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Investigation on mechanical properties and water absorbency of jute glass reinforced epoxy composite

Abstract

Fiber reinforced composite materials are attractive because of their properties such as high toughness, water resistance and can be adapted to meet the specific needs of a variety of applications. Incorporation of natural fibers can reduce the dependency over synthetic fibers. In this work, Jute glass fiber reinforced composites are fabricated by simple hand lay-up technique using epoxy resin as a matrix and various mechanical properties like tensile strength, flexural strength, impact strength and also the water absorption properties of the composite specimens are evaluated and analysed thoroughly. It is observed that incorporation of optimum amount of jute fibre with glass fibre improved mechanical properties can be achieved. Finally cost of composites are analysed and compared.

Keywords: Jute glass woven composites, water absorption, impact loading, hand layup

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Introduction

A composite is a mixed material produced from two or more components constituting reinforcing matrix and a compatible matrix in order to achieve specific properties.[1] Composite materials are popular because of its light weight, high strength, high design and shaped freedom[2] and are used in many sectors such as armor, bullet proof jacket, protection for vehicle, car blanket, ballistic barrier, shelter for storage under special conditions.[3] Glass fibre reinforced composite materials are common and used for wide variety of applications.[4,5] Glass fiber with epoxy resin gives the pleasing finishing and resistance to flammability.[6] Natural fibers like jute exhibit superior mechanical properties are replacing the glass and carbon fibers recently owing to their easy availability easily bio degradable, renewable and low cost.[7,8]

Kundu et al shows jute jute fibers are about seven to eight times lighter than steel[9] and have proper tensile strength, high toughness, low extensibility and ensures better breathability of fabric.[10] Ramesh et al. syudied on sisal-jute-glass fiber reinforced composites and suggested that it can improve the properties and used as an alternate material for glass fiber reinforced polymer composites.[11] M Boopalan et al. showed that addition of banana fiber in jute-epoxy reinforced hybrid composite results good mechanical and thermal properties.[12] Moe Moe Thew and Kin Liao used short bamboo and glass fiber as reinforcement to polypropylene based matrices and improved the adhesion between fiber and matrix.[13] Aleya Fardausy et al. investigated on jute-poly vinyl chloride (PVC) composites and found good tensile strength.[14] Polymer hybrid composites were prepared by hand lay-up method with an appropriate amount of epoxy and polyester resin mixture and Jute, Pineapple leaf and Glass fibers.[15,16]

Many researches have been done to incorporate the natural fibres as reinforcing agent to reduce the dependency of high priced glass fibre as it is not ecofriendly. Jute has the potential to be used as a replacement for traditional reinforcement materials in composites for application which requires high strength to weight ratio and further weight reduction. It has also high tensile strength, low extensibility and ensures breathability of fabrics. In this study, jute and glass fiber reinforced composites were fabricated varying different proportion by simple hand layup method and their mechanical performance has been investigated by experimentally.

Experimental

Materials

In this work, for fabricating the composites specimen 100 % Jute and Glass woven fabrics are used. The fabrics are collected from the local market. The jute and glass fiber of bi-directional woven fabrics with 280gm/m^2 and 400gm/m^2 respectively are used for the fabrication of specimen. The Bisphenol based epoxy resin and HN 2200 type hardener are used. The specifications of the materials are presented in Table 1.

Table 1 Specifications of the raw materials used

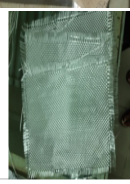
Materials	Specifications	Samples
Jute fibre	Bleached, woven bi-directional jute (100% jute), Weight 280gm/m^2	
Glass fibre	PTFE (Polytetrafluroethylene) coated white E-glass fiber in woven form, Weight 400gm/m^2	

Table continue

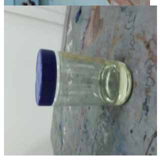
Materials	Specifications	Samples
Epoxy resin	Bisphenol based epoxy resin, Chemical name - Bisphenol A di-glycidyl ether, Chemical formula - $C_{21}H_{24}O_4$	
Hardener	Colorless transparent liquid (HN-2200), Chemical name: Methyl-1, 2, 3, 6-tetrahydrophthalic anhydride. Chemical formula - $C_9H_{10}O_3$	
High temperature mold releasing wax	It is a premium mold release formulated from a blend of hydrocarbon and microcrystalline waxes.	

