



## AN EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF NATURAL HYBRID COMPOSITES

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### ABSTRACT

The present experimental study aims at learning the mechanical behaviour of natural hybrid reinforced jute composites. Samples of Jute-jute-Epoxy, Jute-carbon- Epoxy & jute-kevlar-epoxy hybrids were manufactured using hand layup method. Specimens were cut from the fabricated laminate according to the ASTM standards by water jet cutting machine for different experiments. Testing has been performed under Universal testing machine (UTM). Tensile strength &

compression strength are observed and compared between the hybrids to perceive the change in strength.

**KEYWORDS:** composite materials, natural fibers, mechanical properties, Jute, Kevlar.

### INTRODUCTION

#### A. Jute fiber

The fibers are extracted from the ribbon of the stem. When harvested the plants are cut near the ground with a sickle shaped knife. The small fibers, 5 mm, are obtained by successively retting in water, beating, stripping the fiber from the core and drying. A single jute fiber is a three dimensional composite composed mainly of cellulose, hemicelluloses, and lignin with minor amounts of protein, extractives and inorganic. These fibers were designed, after millions of years of evolution, to perform, in nature, in a wet environment. Nature is programmed to recycle jute, in a timely way, back to basic building blocks of carbon dioxide,

and water through biological, thermal, aqueous, photochemical, chemical, and mechanical degradations.

In order to expand the use of jute fiber-based composites in adverse environments, it is necessary to interfere with nature's recycling chemistry. One of the most studied chemistries to interfere with nature's recycling chemistry and improve performance properties of jute fiber based composites involves reactions with acetic anhydride (Acetylation). Chemical modifications of this type react with accessible hydroxyl groups on the cell wall polymers. These are the same hydroxyl groups involved in the natural degradation chemistries.

## B. Properties of the Jute fiber

**Table 1: Properties of the Jute fiber**

Description	Properties
Specific gravity	1460 Kg/m <sup>3</sup>
Water absorption	13 %
Tensile strength	400-800 Mpa
Stiffness	10-30 KN/mm <sup>2</sup>
Available countries	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan,



**Fig 1: Jute Fiber Plant & Jute-fiber-hanging-out-to-dry- in-the-sun**

## C. Cost of Fibers

The cost of the cellulose fibers is also a factor that could influence fiber selection. Fiber prices tend to fluctuate considerably and are dependent on a number of factors, such as supply and demand, quality and exchange rates. A comparison of the relative costs of a number of fibers can be seen in Table 2.

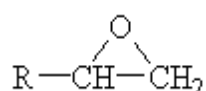
**Table 2: Natural Fiber Costs.**

Fiber	Price	Price Rs /
<b>Jute</b>	0.3 – 0.7	15 – 75
<b>Hemp</b>	0.5-1	25- 50
<b>Flax</b>	0.4-0.8	20 - 40
<b>Sisal</b>	0.4-1	20 -50
<b>Wood</b>	0.2-0.4	10 - 20
<b>Glass</b>	1.5-3.2	75 - 160
<b>Carbon</b>	10-200	500 –

## D. Resin System

### i. Epoxy Resins

Epoxy resin is defined as a molecule containing more than one epoxide groups. The epoxide group also termed as, oxirane or ethoxyline group, is shown below,

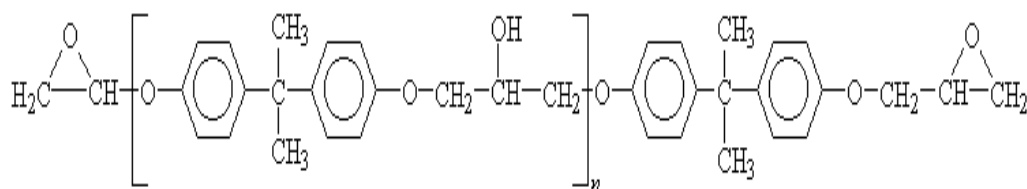


These resins are thermosetting polymers and are used as adhesives, high performance coatings and potting and encapsulating materials. These resins have excellent electrical properties, low shrinkage, good adhesion to many metals and resistance to moisture, thermal and mechanical shock. Viscosity, epoxies equivalent weight and molecular weight are the important properties of epoxy resins.

### ii. Types of Epoxy Resins

#### a. Diglycidyl Ether of Bisphenol-A (DGEBA)

Diglycidyl ether of bisphenol-A (DGEBA) is a typical commercial epoxy resin and is synthesized by reacting bisphenol-A with epichlorohydrin in presence of a basic catalyst.

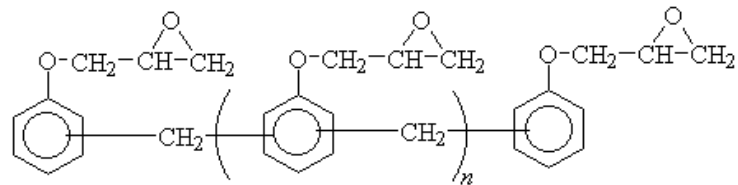


#### *Structure of DGEBA*

The properties of the DGEBA resins depend on the value of  $n$ , which is the number of repeating units commonly known as degree of polymerization. The number of repeating units depend on the stoichiometry of synthesis reaction. Typically,  $n$  ranges from 0 to 25 in many commercial products.

