# A Comparative study on Properties of Natural Fiber Reinforced Composites: A Review

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***Abstract:***

***This review paper enumerates the comparative study of Chemical, Mechanical, Flexural, and impact properties of Natural fiber polymer matrix composites with natural fibers like Hemp, Sisal, Kenaf, Jute, Coir, Abaca and comparing with Glass fiber. Today the natural fibers reinforced composites drawing attention due to their renewable, low weight, recyclable, non- corrosive, biodegradable uniqueness, but at the same time mechanical properties are poor compared to glass fiber. These natural fibers have potential to replace synthetic fibers in automobile applications, transportation, packaging etc. At the fiber–matrix interface the chemical, mechanical and reaction bonds can be made strong enough by applying coupling agents, proper drying and chemical treatment, this tends to improve the mechanical properties of natural fiber composites.***

***Keywords:*** *Natural fibers, chemical, mechanical flexural, and impact properties, additive filler materials.*

## 1. Introduction

### Composites

Composites are the anisotropic, non homogeneous structural materials made up of two or more materials (Matrix and fiber) having different physical or chemical properties, combined together to produce a material which is having entirely different and enhanced properties. The specific modulus and specific strength of composites are high. Specific modulus (E/ρ) measures the mechanical advantage. Ex: The strength of a graphite/epoxy unidirectional composite will be same as that of steel, but specific strength (σ/ρ) is three times greater than steel. It means cross section of graphite/epoxy is same, but mass is 1/3$^{rd}$ of steel. The Bricks made up of clay and reinforced with Straw is a primitive example of the application of composites. The individual constituent's clay and straw cannot meet the purpose, but when they put together the straw serves the purpose of blunting the unwanted crack in the dry clay. Straw acts as reinforcement and clay acts as matrix and is a Green composite where both the reinforcement and matrix are the renewable natural resources.

### Fibers, Matrices, and, Fiber-Matrix Interface.

**Fibers:**

Fibers are used as Reinforcement and following four factors of fibers, contributes to the mechanical performance of a composite

a) **Length:** Long fibers improve impact resistance, surface finish, and short fibers provide low cost, easy to work and high strength.
b) **Orientation:** Fibers oriented in one direction provides high strength and stiffness in that direction, and fibers oriented in more than one direction gives strength and stiffness in those directions.
c) Shape: fibers with circular shape are easy for manufacturing and handling.
d) **Material:** Material of fibers decides mechanical properties of composites like elastic moduli, strength etc.,

**Matrix:**

The matrix holds, protects and distributes the load to the reinforcing fibers. Matrix has low mechanical properties compared to fibers. Matrix influence the following performances of composites i.e. compressive strength, Shear strength, Shear modulus, Thermal coefficient of expansion, Thermal resistance, Fatigue strength etc.,

**Fiber Matrix interface:**

Chemical, mechanical, and reaction bonding between fiber and matrix forms at interface, and it determines load distribution to the fiber and place a major role in improving mechanical properties of composites.

## Natural fiber composites:

Natural fiber reinforced composites are the composites in which fibers of Plants like, Hemp, Sisal, Flax, Kenaf, Jute etc., and fibers of Animals like wool, silk etc., reinforced in polymer or natural matrices. As the development in Technology grown and demand for the higher end properties, to withstand more temperature, stress for different applications is needed. And is almost fulfilled by the invention of synthetic fibers and plastics i.e., Glass, Aramid, Graphite etc as reinforcement fibers and Epoxies, Polyesters (Thermo set), Polyethylene, polystyrene (Thermoplastics) as matrices.

## Why Natural fiber composites?

Fiber reinforced plastics(FRP) and glass fiber in FRP (GFRP) composites have excellent properties such as high strength, chemical stability, but recycling and disposal after usage affects seriously the environment. On the other hand natural fibers are renewable, non-corrosive, low weight, recyclable biodegradable, and high thermal insulation property due to presence of lumen, these advantages made them potential to replace the synthetic fibers. And at the same time natural fibers having disadvantages like, moisture absorption, quality variations, thermal instability, and poor mechanical properties compared to glass fiber [1].