Table 2 Laminate stacking sequence

Samples	Stacking sequence	Matrix %	Weight % of fibres (reinforcement)		Thickness of composites (mm)
			jute	Glass	
S1	JJJ	70	30	0	3.1
S2	JGJ		20	10	2.5
S3	GJG		10	20	2.1
S4	GGG		0	30	1.5
S5	JGJG		15	15	2.8

Composite fabrication process

The fabrication process of the composites is carried out by conventional hand lay-up process. Here the glass and jute fibres are used as reinforcement and epoxy resin used as matrix. The corresponding hardener (HN-2200) and epoxy resin was mixed in a proportion of 10:1 by percentage of weight. Composites of different compositions are prepared with reinforcement and matrix as 30% and 70% respectively by weight. The composite specimens were put under heavy load for about 24 hours and the curing carried out at room temperature. After the curing process the samples are cut with suitable dimensions for tests. Table 2 presents the laminate stacking sequence.

Test methods

Tensile test: Tensile test also known as a tension test is one of the most common types of mechanical testing where tensile force applies on a material to measure the specimen's response to the maximum stress.[17] The fabricated composites are cut using a hand grinding machine to get the specific dimension (dog bone shape) for tensile testing as per ASTM:D638 standards. The schematic diagram of tensile test specimen is shown is Figure 1. The test was carried out using a universal testing machine (UTM) at a room temperature with 40% relative humidity. The tensile stress is recorded with respect to increase in strain. The specimen was placed in the grip of the tensile testing machine and the test is performed by applying tension until it undergoes fracture. The corresponding load and strain obtained are plotted on the graphs. Figure 2 presents the cut sample specimen for tensile test.

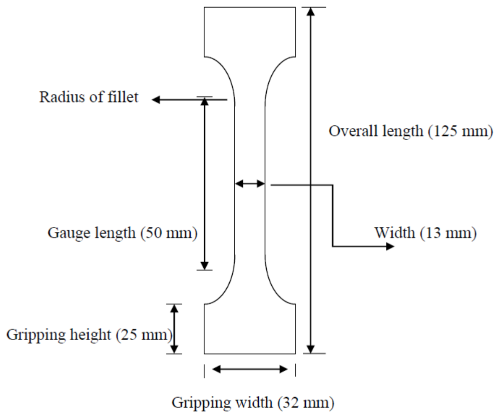


Figure 1 The schematic diagram of tensile test specimen.

Flexural test: The flexural test is performed on the same tensile testing machine (UTM) as per the ASTM: D790 standards. According to the standard test procedure the specimens are cut into 125 mm long, 12.7mm wide and 3mm thick. In this method, the outer rollers are 64mm apart and specimens tested at a strain rate of 0.2mm/min. The test is performed at room temperature. There are three different types of specimens are used in this test which are shown in Figure 3. The specimen is subjected to a load at its center between the supports and force is applied until it breaks. Flexural test determines the maximum stress induced in the outer most fibre.

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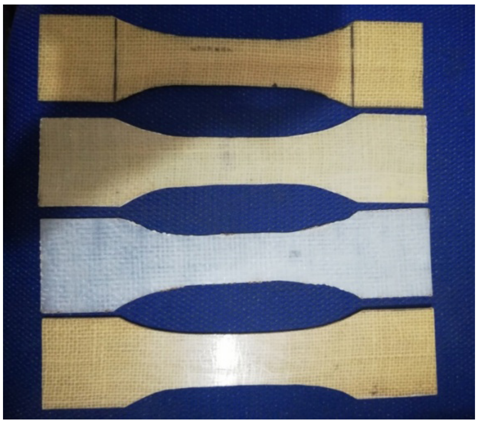

Figure 2 Specimen for tensile test.

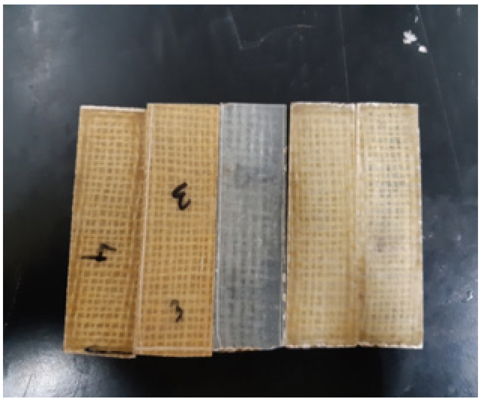

Figure 3 Specimen for flexural test.

