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Studies on Mechanical Performance of Hemp/Jute Reinforced Epoxy Hybrid Composites

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ABSTRACT

Natural fibre reinforced polymer composites has captured the attentions of the major manufacturing industries such as automotive, construction and packaging due to their light weight requirements, competitive specific strength and consumer demands for the new material that can substitute for conventional non-renewable reinforcing materials because of environmental concern. Amongst the various natural fibres available, jute is not only of low cost but also commercially available in abundance in the form of woven mat. Hemp fibre is superior in strength compared to jute; but it is more expensive than jute. As such, to compromise between the cost and performance, a hybrid composite with hemp and jute as reinforcing material has been studied. The current research work is focused to investigate the mechanical performance of developed hemp/jute reinforced epoxy hybrid composites as compared to baseline pure hemp and jute epoxy composite. The one of the major drawback of natural fibre based composite is their tendency to absorb moisture. In order to overcome this drawback, layer of woven glass mat was placed at the outer of hybrid laminate as skin protection, one on each side. Mechanical properties such as tensile, flexural and shear strength were obtained for the pure as well as hybrid composites. From the experimental tests result, it was observed that hybrid composite with glass as outer layer shows higher mechanical properties followed by hemp-epoxy composites. Hemp-jute- epoxy hybrid composite found to be performing better as compared to pure jute-epoxy composites. All the composites were characterized for the above tests and results indicates that the hybridization of jute with hemp and jute-hemp with the glass fibre improves the properties and can be considered as potential replacement to glass fibre reinforced polymer composite in the secondary application.

***Keywords*— Epoxy matrix, Hybrid composites, Mechanical properties, Natural Fibres.**

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I. INTRODUCTION

The use of plant derived natural fibres as filler or reinforcement in polymer composites for making sustainable and low cost engineering materials has captured the great attentions of researchers in recent years. Because of environmental growth of awareness, norms and regulations as well as consumer demands has forced to manufacturing industries such as (automotive, construction and packaging) to come out with the new bio based materials that can be used as substitute for conventional non-renewable reinforcing materials such as glass fibre [1]. The natural fibres like jute, sisal, hemp, kneaf, banana and coir etc. are renewable, none-abrasive and environmental friendly so widely used as the filler material for the bio-composites [2, 3]. The natural fibre based composites exhibit the excellent properties such as

low density, high specific strength, stiffness, impact strength and high degree of flexibility during processing [1,4]. However natural fibre based composites have many advantages over the synthetic fibres such as low weight, low cost, recyclable, environmental friendly and causes no skin itching problem as like the synthetic fibres [5,6]. It also suffer from some limitations like low modulus, hydrophilic character of the natural fibre that leads to moisture absorption, lower mechanical properties as compared to synthetic fibre and fibre strength depends on geographical origin and climatic growth condition [7,8].

