noise and vibrations during the applications like automobile and the sporting goods.
- Non-corrosiveness is another important feature of FRPs.
- FRPs need additional surface coatings to prevent them from the environmental damages due to moisture, chemicals, Ultra Violet rays etc.,
- The composite manufacturing is highly differing from these conventional methods and they need less energy, pressure and force than the manufacturing processes used for metals.

- Parts can be integrated to near net shape in FRPs. Parts integration reduces the number of parts, the number of manufacturing operations, and the number of assembly operations. Hence the finishing operations like grinding, milling, drilling, machining etc., are not need in FRP manufacturing.

1.3.2 Advantages and drawbacks of natural fibers

- Low density– resulting in specific stiffness comparable to that of E-glass.
- Environmental friendly – renewable resource, production uses CO2 and gives back oxygen, less energy required for production compared to E-glass.
- Good thermal and acoustic insulating properties
- Less abrasive nature of the fibers – reduced tool wear and less skin
- Irritation for workers compared to glass
- Raw material costs are lower or comparable to E-glass
- Waste disposal - excess fiber is biodegradable or can be burned for disposal.
- Aesthetic appearance of a natural material.

However, natural fibers have certain drawbacks such as,

- Lower strength properties, particularly its impact strength.
- Variable quality, depending on unpredictable influences such as weather.
- Moisture absorption, which causes swelling of the fibers.
- Restricted maximum processing temperature.
- Lower durability, treatments can improve this considerably
- Poor fire resistance

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.1.4 Natural-Glass Fiber Hybrid Composites

In addition to surface modification, another technique adopted to enhance the mechanical strength of a natural fiber composite is use combined natural and synthetic fiber (like glass) as reinforcement in same matrix material. This results in hybrid composite. Glass fiber being much stronger and stiffer than a natural fiber, is expected to improve the performance of resulting hybrid composite. However, the magnitude of improvement depends upon relative fiber weight or volume fraction, arrangement of two fibers, compatibility of both the fibers with resin, geometry of fibers (unidirectional, chopped, mat), interfacial bonding etc. Besides improving impact performance, the incorporation of glass fibers, reduces the cost, which is a limitation for the application of graphite fiber composites.

Different types of hybrid composites are -

- Interply Hybrid Composites: Laminate made up of plies of different fibers. Ex. G/Epoxy, C/epoxy & Aramid/epoxy.
- Intraply Hybrid Composites: A ply made up of 2 or more fibers intermingled.
- Intra-Interply Hybrid Composites: Combination of Intraply and Interply hybrid.
- Sandwich hybrids (core-shell): in which one material is sandwiched between two layers of another.

1.4.1 Need for natural – synthetic fiber hybrid composites

Despite the attractiveness of natural fiber reinforced polymer matrix composites, they suffer from low strength; lower modulus compared to synthetic fiber reinforced composites such as glass fiber reinforced plastics Also it is shown that the hydrophilic nature of natural fibers adversely affects the hydrophobic matrix resulting in poor strength

In addition to this, natural fibers are environmental sensitive, and have relatively poor moisture resistance that causes degradation in the strength of the natural fiber composites. Hence use of natural fiber alone in polymer matrix is inadequate in satisfactorily tackling all the technical needs of a fiber reinforced composite. In an effort to develop a superior, but economical composite, a natural fiber can be combined with a synthetic fiber in the same matrix material so as to take the best advantage of the properties of both the fibers. This results in a natural-synthetic fiber hybrid composite. The most common synthetic fiber used in these hybrid composites is the glass fiber because of low cost and ease of availability compared to other synthetic fibers.

The most common thermoset polymer used for natural fiber reinforcement is the unsaturated polyester (isothalic or orthothalic) because of its low viscosity, fast curing time and low cost. Isothalic (isophthalic) polyester laminating resin is a grade up from orthothalic polyester laminating resin and is often used for applications, where a greater heat resistance is required. It is stronger than orthothalic resin, exhibits better UV, chemical and water resistance and is excellent for underwater repairs where water resistance and strength are important.

