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Characterization of Natural Fiber Reinforced Composites

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Abstract— **With advancements in the methods of research, the branch of Material science has seen its extremes but there are some areas upon which much attention should be focussed. One such area is the natural composites. Taking the ecological problems created by synthetic material into account, there is a need to search for the alternatives for which the nature gives answer which furnishes us with a wide variety of plant material with extraordinary properties leaving us to explore its engineering applications. This work focuses on the extraction of fibers from pineapple leaf, sisal plant, and date palm leaf. Hand layup technique is being used to prepare the samples of composites. ASTM standards are being followed while fabricating the natural fiber reinforced composite. The properties such as tensile strength, flexural strength and impact strength and hardness are to be studied. The corresponding strengths are to be compared to select the best alternative**

Index Terms-- **Composites, Natural Fiber, Pineapple, Sisal**

I. INTRODUCTION

In the fast developing society there is a requirement of materials with unusual combination of properties, which cannot be met by conventional metal alloys, ceramics, and polymeric materials. Many of our modern technologies demand not only the strength, but also high performance, specific service materials. In order to fulfill the above requirements lot of research work has been done in the area of material science.

At last, Composite materials are chosen as one of the best engineering materials. The flexibility that can be achieved with composite materials is immense. Merely by changing the composition, variety of properties can be obtained thus making the composites versatile and reliable substitutes for the conventional structural materials. Composite materials have a long history of usage. Their beginnings are unknown, but all recorded history contains references to some form of composite material. More recently, fiber reinforced resin composites that have high strength-to-weight and stiffness-to-weight ratios have become important in weight sensitive applications such as aircraft and space vehicles.

The increasing population needs more and more construction materials. Wood and metals are the construction materials, which have been extensively consumed in building construction, vehicle body, furniture, etc., The growth rate of material resources is not in pace with that of population . To meet the deficiency, man has to find suitable substitutes. The materials from natural resources under-explored and unused so far, if put to effective. Utility will solve the problem arising out of the inadequacy of conventional materials.

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II. DEFINITION OF COMPOSITE MATERIAL

Composite materials are materials composed of two or more distinct constituent materials or phases, with properties that are different from the constituent properties. These materials consist of one or more discontinues phases called reinforcement embedded in a continuous phase called matrix. Their orientation and distribution influence the properties and performance of the composite material.

1.2 CLASSIFICATION OF COMPOSITE

1.2.1 Classification by the form of constituents

Composites can be classified by the form of the components or by their nature. As a function of the form of the constituents, composites are classified into two large classes:

Composite Material with fiber and composite with particles. The commonly accepted classification of composites is:

a) Fibrous composites
b) Laminated composites
c) Particulate composites

1.2.2 Fibrous Composite

A composite material is a fiber composite if the reinforcement is in the form the fibers. The fibers used are either continues or discontinues in the form chopped fibers, short fibers etc. The arrangement of fibers and their orientation allows to tailor the mechanical properties of the composites to obtain the materials ranging from strongly an-isotropic to isotropic in one plane.

1. The Nature of constituents
2. The proportions of the constituents
3. The orientation of the fibers

The fibrous composites are formed by embedding and binding together of fibers by a continuous matrix. According to the definition fiber is a material in an elongated form such that it has a minimum length to a maximum average transverse dimension of 10:1, a maximum cross-sectional area of $5.2\times10.4cm^2$ and a maximum transverse dimension of 0.0254 cm. A fiber is inherently much stiffer and stronger than the same material in bulk form, because of its perfect structure. Commercially available fibers are of glass, boron, Kevlar and graphite. The matrix is meant for bonding the fibrous so that they act in concert.

The composite, resulting from the combination of fibers and matrix, possess higher specific stiffness and specific strength, and is lighter than conventional engineering materials.

1.2.3 Laminated Composite

Bonding layers of different material or same materials makes laminated composites. In this class of composites, discontinuous matrix or mechanical fasteners are used at times to keep the layers together. Depending upon the ways of fabrication, behavior, or constituent materials of laminates, laminated composites are commonly called as bimetal, clad-metals, laminated or safety glass, plastic based laminates, laminated fibrous or hybrid composites and sandwiches.

