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Development of High Strength Natural Fibre based Composite Plates for Potential Application in Retrofitting of RC Structure

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Abstract

The potential application of green fibre based composite plate in retrofitting of structure is growing up in construction industry nowadays. The aim of this research was to develop high strength natural fibre based composite plates for the possible application in strengthening of reinforced concrete structure. The plates were fabricated using kenaf fibre, jute fibre and jute rope respectively. The fibres and rope were chemically treated using 6% NaOH solution to enhance the tensile strength of fabricated plates. In fabrication process, a special technique was applied to compact the treated and untreated fibres to obtain the highest tensile strength of composite plates. The physical and mechanical properties of the fabricated composite plates were then experimentally investigated. In general, results showed that the chemical treatments had an influence to enhance the tensile strength of the plates. The tensile strength of composite plates with treated kenaf fibre, jute fibre and jute rope were 137 MPa, 136 MPa and 113 MPa respectively. While those of untreated kenaf fibre, jute fibre and jute ropes were 131 MPa, 136 MPa and 110 MPa respectively. Kenaf and jute fibre composite plates had shown higher tensile strengths as compared to those of jute rope. The natural fibre composite plates were found to be linearly elastic in nature and had shown brittle failure. The moisture content and the water absorption of the plates with treated fibres were found to be lower as compared to those of untreated fibres. In terms of tensile strength of fabricated plates, kenaf, jute and jute rope composite plates could be used in retrofitting of structures.

Keywords: Alkali, Jute Fibre, Jute Rope Fibre, Kenaf Fibre, Natural Fibre Composite

1. Introduction

Generally, natural fibres have been widely used for non-structural applications such as rope, binder twine, bag, broom, fish lines and filters[1]. There are many varieties of natural fibre exist and the most common natural fibres used in industrial application are baste fibres obtained from the outer cell layers of plant stems, such as hemp, jute, flax, kenaf, and sisal[2–4].

The interfacial property between the fibers and the resin play an important factor on the mechanical properties of the fiber composite[5,6]. Due to that, several studies have being investigated and conducted to improve the interfacial bonding thus improving the fiber properties[7–11]. The chemical treatment of fibers one of the techniques used to improve the interfacial bond between the fiber and the resin matrix by modifying the fiber surface and the fiber strength[12]. Moreover, it reduces the water absorption and improves the mechanical properties of the fiber[13]. Chemical treatment of the fiber can stop moisture absorption process and increase the surface roughness[14,15]. Therefore, chemical treatment can be considered in modifying and improving the properties of natural fibers[16,17]. Many studies have shown various treatments methods which could modify and improve the mechanical properties of natural fibers such as alkali, saline and peroxide treatments[18]. Alkaline

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treatment is one of the most typical and simple chemical treatments methods with least environmental effect[10,18].

Although, a significant number of research works have been conducted to develop composite plates using natural fibers for automotive industry, however, fabrication of high strength natural fiber based composite plates for strengthening of reinforced concrete structure is seldom found. In this study, three different types of natural fibers i.e. kenaf, jute and jute rope had been used to fabricate the high strength composite plates for the potential use in retrofitting of structure. The effects of alkaline treatment on the three different types of natural fibers in the composite plates had also been investigated. The physical and mechanical properties of the composite plates were experimentally analyzed.

2. Experimental Programme

2.1 Specimen Preparation

The composite plates were fabricated using six different categories of natural fibres as shown in Table 1. The main variables of the specimens were treated and untreated fibre based composite plates using kenaf fibre, jute fibre and jute rope. Three specimens were prepared from each batch. The specimens were fabricated by had lay-up technique using treated and untreated fibres and epoxy resin. The details of all specimens are shown in Table 1.

2.2 Materials

The raw kenaf fibre, jute fibre and jute rope as shown in Figure 1 were dried and cleaned. All fibres were combed and straightened. The defect on the fibre such as dark spot and some weak fibre were eliminated. The composite plates were fabricated using fibres and epoxy resin (adhesive). Hand lay-up technique was applied to fabricate the plates. The adhesive was mixed properly with BBT-7892A resin and BBT-7892B hardener. BBT-7892 is a two component liquid epoxy laminating system, which is specially designed for wet hand lay-up process in composite for high heat resistance applications. The mix ratio of adhesive used was 5:1 by weight. The epoxy resin and the hardener were supplied by Berjaya BintangTimurSdn. Bhd.

