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# Experimental Investigation and Analysis A Mechanical Properties of Hybrid Polymer Composite Plates

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**Abstract :** The hybrids composite has emerged and have the potential reinforcement material for composites and thus gain attraction by many researchers. This is mainly due to their applicable benefits have they offer low density, low cost, renewable, biodegradability and environmentally harmless and also comparable mechanical properties with synthetic fiber composites. In the project natural fiber and glass hybrid composites were fabricated by using epoxy resin combination of hand lay-up method and cold press method. Specimen was cut from the fabricated laminate according to the ASTM standard for different experiments for tensile test, flexural text, and impact test. A significant improvement in tensile strength was indicated by the woven fiber glass hybrid composites. In this hybrid composite laminates banana-glass-banana (BGB) and glass-banana-glass (GBG) exhibit higher mechanical properties due to chemical treatment to natural fibers. So, the hybrid composite material shows the highest mechanical properties. This High performance hybrid composite material has extensive engineering applications such as transport industry, aeronautics, naval, automotive industries.

**Keywords:** Hybrid composites, mechanical properties, epoxy, hand layup.

## I. INTRODUCTION

In recent years, polymeric based composites materials are being used in many application such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance. Natural fibres are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. The information on the usage of banana fibre in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, have investigated banana fibre reinforced polyester composites and found that the optimum content of banana fibre is 40%. The analysis of tensile, flexural, and impact properties of these composites revealed that composites with good strength could be successfully developed using banana fibre as the reinforcing agent. The source of banana fibre is the waste banana trunk or stems which are abundant in many places in the world.

Nature continues to provide mankind generously with all kinds of rich resources in plentiful abundance, such as natural fibres from a vast number of plants.

However, since the last decade, a great deal of emphasis has been focused on the development and application of natural fibre reinforced composite material in many industries. Needless to say, due to relatively high cost of synthetic fibres such as, glass, plastic, carbon and Kevlar used in fibre reinforced composite, and the health hazards of asbestos fibres, it becomes necessary to explore natural fibre, like banana fibres.

The natural fiber present important advantages such as low density, appropriate stiffness, mechanical properties with high disposability and renewability. In this project are used the natural fibre of banana. Moreover, these banana fiber are recycle and biodegradable.. Banana fiber, a lingo-cellulosic fiber, obtained from the pseudo-stem of banana plant (Musa sepientum), is a bast fiber with relatively good mechanical properties. In tropical countries like India, fibrous plants are available in abundance and some of them like banana are agricultural crops. Banana fiber at present is a waste product of banana cultivation. Hence, without any additional cost input, banana fiber can be obtained for industrial purposes. Banana fiber is found to be good reinforcement in polypropylene resin. The properties of the composites are strongly influenced by the fiber length.

Table 1

*Comparison between natural and glass fibres*

| | Natural fibres | Glass fibres |
|---|---|---|
| Density | Low | Twice that of natural fibres |
| Cost | Low | Low, but higher than NF |
| Renewability | Yes | No |
| Recyclability | Yes | No |
| Energy consumption | Low | High |
| Distribution | Wide | wide |
| $CO_2$ neutral | Yes | No |
| Abrasion to machines | No | Yes |
| Health risk when inhaled | No | Yes |
| Disposal | Biodegradable | Not biodegradable |

## 1.2 OBJECTIVES

Keeping in view the above mentioned knowledge gaps, the following objectives were chosen for the present research project work.

a) Fabrication of a new class of epoxy based hybrid composites reinforced with oriented glass fibers and banana fibers.

b) Evaluation of mechanical properties such as tensile strength, flexural strength and micro hardness for these composites.

c) To study the influence of fiber parameters such as fiber and fiber loading on the mechanical behaviour of the composites.

## TYPES OF COMPOSITE MATERIALS

Broadly, composite materials can be classified into three groups on the basis of matrix material. They are

i. Metal Matrix Composites (MMC)
ii. Ceramic Matrix Composites (CMC)
iii. Polymer Matrix Composites (PMC)

### i. Metal matrix composites

Higher specific modulus, higher specific strength, better properties at elevated temperatures and lower coefficient of thermal expansion are the advantages of metal Matrix Composites over monolithic metals. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

### ii. Ceramic matrix Composites

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Naturally it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites.