1.2.4 Particle Composite

A composite material is a particle composite then the reinforcement is made of particles. Particles improve properties such as stiffness, behavior with temperature, resistance to abrasion, decrease of shrinkage.

1.3 FIBERS

Technologically, the most important composites are those in which the dispersed phase in the form of a fiber. The basic principle used in FRC is that materials generally stronger in fiber form than in bulk form due to minimum number of defects contained by them. The number of defects and dislocations increases as the thickness of a material increases.

The reinforcement caused by fibers, in the matrix is governed by the following parameters:

1) Fiber dispersion
2) Fiber matrix adhesion
3) Fiber aspect ratio
4) Fiber orientation and
5) Fiber volume fraction

Classification of Fibers:

1. Natural Fibers: coir, Jute, Bamboo, Palm, Corn etc.
2. Man Made Fibers: Carbon, Boron, Glass, Kevlar, Graphite etc.

1.3.1 Natural Fibers:

The science of fiber crops studies the importance, distribution, origin, botany, ecological conditions, agronomy, harvest method, quality determination and processing of different species of fibers. Secondary only food processing plants, fiber-producing plants play a significant role in early and modern civilization. Fiber is an anatomical structure obtained from stems, leaves, roots, fruits and seeds. It is derived from meristematic tissue of primary or secondary origin depending on the species. Vegetable fibers consist of cellulose, lignocelluloses, pectin and hemicelluloses depending on the vegetable species. Worldwide, despite the availability of modern synthetic fibers, vegetable fibers remain in great demand and compete with wool, silk, and synthetics for quality resistance, durability, color, and luster. Due to the intense competition between natural and industrial fibers, a need exists for analysis of the growth and productivity of those fiber crops face varying problems in their thrust to increase fiber productivity, not the least of which are restrictions due to uncontrollable agro climatic conditions and economic constraints at grassroots levels. The place of cotton as a fiber crop has already been well documented, therefore this work concentrates mainly on vegetable fibers that are long, called long vegetable fibers.

According to very complete compilation of M.Vernardin in his Nomenclature of Fibers Textiles, the number of plant fibers used by the human species is more than 550 and perhaps 700.The natural fibers are generally subdivided into

a) Animal fibers
b) Mineral fibers
c) Vegetable fibers

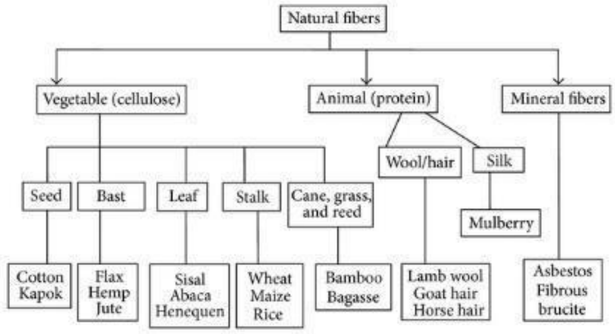

Fig. 1.1: Classification of Natural Fibers

Mechanical properties of the NFRC:

High Strength and well Structure of FRC is obtained by dependent on the various parameters. Some of the few parameters are the orientation of fiber, strength of fibers, physical properties of fibers, and interfacial adhesion properties of fibers. Characteristic components of natural fibers such as orientation, moisture absorption, impurities, physical properties, and volume fraction play a constitutive role in the determination of mechanical properties.

III. LITERATURE REVIEW

Subramanian Raman, Chattopadhyay Subhanjan,Salil Kumar and Sharan Chandran M [1] investigated on fabrication and testing of the Jute-Epoxy braided as well as short fiber reinforced composite which is of low cost, low density, high specific strength, no health risks, renewable, environment friendly and lower energy requirement for processing. The jute fibers used have undergone alkali treatment to improve their properties and blended with epoxy resin and cured. The later stage of this work deals with the Tensile Test of both types of specimens, Impact & Flexural test of braided composite according to the ASTM standards for Plastics. Further an extensive comparison of braided & short fiber composite has been done along with finite element analysis to validate the results.