### b. Novolac Epoxy Resins

Novolac epoxy resins are glycidyl ethers of phenolic novolac resins. Phenols are reacted in excess, with formaldehyde in presence of acidic catalyst to produce phenolic novolac resin. Novolac epoxy resins are synthesized by reacting phenolic novolac resin with epichlorohydrin in presence of sodium hydroxide as a catalyst.



**Structure of novolac epoxy resin**

### E. Manufacturing of composites

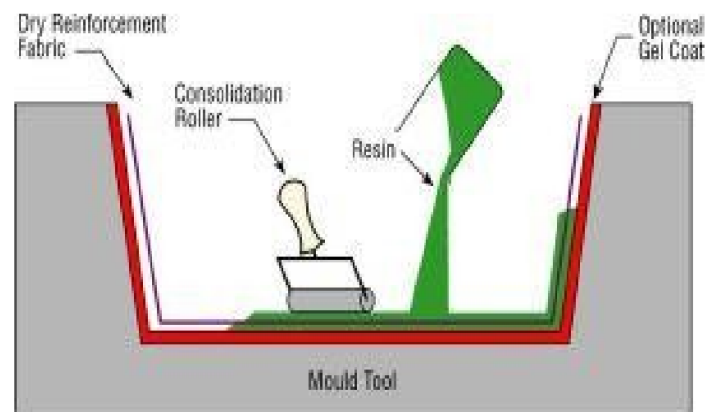
Taking composite materials as a whole, there are many different material options to choose from in the areas of resins, fibers and cores, all with their own unique set of properties such as strength, stiffness, toughness, heat resistance, cost, production rate etc. However, the end properties of a composite part produced from these different materials is not only a function of the individual properties of the resin matrix and fiber (and in sandwich structures, the core as well), but is also a function of the way in which the materials themselves are designed into the part and also the way in which they are processed. This section compares a few of the commonly used composite production methods and presents some of the factors to be borne in mind with each different process, including the influence of each process on materials selection.

#### a. Hand Lay-up Process

Hand lay-up is an open molding method suitable for making a wide variety of composites products including: boats, tanks, bathware, housings, RV/truck/auto components, architectural products, and many other products ranging from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds.

First a gelcoat is applied to the mould using a spray gun for a high-quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly

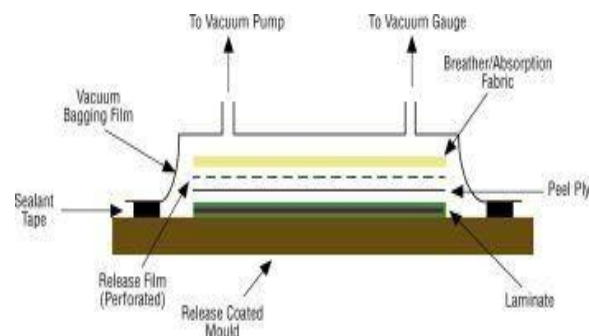
wetting the reinforcement, and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials, such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate to produce sandwich construction.



**Fig. 2 Hand Lay-up Process**

### b. Vacuum Bagging

In the simplest form of vacuum bagging, a flexible film (PVA, nylon, mylar, or polyethylene) is placed over the wet lay-up, the edges sealed, and a vacuum drawn. A more advanced form of vacuum bagging places a release film over the laminate, followed by a bleeder ply of fiberglass cloth, non-woven nylon, polyester cloth, or other material that absorbs excess resin from the laminate.



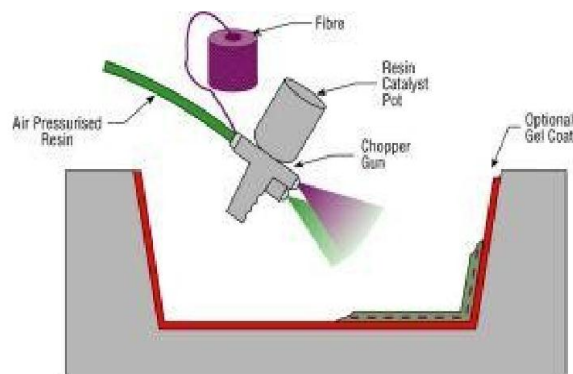
**Fig. 3 Vacuum Bagging**

A breather ply of a non-woven fabric is placed over the bleeder ply, and the vacuum bag is mounted over the entire assembly. Pulling a vacuum from within the bag uses atmospheric pressure to eliminate voids and force excess resin from the laminate. The addition of pressure further results in high fiber concentration and provides better adhesion between layers of sandwich construction. When laying non-contoured sheets of PVC foam or balsa into a

female mold, vacuum bagging is the technique of choice to ensure proper secondary bonding of the core to the outer laminate.