In order to enhance their properties researchers turns their attentions towards the hybridization of natural fibre with synthetic one. The possible combination of hybrid composites of the natural fibres includes natural-natural and natural-synthetic types [9]. Few study regarding hybridization of different natural fibre based composites are presented below. Ramesh et al. [10] have observed that the jute and sisal fibres are more attractive due to their light weight, high specific strength and biodegradability. Mixing of the glass fibre with the natural improves the properties of natural fibre based composites. In this study sisal-jute-glass fibre reinforced hybrid composites are developed. The result shows that mechanical properties such as tensile strength, flexural strength and impact strength improved significantly and incorporation of the sisal jute with glass-fibre reinforced polymer (GFRPs) used as a replacement for glass reinforced polymer composite. From the test result it is observed that glass-jute fibre composite gives maximum tensile strength. The jute-sisal fibre based composite is capable of having maximum flexural strength and maximum impact strength is obtained from the sisal fibre based composite. Boopalan et al. [3] have investigated and compared the mechanical and thermal properties of the jute and banana natural fibre based hybrid composites. The aim is to improve the mechanical properties, so jute fibre is hybridized with banana fibre. The jute and banana (jute/banana) based hybrid composite where prepared with various weight ratio as (100/0, 75/25, 50/50, 25/75, and 0/100). Different test such as tensile, flexural impact, thermal and water absorption where carried out for hybrid composite sample. From the achieved result it is observed that addition of banana fibre in jute epoxy composite up to 50% by weight yields increasing the mechanical and thermal properties and decreases the water absorption properties. The development of damage and fracture of the sample were observed under scanning electron microscope. The 50/50 weight ratio of jute and banana natural fibre based composite shows good tensile strength, thermal property and less water absorption as compared to the other weight to strength ratio of jute banana hybrid composites. Addition of the jute in the composites results in the 17% increase in the tensile strength, 4.3% increase in flexural strength and 35.5% increase in impact strength. Ramnath et al. [11] have studied the characterization of abaca jute fibre based composites for tensile, flexural, impact and shear strength. The stacking sequence of the composite is such that jute fibre is lies at the centre and on both sides of jute fibre abaca fibre is placed, glass fibre is used as outer layer for better finish and to improve the strength. The composite is prepared with the help of hand layup technique and volume fraction of the fibre is maintained approximately 0.40 by weight. From the result it is found that the hybrid composite of jute and abaca fibre based composite gives the better tensile and shear strength as compared to the pure abaca fibre based composites. However the abaca fibre based composites has the good flexural and impact strength than that of hybrid composite of jute and abaca. R. Petrucci et al. [12] have studied the manufacturing of hybrid composite by vacuum infusion method and comparison of characterization of different hybrid composite laminate based on basalt as the inner core material. In all case of the hybrid composite the volume fraction is maintained in between 21-23% in an epoxy resin. Laminates have been subjected to the various tests such as tensile, flexural and inter laminar shear strength. From the mechanical testing it is observed that mechanical performance of all the hybrid laminates appears superior to that of pure hemp and flax fibre reinforced laminates. Out of the three different combinations the glass-basalt-flax hybrid shows the best performance. N. Venkateswaran et al. [13] studied the effect of hybridization on mechanical properties such as tensile strength, flexural strength, impact strength and moisture absorption characteristic of Banana-Sisal fibre based hybrid composites. They have observed that addition of sisal fibre in composite, results in 16% increase in tensile strength, 4% increase in flexural strength and 35% increase in impact strength. In moisture absorption study of banana-sisal fibre based hybrid composite at 50/50 weight percentage of both fibres in the laminate shows the minimum up take of moisture.

Hybridization has profound effect on the water absorption characteristic of natural fibre. In order to improve water absorption resistance characteristic of natural fibre based composites glass fibre reinforcement is prominently used in the hybridization of natural fibre based composite composites [14]. In the present study the mechanical properties of jute fibre; hemp fibre, jute-hemp fibre and jute-hemp- glass fibre based pure and hybrid composites are studied. The hybrid composites are manufactured by simple hand lay-up technique under same laboratory condition at room temperature. The properties such as tensile, flexural and in plane shear are studied and presented in great details. The addition of the glass fibre as an outer covering to the natural fibre based composite gives the batter surface finish and increases moisture resistance with enhancing the mechanical properties.

II. MATERIALS

In the present study, for fabricating the composite laminates jute, hemp and glass fibers are used. The raw woven mats of jute and hemp are obtained from Faridabad, Hariyana, India. The epoxy resin and hardener are provided by M/s K.S industries Ltd., Pune, Maharashtra, India.

A. Natural Fibers

Over the past few decades, plant fibers have captured the great attention of researchers and scholars due to their advantages such as low density, low cost, biodegradability and high flexibility during processing.