1.4 Motivation

Need for research of newer material that are friendly to our health and environment. Usage of plastic materials are very much higher in the modern world. We need to control or reduce the usage of plastics for eliminating the plastic wastes from earth since they are non - bio degradable, Hybrid Glass/Natural fibre/Epoxy based composites can act as replacement of plastic. They have the properties like eco friendliness, biodegradability and aesthetical properties. And also they are light weight and have low conductivity but they exhibit better mechanical properties than any other materials. More improved mechanical properties can be achieved by hybrid composites. Utilization of waste materials are possible. This project's focus will be given on the development and characterization of Hybrid Glass/Areca fiber/Epoxy based composites.

CHAPTER 2
LITERATURE REVIEW

2.1 Composite material

As defined by (Jartiz et. al. 1965), 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.

(Berghezan et. al. 1966) 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 shortcomings in order to obtain an improved material ".

As defined by (Mallick et. al. 2007), Fiber-reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to a matrix with distinct interfaces (boundaries) between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone.

(Arun raju et. al. 2019) made a review on recent researches in fiber reinforced composite materials. Natural fibers are inherently weak, has high water absorption rate, low impact strength these impediments can be surmounted by the use of fiber treatments such as enzyme treatment, isocyanate treatment, benzolyzation treatment, alkaline treatment, acetylation treatment, permanganate treatment, corona treatment, silane treatment, maleated coupling and so on has proven to overcome the inherent shortcomings of the fiber to be included into the matrix are discussed.

2.2 Areca Fiber Reinforced Polymer Composites

(Chethan et. al.) have studied the 3-point bending analysis of untreated natural areca sheath fiber reinforced polymer matrix bio-composites and have found that epoxy resin reinforced with 30 wt% of areca fiber shows the highest flexural strength.

(Binoj et.al.) Have investigated the morphological, physical, mechanical, chemical and thermal characterization of sustainable areca fruit husk fibers and proved it as a potential alternate for hazardous synthetic fibers and its advantage as reinforcement in polymer matrix composites.

(Sunil kumar et. al.) have studied the water absorption and diffusion properties of areca fiber reinforced epoxy and vinyl ester composites and found that the water absorption and diffusion coefficient increases with fiber loading. They also have concluded that epoxy based composite material is more favorable against water absorption when compared to vinyl ester composite material.

(Kishore Dinakaran. et. al.) Use of natural fiber as reinforcement is a burgeoning field of research because of the ease of procuring raw materials, biodegradable and environment friendly nature along with mechanical properties of the resulting composites that are comparable to synthetic fiber-reinforced composites. Areca owing to these very reasons along with low cost, light-weight further advocated by its tensile strength has pervaded the field of composite manufacturing. Different natural fibers have been used by many researchers for the development of bio-composites, but areca leaf fibers as a feasible fiber has seldom been researched or spoken about. This research article sheds light on the development and study of mechanical behavior of a natural fiber reinforced epoxy composite of areca fiber with different configuration of areca fiber orientation.

(Yusraih et. al.) have found drastically drop in lignin and hemicellulose percentage after alkali treatment of fibers. An increase in elongation at break and improvement in interfacial shear strength has been observed.

(C.V. Srinivasa et. al.) Natural Fibers composites are considered to have potential use as reinforcing material in polymer matrix composites because of their good strength, stiffness, low cost, environmental friendly and biodegradable. In present study, mechanical properties for natural fiber composites were evaluated. Here, areca fiber is used as new natural fiber reinforcement and epoxy resin as matrix. The extracted areca fibers from areca husk were chemically treated to get better interfacial bonding between fiber and matrix. Composite were prepared with randomly orientated fibers with different proportions of fibers and matrix ratio. Mechanical tests i.e. impact and hardness tests were performed and the results are reported. The results showed that, as the fiber volume fraction and composite post curing time increases the mechanical properties of the composite increases.

(Padmaraj et. al.) has developed alkali treated areca fiber reinforced biodegradable composite material and found that the composite can withstand a maximum load of 45.29N.

2.3 Glass Fiber- Reinforced Polymer Composites

(TP Sathishkumar et. al.) Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fiber reinforced polymer composites were reported.