## Filler Materials and Resins

### Filler materials:

The suitable mechanical properties can be improved by adding fillers and composites can be made low cost with high strength. A Cenosphere made of Silica and alumina filled produced during coal combustion in thermal power plants can be used as a filler to produce a light weight composite. The Tensile strength and Hardness property increases with increase in the percentage of filler material. Other filler materials include Silicon carbide, tungsten carbide, rice husk, natural rubber, etc., by adding the fillers it not only increases the strength, but also increases the mechanical properties. [2, 4]

**Table 1 to Table 7,** shows the physical properties of silicon carbide, Tungsten carbide, Aluminum oxide, Fly ash, Cenosphere, Rice husk, and Natural rubber filler materials.

**Table 1: Properties of Silicon carbide: [2, 4]**

| *Physical property* | *Values* |
|---|---|
| *Density (g/cc)* | *3.1* |
| *Elastic modulus Gpa)* | *410* |
| *Compressive strength(Mpa)* | *3900* |
| *Hardness(kg/mm$^2$)* | *2800* |
| *Flexural strength (Mpa)* | *550* |

| *Physical property* | *Values* |
|---|---|
| *Density (g/cc)* | *15.63* |
| *Elastic modulus (Gpa)* | *530-700* |
| *Compressive strength(Mpa)* | *2700* |
| *Hardness(kg/mm$^2$)* | *1400* |

**Table 2: Properties of Tungsten carbide: [2, 4]**

**Table 3 :properties of Aluminum oxide (Al2O3)[2,4]**

| *Physical property* | *Values* |
|---|---|
| *Density (g/cc)* | *3.89* |
| *Elastic modulus (Gpa)* | *375* |
| *Compressive strength(Gpa)* | *2.6* |
| *Hardness(kg/mm$^2$)* | *1440* |

**Table 4: properties of Fly Ash**

| *Physical property* | *Values* |
|---|---|
| *color* | *Whitish gray* |
| *Density (g/cc)* | *1.49* |
| *Specific gravity* | *2.3* |
| *Fineness (cm$^2$/gm)* | *3200* |

**Table 5: properties of Cenosphere**

| *Physical property* | *Values* |
|---|---|
| *color* | *Gray/White* |
| *Density (g/cc)* | *0.85* |
| *Size (µm)* | *0.39-0.45* |
| *Thermal conductivity(W/m k)* | *0.036-.060* |

**Table 6: properties of Rice husk**

**Table 7: properties of Natural rubber**

| Physical property | Values |
|---|---|
| Specific gravity | 0.92 |
| Tensile strength | >20 Mpa |
| Hardness | 62-72 IRHD (International rubber hardness degrees) |
| Dielectric constant | 2.37 |

### Resins:

Different Resins can be used as a matrix with natural fiber composites depending on the requirements of the applications. Some important resins used and its properties are shown in **Table 8 and Table 9**. [2, 4]

**Epoxy Resin:**

**Table 8: Properties of Epoxy resin [2, 4]**

| Properties | Values |
|---|---|
| Viscosity @25° c | 12000-13000 |
| Tensile strength (Mpa) | 73 |
| Flexural strength(Mpa) | 60 |
| Modulus of Elasticity (Gpa) | 5.0 |

**Polyester Resin:**

**Table.9: Properties of Polyester resin [2, 4]**

| Properties | Values |
|---|---|
| Viscosity @25° c | 250-350 |
| Tensile strength (Mpa) | 40 |
| Flexural strength(Mpa) | 45 |
| Modulus of Elasticity (Gpa) | 3.3 |

## Properties of Natural fibers

In this study Chemical, Mechanical, Flexural and Impact properties of Hemp, Sisal, Kenaf, Jute, Coir and Abaca are studied.

| Physical property | Values |
|---|---|
| color | Gray |
| Size | <45 Microns |
| Specific gravity | 2.3 |

The incompatibility between the Hydrophilic nature of natural fibers, and the hydrophobic nature of thermoplastics matrix leads to poor fiber-matrix interface bonding, and fiber can be chemical treated to improve mechanical properties.

| Types of fibers | Cellulose (wt %) | Hemi cellulose (wt %) | Lignin (wt %) |
|---|---|---|---|
| Hemp | 57-77 | 14-22.4 | 3.7-13 |
| Sisal | 78 | 25.7 | 12.1 |
| Kenaf | 45-57 | 8-13 | 21.5 |
| Jute | 59-71.5 | 13.6-20.4 | 11.8-13 |
| coir | 37 | 20 | 42 |
| Abaca | 56-63 | 20-25 | 7-13 |

**a. Chemical composition / properties:**

These are the properties of material becomes evident during or after a chemical response. **Table 10** shows chemical composition of different natural fibers.