The natural fiber based composites are reasonably strong, shows high weight to strength ratio and free from the health hazard. Natural fibers such as jute, hemp, sisal, banana, coir and flax are widely used as reinforcing material to fabricate the environmental friendly and bio-degradable composite materials. Such composites are called as bio-composites or green composites but the problem with the natural fiber based composite is that it tends to absorb the moisture because of its hydrophilic nature and that can be overcome by hybridization. The physical properties of hemp and jute used in the current study are shown in the Table I.

TABLE I

PHYSICAL PROPERTIES OF JUTE AND HEMP

Physical properties	Jute	Hemp
Density (g/cc)	1.4	1.6
Diameter (mm)	0.60	0.35
Tensile Strength (MPa)	108	192.26
Young's modulus (GPa)	3.42	4.3

B. Jute Fiber

Jute fiber plants takes near about 3-4 months to grow a height of 12-15 ft. in the field during the season then it is cut in to the bundles and kept immersed in the water for "retting" process. Retting is the process of extracting the fiber from long lasting life stem or bast of the fiber plant. When the jute stalk is well retted, the stalk is clustered in bundles and hit with a long wooden hammer to make the fiber loose from the jute hurd or core. After losing the fiber, the fiber is washed with water and squeezed for dehydration. The extracted fibers is further washed with fresh water and allowed to dry. Finally, they are tied into small bundles to be sends in to the industries for further processing to form a jute fiber mates and other forms. With the help of jute fiber we can produce various lifestyle products. Out of all the natural fiber reinforcing material jute appears to be promising material because of its good reasonable properties, inexpensiveness and commercially availability in the required form and in abundance quantity.

C. Hemp Fiber

Hemp fiber plant is normally ready to harvest in 2-3 month after seeding. That grows to height anywhere from 4-15 ft. and (3-4cm) in diameter. After complete growth of plant, plants are cut at 2-3cm above the soil and left on the ground to dry. The cut hemp is laid in swatches to dry up to 4 days and this was traditionally followed by retting. With the help of the retting we can separate the bark of the plant that contains long tough bast fiber from core that is called as hurd or shives (short fibers) and these are used for building materials. In the modern times hemp is used for industrial purposes including paper, textile, and bio based plastics composites, clothing and construction. Now a day's hemp frequently used in the automobile industries because of its good tensile and flexural properties.

D. Glass Fiber

Glass fiber is a material that contains very fine fibers of glass. It shows good properties such as light in weight, extremely strong, and robust. It is formed when thin strands of silica glass are extruded into many fibers with small diameters. Its weight properties are also very favorable when compared to metals, and it can be easily formed in to different shapes using molding processes. Such individual filaments are now clustered together to form a bundle of fiber. They are then woven in a machine to produce woven mat in general, such mates or other forms of glass fiber is used as a reinforcing material for composites to form a very strong and light weight fiber reinforced polymer (FRP) composite material.

III. FABRICATION OF COMPOSITE LAMINATE

In this study, four different types of laminates of jute, hemp and glass fiber reinforcement were proposed with the help of hand lay-up technique in a closed of dimension 0.3m x 0.3m at the room temperature using the Epoxy resin-520 and Epoxy hardener-PAM and they were mixed in the ratio of 10:1 by weight as suggested. Epoxy resin and hardener mixture was stirred thoroughly before fiber mats were introduced in the matrix material. Each laminate was cured under certain pressure near about 24hr in the mould and further cured at room temperature at least 12 hrs before it come to use. The proposed laminates are labeled as Jute/Epoxy laminate (J/E), Hemp/Epoxy laminate (H/E), Jute-Hemp/Epoxy laminate (J-H/E) and Jute-Hemp-Glass/Epoxy laminate (J-H-G/E). Each laminate consist of 6 layers of woven fibers mats of respective fiber. The proposed laminates are shown in the Fig.1 their stacking sequence and volume fraction is given in the Table. II