### c. Spray up process

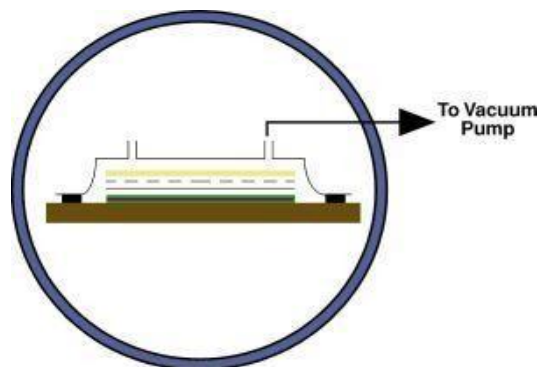
Spray-up or chopping is an open mold method similar to hand lay-up. A chopped laminate has good conformability and is sometimes faster than hand lay-up in moulding complex shapes. In the spray-up process the operator controls thickness and consistency, therefore the process is more operator dependent than hand lay-up.



**Fig. 4 Spray-up Process**

### d. Autoclave Processing

Moulding of prepregs is usually done in an autoclave (effectively a pressurized oven). The autoclave process offers one of the highest manufacturing standards for composites. Fabrics and fibers are pre-impregnated by the prepreg manufacturer, under heat and pressure or with solvent, with a pre-catalysed resin. The catalyst is largely latent at ambient temperatures giving the materials several weeks, or sometimes months, of useful life when defrosted. However, to prolong storage life the materials are stored frozen. The resin is usually a near solid at ambient temperatures, and so the pre-impregnated materials (prepregs) have a light sticky feel to them, such as that of adhesive tape.



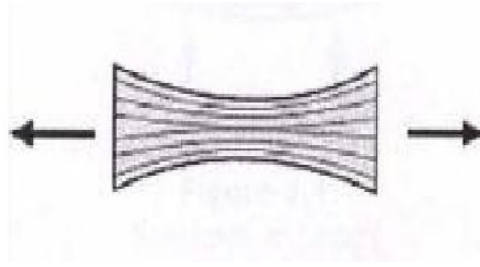
**Fig. 5 Autoclave Processing**

Unidirectional materials take fiber direct from a creel, and are held together by the resin alone. The prepregs are laid up by hand or machine onto a mould surface, vacuum bagged and then heated to typically 120-180°C. This allows the resin to initially reflow and eventually to cure. The autoclave provides additional pressure for the moulding, which can apply up to 5 atmospheres to the laminate.

## F. Testing of composites

Although composites have very favourable properties, they must withstand the same rigorous testing as steel and metal parts. This is to ensure that composites meet the demands of industry and international standards. Testing becomes essential in determining how the composites will perform many years down the line. Hence this has become a major part of production and design. There are four types of loads that any material in a structure has to withstand: Fracture, Flexural, Tension, Compression, and Shear.

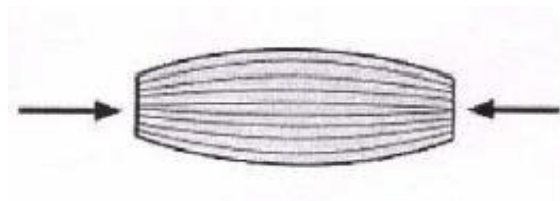
### a. Tension



**Fig.6 Specimen in Tension**

Figure 6 shows a tensile load applied to a composite. The response of a composite to tensile loads is very dependent on the tensile stiffness and strength properties of the reinforcement fibers, since these are far higher than the resin system alone.

### b. Compression



**Fig. 7 Specimen in Compression**

Figure 7 shows a composite under a compressive load. Here the adhesive and stiffness properties of the resin system are crucial, as it is the role of resin to maintain the fibers as straight columns and to prevent them from buckling.

## LITERATURE REVIEW

**Li et al.** Conducted a research to study the mechanical properties, especially interfacial performances of the composites based on natural fibers due to the poor interfacial bonding between the hydrophilic natural fibers and the hydrophobic polymer matrices. Two types of fiber surface treatment methods, namely chemical bonding and oxidization were used to improve the interfacial bonding properties of natural fiber reinforced polymeric composites. Interfacial properties were evaluated and analysed by single fiber pull-out test and the theoretical model. The interfacial shear strength (IFSS) was obtained by the statistical parameters. The results were compared with those obtained by traditional ways. Based on this study, an improved method which could more accurately evaluate the interfacial properties between natural fiber and polymeric matrices was proposed.

**Joshi et al.** Compared life cycle environmental performance of natural fiber composites with glass fiber reinforced composites and found that natural fiber composites are environmentally superior in the specific applications studied. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for the following reasons: (1) natural fiber production has lower environmental impacts compared to glass fiber production; (2) natural fiber composites have higher fiber content for equivalent performance, reducing more polluting base polymer content; (3) the light-weight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications; and (4) end of life incineration of natural fibers results in recovered energy and carbon credits.