**Table 10: Chemical composition of Natural fibers [5]**

**b. Mechanical properties**:

These properties of material become evident during connected load. **Table 11** shows different mechanical properties of different fibers.

**Table 11: Mechanical properties of Natural fibers [5, 6]**

| Types of fibers | Tensile strength (Mpa) | Young's modulus(Gpa) |
|---|---|---|
| Hemp | 550-900 | 70 |
| Sisal | 600-700 | 38 |
| Kenaf | 930 | 53 |
| Jute | 320-800 | 8-78 |
| Coir | 175 | 4-6 |
| Abaca | 400-980 | 6.2-20 |
| E glass | 2000-3500 | 70 |

| Type of Fiber | Tensile strength (MPa) | Resin used |
|---|---|---|
| Hemp | 50 | Poly ester |
| Sisal | 29.7 | Epoxy |
| Jute | 32.3 | Poly ester |
| Coir | 13.05 | Poly ester |
| Glass | 678 | Epoxy |

The mechanical properties of Natural fiber reinforced polymer matrix composites can be increased by adding fillers, such as Sic, Tungsten carbide, $Al_2O_3$, cenosphere, fly ash, [4, 25]. **Table 12** and **Table 13**

| *Types of fibers* | *Impact strength KJ/m$^2$* |
|---|---|
| *Hemp* | *7.41* |
| *Sisal* | *8.36* |
| *Coir* | *8.37* |
| *Glass fiber/E-glass* | *17.82* |

show the Tensile strength of different fibers with and without fillers.

**Table.12: Tensile strength of different natural fibers composites with different Resins/polymer without Fillers [4, 6]**

| *Type of Fiber* | *Filler material* | *Resin* | *% of Filler* | *Tensile strength* |
|---|---|---|---|---|
| *Jute* | *Fly ash* | *Polyester* | *10* | *28.94* |
| *Jute* | *Rice husk* | *Epoxy* | *5* | *44.63* |
| *Jute* | *Rubber* | *Epoxy* | *10* | *74.81* |
| *Coir* | *Sea shell powder* | *Polyester* | *10* | *31* |

**Table.13: Tensile strength of different natural fibers composites with different resins with fillers [4, 5, 6, 14]**

| *Types of Fibers* | *Flexural strength (Mpa)* | *Resin used* |
|---|---|---|
| *Hemp* | *99* | *polyester* |
| *Coir* | *35.42* | *Polyester* |
| *Jute* | *105* | *polyester* |

**c. Flexural Strength:**

It is the measure of resist to failure in Bending. **Table 14** and **Table 15** shows the flexural strength of natural fibers with and without fillers

| *Type of fiber* | *Filler material* | *Flexural strength* | *Resin used* |
|---|---|---|---|
| *Jute* | *$Al_2O_3$ 10%* | *59* | *Epoxy* |
| *Sisal/Glass* | *Sic 9%* | *467.5* | *Epoxy* |
| *Coir* | *Seashell powder* | *56.174* | *Polyester* |

**Table.14: Flexural strength of Natural fiber without filler [4, 5, 14]**

**Table.15: Flexural strength of Natural fiber And Glass fiber with filler [4, 5, 14]**

**d. Impact properties**:

It is the measure of amount of energy absorbed before fracture due to impact load.
**Table 16** shows the impact strength of different fibers

**Table.16: Impact strength, of Natural fiber And Glass fiber [7, 8, 14, 15, 27]**

The Impact strength of the fiber reinforced polymer composites is higher strength compared to polymer composites with particulate and flakes. The Natural fiber reinforced polymer composites shows lesser strength compared to glass fiber reinforced with epoxy matrix by poor interfacial bonding, due to Hemi cellulose, and strength can be increased by treating the natural fiber with acidic and alkaline solutions. Whereas the glass fiber reinforced epoxy composite shows high strength, due to perfect bonding of glass fiber with epoxy matrix. [27].