2.3 Treatment with NaOH

The natural fibres, kenaf, jute and jute rope were treated with Sodium Hydroxide (NaOH) solution of 6% concentration (by weight) to fabricate the composite plates with treated fibres. The fibres were soaked in the alkali solution for 24 hour at room temperature, then washed and dried in an oven at 100°C for 24 hour.

Table 1. Specimen name

Fibre	Specimen ID.	Description of Specimens
Kenaf	TK1	Treated kenaf fibre with 6% NaOH
	TK2	
	TK3	
	K1	Untreated kenaf fibre
	K2	
	K3	
Jute	TJ1	Treated jute fibre with 6% NaOH
	TJ2	
	TJ3	
	JU1	Untreated jute fibre with
	JU2	
	JU3	
Jute Rope	TJR1	Treated jute rope fibre with 6% NaOH
	TJR2	
	TJR3	
	JRU1	Untreated jute rope fibre
	JRU2	
	JRU3	

Figure 1. Kenaf fibre, jute fibre and jute Rope.

2.4 Method of Fabrication

The composite plates were fabricated using steel mould with the dimensions of 400mm length x 110mm width x 6mm thickness. The steel mould was cleaned and a thin layer of grease was applied for easier releasing the composite plate after setting the adhesive. The mix ratios of all composite plates are shown in Table 2. The fibres were divided into equal layers with approximately equal

Table 2. Mix proportion of fibre composite plates

Specimen		Weight of plate (g)	Fibre content by weight (%)	Mix proportion (Kg/m^3)	
Fibre	ID.			Fibre	Adhesive
Kenaf	TK1				
	TK2	364	44	559	713
	TK3				
	UK1				
	UK2	341	47	559	633
	UK3				
Jute	TJ1				
	TJ2	356	45	559	685
	TJ3				
	UJ1				
	UJ2	335	47.8	559	612
	UJ3				
Jute Rope	TJR1				
	TJR2	363	44	559	710
	TJR3				
	UJR1				
	UJR2	353	45	559	675
	UJR3				

weight. The first layer of the fibre was put in the mould then the adhesive was poured. The first layer was pressed gently using spatula from the centre part of the fibre to both ends. The steps were repeated for the next layers. During the fabrication process, the fibres were pressed gently to ensure that there were no air void inside the layers and the fibres were fully soaked with the epoxy. Once, the epoxy was going to set, the semi solid composite plate was compressed using clamps, to allow the trapped air and extra adhesive to come out. Finally, the plate was cured at room temperature for one day before removed it from the mould. Due to the properties of epoxy resin, the composite plate was kept for curing for 7 days in room temperature before testing. The fabricated composite plates are shown in Figure 2.

2.5 Testing Procedure

The physical and mechanical properties of the natural fibre composite plates were experimentally investigated as per ASTM standards. The densities of the natural fibre composite plates were being determined as per Archimedes methods in the ASTM D3800. Water absorption and moisture contents of the composite plates had being conducted according to ASTM D5229/D 2339M.

Figure 2. Fabricated composite plates.

A total of 3 samples for each type of plates were selected for tensile test as shown in Figure 3(a) and (b). The samples were cut the dimension of 250mm x 15mm x 6mm. Then it was tested using Instron Universal Testing Machine, equipped with a 50 kN capacity load cell. The tensile tests were carried out as per ASTM D3039, as shown in Figure 4.

Figure 3. Test specimens (a) Fibre plate, (b) Rope plate.

Figure 4. Testing of specimens using UTM.

3. Experimental Results

3.1 Properties of Composite Plates

The physical and mechanical properties for the three different types of treated and untreated natural fibre composite plates are summarized in Table 3. The average tensile strengths of untreated kenaf, jute and jute rope composite plates were found to be 131 MPa, 136 MPa and 110 MPa respectively. The untreated jute fibre composite plate had shown higher tensile strength as compared to kenaf fibre composite plate. It could be due to better tensile property of jute fibre as compared to kenaf. Results also showed that both kenaf and jute fibre composite plate showed higher tensile strength than jute rope composite plate. In general, the compaction of fibre would affect the amount of fibres in composite plate which would influence the properties of composite plates. Both kenaf and jute fibre had shown better compaction as compared to rope, thus, showed better tensile strength. Results also showed that the composite plates with treated fibres had higher tensile strength as compared to those of untreated fibres. Treated jute has the highest average tensile strength of 137 MPa as compared to the treated kenaf and jute rope composite plates. The highest average tensile strength of composite plate was found to be almost half of the yield strength of steel plate.