(Alexandre Landesmann, et. al.) This paper presents the results of an experimental investigation aiming at determining the mechanical properties of Glass Fiber Reinforced Polymer (GFRP) element produced by the Brazilian industry to classify it for structural applications.. The material samples used in this work were (i) prepared in accordance to ABNT-NBR15708:2011 recommendations, (ii) extracted from web and flange parts of different geometries of one standard H-shaped GFRP single profile, (iii) 2D fiber-reinforced fibrous and (iv) exhibited fibers' orientation on the longitudinal/pultrusion direction. A fairly extensive experimental program was carried out to cover both stiffness and strength structural characteristics of GFRP element, comprising the following mechanical failures modes: (i) direct tension and compression, (ii) two- point flexural bending, (iii) pin-bearing pushed-out and (iv) interlaminar shear deformation. Based on the obtained results, it was possible to conclude that the GFRP element analyzed displays structural classification compatible to E17 class mechanical requirement.

2.4 Hybrid Composites

(S. Mishra et. al. 2003) conducted Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites and Mechanical properties of PALF/glass and sisal/glass fiber reinforced polyester composites have been described. The tensile, flexural and impact properties of PALF and sisal reinforced polyester composites are observed to have improved by the incorporation of small amount of glass fibers.

In the study of (N. Venkateshwaran et al. 2012) the tensile strength and modulus of short, randomly oriented natural fiber reinforced hybrid composites was predicted using the Rule of Hybrid Mixtures (RoHMs) equation. It was observed that the RoHM equation predicted tensile properties of hybrid composites are little higher than experimental values.

In the study of P.Vignesh et al. **A Study on Mechanical Behaviour of Hybrid Reinforced Composites (2014)** have selected the fiber materials such as PALF (Pineapple Leaf Fiber) and avian. Resin type has been chosen as epoxy E -5013 with Heraldihyde. Preparation method has been the hand lay-up method. Testing methods has also been selected and concludes that the combination of two fiber result more strength. Alkali treatment is necessary to improve property, thus thermoplastic has more benefits than others. Various condition wet, moderate and dry three modules been viewed. Tensile strength increases with addition of fiber. Void content will decrease the strength of specimens. SEM, XRD, TGA testing methods are followed and different types of resin have been viewed. Energy required to produce natural fiber is lesser than synthetic one. Finally through mixing of plant and animal fiber we can attain the good mechanical behavior of the specimen.

T.Karthikeyan, et al **Analysis of Mechanical Properties of Hybrid Composites Experimentally (2016)**. Due to increasing environmental concerns natural fibers are once again being considered as reinforcements for polymer composites. This present work evaluated the effect of mechanical properties of hybrid fiber reinforced epoxy composites. In this work hybrid fiber is used as reinforcement which treated with NaOH solution for enhancing the bonding strength between fiber and resin by removing moisture contents. Samples of hybrid fiber reinforced composites were fabricated by compression moulding and investigated their mechanical properties. The work of this experimental study has been carried out to determine the mechanical properties due to the effect of hybrid (carbon+flax) + carbon) fiber with orientations as 00/900 orientation. The results of this study indicate the orientation 00/900 gives better mechanical properties when compared with the other orientations.

(Sanjay M et al 2015) made a Study on Mechanical Properties of Natural -Glass Fiber Reinforced Polymer Hybrid Composite. Natural fiber reinforced composites are used in many engineering applications, because of its superior properties such as specific strength, low weight, low-cost, fairly good mechanical properties, non-abrasive, eco-friendly and bio-degradable characteristics. In corporation of natural fibers with GFRP can improve the properties and used as an alternate material for glass fiber reinforced

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polymer composites.

In the present study of (PramendraKumar et. al. 2018) the fabrication and mechanical characterization of glass and jute reinforced epoxy composites for industrial safety helmet has been carried out with varying weight percentage of glass and jute fibers.