## 2. LITERATURE SURVEY

It is found that many works have been carried out to study the properties of different Natural fibers, and to improve the properties and some of them are as follows.
***Ryosuke Osugi, et al*** [1] conducted the experimental method to study the thermal conductivity of Manila Hemp fiber with poly lactic acid (PLA) and epoxy as matrix ***K.G.Prakash, et al*** [2] studied the tensile properties, hardness properties and chemical properties of the hemp fiber reinforced polymer matrix composites with filler materials. The result shows that the hemp fiber reinforced polymer matrix composites with particles having good strength with equivalent mechanical and chemical strength. ***Tushar Sonar, et al*** [3] concluded from their study that, Natural fibers need to be treated chemically so as to improve interfacial adhesion between fiber surface and polymer matrix. The chemically treated natural fibers show better improvement in properties than untreated fibers. ***Abhilash Gouda T H, et al*** [4] studied to estimate and understand the effect of different natural fibers and filler materials that are used in fabrication of polymer composite material and analyze the verified results like tensile and flexural. In this study different composites are prepared with jute, hemp, coir, sisal, bamboo and, banana fibers and filler materials like silicon carbide, tungsten carbide, fly ash, egg, rubber, and rice husk etc. ***K. Srinivas, et al*** [5] made a review on Chemical and Mechanical Properties of Natural Fiber Reinforced Polymer Composites and the chemical