**Rana et al.** In their work showed that the use of compatibilizer in jute fibers increases its mechanical properties. At 60% by weight of fiber loading, the use of the compatibilizer improved the flexural strength as high as 100%, tensile strength to 120%, and impact strength by 175%. The following conclusions may be drawn from this paper:

1. The sharp increase in mechanical properties and decrease in water absorption values after addition of the compatibilizer.
2. All these results justify that the role of jute fiber was not as a filler fiber but as a reinforcing fiber in a properly compatibilizer system.
3. This system produced a new range of low-energy, low- cost composites having interesting properties and should be given priority over costly and high-energy synthesis reinforcing fiber wherever possible.



**Gassan and Bledzki et.al** Used the coupling methods to improve the properties of composites. Composites have high level of moisture absorption, poor wettability, and insufficient adhesion between untreated fibers and the polymer matrix leads to deboning with age. To improve the properties of the composites, the natural reinforcing fibers can be modified coupling methods. The coupling agents have chemical groups which can react with fibbers or polymer and thus improve the interfacial adhesion.

This paper concerns with the use of MAH-PP copolymers as coupling agents in jute-propylene composites. It is found that the flexural strength was increased by 40% and flexural modulus by 90%. SEM investigation showed the improved fibbers-matrix adhesion which was due to the chemical bonds between fibbers and matrix provided by the coupling agent.

**Monteiro SN. Rodriquez et al.** Tries to use the sugar cane biogases waste as reinforcement to polymeric resins for fabrication of low cost composites. They reported that composites with homogeneous microstructures could be fabricated and mechanical properties similar to wooden agglomerates can be achieved.

**Hassan et al.** has converted the biogases into a thermo formable material through etherification of the fibbers matrix. The dimensional stability and mechanical properties of the composites prepared from esterifies fibers were reported in this work.

## OBJECTIVES

**The objectives of this project are as follows**

1. The primary objective of the present work is to fabricate composite laminates with
  - a) Jute fabric + Jute fabric + Epoxy resin of 3mm thickness
  - b) Jute fabric + carbon fiber + Epoxy resin of 3mm thickness
  - c) Jute fabric + Kevlar fiber + Epoxy resin of 3mm thickness, using simple hand layup technique.
2. To conduct tensile test and compression test for
  - a) Jute fabric + Jute fabric + Epoxy resin of 3mm thickness
  - b) Jute fabric + carbon fiber + Epoxy resin of 3mm thickness
  - c) Jute fabric + Kevlar fiber + Epoxy resin of 3mm thickness, as per ASTM standard D3039.
3. To obtain various results for these tests i.e. Ultimate Load in KN, Maximum Tensile strength and Compressive Strength in Mpa, and Displacement at Ultimate Load in mm for

the specimens used and to compare the values obtained for these specimens.

4. Comparison of Jute fabric + Jute fabric + Epoxy resin, Jute fabric + carbon fiber + Epoxy resin and Jute fabric + Kevlar fiber + Epoxy resin is done.

## EXPERIMENTAL DETAILS

### A. Materials

**Table 3: materials used and moulding process**

Reinforcing Fiber	Jute Fiber 500gsm, Kevlar Fiber 200gsm & Carbon Fiber 200gsm.
Matrix System	Epoxy Resin (lapox L-12 Atul ltd) & Hardener K-6.
Moulding Process	Hand lay-up followed by Room t moulding.
Reinforcements:	matrix ratio: 65:35

### B. Fabrication of the test laminates

Test laminates of 300 mm X 300 mm were initially fabricated to prepare mechanical test specimens by Hand lay-up followed by Room temperature.

### C. Preparation of the Resin Hardener System

The resin and hardener were to be mixed in a ratio of 100:10 by weight, as follows

1. An empty bowl and brush were taken and weighed.
2. Resin was added to the bowl and the brush setup and was placed on the electronic balance, till it registered the constant weight.
3. The hardener was added to the bowl and bowl was removed from the balance.

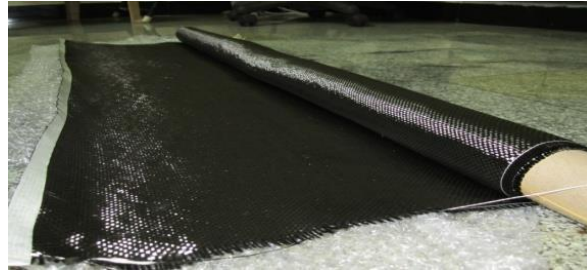
The resin and hardener were mixed thoroughly using the brush and is used immediately in the preparation of the laminate. From now on this mixture will be referred to as a “resin system”.

### D. Preparation of the reinforcing material

The fabric used was jute fiber of 500gsm, Kevlar fiber of 200 gsm and Carbon fiber in the form of rolls. The fabric roll is spread on the flat surface and required dimension of 300 mm x 300 mm is marked using the marker pen on the fabric spread and cut using a scissor manually. Required such layers of fabric were cut to get the required thickness of laminate in this study.