2.5 Objectives

The objectives are:

- To study feasibility of Hybrid Glass/Areca fiber/Epoxy composites as a material for helmet manufacturing.
- To fabricate and test different combinations of Hybrid Glass/Areca fiber/Epoxy composites.
- To evaluate different mechanical properties of the selected composites.
- To compare the hybrid composite with commonly used plastic material in helmet manufacturing
- To study the feasibility of ecofriendly hybrid composites as a replacement for commonly used plastics material in helmet manufacturing.

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CHAPTER 3

METHODOLOGY

To studying the objectives the following methodology is prepared.

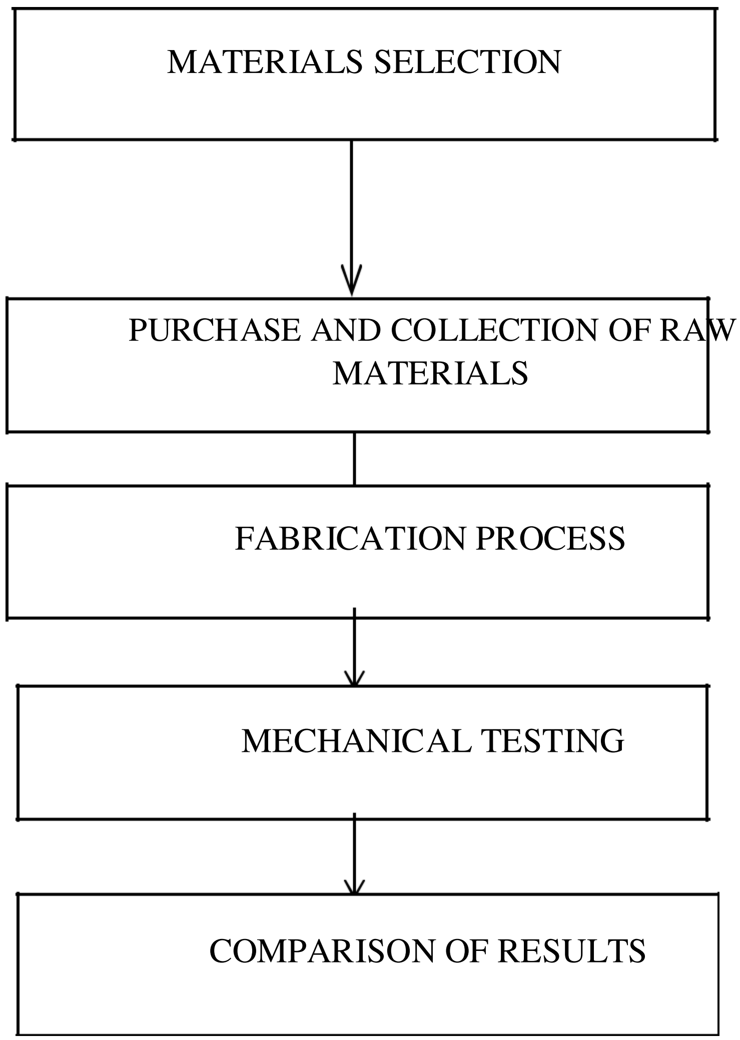

Fig 3.1 Methodology

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3.1 Material Selection

3.1.1 E-glass fiber

Fiberglass is a type of fiber-reinforced plastic where the reinforcement fiber is specifically glass fiber. The glass fiber may be randomly arranged, flattened into a sheet (called a chopped strand mat), or woven into a fabric. The plastic matrix may be a thermosetting plastic – most often epoxy, polyester resin – or vinyl ester, or a thermoplastic.

In this study we are used E-glass fiber as one of the reinforcement material. The "E" in E-glass stands for electrical because it was designed for electrical applications. However, it is used for many other purposes now, such as decorations and structural applications. Fiberglass is a strong lightweight material and is used for many products. The woven mat form of E-glass fiber used for the study is given in Fig 3.2. Although it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily molded into complex shapes. Applications of fiberglass include aircraft, boats, automobiles, bath tubs and enclosures, swimming pools, hot tubs, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards, and external door skins.