### iii. Polymer Matrix Composites

Polymeric matrix composites are the most commonly used matrix materials. 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. By reinforcing other materials with polymers these difficulties can be overcome. Secondly high pressure and high temperature are not required in the processing of polymer matrix composites. For this reason polymer composites developed rapidly and became popular for structural applications with no time. Polymer composites are used because overall properties of the composites are superior to those of the individual polymers.

## II. EXPERIMENTAL

### 2.1 MATERIALS AND METHODS

**THE MATRIX**

The materials used for matrix are epoxy, unsaturated polyester and vinyl ester. Epoxy resins are the most common matrices for high performance advanced polymer composites, but they are also inherently brittle because of their high degree of cross linking. The densely cross linked structures are the basis of superior mechanical properties such as high modulus, high fracture strength, and solvent resistance. However, these materials are irreversively damaged by high stresses due to the formation and propagation of cracks. These lead to dangerous loss in the load-carrying capacity of polymeric structural engineering materials. Currently the unsaturated polyesters are the most widely used polymer in construction [6].

**HARDENER**

A substance of mixture added to a plastic composition to take part in and promote or control the curing action, also a substance added to control the degree of hardness of the cured film. See also curing agents, catalyst and cross-linking [6].

All working times (pot life) are based upon an optimum working temperature of about 80 degrees F. temperatures variations will greatly affect curing times, and when below 65F can sometimes double curing times. Other factors that affect epoxy curing can be moisture and humidity, as well as the thickness of lamination.

**GLASS FIBERS**

The most common reinforcement for the polymer matrix composites is a glass fiber. Most of the fibers are based on silica (sio2), with addition of oxides of ca, b, na, fe, and al. the glass fibers are divided into three classes -- e-glass, s-glass and c-glass. the e-glass is designated for electrical use and the s-glass for high strength.

*Fig 1 Glass fiber*

The Researchers now a days developed equipment to make the glass fiber dust in to powder or particle cullet either by calcinations and pulverization or by pyrolysis. This enabled the company to re-use the fiber dust as glassmaking material.

This chapter details the materials used and methodologies adopted during the fabrication, sample preparation, mechanical testing and characterization of the hybrid composites. The raw materials used in the study are:

i) Epoxy resin
ii) Banana Fiber
iii) Glass Fiber (S-Glass)
iv) Hardener

**Epoxy resin**

Epoxy resins are available in liquid and solid forms and are cured into the finished plastics by a catalyst. They are cured at room temperatures as well as elevated temperatures of about $275^0$C. The erosion resin of grade LY-556 was used of density 1.1-1.2gm/cc at 298K. It having the following outstanding properties has been used as the matrix material.

a) Excellent adhesion to different materials.
b) High resistance to chemical and atmospheric attack. High dimensional stability.
c) Free from internal stresses.
d) Excellent mechanical and electrical properties. Odourless, tasteless and completely nontoxic. Negligible shrinkage.

**2.2 Banana fiber and Alkali treatment**

Banana fiber is a natural fiber with relatively good mechanic properties. The diminutive second-generation Mercedes-Benz A-Class designed the spare tire recess covered with a composite material, polypropylene thermoplastic with embedded banana fibers, abaca, with high tensile strength and rot-resistant. It can withstand stone strikes and exposure to the environment, such as ultraviolet from the sun, water, some chemicals. Using abaca fiber is saving energy because conventional glass fibers production requires 60% more energy than this natural fiber[5].

Sodium Hydroxide (NaOH) treatment removes impurities from the fiber surface, Banana fiber sample were treated with three different conc. of NaOH to soften the fiber and make it suitable for spinning. The concentrations used were 0.5%, 1%, 1.5% weight/volume. Treatment was done with sample: liquor ratio of 1:30.Standard procedure used in the institute is as follows[5]. In the present study 200 grams of banana fibres were used per concentration. Since the NaOH used was 1:30 total solution used in each case was 6 litres. For preparation of NaOH solution, 1% NaOH solution was used [5].

