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Development of jute rope hybrid composite plate using carbon fibre

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Abstract. Jute rope is one of the most popular materials used for composites in various industries and in civil engineering. This experimental study investigated two types of jute rope with different diameters for jute rope composite plates to determine the best combination of jute rope and carbon fiber in terms of ratio and physical and mechanical properties. Eight combinations of carbon fiber and jute rope with different percentages of carbon fiber were analyzed. Tensile tests for the jute rope composite plate and hybrid jute rope composite were conducted, and the mechanical and physical properties of the specimens were compared. Thereafter, the ideal combinations of jute rope with an optimum percentage of carbon fiber were identified and recommended. These particular combinations had tensile strengths that were 2.23 times and 1.76 times higher than other varieties in each type.

Keywords: carbon fibre; hybrid; polymer-matrix composites; mechanical properties; jute rope

1. Introduction

The current use of structures is changing because of the manner by which people utilize them and the increasing pace of technological development. However, given that building structures takes a considerable time to complete and is costly, civil engineering solutions are constantly being explored to devise techniques for the upgrade of existing structures to address present needs. Several factors, such as the harsh environment, concrete corrosion, and non-usage of high-quality materials, are cited as reasons for developing, repairing, and enhancing the integrity of a structure. Strengthening concrete structures is one of the current and most intellectually challenging preoccupations in civil engineering; this endeavor started two decades ago and is still expanding. External bonding of plates is among the most popular methods for strengthening structures. Among the advantages of this method are flexibility for use in any condition, use of simple equipment, and simplicity of application. Steel plates were initially used for external strengthening but corrosion and rusting are major drawbacks in this process. Therefore, the search for corrosion- and rust-resistant materials led civil engineers to identify fiber-reinforced plates (FRP) as materials that do not exhibit

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the disadvantages associated with steel plates. Numerous studies on FRP have been conducted and researchers have explored various techniques to develop and increase the tensile capacity of this material. FRP is developed from both carbon (CFRP) and glass (GFRP). Despite the popularity of these materials, both exhibit a few downsides, such as their high cost and the associated health-related issues resulting from their use. Currently, natural fibers (e.g., jute, banana, sisal, abaca, coir, and pineapple) are commonly used in the FRP industry. These materials are inexpensive, pose no health risks, and renewable. Shifting the fabrication of composite materials from using synthetic fibers to biodegradable, renewable, and inexpensive ones because of environmental concerns is increasing progressively. Sisal, jute, abaca, pineapple, and coir exhibit specific satisfactory properties, such as low density, low abrasion, multifunctional, good thermal properties, enhanced energy recovery, and cause minimal skin and respiratory irritations (Huq *et al*. 2011, Chin and Yousif 2009, Kulkarni *et al*. 2014, Guptaa *et al*. 2015). Given these benefits, natural fibers have received considerable attention from researchers and civil engineers. Basak *et al*. (1996) analyzed the energy consumption of both glass and natural fibers and determined that a 60% energy savings per ton of product could be achieved by using vegetal fibers instead of glass ones. Other benefits of using natural fibers include the preservation of ecological balance and employment opportunities for people living in rural areas in such countries as India and Bangladesh, where the jute plant is common (Ramesh *et al.* 2013a). Therefore, developing materials using natural fibers has become attractive among researchers and engineers in their endeavor to determine the best method to increase and develop the mechanical and physical properties of these natural fibers (Ramesh *et al.* 2013b, Hossain *et al.* 2013, Ramnath *et al*. 2013, Ku *et al.* 2011, Sen and Jagannatha Reddy 2013, Nirbhay *et al*. 2015).

Jute is one of the natural fibers used in polymer composites, and is suitable for primary structural applications, indoor elements in housing, temporary outdoor applications (e.g., low-cost housing for protection and rehabilitation), and transportation. Providing insulation is one of the objectives of using jute, as seen in automotive door/ceiling panels and panels separating the engine and passenger compartments (Khondker *et al.* 2005). Jute fibers have become one of the most commonly used natural cellulosic fibers in recent decades (Basak *et al*. 1996). These fibers have gained popularity and attracted considerable attention because of their outstanding properties. Biological, chemical, or biochemical methods are used for degumming the jute plant stem to extract the jute fiber, which mainly comprises cellulose, hemicellulose, and lignin (Basak *et al*. 1996, Hill *et al.* 1998, Khan and Ahmad 1996, Ali *et al*. 2015). A bundle of long chains of cellulose molecules with lignin and hemicellulose are contained in a single jute fiber. These materials act similar to cement agents, thereby providing fiber tenacity and flexibility. These properties result in a coarse and hard fiber, which is ideal for producing high-quality textiles (Khan and Ahmad 1996, Joko *et al*. 2002). Producing considerably fine and soft jute fiber requires a purifying process to remove non-cellulosic materials. However, a specific amount of non-cellulosic materials should be maintained to ensure adequate tenacity and length of the fiber. Thus, refining the jute fiber is necessary to produce considerably soft and fine fiber. Asharful *et al.* (2015) investigated the fabrication of jute rope composite plates for flexural strengthening. They used the hand lay-up method to fabricate jute rope composite plates with a tensile strength of 99.97 N/mm^2. Table 1 presents the methods and different combinations of jute fiber with other materials.

Moreover, this fiber is a potentially ideal material for plate fabrication (Ramesh *et al*. 2013b, Vijaya *et al*. 2013, Misra 2015). Although numerous studies on fabricating composite plates using jute fiber for the automotive and other industries have been conducted, studies on the fabrication of jute rope composite plates to strengthen reinforced concrete beams were seldom performed.