**Fig 8 Jute fabric 500gsm**



**Fig 9 Carbon fabric plain view 200gsm**



**Fig 10 Kevlar fabric 200gsm**

**Table 4: Material Properties**

SI No	Material	Density (g/cm <sup>3</sup> )	Volume fraction (%)	Ultimate Tensile strength	Modulus (Gpa)
1	Jute Fabric	1.3	0.325	393	13
2	Kevlar Fiber	1.44	0.325	3620	76
3	Carbon Fiber	1.76	0.325	4500	250
4	Epoxy	1.18	0.35	60	4.4

### E. Specimen Calculations

Ex: Jute/Jute / Epoxy:

a) Density of laminate =

$$\left( \frac{\text{Weight fraction of Jute fiber} \times \text{Density of Jute fiber}}{\text{Jute fiber}} \right) + \left( \frac{\text{Weight fraction of Jute fiber} \times \text{Density of Jute fiber}}{\text{Jute fiber}} \right) + \left( \frac{\text{Weight fraction of resin} \times \text{density of epoxy resin}}{\text{epoxy resin}} \right)$$

b) Mass of laminate = Density  $\times$  Volume of sample

c) Mass of resin and hardener used (35%) = Mass of laminate  $\times$  .35

d) Ratio of mass of resin to mass of hardener = 100:10

e) Mass of resin = Mass of resin and hardener  $\times$  (100/110)

f) Mass of hardener = Mass of resin and hardener  $\times$  (10/110)

g) Mass of Jute fiber used = Mass of laminate  $\times$  0.325 + Mass of laminate  $\times$  0.325 = 220.76 g.

h) Mass of each Jute fiber = 26.61 g.

i) Number of Jute fiber plies used

To prepare one laminate of 3mm thickness =

$$\frac{\text{Mass of Jute fiber used}}{\text{(Mass of each Jute fiber)}} = 8 \text{ plies}$$

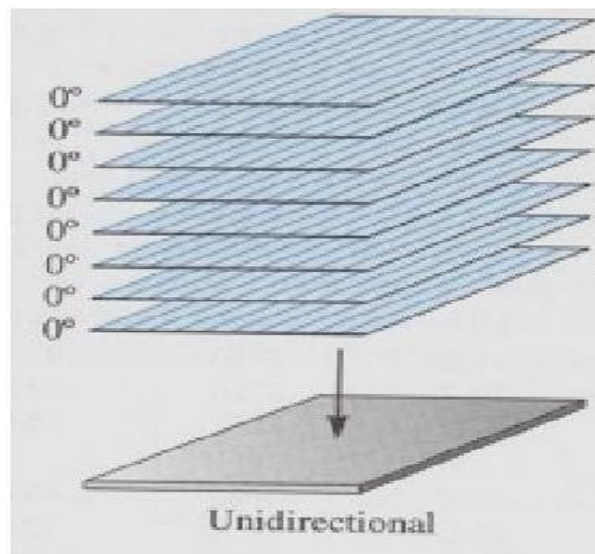
Number of fiber layers for each laminates:

- 1) Jute + Jute + Epoxy laminate 3mm thickness = 8 layers
- 2) Jute + kevlar + Epoxy laminate 3mm thickness = 13 layers
- 3) Jute + Carbon + Epoxy laminate 3mm thickness = 11 layers

### F. Layup process for laminate preparation

1. The resin and the hardener of required quantities are taken in a previously weighed empty bowl. They are mixed properly in the bowl using a paintbrush. The mixture is used immediately in the preparation of the laminate which otherwise would start gelatine.
2. A highly polished flat mould was cleaned and wiped dry with acetone
3. PVA wax was applied and was left for 20 minutes to dry. The wax was then applied in order to form a thin realizing film.
4. A small quantity of resin system was coated on the mould surface and then a layer of the fabric (300 x 300mm) already cut was placed on that.

5. The resin system was applied on the fabric to wet it and then the next layer of fabric was placed. The same procedure was followed till the required layers were placed ensuring adequate impregnation.
6. The mylar sheet was stuck on the topmost ply and specimen were rolled using roller. Repeat the same procedure for other two composites.
7. Finally, the specimen was allowed to cure for 48hrs.
8. After RT curing, the specimens were hardened. The hardened specimens are ejected from the mould.
9. The laminates were properly labelled and kept aside for further processing.