Fig 3.2 Woven E-glass fiber

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The process of manufacturing fiberglass is called pultrusion. The manufacturing process for glass fibers suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals to liquid form. It is then extruded through bushings, which are bundles of very small orifices (typically 5 –25 micrometers in diameter for E-Glass, 9 micrometers for S-Glass). These filaments are then sized (coated) with a chemical solution. The individual filaments are now bundled in large numbers to provide a roving. The diameter of the filaments, and the number of filaments in the roving, determine its weight, typically expressed in one of two measurement systems yield, or yards per pound (the number of yards of fiber in one pound of material; thus a smaller number means a heavier roving). Examples of standard yields are 225yield, 450yield, 675yield. tex, or grams per km (how many grams 1 km of roving weighs, inverted from yield; thus a smaller number means a lighter roving). Examples of standard tex are 750tex, 1100tex, 2200tex.

These roving's are then either used directly in a composite application such as pultrusion, filament winding (pipe), gun roving (where an automated gun chops the glass into short lengths and drops it into a jet of resin, projected onto the surface of a mold), or in an intermediary step, to manufacture fabrics such as chopped strand mat (CSM) (made of randomly oriented small cut lengths of fiber all bonded together), woven fabrics, knit fabrics or uni-directional fabrics.

An individual structural glass fiber is both stiff and strong in tension and compression—that is, along its axis. Although it might be assumed that the fiber is weak in compression, it is actually only the long aspect ratio of the fiber which makes it seem so; i.e., because a typical fiber is long and narrow, it buckles easily. On the other hand, the glass fiber is weak in shear—that is, across its axis. Therefore, if a collection of fibers can be arranged permanently in a preferred direction within a material, and if they can be prevented from buckling in compression, the material will be preferentially strong in that direction.

Furthermore, by laying multiple layers of fiber on top of one another, with each layer oriented in various preferred directions, the material's overall stiffness and strength can be efficiently controlled. In fiberglass, it is the plastic matrix which permanently constrains the structural glass fibers to directions chosen by the designer. With chopped strand mat, this directionality is essentially an entire two dimensional plane; with woven fabrics or unidirectional layers, directionality of stiffness and strength can be more precisely controlled within the plane.

A fiberglass component is typically of a thin "shell" construction, sometimes filled on the inside with structural foam, as in the case of surfboards. The component may be of nearly arbitrary shape, limited only by the complexity and tolerances of the mold used for manufacturing the shell.

The mechanical functionality of materials is heavily relied on the combined performances of both the resin (AKA matrix) and fibers. For example, in severe temperature condition (over 180 °C) resin component of the composite may lose its functionality partially because of bond deterioration of resin and fiber. However, GFRPs can show still significant residual strength after experiencing high temperature (200 °C).

Table 3.1 Property values of E-glass fiber

PROPERTY	**E-GLASS**
Specific gravity	2.54
Young's modulus (Gpa)	72.40
Ultimate tensile strength (Mpa)	3447
Coefficient of thermal expansion (**µ**m/m/**C** **o**	5.04

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Table 3.2 Chemical composition of E-glass fiber

MATERIAL	E-GLASS(wt %)
Silicon oxide	54
Aluminum oxide	15
Calcium oxide	17
Magnesium oxide	4.5
Boron oxide	8
Others	1.5

3.1.2 Areca Fiber

It is known that synthetic fibers exhibit outstanding properties, which explains their broad application in various industries. However, these human-made fibers can cause environmental problems, when it considering landfills, because of their non - biodegradability, which makes them harmful to the environment. Due to environmental concerns, natural fibers have been proposed to be utilized in composites, either as individual fibers or as hybrid reinforcement fibers. Natural fibers are extracted from natural sources, such as animals, plants and minerals, by several methods, such as chemical and thermal modifications, before being used in composites. Areca catechu, is a species of palm belonging to the family of Arecaceae/Palmae, grows vertically, to the height of 10 m to 20 m, the stem is straight, solitary and slender, 10 cm to 15 cm in diameter, with marks of annulated scars of fallen leaf sheaths. Areca fibers are predominantly extracted not only from the fruit as areca husk, but also from leaf stalks and fronds.