Table 1 Different methods and combination of material with jute rope

Author	Method of fabrication	Fibre		Tensile strength (MPa)
Ramesh *et al*. (2013a)	Hand layup	Sisal/GFRP		68.55
		Jute/GFRP		62.99
Ramesh *et al*. (2013b)	Hand layup	Glass/Sisal		176.20
		Glass/Jute		229.54
		Glass/Jute/Sisal		200
Vijaya Ramnath *et al*. (2013)	Hand layup	GFRP/Abaca		44.5
		GFRP/Jute		46.5
		GFRP/Abaca/Jute		57
Vijaya Ramnath *et al*. (2014)	Hand layup	GFRP/Abaca/Jute (orthogonal to the fibers 90°)		200-299
		GFRP/Abaca/Jute (parallel to fibres 0°)		231-322
		GFRP/Abaca/Jute (an angle of 45° to the fibres)		258-375
Jingcheng Zeng	Pressed with temperature	Jute fibre	49.5 (μm)	384
			61.5 (μm)	252
			75 (μm)	180
			76.5 (μm)	178
			112.5 (μm)	90
Venkateshwaran *et al*. (2012)	Hand layup	Banana Fibre		40.69
		Jute Fibre		26.53
		Banana/Jute/Banana		54.76
		Jute/Banana/Jute		32.63
Srinivasan *et al*. (2014)	Hand layup	GFRP/Banana/Flax		30
		Flax Fibre		32
		Banana Fibre		39

The current study focuses on developing jute rope composite plates and achieving the maximum tensile strength of the fabricated plate. Two types of jute rope with different diameters were used to determine the effect of radius on strength. Moreover, we also attempted to develop a jute rope composite plate that combines jute rope and different percentages of carbon fiber to determine the best combination that can achieve a high capacity.

2. Experimental work

2.1 Materials

2.1.1Jute rope

The jute plant grows in approximately three months and reaches a height between 12 ft and 15 ft

Table 2 Properties of jute ropes

Jute properties	Rope type A	Rope type B
Diameter (mm):	2.70	0.95
Tensile strength (N/mm^2)	104	123

Fig. 1 Jute rope type A and type B

during the jute season. A variety of lifestyle products have been produced and differentiated into a number of forms from the jute plant (Ramesh *et al*. 2013b). The current study selected two types of jute rope based on rope diameter and Fig. 1 shows two types of jute rope. Thereafter, tensile tests for both types of jute rope were performed. Table 2 presents the properties of jute, while Figs. 2(a) and 2(b) illustrate the stress–strain curves.

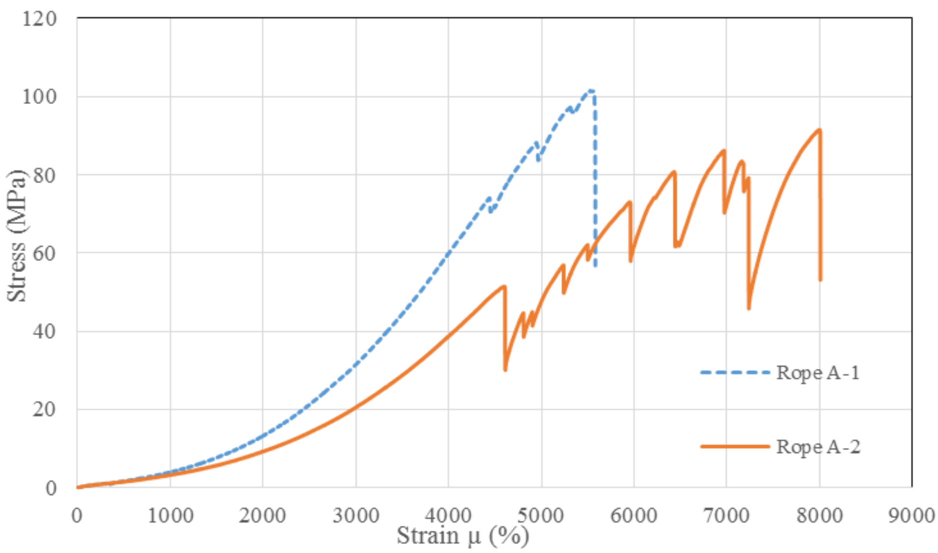

Fig. 2(a) Stress-strain curves for rope type A

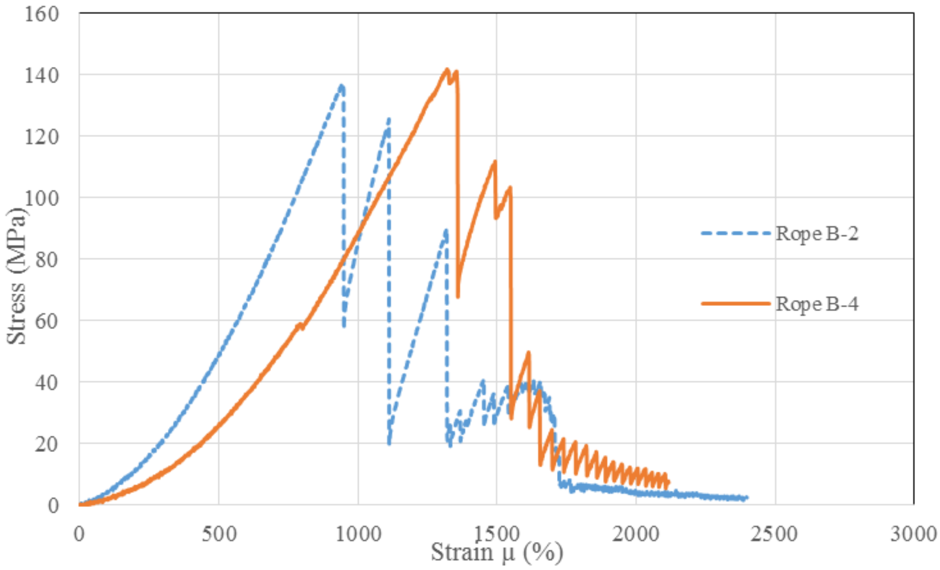

Fig. 2(b) Stress-strain graph for rope type B

2.1.2 Resin epoxy

Epoxy BBT-7892 (Berjaya Bintang Timur Sdn, Bhd Malaysia) was used for this study. BBT-7892 is a two-component liquid epoxy laminating system that is particularly designed for the wet hand lay-up process involving composites for high heat resistance applications. This epoxy provides two sets, namely, BBT-7892A and BBT-7892B, with a mix ratio of 5 to 1 for both sets.