TABLE II

STACKING SEQUENCE AND VOLUME

FRACTION OF PROPOSED LAMINATES

Sr. no	Proposed laminates	Stacking Sequence	Volume fraction (%)			
			Jute	Hemp	Glass	Matrix
1	Jute/Epoxy (J/E)	J-J-J-J-J-J	40	0	0	60
2	Hemp/Epoxy(H/E)	H-H-H-H-H	0	40	0	60
3	Jute-Hemp/Epoxy(J-H/E)	J-H-J-H-J-H	20	20	0	60
4	Jute-Hemp-Glass/Epoxy (J-G-H/E)	G-J-H-J-H-G	13.5	13.12	13.09	60


Fig.1 (a) J/E laminate Fig.1 (b) H/E laminate

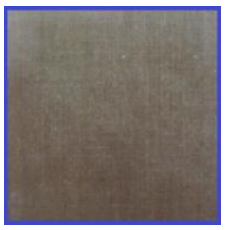
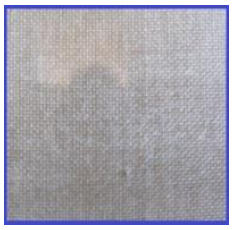

Fig.1(c) J-H/E laminates Fig.1 (d) J-H-G/E laminate

IV. MATERIAL CHARACTERIZATION

A. *Tensile Test*

Tensile test were performed following the ASTM D3039 standard using the universal testing machine (Model No-STS248) with an accuracy of ± 1%. The cross head speed for tensile test was set at 10mm/min. Test process involves placing test specimen in the universal testing machine (UTM) and applying tensile force on it until it going to brakes. During the application of the tensile load elongation of the gauge section is recorded against the applied load. The same procedure is carried out for the different type of composites. This experiment is repeated for several numbers of specimens of each laminate to get more accurate result and to minimize the error. The tensile test specimen of different types of composites and experimental setup for tensile test is given in Fig.2 and Fig.3 respectively.

Fig.2 Tensile test specimens

Fig.3 Experimental setup for tensile test

B. *Flexural Test*

Flexural test was carries out using the universal testing machine (Model No-STS248) with an accuracy of ± 1% according to the ASTM D790. The specimen dimensions are given as 13mm x 80mm x 3mm and the overhang length of 50mm at both the support. The crosshead speed for flexural test was set at 5mm/min. Minimum three specimens from each laminate was tested to obtain a satisfactory result. The experimental setup for flexural test given in fig.4

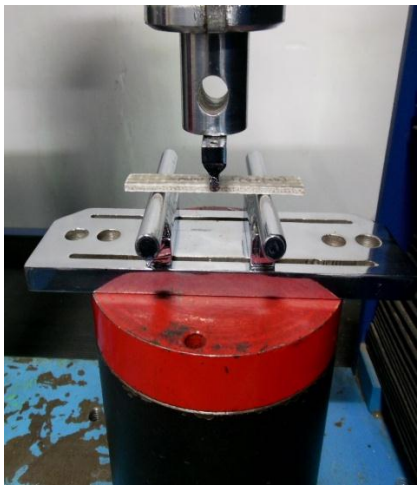

Fig.4 Experimental setup for flexural test

C. *In Plane Shear Test*

The in plane shear test was performed on the same universal testing machine as per the ASTM D5379. Normally shear stress is less when compared to the bending stress in loading condition. But sometimes, the shear stress becomes very important in certain design calculations. The shear test specimens and experimental setup is shown in the Fig.5 and Fig.6

Fig.5 Shear test specimen

Fig.6 Shear test setup

V. RESULTS AND DISCUSSIONS

In the recent time use of composite materials in different field is increasing rapidly due to their improved properties scholars and engineers are working together to come out with higher purpose materials. In the present research natural-natural fibres and natural-synthetic fibres are reinforced together to come out with the novel hybrid composite material. The test specimens are prepared from the proposed composite laminates as per ASTM standards and mechanical properties are evaluated under tensile, flexural and shear loading using the universal testing machine. Test results for tensile test, flexural test and in plane shear test of four types of proposed composite laminates are presented in the Table III