The natural areca fiber is inexpensive, abundantly available and a very high potential perennial crop. The botanical name of areca is Areca Catechu Linnaeus and it belongs to the Arecaceae (Palmae), palm family and Arecoideae subfamily. Karnataka is India's largest areca nut producing state which has a share of around 50% areca productions in the country. In Dakshina Kannada, areca is one of the major crops and is cultivated in 27,600 hectares with an annual production of about 40,000 tonnes. Hence, enormous quantity of unmanaged areca husk is available for further processing. The areca husk is a hard fibrous material covering the endosperm and constitutes about 60-80% of the total weight and volume of the areca fruit. The areca husk fiber is composed of cellulose with varying proportions of hemicelluloses (35–64.8%) and lignin (13.0–26.0%), pectin and protopectin1-3. Presently, this highly cellulosic material is being used as a fuel in areca nut process. Thus the use of this husk fiber as structural material requires a detailed study on physical, chemical and mechanical characteristics.

Mechanical behaviour of areca composites was studied by few investigators and they found to have a good flexural strength and adhesion tensile properties at 60% fiber loading4-

8. Alkali treated areca/epoxy and alkali treated areca/polypropylene composites showed improved tensile strength values 9-10. Chemical interlocking at the interface was enhanced and better adhesion with the matrix was observed after potassium permanganate treatment of natural lignocellulosic fibers10-11. 6% and 33% improvement on tensile strength and moisture resistance properties were reported for benzoyl chloride treated flax fiber reinforced low density polyethylene composites12.

Acrylic acid treated abaca fiber reinforced polypropylene composites showed better mechanical performance compared to untreated abaca/polypropylene composites13. Acrylated jute fiber reinforced epoxy-phenolic matrix composites showed increase in tensile strength and flexural strength values by 42.2% and 13.9% respectively14. Flexural strength and impact strength increased with increase in fiber loading up to 50% for abaca reinforced MAH-PP composites15. Abaca-epoxy polymer composites showed increase in impact strength up to 40% fiber loading and then showed a decline. Benzene diazonium chloride treated abaca-epoxy composites with 40% fiber loading showed high impact strength value compared to untreated and other chemically treated abaca-epoxy composites with same 40% fiber loading16. Several researchers showed that impact strength increased with increase in fiber loading17-19.

Hence, surface modifications of natural fibers by chemical treatments are more important in the field of technical utilization of natural fiber reinforced polymer composites in various engineering applications. Epoxy resin is the most commonly used matrix material in natural fiber reinforced polymer composite fabrication because of its good adhesive nature, good chemical and environmental resistance, good electrical insulating properties and good mechanical properties.

Impact strength is the capability of the material to withstand a suddenly applied load and impact tests are used in studying the toughness of a material. Impact strength is a very important property of a material governing the life of a structure. The capacity of the aircraft to withstand the impact depends on the strength of the material.

Areca catechu fibers can be extracted from its fruit, frond and stalk. The size and physical features of the extracted fibers vary depending on the tree part, from which they were extracted. The method of extraction also affects the properties of the fibers. The frond fiber from areca

Fig 3.3 Different parts of Areca catechu tree used to produce different types of fibers.

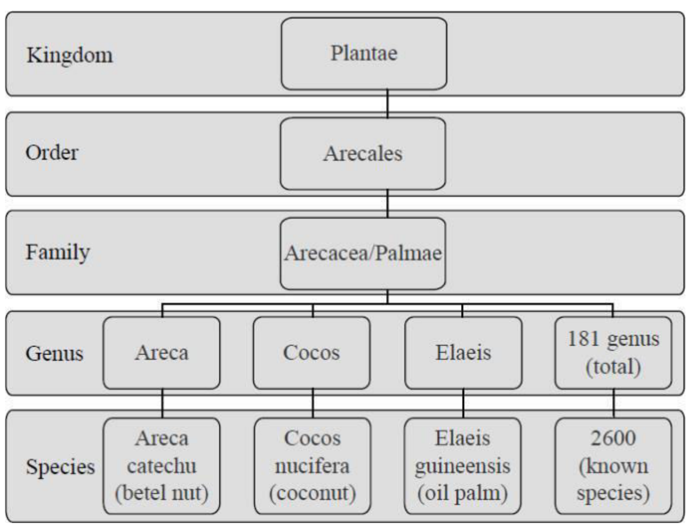

Fig. 3.4 Scientific classification of Arecaceae/Palmae family.