2.1.3 Carbon fibre

Carbon graphite is known as carbon fiber or graphite fiber. Carbon fiber is a material comprising fibers measuring between 5 μm and 10 μm in diameter. Most of these fibers comprise carbon atoms. The carbon fiber structure of carbon fiber-based products is characterized as bonded crystals that are aligned parallel to the long axis of the fibers. Hence, the alignment of crystals results in a high strength-volume ratio of the fiber, thereby making it strong despite its size. Forming a tow entails several thousand carbon fibers to be bonded, which could be used individually or woven into a fabric.

Carbon fiber properties, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance, and low thermal expansion, have enhanced the popularity of this material in the aerospace industry, civil engineering, military, motorsports, and other competition sports.

2.2 Test specimens

Two types of jute rope were combined with carbon fiber to provide the specimens. Four combination types of jute rope and carbon fiber were considered for each type of jute rope. Three samples were made for each type of combination to replicate and realize the results. Table 3 presents the specimens used in this study.

Table 3 Different types of combination fabricated plates

Type of jute rope	Description	Specimen ID	
Jute rope type A	Three layers jute rope	AJ3	AJ3 (1) AJ3 (2) AJ3 (3)
	There layers jute rope and two layers carbon fibre	AJ3C2	AJ3C2 (1) AJ3C2 (2) AJ3C2 (3)
	Three layers jute rope and three layers carbon fibre	AJ3C3	AJ3C3 (1) AJ3C3 (2) AJ3C3 (3)
	Two layers jute rope and three layers carbon fibre	AJ2C3	AJ2C3 (1) AJ2C3 (2) AJ2C3 (3)
Jute rope type B	All jute rope	BJ4	BJ4 (1) BJ4 (2) BJ4 (3)
	Two layers jute ropes and one layer carbon fibre	BJ2C1	BJ2C1 (1) BJ2C1 (2) BJ2C1 (3)
	Three layers jute ropes and two layers carbon fibre	BJ3C2	BJ3C2 (1) BJ3C2 (2) BJ3C2 (3)
	Four layers jute ropes and three layers carbon fibre	BJ4C3	BJ4C3 (1) BJ4C3 (2) BJ4C3 (3)

2.3 Plate fabrication

A combination of jute rope and carbon fiber in these types of fabricated plate is produced using the hand lay-up method.

The jute ropes were initially prepared and cut. Once the jute ropes were cut, the mold was cleaned and oil was applied. The entire mold must be covered with plastic sheets. The next step involved preparing the epoxy resin. Epoxy resin BBT-7892 sets A and B were mixed and stirred until the solution became consistent.

The preceding steps will be used for both types of jute rope. However, the succeeding steps were quite different in terms of using the jute rope because of its diameter.

2.3.1 Plate preparation with jute rope type A

The jute rope was placed in the prepared epoxy resin for approximately 5 min to 7 min. Given the large diameter of jute rope type A, this rope was observed for approximately 5 min to 7 min while in the resin epoxy. Thereafter, the jute ropes were placed one after the other into the mold. Each layer needed sufficient jute ropes to fill all the gaps in the layer. One of the combinations was three layers of jute rope; thus, the plate was completed by repeating the aforementioned steps thrice. Other combinations had two and three layers of carbon fiber. For these combinations, a layer of carbon fiber was placed on top of each layer of jute rope; thereafter, the next layer of jute rope was placed. The jute rope should be laid straight inside the mold and prevented from being moved when

Fig. 3(a) Spreading adhesive

Fig. 3(b) Applying carbon fiber on jute ropes

applying the other layers. Moreover, the jute ropes should be compressed in all the steps involved.

2.3.2 Plate preparation with jute rope type B

The jute rope was mixed with the epoxy resin in the mold instead of being placed in the adhesive because of this rope's short diameter. In this step, a thin layer of adhesive was applied to the plastic sheet and then the jute ropes were placed layer by layer. After placing the first layer of jute rope on the thin layer of epoxy resin, the adhesive was applied and spread evenly on top of the jute ropes (Fig. 3(a)). Each layer of jute ropes was placed in the same manner and the same steps were followed. For the plates with carbon fiber, the carbon fiber was applied after placing the first layer of jute ropes as shown in Fig. 3(b).

The remaining steps were the same for both types of jute rope. Applying the load and compressing the plate were done gradually. The pressure for loading is 247.27 gr/cm^2 (24249.2 N/m^2); a ratio of 10 kg per min for loading is highly effective. The gradual loading was continued until the steel plate on top of the mold reached and touched the lower part of the mold.

For compacting, the plate was underloaded for at least one day because of the properties of the epoxy resin. Table 4 shows the average mix ratio and percentages of the fabricated plates' contents for types A and B.

2.4 Curing of fabricated plate

Curing the fabricated plate is an essential process in this study. Once the composite plate has been fabricated, it needs seven days at room temperature to achieve the maximum adhesive strength.