The average modulus of elasticity of treated kenaf fibre, jute fibre and jute rope composite plates were 14.91 GPa, 17.79 GPa and 10.37 GPa, respectively. While, untreated kenaf fibre, jute fibre and jute rope were 13.19 GPa, 14.45 GPa and 10.21 GPa respectively. The enhancement was due to the strong interfacial adhesion of the treated fibres compared to untreated fibres.

The density of untreated kenaf fibre, jute fibre and jute rope composite plates were found to be 1.04 g/cm^3, 1.05 g/cm^3 and 1.07 g/cm^3 respectively. In general the density of the natural fibre based composite plates were

Table 3. Experimental results of natural fibre composite plates

Specimen ID.	Tensile strength (Mpa)	Average tensile strength (Mpa)	Modulus of elasticity (Gpa)	Average modulus of elasticity (Gpa)	Physical properties		
					Density (g/cm^3)	Moisture content (g/cm^3)	Water absorption (%)
TK1	140	136	15.24	14.91	1.16	3.41	6.79
TK2	145		16.94				
TK3	124		12.56				
UK1	146	131	14.55	13.19	1.04	4.42	9.61
UK2	123		12.29				
UK3	124		12.72				
TJ1	127	137	14.48	17.79	1.22	2.44	2.82
TJ2	137		14.38				
TJ3	148		15.50				
UJ1	156	136	14.44	14.54	1.05	3.38	8.14
UJ2	110		13.55				
UJ3	143		15.64				
TJR1	106	113	10.99	10.37	1.18	3.92	4.91
TJR2	113		9.83				
TJR3	119		10.29				
UJR1	110	110	10.79	10.21	1.07	4.35	6.04
UJR2	119		10.27				
UJR3	100		9.58				

lower than steel plate (7.8 g/cm^3) and CFRP laminate (1.6 g/cm^3)[17]. It could be due to low density of nature fibre. However, once the fibre was treated, the density of composite plates increased as shown in Table 3. It happened due to chemical coating on fibres. The coating would increase the weight of fibres, thus, the overall density of plates also increased.

Results also showed that the chemical treatments of fibre with alkali had an influence on the reduction on the moisture content of composite plates. The alkaline solution reduced the moisture of fibres through the hydration process, thus reduce the moisture content of composite plates. The moisture content had effects on durability of composite plates. The composite plates with lesser moisture content would enhance the durability of plates. The 6% NaOH solution also reduce the water absorption rate of composite plates. The water absorption rates of untreated kenaf fibre, jute fibre and jute rope composite plates were 9.61%, 8.14% and 6.04%, respectively. Whereas, the treated kenaf fibre, jute fibre and jute rope composite plates had 6.74%, 2.82% and 4.91% water adsorption respectively.

3.2 Stress-strain Behaviour of Composite Plates

A selected failure tensile mode of the composite plate is shown in Figure 5. It was observed that the natural fibre composite plates failed with adhesive rather than deboning of fibre or fracture of the composite along the direction of the fibre.

The stress strain behaviour of kenaf fibre, jute fibre and jute rope composite plates are shown in Figure 6, Figure 7 and Figure 8 respectively. All the plates had shown almost linear elastic nature until it would fail. The results of all three samples in each group were found to be compatible. However, the ultimate strengths of plates in each group were found to be bit non consistency.

3.3 Comparative Analysis of Composite Plates

The treated fibre based composite plates had shown bit higher tensile strength and lower density as compared to un-treated fibre based composite plate. The jute rope composite plate had shown the maximum tensile strength of 136 MPa and 137 MPa with untreated and treated fibre respectively. That particular treated fibre based composite plates had shown approximately 0.8% higher tensile

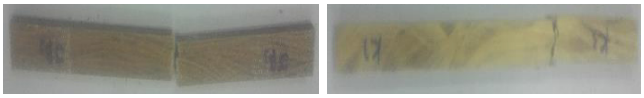

Figure 5. Failure mode of composite plates due to tensile force.

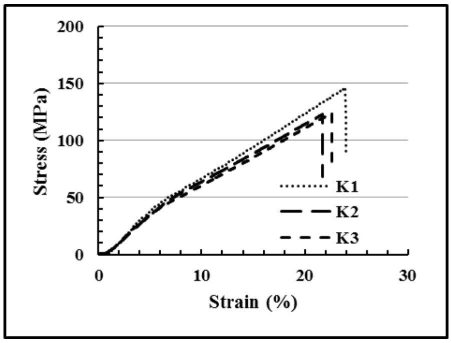

Figure 6. (a) Stress-strain behaviour of untreated kenaf composite plate.