Fig 3.5 woven areca fiber

Table 3.3 Physical dimensions of areca fiber

Diameter (mm)	**Length (mm)**				**Density (g/cm^3)**
	Short	**Medium**	**Long**	**Average**	
0.285	18 -29	30-38	39-46	29-38	1.05

Table 3.4 Chemical composition of areca fibers

Cellulose (wt%)	66.08
Hemicellulose (wt%)	7.40
Lignin (wt%)	19.59
Wax (wt%)	19.59
Moisture (wt%)	0.72

3.1.3Matrix

The resin acts as the matrix of the composite to ‘bind’ the composite materials together and transfer the component stresses that may act on the part to the fibers in the composite.

- **Epoxy Resin LY556**
- Epoxy resins are characterised by their very good electrical properties and chemical

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resistance, good strength and low absorption of moisture.

They are versatile resins, offering particularly excellent resistance to corrosion (solvents, alkalis and some acids), high strength/weight ratio, dimensional stability and adhesion properties. They are linear polymers produced by condensing epichlorhydrin with bisphenol A. Other formulations are glycidyl esters (for vacuum impregnation, lamination and casting), glycidyl ethers of novolac resins, and brominated resins. They differ from polyesters and vinyl esters in that they do not contain any volatile monomer component. Different resins are produced by varying the ratios of the components.

The resins are relatively high in viscosity, so that they are usually moulded at temperatures in the region of 50-100°C, or dissolved in an inert solvent to reduce viscosity to a point at which lamination at room temperature becomes possible. Curing agents, also referred to as catalysts, hardeners or accelerators, are used, acting either by catalytic action or directly reacting with the resin

With correct additives, epoxy resins can exhibit outstanding resistance to heat (some up too 290°C) and electrical insulation properties. They can be either liquid or solid form and can be formulated to cure either at room temperature of with the aid of heat. Heat curing is more common for situations where maximum peformance is required. Epoxies generallly cure more slowly than other thermset resins. Cold -cure types are available, but performance is usually better when curing at 40 -60°C. Epoxies are frequently used in aerospace and defence, chemical plant and high performance automotive applications.

- **Hardener HY951**

Hardeners are almost always necessary to make an epoxy resin useful for its intended purpose. Without a hardener, epoxies do not achieve anywhere near the impressive mechanical and chemical properties that they would with the hardener. The correct type of hardener must be selected to ensure the epoxy mixture will meet the requirements of the application. Research should always be done on both the resin and the hardener to make sure the final epoxy mixture will perform satisfactorily. Common examples of epoxy hardeners are anhydride-based, amine-based, polyamide, aliphatic and cycloaliphatic.

Hardeners are used to cure epoxy resins. However, simply adding a hardener to an epoxy resin may not cause the epoxy mixture to cure quickly enough. If this is the case a different hardener may be required. Also, hardeners with certain additives can be used. These hardener additives serve as catalysts that speed up the curing process Aradur HY 951 is a hardener which is used with the epoxy resin which is used for the encapsulation or coating of low voltage and electronic components. Physical properties of the epoxy resin systems such as tensile, compression, flexural properties, etc. are also influenced by epoxy hardeners. The performance of epoxy hardeners in the epoxy resin system depend on the chemical characteristics while applying the epoxy resins system. The chemical characteristics of the epoxy resins that influence epoxy hardeners are: viscosity, amount and kind of diluents and filers in epoxy resin. The physical characteristics of the epoxy resins system influencing the behavior of epoxy hardeners in the epoxy resin systems are: temperature of the work area, temperature of the resins systems.

CONCLUSION

The properties and mechanical characteristics of Hybrid composite were studied. The various mechanical tests such as tensile, impact, density, water absorption is propose to performance in next phase of project and the evaluated results will be used to find which proportion of hybrid composite material have maximum performance.

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