2.5 Testing the mechanical and physical properties of the fabricated plate

Table 4 Mix ratio details of specimen

Specimen ID	Weight of fibre (g)		Weight of epoxy (g)	Fibre content (%)		Weight of plate (g)	Volume (m^3)	Composition (Kg/m^3)		
								Fibre		Adhesive
	Jute	Carbon		Jute	Carbon			Jute	Carbon	
Jute Rope Composite Plate Type A										
AJ3	90	0	184	33	0	274	$2.33x10^{-4}$	386	0	790
AJ3C3	90	15	176	33	5.5	281	$2.33x10^{-4}$	386	64	755
AJ2C3	60	15	135	28	7.1	210	$1.78x10^{-4}$	337	84	758
AJ3C2	90	10	171	34	3.8	271	$2.30x10^{-4}$	391	43	743
Jute Rope Composite Plate Type B										
BJ4	206	0	444	32	0	650	$5.2x10^{-4}$	396	0	854
BJ2C1	204	12	463	30	1.8	679	$5.17x10^{-4}$	395	23	896
BJ3C2	200	24	455	29.5	3.54	679	$5.45x10^{-4}$	367	44	835
BJ4C3	192	36	491	27	5	719	$5.68x10^{-4}$	338	63	864

Fig. 4 Universal testing machin INSTRON for tensile test

2.5.1 Density and specific gravity

Density and specific gravity were calculated based on ASTM D792-13 (Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement) (ASTM D792-13, 2013).

2.5.2 Moisture absorption properties

Moisture absorption properties were investigated based on ASTM D 5229/D 5229M (Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials) (ASTM D5229/D5229M, 2004).

2.5.3 Tensile test

Tensile test was performed on the plates to determine their strength. This test was conducted based on ASTM Designation: D 3039/D 3039M – 08 (Standard Test Method for Tensile Properties of Polymer Matrix Composite materials), (ASTM D3039/D3039M 2000). The graph of the sample plates is provided. The tensile test was conducted using an INSRONT Universal Testing Machine 3369 50 KN Dual Column Testing Systems. Fig. 4 shows the tensile test machine and rupture of the plates.

3. Experimental results

3.1 Physical properties of the jute rope composite plate

Table 5 shows the average results of the density, specific gravity, and moisture absorption tests. Although increasing the percentage of carbon fiber enhanced the density of the fabricated plate with jute rope type A, the extent of enhancement was negligible. The density of the fabricated plate with jute rope type B was almost the same with the different percentages of carbon fiber. The percentage of moisture absorption was also approximately the same for both types of fabricated plate because the properties of carbon fiber are not compatible for water or moisture absorption. Based on the composite plate ratio, the major component of the plates was made by the jute rope and epoxy resin, while the percentage of carbon fiber was from 1.8% to 7%. Therefore, the amount of carbon fiber had a limited effect on density, specific gravity, and moisture absorption.

3.2 Mechanical properties of the jute rope composite

Table 6 shows the mechanical properties of the jute rope composite plates for types A and B. Unlike the physical properties, the mechanical properties were affected by the percentage and number of carbon fiber layers used for the fabricated plate. In type B, the mechanical properties were increased by adding each layer of carbon fiber, as the strain–stress curves of these specimens show (Fig. 5). A fabricated plate without carbon fiber (BJ4) reached a tensile strength of 99.97 N/mm^2; adding 1.8% carbon fiber to the same plate (BJ2C1) increased the tensile strength to 120.58 N/mm^2. Meanwhile, 3.5% carbon fiber (BJ3C2) enhanced the tensile strength to 151.76 N/mm^2. Adding 5% carbon fiber (BJ4C3) increased the tensile strength by 76.25% at 176.20 N/mm^2.

Table 5 Details of weight, density, specific gravity and moisture absorption

Specimens ID	Density (gr/cm^3)	Specific Gravity	Moisture absorption (%)
	Type A		
AJ3	1.15	1.15	2.99
AJ3C2	1.18	1.18	2.60
AJ3C3	1.20	1.20	2.65
AJ2C3	1.22	1.22	2.50
	Type B		
BJ4	1.20	1.20	2.39
BJ2C1	1.20	1.20	2.07
BJ3C2	1.17	1.16	2.35
BJ4C3	1.20	1.20	2.23

Table 6 Mechanical properties of jute rope composite plate type A and B

Specimen		Cross-section area (mm^2)	Maximum load (N)	Modulus of elasticity (MPa)		Tensile strength (N/mm^2)	
Jute rope composite type A							
	AJ3(1)	142.65	10060.41	3965		70.52	
AJ3	AJ3(2)	163.7	12060.39	3833	3957	73.67	72.69
	AJ3(3)	147.4	10891.66	4073		73.89	
	AJ3C2(1)	140.30	21392.81	5851		152.48	
AJ3C2	AJ3C2(2)	143.34	25592.49	6447	6245	178.54	162.72
	AJ3C2(3)	141.05	22164.38	6436		157.13	
	AJ3C3(1)	150.97	20439.49	6347		135.38	
AJ3C3	AJ3C3(2)	152.27	20842.45	6353	6355	136.88	142.17
	AJ3C3(3)	155.74	24023.28	6365		154.25	
	AJ2C3(1)	114.94	19268.18	7906		167.63	
AJ2C3	AJ2C3(2)	118.84	18107.73	7620	7883	152.37	160.62
	AJ2C3(3)	113.54	18380.47	8122		161.88	
Jute rope composite type B							
	BJ4(1)	143.45	13571.66	4541		94.60	
BJ4	BJ4(2)	146.76	15631.13	4459	4436	106.50	99.97
	BJ4(3)	144.64	14294.08	4309		98.82	
	BJ2C1(1)	141.55	15360.54	5417		108.51	
BJ2C1	BJ2C1(2)	147.16	17028.61	5479	5535	115.71	120.58
	BJ2C1(3)	145.88	20064.59	5708		137.54	
	BJ3C2(1)	149.82	25154.13	6565		167.89	
BJ3C2	BJ3C2(2)	157.70	20963.19	6026	6313	132.93	151.76
	BJ3C2(3)	151.31	23375.69	6348		154.48	
	BJ4C3(1)	157.23	27137.39	6673		172.60	
BJ4C3	BJ4C3(2)	161.45	29721.31	6839	6721	184.09	176.20
	BJ4C3(3)	158.92	27322.36	6652		171.92	