and mechanical properties of the different natural fibers composites were compared. Present days natural fibers are attracting many scholars and researchers due to its cost and largely available in nature also processing of these fibers is not hard in comparison to the conventional fiber's production. Also, Environmental awareness and a growing concern with the greenhouse effect have triggered the construction, automotive, and packing industries to watch out for eco-friendly materials that can replace conventional synthetic polymeric fibers. ***Jena Pandey, et al*** [6] in this, Jute textile reinforced polymer (JFRP)composite system was developed and its tensile, flexural behavior was characterized and compared with that of carbon textile (CFRP) and glass textile (GFRP) reinforced polymer composite. The work carries out the study of failure modes. ***Dr P V Senthiil, et al*** [7] work focuses on the fabrication of polymer matrix composites by using natural fibers like jute, coir, and hay which are abundant in nature in desired shapes by the help of various structures of patterns and calculating the material characteristics (flexural modulus, flexural rigidity, hardness number, % gain of water, wear resistance, bonding structure) by conducting tests like flexural test, hardness test, water absorption test, wear test, SEM analysis and their results. ***S. P. Kumar Gudapati, et al*** [8] work is carried out to investigate the thermal conductivity characterization of Areca Palm fiber reinforced polymer composites. The results are explicated by varying the volume fraction, temperature and also the fiber angles ($0^0$,$45^0$,$90^0$). There is discrepancy in thermal conductivities with the fiber orientation. At maximum volume fractions, the Areca Palm FRPC attained the values of 0.175W/m.K, 0.181W/m.K, 0.188W/m K for the fiber angles of $0^0$,$45^0$,$90^0$ respectively. ***C.H.Chandra Rao, et al*** [9] study investigated the wear behavior of treated and untreated coir dust filled epoxy resin matrix composites were studied. The effect of treated and un treated coir dust concentration (10%, 20% and 30%), varying loads (10, 20 and 30N) and varying velocities (300, 400 and 500) on the abrasive wear rate of composite has been analyzed. In this research work, jute fiber reinforced polypropylene matrix composites have been developed by hot compression molding technique with varying process parameters, such as fiber condition (untreated and alkali treated), fiber sizes (1, 2 and 4 mm) and percentages (5%, 10% and 15% by weight). The developed jute fiber reinforced composites were then characterized by tensile test, optical and scanning electron microscopy. The results show that tensile strength increases with increase in the fiber size and fiber percentage; however, after a certain size and percentage, the tensile strength decreases again. Compared to untreated fiber, no significant change in tensile strength has been observed for treated jute fiber reinforcement. ***P. Hema Amity, et al*** [11] 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. ***Amit Kumar Tanwer*** [12] In present study, mechanical properties for these natural fiber composites were evaluated. Here, these natural fibers are the fiber reinforcement and epoxy polymer resin as a matrix material. Composite were prepared with different longitudinal (Unidirectional) natural fiber reinforced with epoxy based polymer. Mechanical test i.e. tensile test were performed on UTM machine and the results are reported. The result showed tensile and compressive strength of different unidirectional natural fiber reinforced epoxy polymer composites and presented the conclusion. ***I.S. Aji, et al*** [13] this review however will focus on Kenaf; a very important natural fiber with robust mechanical properties. Good number of journal papers have been reviewed here that touch on cultivation of kenaf and its consequent effect, chemical treatment of natural fibers, matrix combinations, processing techniques, and environmental effects on composite. ***T. N. V. Ashok Kumar, et al*** [14] the main aim of this work is to fabricate and investigate mechanical properties of hemp natural fiber reinforced polyester composites. The fibers were treated with 10% of NaOH, for 2-3 hours under constant stirring and kept for a day at room temperature and then dried in open air for 3-4 days. The chemical treatment is used to increase the tensile strength and removes the moisture content from the fibers. ***Amal A.M. Badawy*** [15] the impact behavior of glass fibers reinforced polyester (GFRP) was experimentally investigated using notched Izod impact test specimen. The experimental program was carried out on unidirectional laminate of GFRP in directions $0^0$, $45^0$and $90^0$ in additions to cross-ply laminate. ***Sai Raj Taj, et al*** [16] Many types of natural fibers have been investigated for use in plastics including Flax, hemp, jute, straw, wood fiber, rice husks, wheat, barley, oats, Natural fibers are increasingly used in automotive and packaging materials, ***T. Vinod Kumar et al*** [17] The effect of Coconut shell powder on the mechanical properties of coconut fiber reinforced epoxy composites is presented in this paper Coconut shell powder (filler) at different contents. It was found that the addition of filler had an in significant effect on the mechanical properties. ***Kotresh Sardar, et al*** [18] this paper constitutes the study of Mechanical Properties like Tensile Strength of 10%, 20%, 30% and 40% KFRPC material used as Bio-material. An attempt is made to develop the 10%, 20% 30% and 40% KFRPC material with low density, economical for tissue implant with respect to biocompatibility and the mechanical behavior of human tissues, such as Tendon. ***K.G. Prakash, et al*** [19] this paper presents an experimental investigation on the mechanical properties for Abaca natural polymer reinforced omposites. The raw material used in the present work is long Abaca fiber. The epoxy resin and hardener are mixed according to the weight ratio. The tests were carried out as per ASTM standards. ***M P West man, et al*** [20] the need for renewable fiber reinforced composites has never been as prevalent as it currently is. The following preliminary research has investigated the use of Kenaf, *Hibiscus cannabinus, as* a possible glass replacement in fiber reinforced composites. ***Layth Mohammed et.al*** [21] the aim of this review article is to provide a comprehensive review of the foremost appropriate as well as widely used natural fiber reinforced polymer composites (NFPCs) and their applications. In addition, it presents summary of various surface treatments applied to natural fibers and their effect on NFPCs properties. ***Shrikant M. Harle*** [22] the aim of this review article focuses on how now a days, natural fibers have received much more attention from the structural engineers all over the world and utilization of natural fibers as reinforcement in polymer composite ***U.S. Bongarde, et al*** [23] This paper deals with review of different natural fibers reinforced polymer composite with its manufacturing processes and characterization especially coir and jute fiber. ***Pradip Sature, et al*** [24] the focus of current research work is to investigate the mechanical characteristic and performance of blended jute/hemp epoxy composites as compared to pure jute and hemp fiber reinforced composites. ***Arpitha G R, et al*** [25] this paper presents a brief overview of the tensile properties of fiber reinforced polymer materials. The tensile properties of the natural fiber reinforced polymer composites have been compared with that of synthetic fiber reinforced polymer composites and fiber reinforced composites with particles. ***Thingujam Jackson Singh, et al*** [26] this review focus on in recent years, due to the depletion of the non-renewable resources and increasing environmental consciousness, the researchers are working to develop a new material for replacement. Natural fibers like bamboo, sisal, jute, coir, hemp, etc being a strong contender for replacing the synthetic fibers like glass, carbon, etc. ***Bhanu prakash N, et al*** [27] The present work describes the development of impact strength of different types of polymer composites with glass fiber reinforcement, epoxy resin and different filler ranging from fibers, particulates and flakes. ***Shrikant M. Harle*** [28] this paper will provide a review on the different properties of natural FRP composites for various applications in the civil infrastructure. ***Venkateswara Rao T, et al*** [29] This experimental study has aims to investigate the mean tensile strength, tensile modulus, specific tensile strength, specific tensile modulus, mean flexural strength, flexural modulus and impact strength of bamboo fiber filled with Fly ash filler reinforced Hybrid composites. The specimens were prepared by Hand lay-up technique. ***Tara Sen, et al*** [30] an attempt is made to study the possibilities of reusing the sisal fibers, bamboo fibers, coir fibers and jute fibers which not only has various applications but also helps to solve the problem of waste disposal at least to a small extent. Economic and other related factors in many developing countries where natural fibers are abundant demand that scientists and engineers apply appropriate technology to utilize these natural fibers as effectively and economically as possible.