Impact loading test: Impact strength is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy. Izod impact strength test is used to measure the impact strength of composite samples by maintaining the standard ASTM D4812. The standard size of the specimen is 75x10x10mm. Figure 4 and Figure 5 presents the samples of impact loading test before and after respectively.

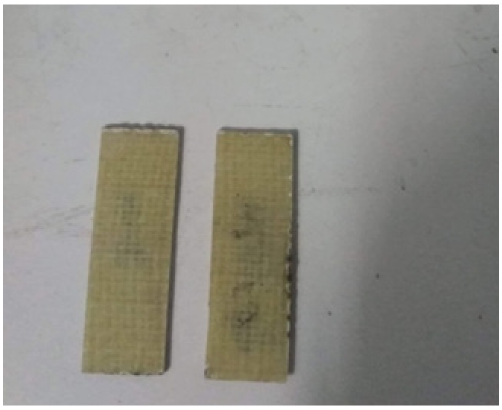

Figure 4 Specimen for impact loading test.

Water absorbency test: This test measures the amount of water absorbed by a specimen or a material under specified conditions. The water absorbency test is carried out according to ASTM D570 and specimens are cut into dimensions 76.2mm in length and 25.4mm in a width by a thickness of the panel. Figure 6 shows the schematic diagram of the specimen. First the specimens are dried in an oven for a specified time and temperature (110˚C) and then placed in desiccators to cool. Immediately after cooling the specimen are weighed. The material is then emerged in water for 2 and 24 hours. Finally the specimens are removed, patted dry with a lint free cloth, and weighed. Water absorption is expressed by weight percentage. The specimens for water absorbency test are shown in the Figure 7.

Figure 5 Specimens after impact loading test.

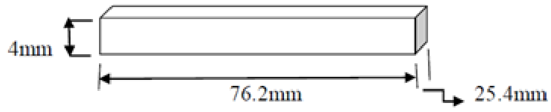

Figure 6 The schematic diagram of water absorbency test specimen.

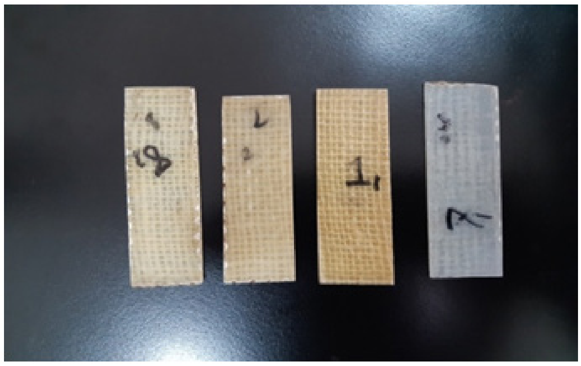

Figure 7 Specimen for water absorbency test.

Results and discussion

Tensile properties

The specimen samples of different compositions are tested in the Universal Testing Machine (UTM). The typical stress–strain graphs for samples S1, S2, S3, S4 and S5 are generated directly from the machine and are presented in Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 respectively. Experimental results of tensile strength of various composites with different weight ratio of reinforcement shown in Table 3.

Figure 13 represent the comparison of tensile strength of specimens. The highest tensile strength achieved in case of hybrid composite of four layers reinforcement and when glass fiber and jute fiber content were 15%-15% of weight of total 30% reinforcement which is composite S5.

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Table 3 Results of tensile strength

Samples	Stacking sequence	Tensile Strength (MPa)	Elastic Modulus (MPa)	Energy (J)	Maximum Force (KN)	Elongation (%)
S1	JJJ	50.7	2047	1.031	640	6.24
S2	JGJ	66.3	3612	4.174	1380	12.78
S3	GJG	129.8	1339	3.557	2180	6.24
S4	GGG	161.7	1111	5.91	2552	9.54
S5	JGJG	218.1	1111	5.91	2552	9.54

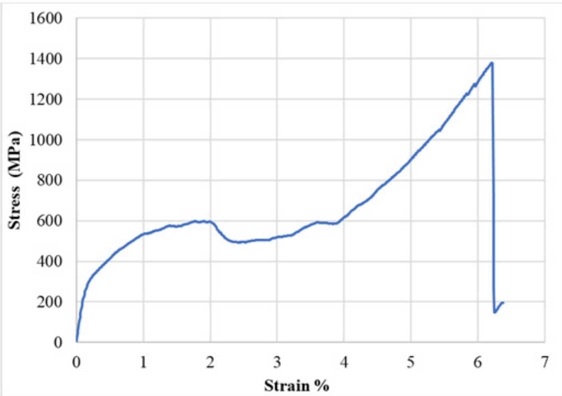

Figure 8 Stress strain curve for tensile test in JJJ composite.