**Fig 11 Unidirectional Specimen orientation**



**Fig. 12 Applying resin over fibers**

**Table 5: Details of the different FWF laminates fabricated**

Laminates (65:35)	Wt. of dry fabric (gra ms)	Wt. of Resin (gra ms)	Wt. of Hard ener (gra ms)	Wt. of laminate before trimmi ng(gra ms)	Wt. of laminate after trimming (grams)	Global Weight Fraction	thickness of the laminate (mm)
Lami nate J+J+ E 3mm	220.76	108.07	10.80	380	340	0.65	3.5
Lami nate J+C+ E 3mm	228.76	111.98	11.2	390	352	0.65	3.5
Lami nate J+k+ E 3mm	245	120.9	12.1	400	378	0.65	3.5

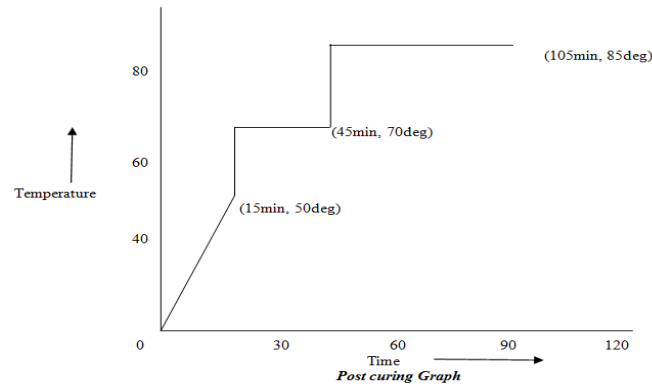
**G. Post curing**

Post curing is a technique used to take to completion in the process of curing as well as to ensure the enhancement of the service temperature limits. The post curing, in essence, increases the glass transition temperature ( $T_g$ ) of the cured composite laminate.

A step post curing cycle has been followed as outlined below

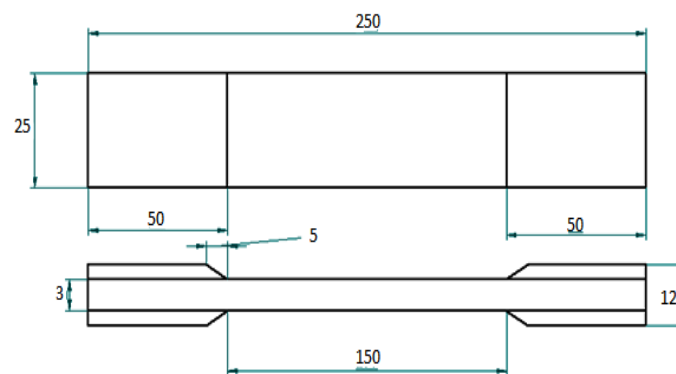
1. The RT-cured specimens were placed in a hot air circulated oven.
2. First specimens were heated to 50°C and maintained at this temperature for 15 minutes.
3. Then the ILSS specimens were heated to 70°C for 30 min.
4. Finally the ILSS specimens were further heated to 85°C for 1 hours and then allowed to cool down to room temperature on its own.

**Fig 13 Post curing oven**



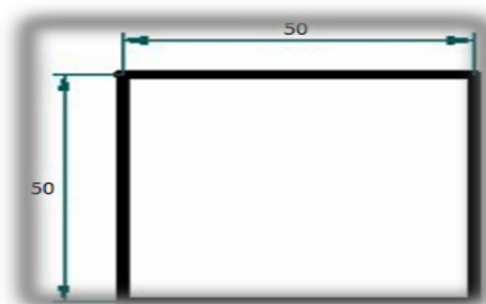
## H. Preparation of specimens as per ASTM standards

Preparation of tensile specimens as per ASTM- D3039 standards for unidirectional laminates.



**Fig: 14 Geometry and dimensions of composite specimens for tensile test**

Preparation of Compression specimens as per ASTM-D1621 standards for unidirectional laminates.



**Fig 15 Geometry and dimensions of composite specimens for compression test**

## I. Testing of Mechanical Property

The steps followed to find the tensile strength are:

- Place the specimen in INSTRON machine fixture.
- In a computer compatible testing, select the testing mode as “tensile”.
- Rotate the adjustable screw to fix the grip very tightly.

- Adjust the load to zero using tare buttons.
- Now slowly rotate the loading knob to start loading.
- Note down the deflection for equal interval of loading.
- Apply the load until the specimen fractures.
- The average loads of 2 specimens were calculated.



**Fig 16 Universal testing machine**

**J. Specimens Prepared for Tensile and compressive tests.**



**Fig 17 Tensile test Specimens Jute/Jute/Epoxy 3mm)**

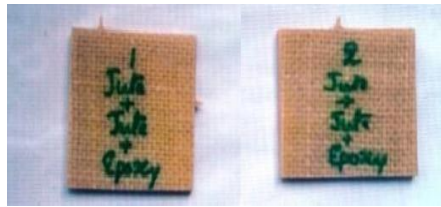


**Fig 18 Tensile test Specimens Jute/Kevlar/Epoxy (3mm)**



**Fig 19 Tensile test Specimens Jute/carbon/Epoxy (3mm)**





**Fig 20 Compression test Specimens Jute/Jute/Epoxy (3mm)**



**Fig 21 Compression test Specimens Jute/Kevlar/Epoxy (3mm)**



**Fig 22 Compression test Specimens Jute/carbon/Epoxy (3mm)**

## RESULT AND DISCUSSION

### A. Tabulation of tensile and compression tests results:

**Table No 6: Tensile test results**

Material	Breaking load(KN)	Maximum displacement	Tensile Strength (Mpa)
Jute/Jute/Epoxy with 3mm thick laminate	3.30	11.5	34.64
Jute/Kevlar/Epoxy with 3mm thick laminate	9.36	16.1	93.20
Jute/Carbon/Epoxy with 3mm thick laminate	9.54	14.9	98.08