The modulus of elasticity of the fabricated plates type B started at 4436 MPa for (BJ4) and was enhanced by adding carbon fiber, thereby reaching 5535, 6313, and 6721 MPa for the fabricated plates (BJ2C1), (BJ3C2), and (BJ4C3), respectively. In this type of jute rope, adding carbon fiber enhanced the modulus of elasticity and tensile strength.

Fig. 6 presents the stress-strain curves of the fabricated plate type A. The behavior of the carbon fiber for jute rope type A was different from that of jute rope type B.

A fabricated plate without carbon fiber (AJ3) had a tensile strength of 72.69 N/mm^2. Adding 5.5% carbon fiber (AJ3C3) did not result in attaining the highest strength; instead, the tensile strength was merely 142.17 N/mm^2. Adding 3.7% carbon fiber to the same plate (AJ3C2) enabled the tensile strength to reach 162.72 N/mm^2. In the fabricated plate type A, decreasing the percentage of jute rope and increasing the percentage of carbon fiber (7.1%) resulted in (AJ2C3) with tensile

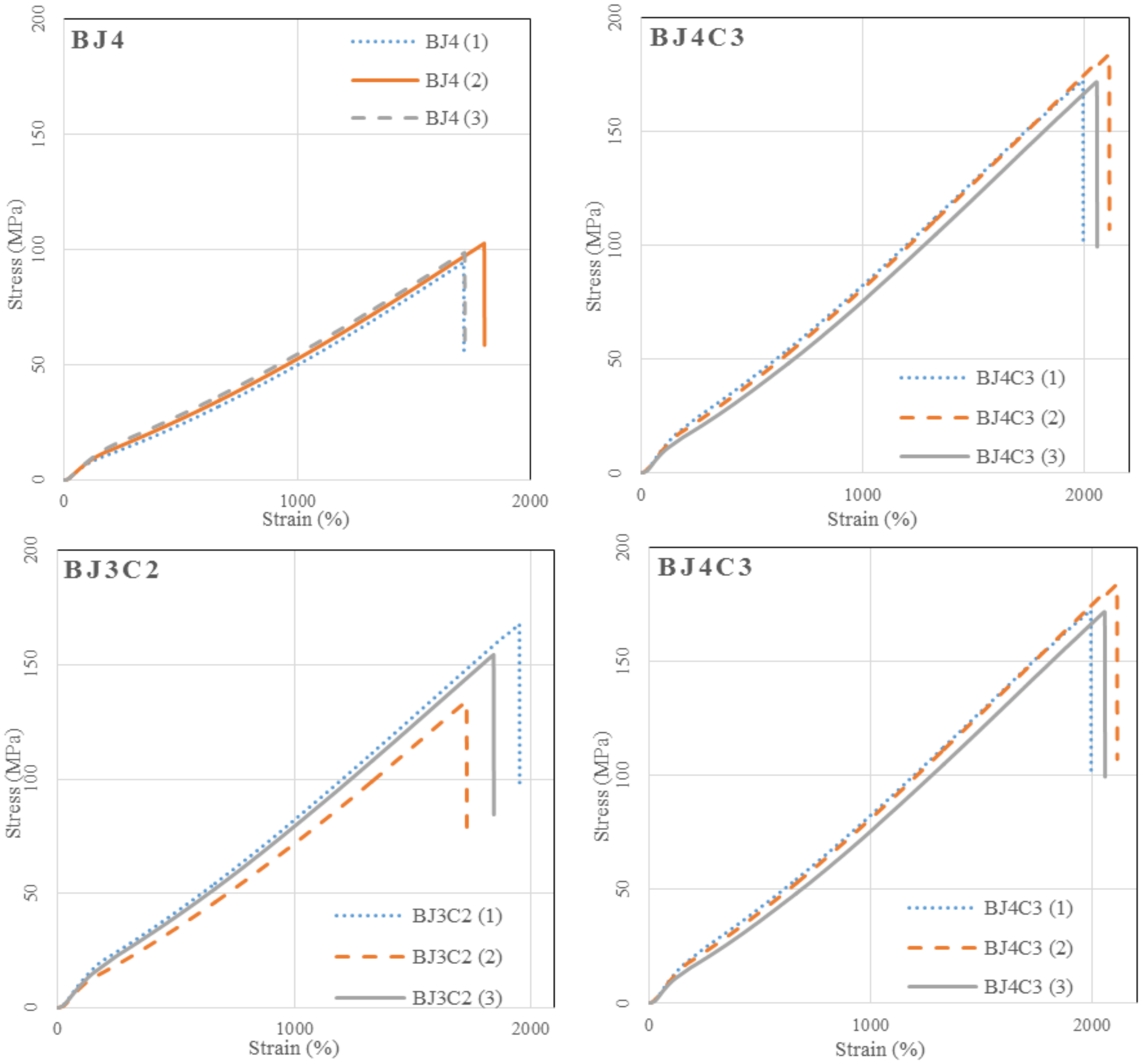

Fig. 5 Tensile tests for jute composite plate type B

strength of 160.62 N/mm^2; this figure is less than that of (AJ3C2). Therefore, the tensile strengths of the aforementioned two plates were approximately the same.