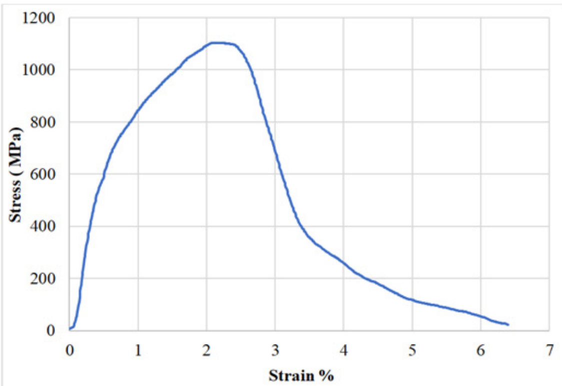

Figure 9 Stress strain curve for tensile test in JGJ composite.

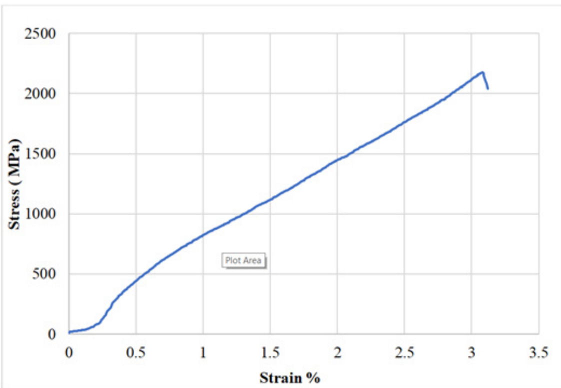

Figure 10 Stress strain curve for tensile test in GJG composite.

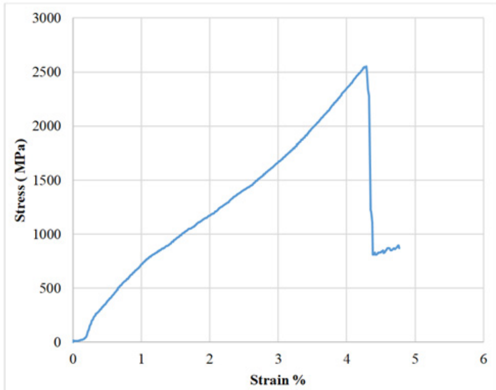

Figure 11 Stress strain curve for tensile test in GGG composite.

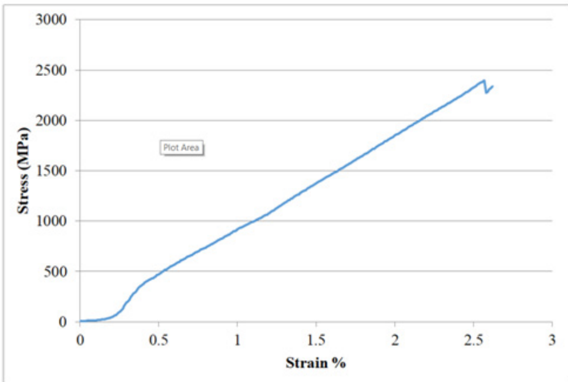

Figure 12 Stress strain curve for tensile test in JGJG composite.

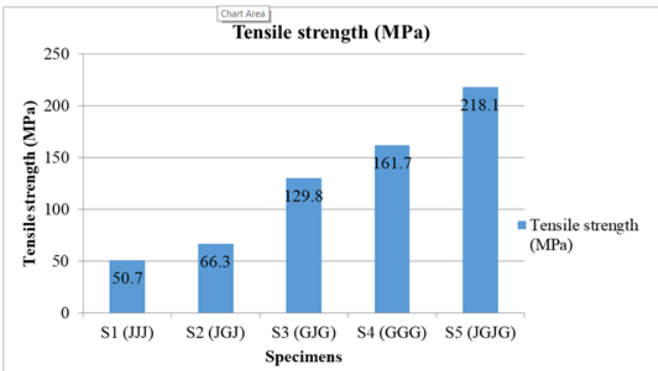

Figure 13 Representation of tensile strength of specimens.