SubbiahJeeva.Ga, SubinKumar.Mb, yabezRaj.D [2] researched on latest Structural materials of high strength, less weight and low cost. In generally strong materials arerelatively dense and light materials have less strength. In order to achieve high strength and less weight, they made composite materials. In composite material they used glass fiber as a base material. In addition to that natural fiber and micro powder for improving the mechanical properties are used. For determining the effect of additives in composite they prepared four different specimens with coconut fiber, banana fiber, sisal fiber and titanium oxide powder respectively. Polyester resin is used as bonding material.

Hukiran.J, Dr. S. Srinivasa Rao, Madhusudan.S [3] work has been carried out to investigate the flexural properties of composites made by reinforcing banana and pineapple as the new natural fibers into epoxy resin matrix. The natural fibers were extracted by retting and manual process. The composites are fabricated using banana and pineapple fiber reinforcements. It has been observed that the flexural properties increase with the increase in the weight fraction of fibers to certain extent. The hybridization of the reinforcement in the composite shows greater flexural strength when compared to individual type of natural fibers reinforced composites. All the composites shows increase in flexural strength in longitudinal direction. Similar trends have been observed for flexural modulus, inter laminar shear strength and break load values.

R.Prem Kumar, Guddakesh Kumar Chandan, R.Ramamoorthi [4] used banana, bamboo and pine apple fibers. By using the above mentioned three reinforcement with epoxy resin, different combinations like banana/bamboo, pineapple/bamboo and banana/pineapple hybrid composites. By the combination of all the three fibers we get bamboo/banana/pineapple hybrid composites. The percentage of resin added is about 70% and the fiber is of 30%. The fabricated samples are ubjected to mechanical and physical tests as per the ASTM standards. The best combination is suggested for the manufacturing of automobile applications.

R.Sakthivela, D.Rajendranb [5] has mainly concentrated on the applicable benefits of NFRC and fibers which offer low density, low cost, renewable, biodegradability and environmentally harmless and also comparable mechanical properties with synthetic fiber composites.

N. Siva, J. John Paul [6] focused on determining the mechanical properties of Pineapple leaf fiber (PALF).This study highlights the fiber preparation using alkali method with different concentrations. It is determined that long fibers with fillers show better tensile strength with 10% conc. NaOH displays higher strength with lower elongation when compared to fibers treated with other concentrations.

K. Devendra, T. Rangaswamy [7] has carried investigation on the mechanical properties of E-glass fiber reinforced epoxy composites filled by various filler materials. Composites filled with varying concentrations of fly ash, aluminum oxide (Al_2O_3), magnesium hydroxide ($Mg(OH)_2$) and hematite powder were fabricated by standard method and the mechanical properties such as ultimate tensile strength, impact strength and hardness of the fabricated composites were studied.

Nicolaetaranu, Gabriel Orpisan, Mihai Budescu, AlexandruSecu, IonelGosav [8] studied the results of a theoretical and experimental study carried out on the possibility of using polymer composites reinforcing elements for a power supply tubular reinforced concrete (RC) column. The composite reinforcing elements are utilized both as longitudinal glass reinforced thermosetting polymer (vinyl-ester) bars and transverse reinforcement made of a glass fiber reinforced polypropylene (GFPP) spiral. This experimental program has been organized to determine the mechanical characteristics of the GFPP spiral and bonding of this composite element to concrete.

J. Sahari and S.M. Sapuan [9] has evaluated the development and properties of natural fiber reinforced biodegradable polymer composites. They are the materials that have the capability to fully degrade and compatible with the environment. Research groups have explored the production and properties of bio composites where the polymer matrices are derived from renewable resources such as poly lactide (PLA), thermoplastic starch (TPS), cellulose and polyhydroxyalkanoates (PHAs).

M. R. Sanjay, G. R. Arpitha, L. LaxmanaNaik, K. Gopalakrishna, B. Yogesha [10] have shown rapid attention in research and development in the natural fiber composite field due to its better formability, abundant, renewable, cost-effective and eco-friendly features. This paper exhibits an outline on natural fibers and its composites utilized as a part of different commercial and engineering applications.

M P Westman, S G Laddha, L S Fifield, T AKafentzis, K L Simmons [11] studied about natural fibers offer both cost savings and a reduction in density when compared to glass fibers. Though the strength of natural fibers is not as great as glass, the specific properties are comparable. Currently natural fiber composites have two issues that need to be addressed: resin compatibility and water absorption. The following preliminary research has investigated the use of Kenaf, Hibiscus cannabinus, as a possible glass replacement in fiber reinforced composites.