The modulus of elasticity for the fabricated plates (AJ2C3), (AJ3C2), and (AJ3C3) were 7883, 6245, and 6355 MPa, respectively. Hence, the modulus of elasticity for the composite plate (AJ3) was 3957 MPa. Thus, increasing the percentage of carbon fiber enhanced the modulus of elasticity.

Adding 3.8% and 3.5% carbon fibers in the fabricated plate types A and B, respectively, resulted in a similar modulus of elasticity. Increasing the carbon fiber in the fabricated plate by 7.1% could achieve the highest modulus of elasticity in both types of fabricated plate. Thus, the modulus of elasticity is dependent on the percentage of carbon fiber. However, the modulus of elasticity of the fabricated plate type B without carbon fiber was approximately 12%, which was higher than that of type A.

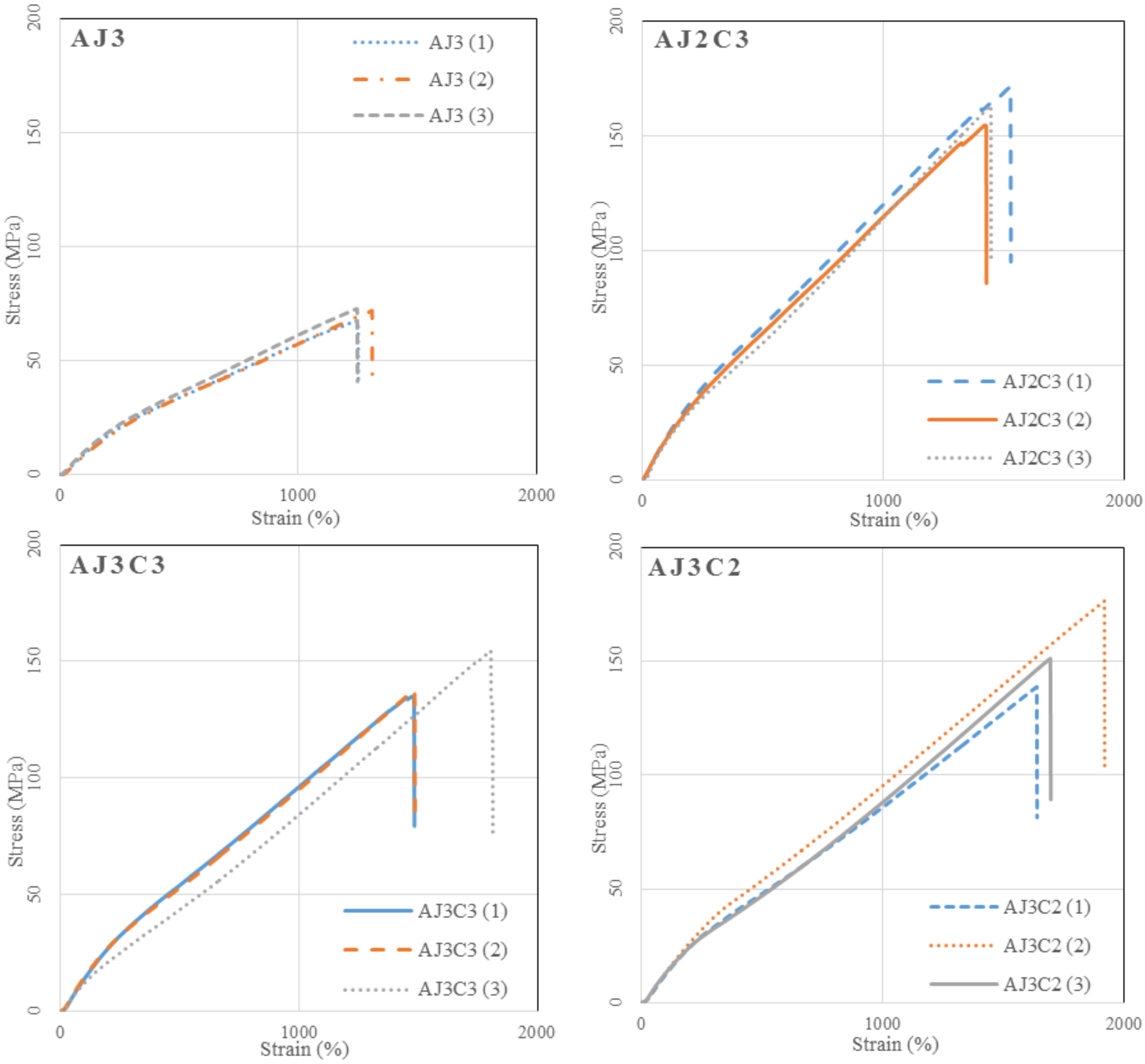

Fig. 6 Tensile tests for jute composite plate type A

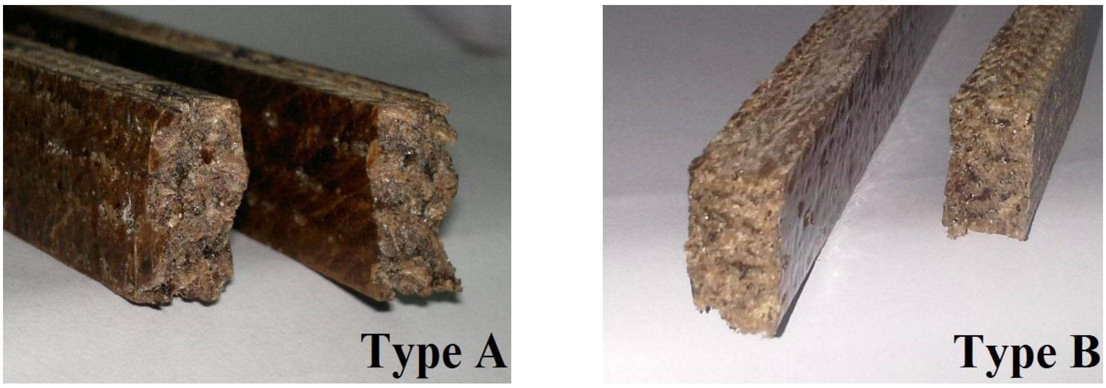

Fig. 7 Rapture of fabricated plates type A and B after tensile test

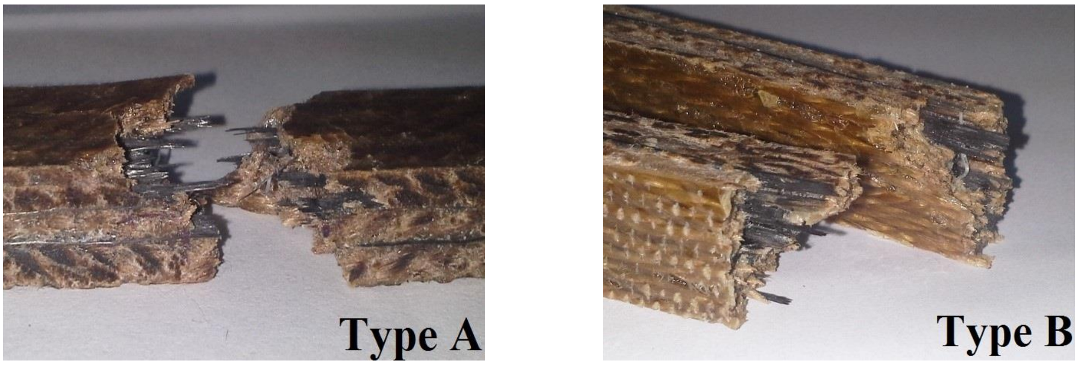

Fig. 7 Continued

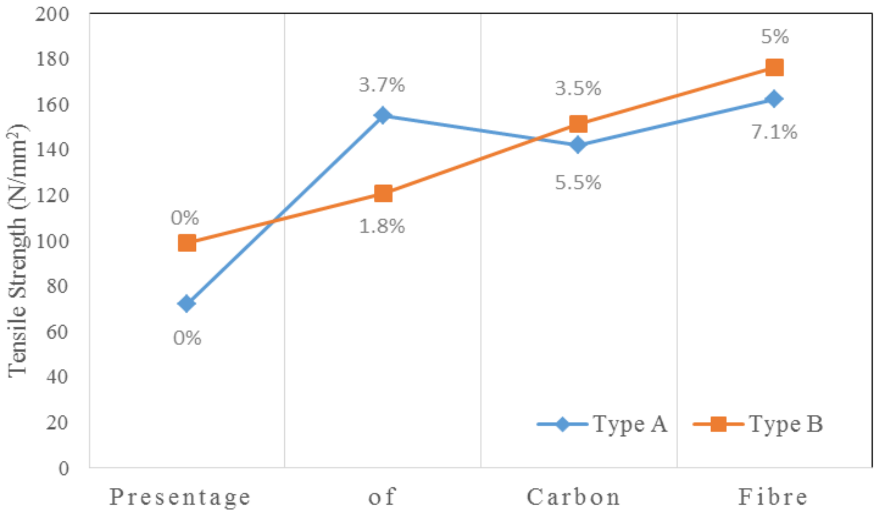

Fig. 8 Average of tensile strength of plates