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It is clear that the increasing amount of glass fibre increases the tensile strength of the composites. However, with the increasing of natural fiber content than synthetic fiber content, the overall tensile strength was decreased. Moreover, increasing of jute fiber reinforcement, the composite becomes more brittle as jute shows brittle behavior and overall strength decreases.

Flexural properties

The composite specimens for flexural test were prepared rectangular in shape and they were carried out in UTM machine in accordance with ASTM standard to measure the flexural strength of the samples. Load with respect to Cross Head Travel is plotted for the determination of flexural strength. The jute-glass fiber reinforced composite sample exhibits a significant difference in strength. The typical stress strain curve generated from machine for samples S1, S2, S3, S4 and S5 are presented in Figure 14, Figure 15, Figure 16, Figure 17 and Figure 18 respectively.

Table 4 presents the overall flexural properties of specimens. The flexural strength of jute-epoxy composite is lower than that of glass-epoxy composites because jute fibers have less stiffness in comparison to glass. The composite gives better flexural strength by the addition of jute fiber with glass fibers than single reinforced composites which is shown in the Figure 19.

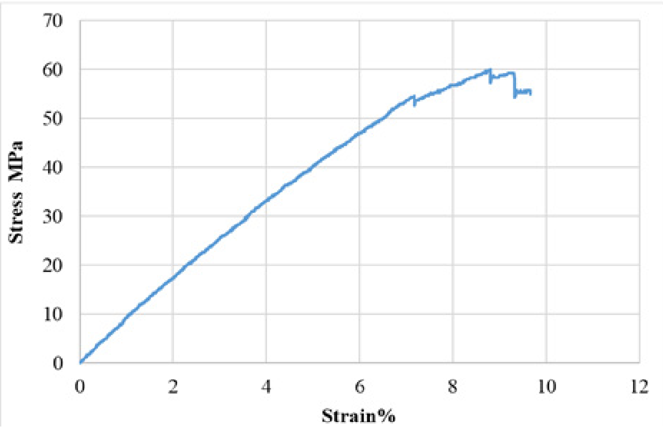

Figure 14 Stress strain curve for flexural test in JJJ composite.

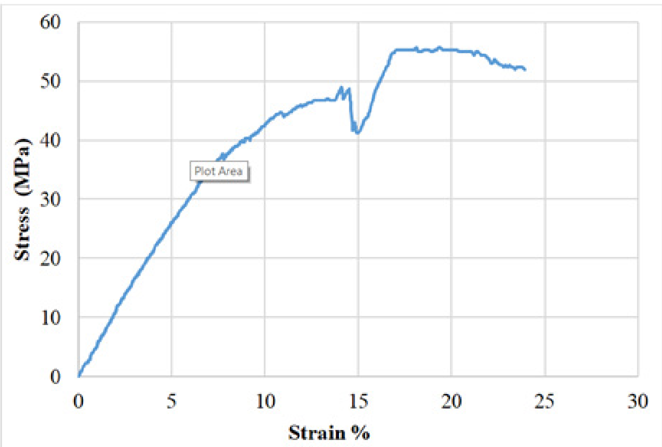

Figure 15 Stress strain curve for flexural test in JGJ composite.

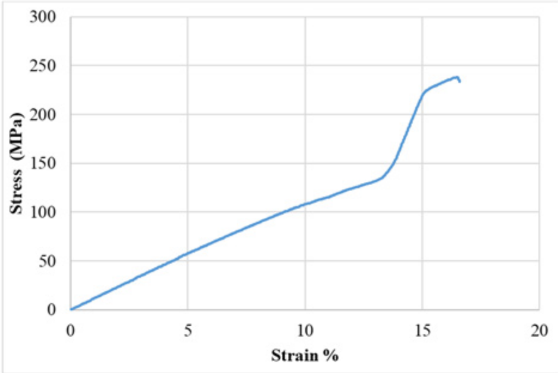

Figure 16 Stress strain curve for flexural test in GJG composite.