→ **Fibre-cell-OH + NaOH Fibre cell-O-$Na^+$ + $H_2O$ + impurities**

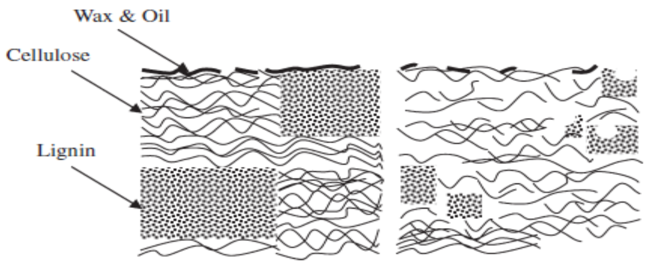

*Fig 2 Chemical reaction*

**Alkaline treatment of banana fibers protocol**

Weigh out required quantity of banana fibers
↓
Check out specific gravity of required conc. Of NaOH
↓
Take NaOH in a glass beaker (1:30 ratio) 4 gm fibre: 120 ml NaOH
↓
Add 1-2 drops of wetting agent i.e. auxypon
↓
Mix the solution properly with the help of a glass rod
↓
Add fibers in a beaker such that fibers are immersed in the solution completely
↓
Keep it for ½ hr. Swirl the solution intermediately
↓

Wash out the fibers with warm water 4-5 times

↓

Wash the fibers with distilled water

↓

Dry the fibers at room temperature on a blotting paper.

*Fig 3 Treatment of banana fiber*

*Table 2*
*Properties of Banana fiber*

| PROPERTIES | BANANA FIBER |
|---|---|
| Cellulose % | 63–64 |
| Moisture content % | 10-11 |
| Density (kg/m$^3$) | 1350 |
| Flexural modulus (GPa) | 2-5 |
| Lumen size (mm) | 5 |
| Tensile strength (MPa) | 54 |
| Young's modulus (GPa) | 3.4878 |

Glass fibers are among the most versatile industrial materials known today. They are readily produced from raw materials, which are available in virtually unlimited supply. All glass fibers described in this article are de-rived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fiber properties such as strength, flexibility, and stiffness. Glass fibers are used in the Manufacture of structural composites, printed circuit boards and a wide range of special-purpose products[2][3].

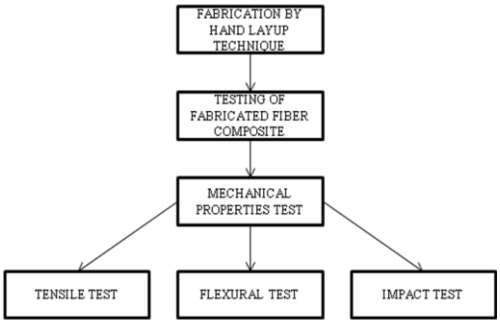

*Fig 4 Methodology*

*Table 3*
***S**-glass fibers properties*

| | **Value in metric unit** |
|---|---|
| Density | $1.8\times10^3$ Kg/m$^3$ |
| Tensile modulus | 5.5 Gpa |
| Compressive modulus | 6.9 Gpa |
| Tensile strength | 48 Mpa |
| Compressive strength | 103 Mpa |

**(a) Description of hand layup technique**

Matrixes/Resins are impregnated by hand into fibers which are in the form of chopped strand mat woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions [2].

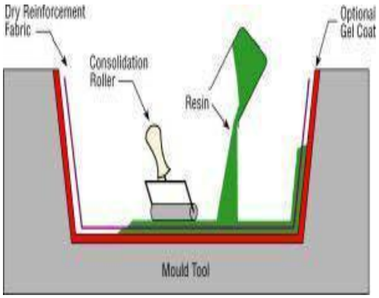

*Fig 5 Hand layup technique*

**(b) Materials Options**

**Resins**: Epoxy, polyester, vinyl ester, phenolic and any other resin.

**Fibers:** Glass, Carbon, Aramid and any other reinforcement, although heavy aramid fabrics can be difficult to wet-out by hand.