T D Jagannatha and G Harish [12] have studied mechanical properties of carbon and glass fibers reinforced epoxy hybrid composites. The vacuum bagging technique was adopted for the fabrication of hybrid composite materials. The mechanical properties such as hardness, tensile strength, tensile modulus, ductility, and peak load of the hybrid composites were determined as per ASTM standards. The mechanical properties were improved as the fibers reinforcement content increased in the matrix material.

K. Al-Kaabi, A. Al-Khanbashi and A. Hammami [13] studied about stringent environmental regulations and increased interest in the preservation of natural resources have forced the composite industry to examine “ecofriendly” components. Efforts are being deployed to find alternative reinforcements and resin systems that are environmentally friendly while providing the same performance as their synthetic counterparts and the potential of using Date Palm Fibers (DPF) as reinforcement in polymeric materials.

Paulo r. L. Lima, RogérioJ.Santos, saulo R. Ferreira, RomildoD. Toledo Filho [14] studied the characterization of the agricultural residues by the production and improvement of sisal fiber, called field bush and refugo and verify the potentiality of their use in the reinforcement of cement-based composites. The residues were treated with wet-dry cycles and evaluated using tensile testing of fibers, scanning electron microscopy (SEM) and Fourier transform infrared (FTIR) spectroscopy. Compatibility with the cement-based matrix was evaluated through the fiber pull-out test and flexural test in composites reinforced with 2 % of sisal residues. The use of treated residue allows the production of composites with good mechanical properties that are superior to the traditional composites reinforced with natural sisal fibers.

Natarajan.N, Bharathidhasan.S, Thanigaivelan. R, Suresh. P [15] studied about natural and synthetic fibers are combined in the same matrix (unsaturated polyester) to make Sisal/Glass fiber hybrid composites using polyurethane resin. The fabrication of hybrid composite has been performed using hand lay-up method. The fabricated hybrid composite has been tested and their mechanical properties are evaluated. Additionally sisal Nano fiber/glass fiber hybrid composite is fabricated by hand lay-up method and tested for comparing the strength with sisal/glass fiber hybrid composite.

3.1. RESEARCH NEEDS

Natural fibers have played a significant role in human civilization since prehistoric times. The human beings depend on them for garments and other simple domestic uses as well as complex applications such as land dwellings and reed-built sailing craft etc.

Modern technological innovations producing synthetic fibers with a wide selection of desirable properties by manipulations of the condensation of short-or-long-chain polymers compete with and in some cases, surpass the production of vegetable fibers in many countries. In short, the research has emphasized synthetic fiber innovations offered by an advancing technology; however, the research to improve the productivity, application and quality of natural fibers has comparatively lagged behind.

The natural fiber-reinforced composite has the advantage of being light, strong, cheap, safe and more environment-friendly. But the use of natural fiber reinforced materials has opened up questions regarding how such material is to be tested for strength and durability. Much work needs to be done before natural fiber reinforced composites can be used in highly demanding situations. Another factor that may be explored is how well the polymer matrix and natural fiber interact, given the contrasting characteristics of repelling water (hydrophobic) and loving water (hydrophilic), respectively. Daimler Benz had used door panels made from natural fiber. However, there is a need to bring the composites within the reach of common man.

The proposed research intends to take up basic studies in fabrication and testing of cost effective lightweight construction materials. In tropical country like India, there are large varieties of regenerative plants and trees with fiber content. Some of them are cultivated over the generations and some are wild plants, trees, and creepers that grow in forests and woods. It is an establishment fact that any material in its fibrous form is stronger than in bulk form. Therefore, these strong fibers are used to reinforce the weak materials. Bamboos, Country Date, Jute, Sisal, Banana and Palms available freely in the countryside have been used in their crude form. Extensive research and development work in the use of Sisal fiber in load carrying structures have been available. However, similar work related to other vegetable fibers is very much limited. The research involves exploring the possible use of variety of cultivated/wild grown fibers in the development of new composites for load carrying structures.