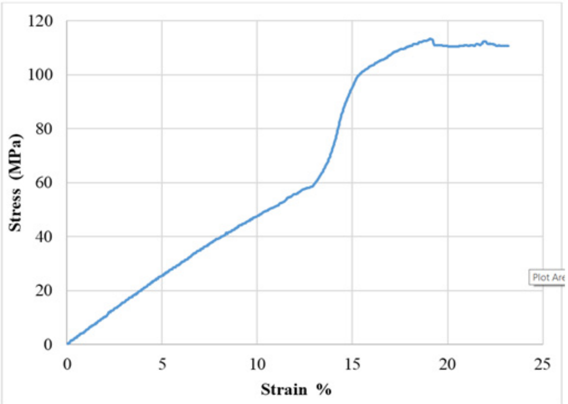

Figure 17 Stress strain curve for flexural test in GGG composite.

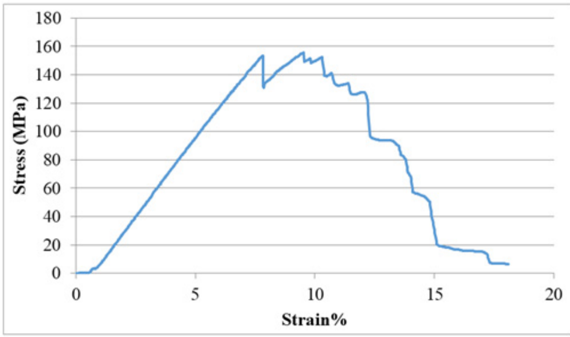

Figure 18 Stress strain curve for flexural test in JJJ composite.

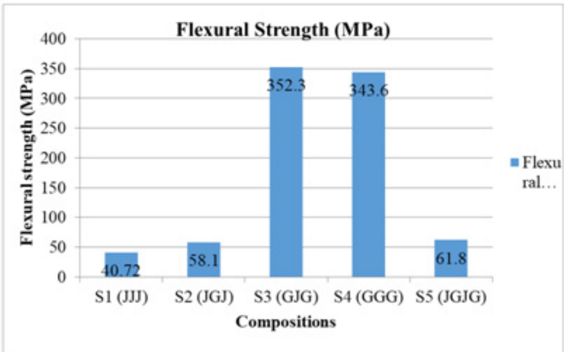

Figure 19 Representation of flexural strength of specimens.

Table 4 Results of Flexural strength

Samples	Stacking sequence	Flexural Strength (MPa)	Strain (%)	Energy (J)	Young's Modulus (MPa)	Maximum Force (N)
S1	JJJ	40.72	1.637	0.2044	3720	60.1
S2	JGJ	58.1	2.715	0.15165	3740	55.7
S3	GJG	352.3	2.076	0.925	13165	355
S4	GGG	343.6	1.719	0.3978	16614	640
S5	JGJG	61.8	2.285	0.84	3650	72

Impact strength properties

The impact strength properties of different composites are shown in the Table 5.

The results indicated that the maximum impact strength is obtained for hybrid composites followed by 15% glass and 15% jute fiber composites as in Figure 20. However, jute composite exhibit low performance compared to other composites. On increasing the amount of jute content, which is more brittle than glass fiber, the overall brittleness of material increases and impact strength decreases. But the optimum amount of natural fiber addition with glass fiber can improve the overall impact strength of the composite.

Absorbency test result

All the specimens were carried out for water absorbency test by maintaining ASTM Standard and calculated the absorbency test in percentage shown in Table 6 and Figure 21.

It is visible that the overall better water resistance was shown by 30% of glass fabric content of total reinforcement which is 0.15% and 0.57% after 2 hours and 24 hours of wetting respectively. It is because of epoxy resin improves the bonding between the glass fabric and matrix and increase inter bonding strength. As a result the chance of absorption of water is reduced. The water absorbency increases with the addition of jute fiber content thus the water resistance reduced because natural fibers tend to be more absorbent than synthetic ones.

Cost analysis

Figure 22 presents the cost of composites for making 1 square feet. Only material costs are included. The cost of composite material reduced with the increasing number of jute fiber content. Fiber glass is an expensive fiber material due to its high cost manufacturing process. It was found that natural fiber jute can be a partial replacement of high cost glass fiber and the total cost can be reduced to a certain extent.