**Cores:** Any core materials can be used provided that should be compatible with resin system, i.e. polystyrene core cannot be used with polyester or vinylester resin system.

**(c) Advantages**

i) Low capital Investment.
ii) Simple principles to fabricate the part.
iii) Low cost tooling, if room-temperature cure resins are used.
iv) Wide choice of suppliers and material types.

The banana fiber and glass which is taken as reinforcement in this study is collected from local sources. The epoxy resin and the hardener are supplied. Wooden moulds having were first manufactured for composite fabrication. The banana fiber and S- Glass fibers are mixed with epoxy resin by simple mechanical stirring and the mixture was poured into various moulds, keeping in view the requirements of various testing conditions and characterization standards. The composite samples of nine different compositions (S-1 to S-4) are prepared. The composite samples S-1 to S-4 are prepared in three different percentages of Glass and banana fibers (15 wt % and 30 wt %).

*Table 4*
*Classifications of glass fibers*

| **Types Of Glass** | **Area Of Application** | **Specification** |
|---|---|---|
| S –glass | Tensile strength | High strength |
| E –glass | Electrical | High electrical resistivity |
| C –glass | Chemical | High corrosion resistance |

This is done while keeping the epoxy content at a fixed percentage (i.e. 50 and60 wt %).Same lengths of banana fiber are used, while keeping the length of the glass fiber constant. The detailed composition and designation of composites are shown in Table 5.

A releasing agent is used on the mould release sheets to facilitate easy removal of the composite from the mould after curing. The entrapped air bubbles (if any) are removed carefully with a sliding roller and the mould is closed for curing at a temperature of 30°C for 24 h at a constant load of 50 kg. After curing, the specimens of suitable dimension are cut using a diamond cutter for mechanical tests as per the ASTM standards. The composition and designation of the composites prepared for this study are listed in the following table. The samples have been prepared by varying the fiber length and fiber loading for the two fibers[2][3]][4].

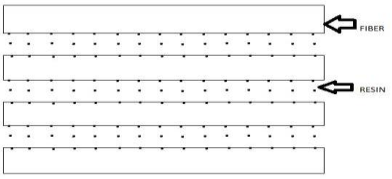

*Fig 6 Fiber and Resin layer*

On addition to hardener the resin will begin to become more viscous until it's not at all liquid and has lost its ability to flow. This is '**Gel Point**' the resin will continue to hardened after it has gelled, until, at some time later. It has obtained maximum hardness and all its properties. This reaction itself is accompanied by the generation of exothermic heat, which, in turn speed up the reaction. This whole process is known as '**Curing**' of the resins.

Curing at high temperature has the added advantage that it actually increases the end mechanical properties of the material. And many resin systems will not reach their ultimate mechanical properties unless the resin is given this '**Postcure**'. This posture process involves increasing the laminate temperature after the initial room temperature cure, which increase the amount of cross linking of the molecules that can take place. To some degree this posture will occur naturally at warm room temperatures, but higher properties and shorter posture times will be obtained if elevated temperatures are used.

*Table 5*
*Designation of Composites*

| **SAMPLE** | **MATRIX** | **REINFORCEMENT** | |
|---|---|---|---|
| | | **SYNTHETIC S-GLASS FIBER** | **NATURAL BANANA FIBER** |
| **S1 YELLOW** | 50 % | 20% | 30 % |
| **S2 BLUE** | 60 % | 20 % | 20 % |
| **S3 GREEN** | 50 % | 25 % | 25 % |
| **S4 RED** | 60 % | 25 % | 15 % |

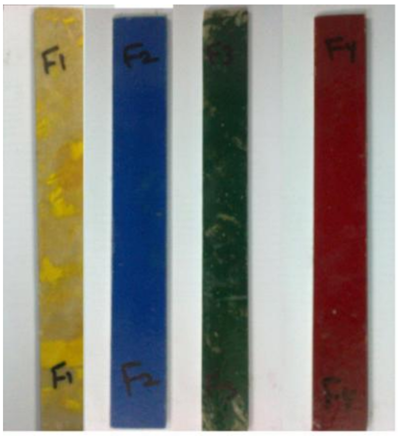

*Fig 7 Fabricated specimens*

# III. RESULTS AND DISCUSSION

## 3.1 TENSILE TEST (ASTM D-638)

The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications.