## 3. CONCLUSIONS:

From the Literature review it is observed that:

- A filler material improves the strength of Natural fiber reinforced composites considerably. Increase in percentage of filler material increases strength.
- Natural fiber reinforced composites have better thermal insulation properties.
- Silicon carbide (3.21 gm/cc) is having less density compared to tungsten carbide (15.63 gm/cc).
- Natural fibers are Cheaper, less weight, biodegradable, easily available compared to synthetic fibers.
- Mechanical property of natural fibers is much less than synthetic fibers.
- Addition of filler materials, chemical modification and proper drying the fibers make them potential to replace in Automobile sector.
- Natural fibers have lumen, which provides great thermal insulation property and is optional function to use them.

# 4. REFERENCES:

[1] Ryosuke Osugi, Hitoshi Takagi "*Thermal Conductivity Behavior of Natural fiber reinforced composites*" Asian Pacific conference for materials and Mechanics 2009 at Yokohama, Japan, November 13-16

[2] K.G.Prakash, Dr.H.K.Rangavittal, Dr.A.Thimmana Gouda "*Effect of Filler material for Hemp fiber reinforced polymer composites in Automobile applications*" (IJMET) volume 8, Issue 11, November 2017

[3] Tushar Sonar, Shirish patil, Vikram Deshmukh, Rishi Acharya "*Natural Fiber Reinforced Composite Material-A Review*" (IOSR-JMCE)

[4] Abhilash gowda TH , Dr.Madhusudhan "*A study on tensile and flexural properties of polymer composites made of different natural fiber and different filler materials :A Review"* (IRJET) Volume:05 Issue:04 Apr-2018

[5] K.Srinivas, A.Lakshumu Naidu, M.V.A.Raju *"A Review on Chemical and Mechanical properties of Natural fiber Reinforced Polymer Composites"* International journal of Perform ability Engineering" Volume 13, No.2, March-2017

[6] Dr, P, V, Senthil, Aakash Sirsshti *"Studies on Material and Mechanical Properties of Natural fiber Reinforced Composites"* (IJES), volume: 3, Issue: 11 2014.

[7] P.Hema Aditya, K.Shiva Kishore, D.V.V.Krishna Prasad "Characterization Of Natural Fiber Reinforced Composites" (IJES) Volume-4, Issue-6, June -2017.

[8] S.P.Kumar Gudapati, K.Supraja, A.V.Ratna Prasad "Thermal Conductivity Characterization of Areca plam Fiber Reinforced Polymer Composites" International Journal of Pure and Applied Mathematics" Volume 119 , No.17, 2018

[9] Amit kumar Tanwer, Roorkee Institute of Technology Roorkee, India"Effect on Mechanical Properties for Jute,Coir and Bamboo Natural Fiber Reinforced Epoxy based Composites" American International Journal of Research in Science Technology, Engineering & Mathematics.

[10] C.H.Chandra Rao, S.Madhusudhan, G.Raghavendra, E.Venkateswara Rao "Investigation in to Wear behavior of coir Fiber Reinforced Epoxy Composites with the Taguchi Method" Volume:2 Issue:5 September-October 2012

[11] H.M.M.A.Rashed, M.A.Islam and F.B.Rizvi "Effects of Process Parameters on Tensile Strength of Jute Fiber Reinforced Thermo plastic Composites" Journal of Naval Architecture and Marine Engineering" June 2006.

[12] Jena Pandey, M.Ramachandran, Kanak Kalita Comparison of Jute fiber over Glass fiber, and Carbon fiber reinforced plastic material composites used for Civil Structure" April-2015.

[13] I.S. Aji, S.M. Sapuan, E.S. Zainudin, and K. Abdan "Kenaf Fibers As Reinforcement for Polymer Composites: A Review" (IJMME), Vol. 4 (2009), No. 3, 239-248.