The modern composites are made of synthetic fibers like glass, carbon, Kevlar, etc. and resinous adhesives like epoxy, polyester, phenolic, etc. disposal of the waste resulting from fabrication and use leads to environmental problem, which gets multiplied in course of time, mainly due to synthetic nature of their constituents. Therefore, there is a need for reducing the environmental pollution by introducing the fiber and matrix, which are easily degradable. For certain applications like packing materials, biodegradable fibers would be ideal. Natural fibers are biodegradable and environment friendly.

3.2. PROBLEM DEFINITION

Modern technological innovations producing synthetic fibers with a wide selection of desirable properties by manipulations of the short-or-long chain polymers. The research has emphasized synthetic innovations offered by an advancing technology, however, the research to improve the productivity application and quality of natural fibers has comparatively lagged behind. Eventually, there is a need to bring the composites within the reach of a common man using renewable and eco-friendly natural resources. Therefore, we would like to extend our study to investigate the mechanical properties of composite by considering some natural fibers which are not explored so far.

3.3. ASPECTS OF THE PROPOSED WORK

Under the proposed work the following aspects have been studied.

1. Selection of natural fibers.
2. Selection of resins.
3. Selection of manufacturing methods to perform lab test.
4. Fabrication of specimens as per ASTM standards.
5. Testing of specimens.
6. Results and Comparison.

IV. MATERIALS REQUIRED

- Natural Fibers: Sisal, Pine apple, Date palm
- Man Made fibers: glass fiber
- Epoxy resin and hardener
- Plastic film of 1mm thickness.
- Aluminum sheets.
- Araldite hardener.
- Measuring flask.

4.2 SISAL FIBER

Sisal fiber is derived from the leaves of the plant. It is usually obtained by machine decortications in which the leaf is crushed between rollers and then mechanically scraped. The fiber is then washed and dried by mechanical or natural means. The dried fiber represents only 4% of the total weight of the leaf. Once it is dried the fiber is mechanically double brushed. The lustrous strands, usually creamy white, average from 80 to 120 cm in length and 0.2 to 0.4 mm in diameter. Sisal fiber is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater.

4.3 PINEAPPLE PLANT

Productions of Pineapple leaf fibers are plentiful for industrial purpose without any supplementary addition and annually renewable and of easy availability.

V. HAND LAYUP METHOD

Hand lay-up refers to the manual method of laying or applying the reinforcement material into the mould. In the hand lay-up process, the reinforcing material (usually natural fibers) is placed in the mold and then saturated with epoxy resin using a brush or a two-component spray system.

5.2.1 Preparation of mould:

- Initially rubber sheets of 3mm thick and 8mm thick are cut according to the dimensions. These rubber sheets act as mold and specimens take their shape that is cut in the rubber sheets.
- The mold made up of 3mm thick is used for the tensile and flexural test specimens.

- The mold of 8mm thick is used for preparation of Impact test specimens.
- All the specimens are of cuboid shape.

5.2.2 Manufacturing

- After the mold preparation process, a plastic film of 1mm thick is placed on working table.
- Then the rubber mold is placed on the plastic film.
- Fibers of sisal, pineapple, glass, and date palm are cut according to length of specimen and weighed using precision balance.
- Then the required epoxy resin mixed with hardener is poured into the mold cavities.
- Then the weighed fibers are placed layer by layer in the mold cavity in such a
- way that each and every layer gets mixed up with resin thoroughly.
- After placing the fiber again a resin is poured.
- Top fiber is pressed tightly in order to avoid air gaps between fiber composites.
- Weighs are placed on it so that hardening gets easier.
- It is left for 24 hours to get hardened.

5.2.3 Removal of Specimens from the mould:

- After 24 hours of hardening process, weighs are removed and specimens are to taken out from the mold carefully without any breakage.
- Mold sheets can be reused.
- Sides of the specimen are finished on grinding machine.