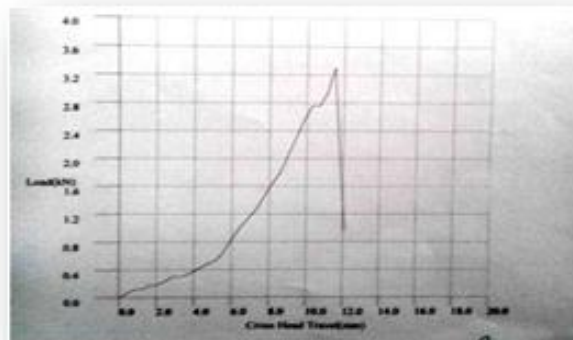
Tensile test result results of Jute/Jute/Epoxy with 3mm thick laminate, Jute/Kevlar/Epoxy with 3mm thick laminate and Jute/Carbon/Epoxy with 3mm thick laminate are tabulated in tabular column above.

**Table No 7: Compression test results**

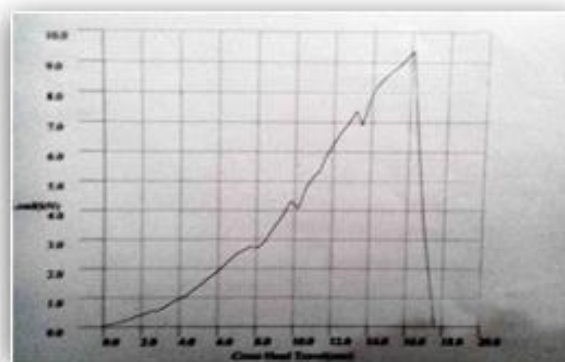
Material	Breaking load(KN)	Maximum displacement (mm)	Compression Strength (Mpa)
Jute/Jute/Epoxy with 3mm thick laminate	5.88	3.1	23.52
Jute/Kevlar/Epoxy with 3mm thick laminate	2.58	1.4	10.32
Jute/Carbon/Epoxy with 3mm thick laminate	6.96	4.2	27.84

Compression test result results of Jute/Jute/Epoxy, Jute/Kevlar/Epoxy and Jute/Carbon/Epoxy with 3mm thick laminates are tabulated in tabular column above.

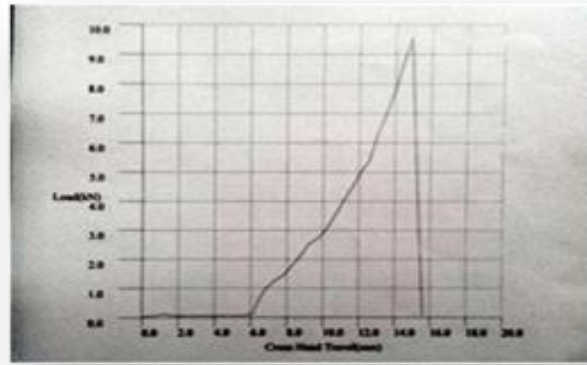
**B. Graphs plotted for Tensile and compression test.**



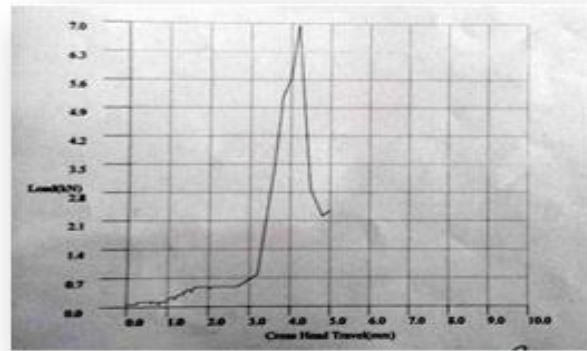
**Graph 1 Tensile Test Results Of Jute/Jute/Epoxy Laminate Composites(3mm),**



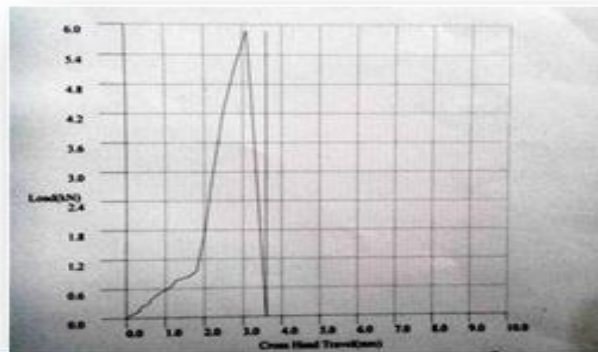
**Graph 2 Tensile Test Results Of Jute/Kevlar/Epoxy Laminate Composites(3mm),**