[14] T. N. V. Ashok Kumar, J. Subash Kumar, J. Vijay Kumar *"Fabrication and Investigation of Mechanical Properties Hemp Fiber Reinforced Polyester Composites"* 2017 IJSRST | Volume 3, Issue 3

[15] Amal A.M. Badawy *"Impact behavior of glass fibers reinforced composite laminates at different temperatures"* in Shams Engineering Journal-ASEJ (2012) 3, 105–111.

[16] Saira Taj, Munawar Ali Munawa, and Shafi ullah Khan *"Natural Fiber Reinforced Composites"* Research gate Received April 2006, accepted March 2007

[17] T. Vinod Kumar, M. Chandrasekaran and V. Santhanam *"Characteristics Analysis of Coconut Shell husk Reinforced polymer Composites"* VOL. 12, NO. 8, APRIL 2017 ISSN 1819-6608, Journal of Engineering and Applied Sciences.

[18] Kotresh Sardar, Dr. K. Veeresh, Manjunatha Gowda *"Characterization and Investigation of Tensile Test on Kenaf Fiber Reinforced Polyester Composite Material"* International Journal of Recent Development in Engineering and Technology Website: (ISSN 2347-6435(Online) Volume 2, Issue 6, June 2014.

[19] K.G. Prakash, Manjunath K.B, Achutananda K.B, Chandru B.G *"Investigation of Tensile, Impact and Moisture Properties of Abaca Natural Polymer Reinforced Composites"* International Journal of Scientific & Engineering Research Volume 8, Issue 12, December-2017

[20] M P Westman, S G Laddh, L S Fifield ,T A Kafentzis and K L Simmons *"Natural Fiber Composites: A Review"* Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830 March 2010.

[21] LaythMohammed, M. N. M. Ansari, Grace Pua, Mohammad Jawaid. and M. Saiful Islam. *"A Review on Natural Fiber Reinforced Polymer Composite and Its Applications"* Hindawi Publishing Corporation International Journal of Polymer Science Volume 2015, Article ID 243947. Accepted 30 August 2015.

[22] Shrikant M. Harle "*The Performance of Natural Fiber Reinforced Polymer Composites: Review"* International Journal of Civil Engineering Research. SSN 2278-3652 Volume5,no3(2014),

[23] U.S.Bongarde1, V.D.Shinde *"Review on natural fiber reinforcement polymer composites"* IJESIT Volume 3, Issue 2, March 2014.

[24] Pradip Sature, Ashok Mache *"Mechanical Characterization and Water Absorption Studies on Jute/Hemp Reinforced Hybrid Composites"* American Journal of Materials Science 2015, 5(3C): 133-139 DOI: 10.5923/c.materials.201502.27

[25] Arpitha G R, Sanjay M R, B Yogesha, *" A review on comparative valuation of fiber reinforced polymer matrix composites"* Advanced Engineering and Applied Sciences: Received 26 August 2014; accepted 01 October 2014.

[26] Thingujam Jackson Singh, Sutanu samanta *"characterization of natural fiber reinforced composites-*

*bamboo and sisal: a review"* IJRET ISSN: 2319-1163, PISSN: 2321-7308 Vol: 03 Special Issue: 07 May-2014.

[27] Bhanu praksh N, T. Madhusudhan *"Investigative study on impact strength variation in different combination of polymer composites"* International Journal of Engineering Research and General Science Volume 3, Issue 2, Part 2, March-April, 2015.

[28] Shrikant M. Harle *"The Performance of Natural Fiber Reinforced Polymer Composites: Review"* International Journal of Civil Engineering Research. ISSN 2278-3652 Volume 5, Number 3 (2014).

[29] Venkateswara Rao T, Venkatarao K , Lakshmi Kanth *"Mechanical Properties of Bamboo Fiber filled with Fly Ash filler Reinforced Hybrid Composites"* (IJERT) ISSN: 2278-0181 ,Vol. 3 Issue 9, September- 2014.

[30] Tara Sen and H. N. Jagannatha Reddy *"Various Industrial Applications of Hemp, Kenaf, Flax and Ramie Natural Fibers"* International Journal of Innovation, Management and Technology, Vol. 2, No. 3, June 2011.