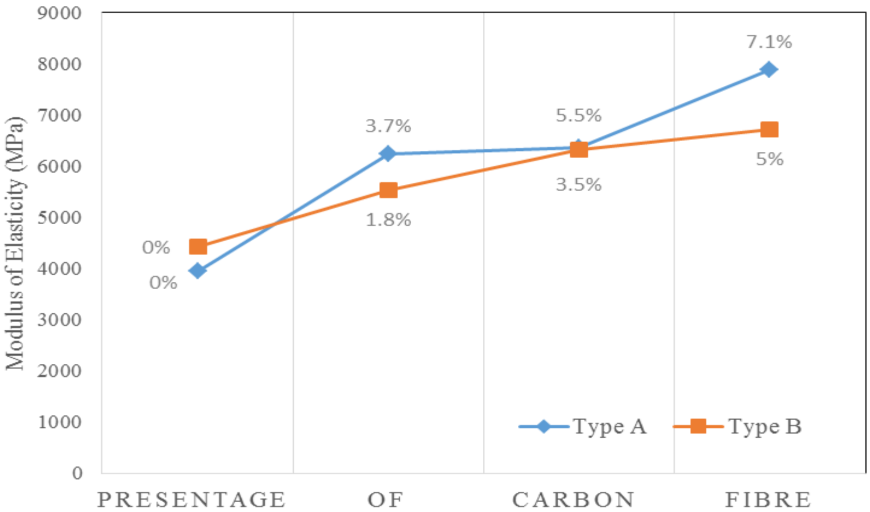

Fig. 9 Average of modulus of elasticity of plates

The fabricated plates belong to a group of homogeneous materials. The properties of these plates are the same in all locations of the fabricated plate. Therefore, the brittle mode failure of the jute rope composite plate for types A and B was observed after conducting the tensile test. By contrast, the failure mode was different for the hybrid jute rope composite plate because of the carbon fiber; these fabricated plates failed by fracture of jute rope followed by carbon fibre. Fig. 7 shows the tested fabricated plates.

4. Conclusions

The following conclusions have been drawn from the study of the jute epoxy composite.

(1) The unidirectional fabrication of the jute rope and hybrid jute rope composite plates was completed by using the hand lay-up technique.

(2) Two types of jute ropes with different diameters were investigated. Four combinations of jute rope with carbon fiber were considered for each type of jute rope. A total of eight types of jute rope composites were analyzed in this study. Three samples were fabricated and tested for each type.