The force per unit area (MPa or psi) required to break a material in such a manner is the ultimate tensile strength or tensile strength at break. Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties.

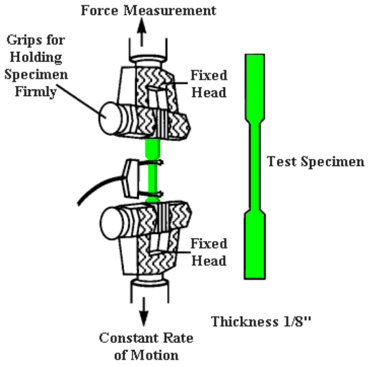

*Fig 8 Tensile Strength*

*Table 6*
*TENSILE STRENGTH*

| S.NO | LENGTH mm | WIDTH mm | THICKNESS mm | TENSILE STRENGTH MPa |
|---|---|---|---|---|
| 1 | 50 | 12.50 | 4.00 | 54.15 |
| 2 | 50 | 12.60 | 3.40 | 27.27 |
| 3 | 50 | 12.90 | 3.80 | 51.80 |
| 4 | 50 | 12.60 | 3.90 | 33.30 |

### 3.2 FLEXURAL STRENGTH (ASTM D-790)

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique.

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol$\sigma$.When an object formed of a single material, like a wooden beam or a steel rod, is bending, it experiences a range of stresses across its depth. At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value. These inner and outer edges of the beam or rod are known as the 'extreme fibers'. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the beam or rod fails is its flexural strength.

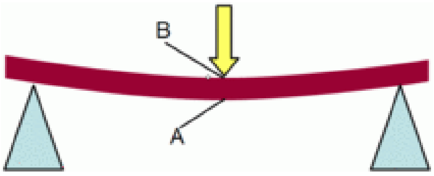

*Fig 9 Tensile Strength*

*Table 7*
*FLEXURAL STRENGTH*

| S.NO | SPAN LENGTH mm | BREADTH mm | THICKNESS mm | FLEXURAL STRENGTH Mpa |
|---|---|---|---|---|
| 1 | 100 | 27 | 4 | 163.1 |
| 2 | 100 | 26.80 | 3.20 | 133.16 |
| 3 | 100 | 27.60 | 3.80 | 116.67 |
| 4 | 100 | 26.80 | 3.80 | 120.15 |

### 3.3. CHARPY IMPACT (ASTM D-256)

The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A major disadvantage is that all results are only comparative. The apparatus consists of a pendulum axe swinging at a notched sample of material.

The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after a big fracture. The notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain.

Impact strength = $E/t \times 1000$

'E'- Energy used to break (J)

't' – Thickness in mm

*Table 8*
*CHARPY IMPACT STRENGTH*

| **S.N** | **BREADTH mm** | **THICKNESS mm** | **ENERGY USED TO BREAK (J)** | **IMPACT STRENGTH (J/mm)** |
|---|---|---|---|---|
| 1 | 10 | 4.00 | 2 | 10 |
| 2 | 10 | 3.40 | 2 | 11.76 |
| 3 | 10 | 3.80 | 2 | 10.52 |
| 4 | 10 | 3.90 | 2 | 10.25 |