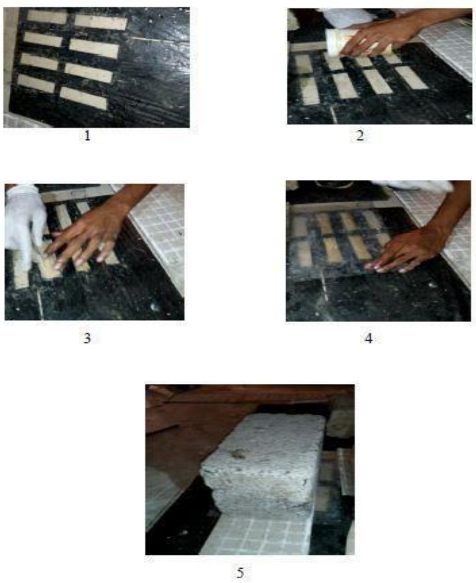

Fig. 5.3 Specimens

5.4 PRECAUTIONS:

- Fibers should be weighed accurately.
- Resin, hardener and catalyst should be mixed thoroughly.
- Hands should be cleaned with thinner and then washed with detergent after touching the resin.
- Specimens should be taken out carefully from the mold to avoid breakage.

VI. TESTING OF COMPOSITES

6.1. TESTING EQUIPMENT

The equipment used for testing of composites aretensometer and impact testing machine, their description as follows

6.1.1. Tensometer:

A 2 ton capacity – Electronic tensometer, METM 2000 ER-I model is used to find the tensile strength of composites. Its capacity can be changed by load cells of 20Kg, 200Kg & 2000Kg. A load cell 200Kg is used for testing composites. Self-aligned quick grip chuck is used to hold composite specimens. A digital micrometer is used to measure the thickness and width of composites. Tensometer is in Fig. 6.1.

Fig.6.1 Tensometer

Fig.6.2 Impact testing machine

6.1.2. Impact Testing Machine:

Impact is a very important phenomenon governing the life of a structure. In mechanics, an impact is a high force or shock applied over a short period of time when two or more bodies collide. In the charpy impact test the V-notched specimen prepared as per standard, is held between two grips and a weight is allowed to swing from a known height in such a way that it hits the notched specimen in its path and breaks. The material absorbs some amount of energy during fracture. In the izod impact test the specimen is held in a vice. Impact testing machine is in Fig. 6.2.

6.2. SPECIMEN STANDARDS

6.2.1. Tensile Test:

The specimens for the tensile test were prepared according to the ASTM D638M Standard. According to this standard the specimen size is 160mmx12.5mmx3mm. The specimens were tested on an electronic tensometer. From the experimental data the stress strain curve is plotted to determine the young’s modulus and tensile strength. A total of 5 different specimens were prepared for each weight fraction.

6.2.2. Flexural Test:

The specimens for the flexural test were prepared according to the ASTM D790M Standard. The dimensions of the specimen as per this standard are 100mmx25mmx3mm. The flexural test performed on the same electronic tensometer that was used to perform the tensile test. Load and deformation values are noted and flexural modulus and flexural strength are determined. A total of 5 different specimens were prepared for each weight fraction.

6.2.3. Impact Test:

The impact test specimens were prepared according to the ASTM D256 Standard. The dimensions of the specimens as per this standard are 63.5mmx10mmx10mm. Impact test (Charpy) was conducted on the specimen and the impact strength is determined. The energy absorbed in the impact test will be a measure of toughness. A total of 5 different specimens were prepared for each weight fraction.

6.3. CALCULATIONS

6.3.1. Tensile Strength:

It is the defined as maximum stress that a material can withstand while being stretched or pulled before failing or breaking.

Tensile strength = P/A

Where P = Maximum load (N),

A = Area of cross section (mm^2).

Tensile strain = dL/L

Where dL = change in length (mm),

L = original length (mm).

6.3.2. Flexural Strength:

It is defined as a material's ability to resist deformation under bending load.

Flexural strength S = $(3PL)/(2bt^2)$

Flexural modulus EB = $(mL^3)/(4bt^3)$

Where L = span length of specimen (mm)

b = width of the specimen (mm)

t = thickness of specimen (mm)

P = maximum load

m = slope of load deflection curve (N/mm)

6.3.3. Impact Strength:

The impact strength of the composite is calculated from the following relation.

Impact strength I = E t

Where E = energy absorbed by the specimen (J)

t = thickness of composites (m)

VII. TENSILE TEST:

From the tensile test conducted on tensometer, tensile strength and young's modulus of fiber composite material are determined and the values obtained are shown in Fig. 7.1 and Fig. 7.2.