(3) In jute rope type A, adding 3.8% carbon fiber (AJ3C2) increased the tensile strength by 123.85% compared to (AJ4). The modulus of elasticity was enhanced 99.21% by adding 7.1% carbon fiber (Fig. 8).

(4) In jute rope type B, the tensile strength and modulus of elasticity increased by 76.97% and 51.5%, respectively, by adding 5% carbon fiber to the fabricated plate (Fig. 7).

(5) In both types of fabricated plate, (BJ4C3) had the highest strength and (AJ2C3) had the highest modulus of elasticity.

(6) Unlike in tensile strength, increasing the percentage of carbon fiber enhanced the modulus of elasticity in both types of jute rope (Fig. 8).

(7) The brittle failure mode was observed for the jute rope composite plate, whereas the failure mode for the hybrid jute rope composite plate was the fracture of the jute rope followed by carbon fiber.

(8) Testing and analyzing numerous samples determined that most of them have linear elastic behavior and exhibit no plastic deformation after the elastic zone fabricated plate failed. A lack of plastic behavior is a drawback for these types of composite plate, thereby necessitating further study in the future.

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Appendix

Resin Epoxy BBT-7892
Certificate of analysis resin epoxy BBT-7892
Product Name: EPOXY A
Costumer: EUROLA INDUSTRIES SDN BHD
Lot Number: EH-78920502235
Customer Order No: Verbal
Quantity: 5 kg
Measures on a product as such

Table A1 Properties of Epoxy A

Properties	Result	Method	Conformant
Colour, Platinum Cobalt	75 Max	ASTM D – 1209	Conform
Viscosity @ 30℃, mPa.s	10300	ASTM D – 445	Conform
Density @ 30℃, g/ml	1.15	ASTM D – 4052	Conform

Measures on a mixed properties (mixing ratio: 100.20, 100 gm mass)

Table A2 Measures on a mixed properties

Properties	Result	Conformant
Pot life @ 30℃	55 minutes	Conform
Curing time @ 30℃	5 hours	Conform

Product Name: EPOXY B
Costumer: EUROLA INDUSTRIES SDN BHD
Lot Number: EH-78920502236
Customer Order No: Verbal
Quantity: 1 kg
Measures on a product as such

Table A3 Properties of Epoxy B

Properties	Result	Method	Conformant
Colour, Platinum Cobalt	50 Max	ASTM D – 1209	Conform
Viscosity @ 30℃, mPa.s	120	ASTM D – 445	Conform
Density @ 30℃, g/ml	1.03	ASTM D – 4052	Conform

Measures on a mixed properties (mixing ratio: 100.20, 100 gm mass)

Table A4 Measures on a mixed properties

Properties	Result	Conformant
Pot life @ 30℃	55 minutes	Conform
Curing time @ 30℃	5 hours	Conform

Epoxy BBT-7892 was provided for this application. BBT-7892 (Berjaya Bintang Timur Sdn, Bhd Malaysia) is a two-component liquid epoxy laminating system, which was specially designed for the wet hand lay-up process in composites for high heat resistance applications. BBT-7892 provides good wetting to most composite materials, such as glass fibre, carbon fibre and aramid. BBT-7892 also exhibits low odour, low shrinkage, and excellent thermal shock. This epoxy provided two sets-BBT 7892 A and BBT 7892 B-, and its mix ratio is 5 to 1 for set A and B respectively. Besides, it is forbidden to mix quantities greater than 500 gm as dangerous heat increases can cause uncontrolled decomposition of the mixture. Mixing smaller quantities will minimize heat build-up.

Recommended usage

The mixing ratio is 20 parts of BBT – 7892 A to 100 parts of BBT – 7892 B. Table A.5 shows the mixed properties of the epoxy resin according to the certificate of the factory.

Table A5 Properties of resin epoxy

Specifications	BBT – 7892 A	BBT – 7892 B
Appearance	Yellow liquid	Colourless to light yellowish liquid
Viscosity @ 30℃, cps	9000 – 13000	100 – 300
Specific Gravity @ 30℃	1.13 – 1.16	– 1.05

Applying

For mixing the epoxy resin BBT-7892, BBT-7892 A and BBT-7892 B were combined in the correct ratio and mixed thoroughly until a uniform mixture was obtained. It must be considered that a heat increase is common during or after the mixture process. It is forbidden to mix quantities greater than 500 gm as dangerous heat increases can cause uncontrolled decomposition of the mixture. Mixing smaller quantities will minimize heat build-up. Table A6 shown the properties of resin epoxy BBT-7892.

Table A6 Mixed properties of resin epoxy BBT-7892

Mixed properties of resin epoxy	
Appearance	Yellow liquid
Pot life @ 30℃ (100gm mass)	30 minutes
Curing time @ 30℃ (100gm mass)	4 – 5 hours
Full curing time @ 30℃	7 days
Heat resistance	150℃

A thin layer of mould release agent was brushed onto the surface of the master mould. Then, a clean cloth was used to polish the waxed surface until it was smooth. The fibreglass was wetted with the mixture and laid onto the mould using a steel roller to remove any trapped bubbles between the fibreglass. The process was continued until the required thickness was achieved. The moulded product was left to cure overnight and removed from the master mould the following day. The mechanical properties of epoxy resin BBT 7892 are presented in Table A7 according to the certificate of the factory.

Table A7 Mechanical properties for epoxy BBT 7892

Mechanical properties	
Tensile strength, MPa	67.56
Tensile modulus, MPa	2895.79
Elongation at break, %	4.9
Flexural strength, MPa	101.35
Flexural modulus, MPa	3516.32
Compress strength, MPa	82.04