TABLE III
EXPERIMENTAL RESULTS OF PROPOSED PURE AND HYBRID COMPOSITE MATERIAL

Samples	Tensile strength (MPa)	Flexural strength (MPa)	Shear strength (MPa)
Jute/Epoxy composite	58.39	74.61	29.33
Hemp/Epoxy composite	75.51	126.07	37.83
Jute-Hemp/Epoxy composite	63.22	109.47	34.86
Jute-Hemp-Glass/Epoxy composite	126.93	191.06	43.09

A. *Tensile Strength Analysis*

The different composite specimen samples are tested in the universal testing machine (UTM). The samples are allowed to break until the ultimate tensile strength occurs. From tensile test data the stress-strain plot is generated to determine the ultimate tensile strength and elastic modulus of different composite material. The stress-strain curve for different combination of composite specimen is shown in Fig.7. The test result shows that Jute-Hemp-Glass/Epoxy composite specimen gives better tensile strength than the other three types of composite and it is followed by the Hemp/Epoxy composite. The Jute-Hemp/Epoxy composite specimen shows the properties in between Jute/Epoxy composite and Hemp/Epoxy composites. Comparative study of tensile strength for different type of composite is shown in fig.8.

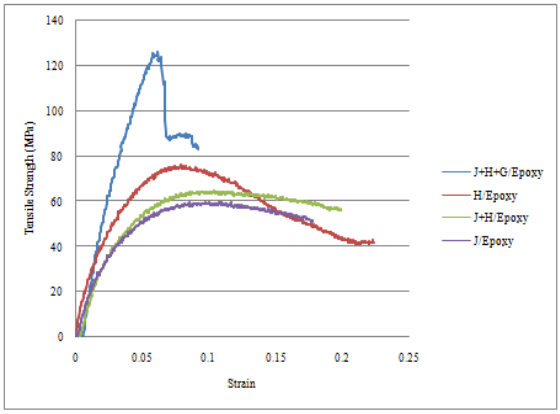

Fig7. Stress-strain plot for tensile test

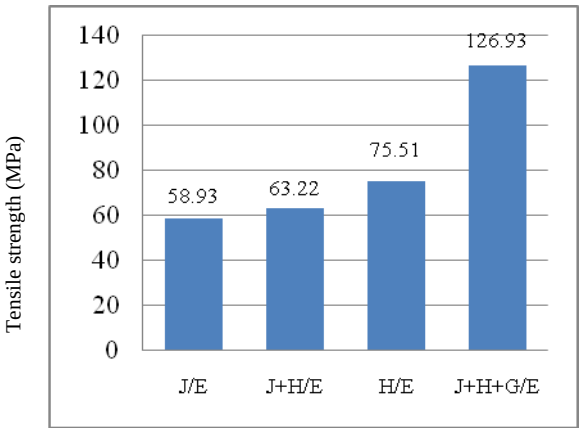

Fig.8 Tensile strength of different composite

B. *Flexural Strength Analysis*

The flexural test was carried out on the same universal testing machine for different types of composite specimens as shown in Fig.4. From the flexural test data the stress-strain plot is generated to determine the flexural strength and flexural modulus of different composite material and it shown in Fig.9 and test results are tabulated in Table III. From the stress-strain plot, it is clear that Jute-Hemp-Glass/Epoxy composite shows highest flexural strength than the other three composite and that is followed by the Hemp/Epoxy composite. The Jute-Hemp/Epoxy hybrid composite shows intermediate flexural strength when compared to pure Jute/Epoxy and Hemp/Epoxy composite. Comparative study of flexural strength for different type of composite is shown in Fig.10