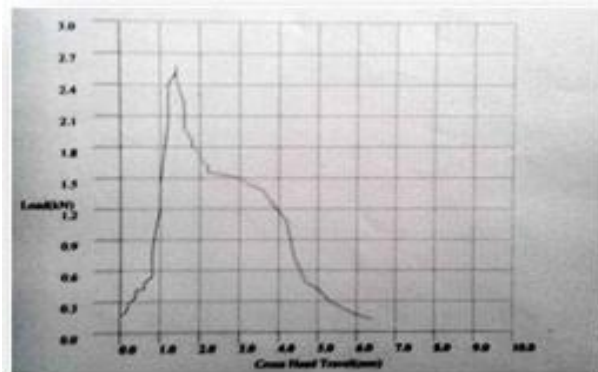
Graph 3 Tensile Test Results Of Jute/Carbon/Epoxy Laminate Composites(3mm),



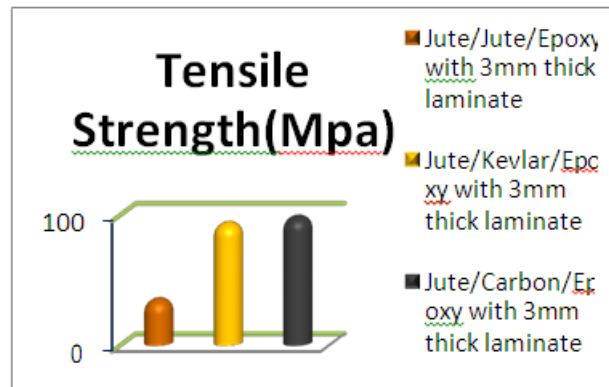
Graph 4 Compression Test Results Of Jute/Jute/Epoxy Laminate Composites(3mm),



Graph 5 Compression Test Results Of Jute/Kevlar/Epoxy Laminate Composites(3mm),

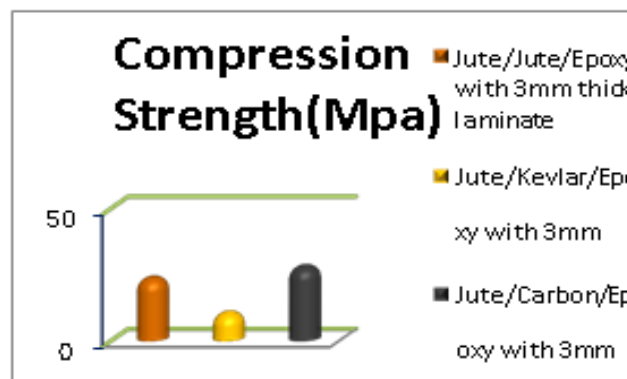


Graph 6 Compression Test Results Of Jute/Carbon/Epoxy Laminate Composites(3mm).



**Graph 7. Comparisons of Tensile Test Results of Jute/Jute/Epoxy, Jute/Kevlar/Epoxy and Jute/Carbon/Epoxy Laminate Composites (3mm thickness),**

From above comparison graph it is clear that Jute/Carbon/Epoxy laminate having 3mm thickness shows more Tensile strength than the Jute/Jute/Epoxy laminate 3mm thickness and Jute/Kevlar/Epoxy laminate 3mm thickness.



**Graph 8 Comparisons of Compression Test Results of Jute/Jute/Epoxy, Jute/Kevlar/Epoxy and Jute/Carbon/Epoxy Laminate Composites (3mm thickness),**

From above comparison graph it is clear that Jute/Carbon/Epoxy laminate having 3mm thickness shows more Compression strength than the Jute/Jute/Epoxy laminate 3mm thickness and Jute/Kevlar/Epoxy laminate 3mm thickness.

## CONCLUSIONS

- Specimens with varying thickness of laminates are fabricated by simple hand layup technique and they are: Jute/Jute/Epoxy laminate composite (3mm), Jute/Kevlar/Epoxy laminate composite (3mm), Jute/Carbon/Epoxy laminate composite (3mm).
- From the composites the test specimens have been prepared in accordance with the ASTM standards for tensile, compression and flexural strength determination.
- Jute/Carbon/Epoxy laminate having 3mm thickness shows more Tensile strength than the Jute/Jute/Epoxy laminate and Jute/Kevlar/Epoxy laminate .

- Jute/Carbon/Epoxy laminate having 3mm thickness shows more Compression strength than the Jute/Jute/Epoxy laminate and Jute/Kevlar/Epoxy laminate.
- In the overall study, the strength of Jute/Carbon/Epoxy laminates has higher value than that of Jute/Jute/Epoxy laminates and Jute/Kevlar/Epoxy laminates in Tension and compression.

### SCOPE OF FUTURE WORK

In this work, the mechanical properties like tensile and compressive strength investigation was carried out on different fibers but at the same time, this work can be extended to other natural fibers such as bamboo, banana etc available in the market.

In addition, other test like

- Moisture absorbtion test
- Impact test
- FFT analysis
- Hardness test
- Thermal conductivity tests can also be addressed in future

Further work can also be done on different polymers and for different percentage of fiber and reinforcement fraction.

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