Table 5 Impact Strength properties of specimens

Samples	Stacking sequence	Specimen Energy (J)	Specimen E/W (J/mm)	Pendulum energy (J)	Impact strength (J/mm²)
S1	JJJ	7.585	3.214	10.028	0.156
S2	JGJ	6.055	3.52	10.028	0.166
S3	GJG	8.008	3.742	10.028	0.169
S4	GGG	5.891	3.386	10.028	0.16
S5	JGJG	6.84	4.071	10.028	0.186

Table 6 Absorbency test result of the specimens

Immersion Time	Sample	Dried sample weight (gm)	Wet sample weight (gm)	Water absorbency (%)
2 –hours	S1	3.57	3.58	0.28
	S2	4.95	4.96	0.2
	S3	5.08	5.09	0.19
	S4	6.48	6.49	0.15
	S5	6.22	6.23	0.16
24- hours	S1	3.99	4.08	2.25
	S2	4.37	4.45	1.83
	S3	4.95	5	1
	S4	7	7.04	0.57
	S5	6.2	6.25	0.8

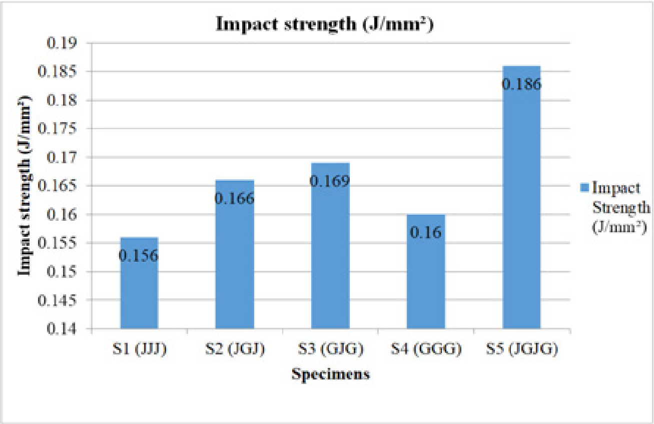

Figure 20 Representation of Impact strength of specimens.

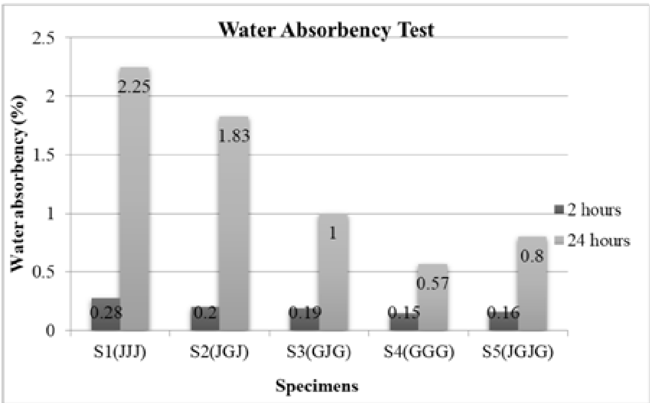

Figure 21 Representation of water absorbency o the composites.

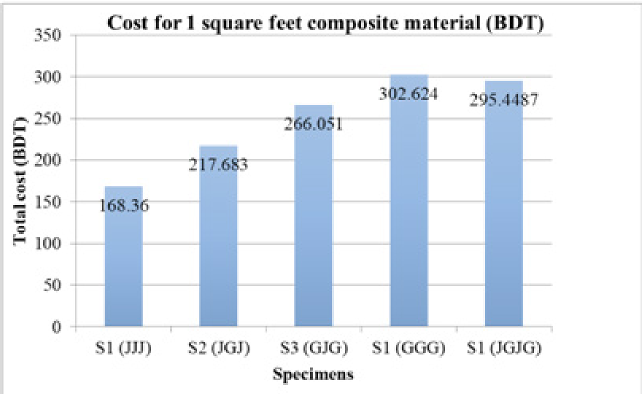

Figure 22 Presentation of cost analysis.

Conclusion

This work showed that by incorporating the optimum amount of natural fibers, the overall strength of glass fiber reinforced hybrid composite can be increased. It is observed that in making of composites for low load bearing applications, jute fiber can be a partial replacement of high cost synthetic fibers. Due to high stiffness and impact strength of Jute reinforced glass epoxy composite, it has good damage tolerance, lighter weight, good surface finish & appearances, weight reduction hence higher fuel efficiency, so they would enjoy wider applications in automobiles and railway coaches and sporting goods such as skis, canoe helmets. However, due to less water absorption, glass-epoxy reinforced composite can be used for door application such as insulated indoor and outdoor, underground piping, tanks, washroom door etc.

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Conflicts of interest

The authors have no conflicts of interest regarding the publication of this paper.

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