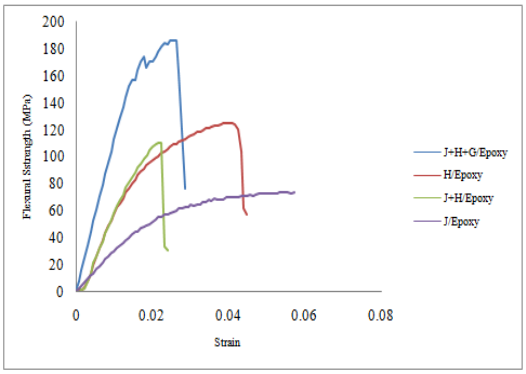

Fig.9 Stress-strain plot for flexural test

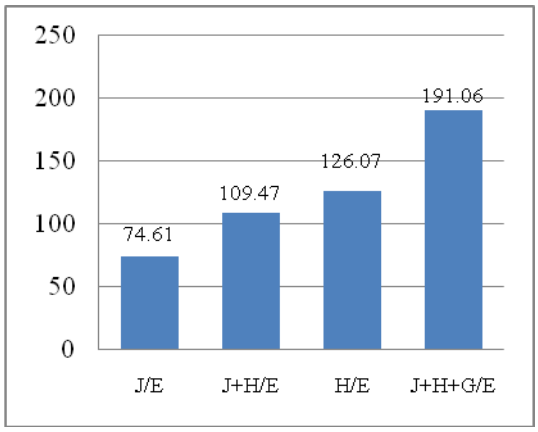

Fig.10 Flexural strength of different composites

C. In Plane Shear Strength

Shear properties of the pure and hybrid composite samples are tested and with the help of experimental data stress-strain curve is generated to determine the shear strength and shear modulus. The results are summarized in the Table III. The comparative study of in plane shear strength of different hybrid composite is shown in the Fig.11. From the comparative study it is asserted that Jute-Hemp-Glass/Epoxy specimens show the better properties than other three composites. Jute-Hemp/Epoxy Composite specimens have intermediate shear properties when compared to Jute/Epoxy composite and Hemp/Epoxy composite.

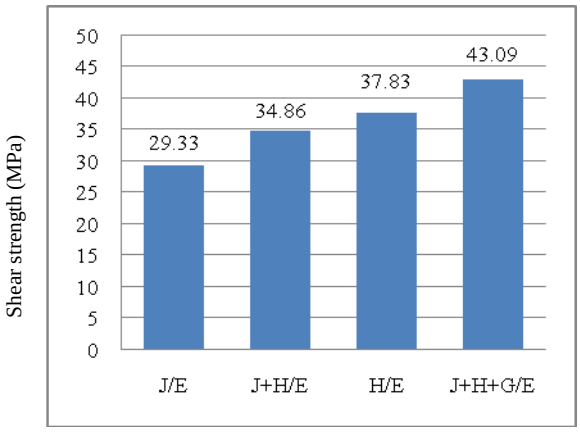

Fig.11 Shear strength of different composite

VI. CONCLUSION

The Jute fibre, Hemp fibre, Jute-Hemp fibre, and Jute-Hemp-Glass fibre reinforced pure and hybrid composites are fabricated by the simple hand lay-up technique under the same laboratory condition. The proposed composites are subjected to the mechanical characterization, such as tensile strength, flexural strength and shear strength. The following conclusions have been driven out from the experimental results.

1. The Jute-Hemp-Glass fibre reinforced hybrid composites have more tensile strength than the other composites and withstand tensile strength up to 126.13MPa. Followed by Hemp fibre reinforced composite which is having tensile strength of 75.14Mpa.
2. The Jute-Hemp-Glass fibre reinforced composite having more flexural load carrying capacity and withstand with strength up to 191.15MPa which is followed by the Hemp fibre reinforced composite which withstand flexural strength up 126.25Mpa.
3. The Jute-Hemp-Glass fibre reinforced composite shows more shear strength when it compared to other three reinforcement and having the shear strength value of 43.09MPa followed by Hemp fibre reinforcement which withstand the strength of 37.58Mpa.
4. Results indicates that the hybridization of jute with hemp and jute-hemp with the glass fibre improves the properties and can be considered as potential replacement to glass fibre reinforced polymer composite in the secondary application.

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