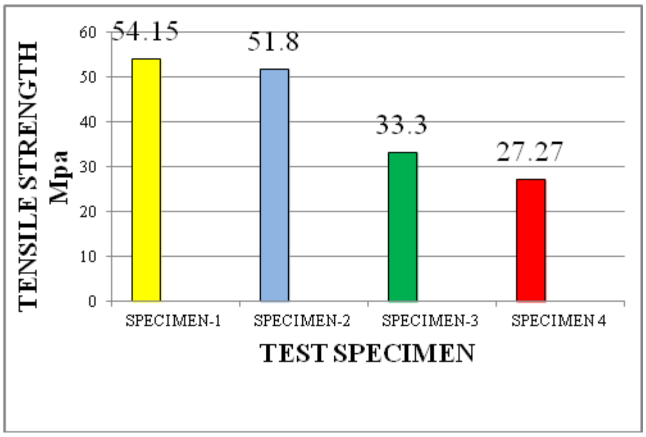

***Fig 10 Results of Tensile Test***

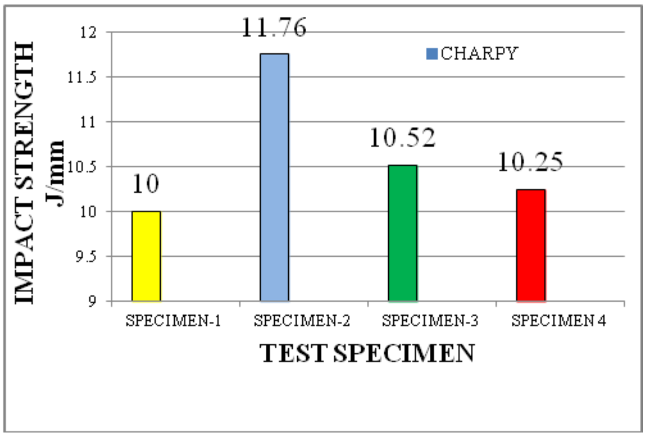

***Fig 11 Results of Charpy Test***

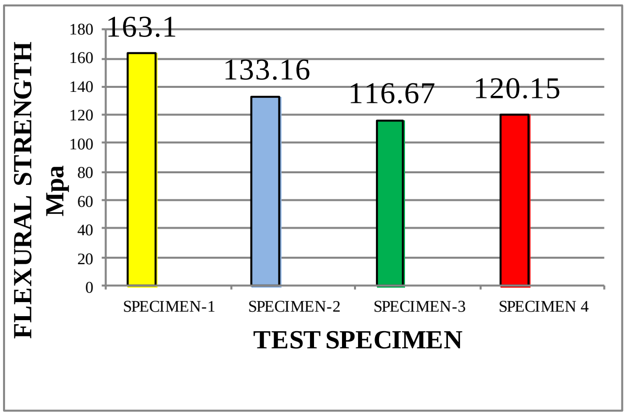

***Fig 12 Results of Flexural Test***

## IV. CONCLUSIONS

A new type of fiber reinforcement composite was experimentally investigated.

Chemical treatment like NaOH will increases the flexural strength of the fiber up to 20-30% and removes the moisture content of the fiber.

The mechanical properties of banana and glass fiber and reinforced epoxy hybrid composites have been investigated. The tensile strength and flexural strength increases with increasing fibre volume fraction. Among all the hybrid fibre composites tested, banana reinforced epoxy hybrid composites registered the highest mechanical properties whereas glass and banana fiber composites showed the highest.

The mechanical properties of the natural fibre and synthetic fiber platescom-posites tested were found to compare favourably with the corresponding tensile and flexural properties increasing volume fraction of fiber percent. Glass fiber dust is so voluminous that it cannot be re-used as glass making material without treatment. It has been disposed of by land filling as industrial waste. However, regarding the glass fiber dust as an important resource for glassmaking the company decided to recycle it.

The future scope of the project is extended by doing the experimental analysis on different proportion of coupling agents and the fiber content in the samples and performs the mechanical and thermal properties test on the specimen. And also implementation of eco-friendly fibers in the automotive parts like car panels, bumper etc. Through implementing this fiber we can achieve light weight and structural component in automotive parts, which in turn fuel efficiency is increased.

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