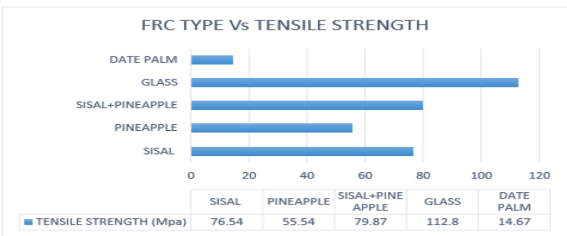

Fig. 7.1: Type of FRC Vs Tensile Strength

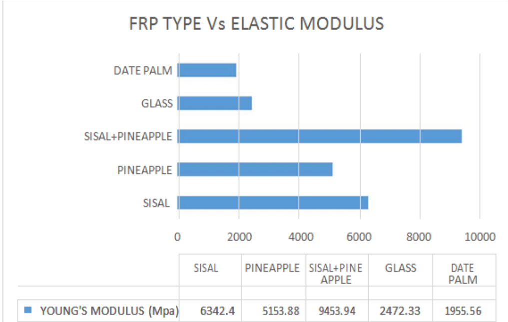

Fig. 7.2: Type of FRC Vs Elastic modulus

7.2 FLEXURAL TEST

From the flexural test conducted on tensometer, flexural strength and flexural modulus of fiber composite material are determined. Fig. 7.3 and Fig. 7.4 shows the variation of the flexural strength and flexural modulus of the composites.

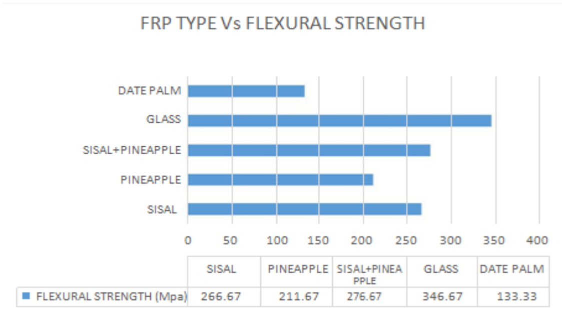

Fig. 7.3: Type of FRC Vs Elastic modulus

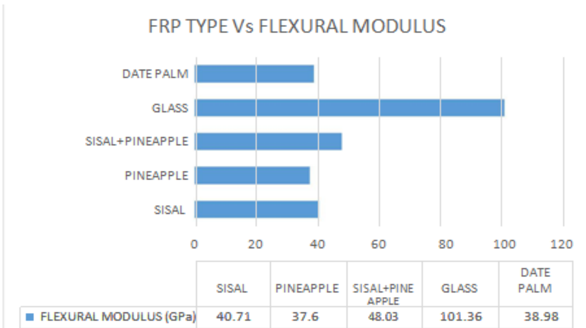

Fig. 7.4: Type of FRC Vs Flexural Modulus

7.3 IMPACT TEST:

Impact test is conducted on the fiber composite material carried upon impact testing machine and the impact strength variation is represented. Graph 7.5 shows the variation of the impact strength of the composites embedded in the epoxy matrix.

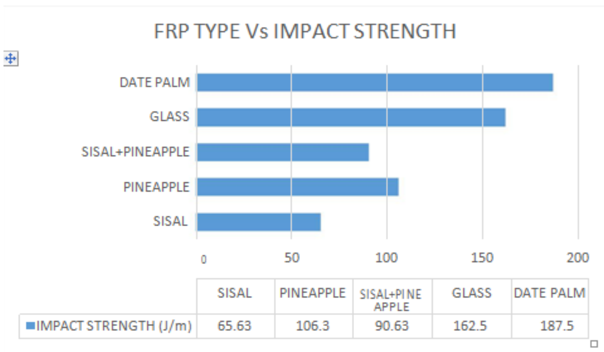

Fig. 7.5: Type of FRC Vs Impact Strength

VIII. CONCLUSION

From the results, it can be concluded that glass Fiber Reinforced Composite has highest Tensile strength, Flexural strength, Flexural modulus than compared to natural FRC. Hybrid FRC consisting of Sisal and Pineapple has superior elastic modulus whereas FRC with date palm is having superior impact strength. Depending upon the application, we can choose suitable FRC.

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