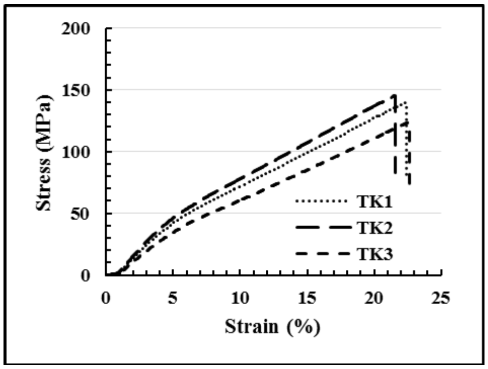

Figure 6. (b) Stress-strain behaviour of treated kenaf composite plate.

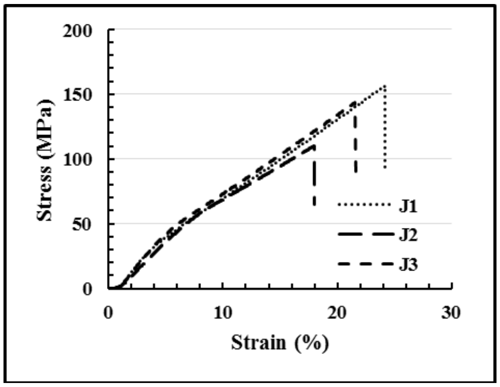

Figure 7. (a) Stress-strain behaviour of untreated jute composite plate.

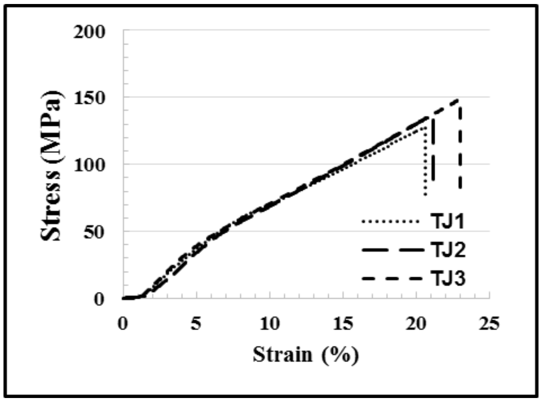

Figure 7. (b) Stress-strain behaviour of treated jute composite plate.

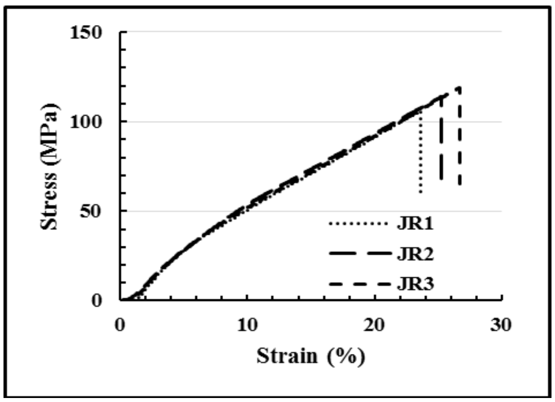

Figure 8. (a) Stress-strain behaviour of untreated juterope composite plate.

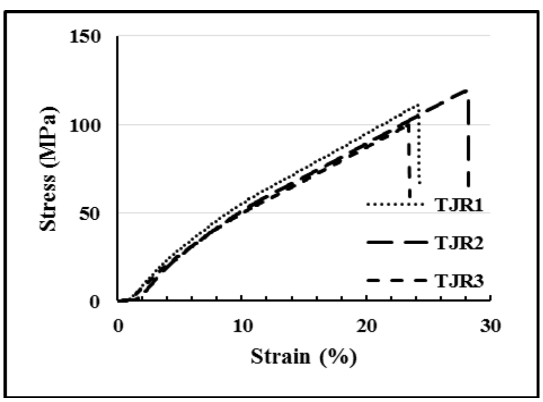

Figure 8. (b) Stress-strain behaviour of treated juterope composite plate.

strength as compared to those of untreated plates. It could be seen that the untreated jute rope composite plate had shown 19% and 26% lower tensile strength as compared to those of kenaf and jute respectively.

4. Conclusion

Jute fibre composite plate had shown the highest tensile strength of 137 MPa as compared to kenaf fibre and jute rope based composite plates. The differences of tensile strengths between jute fibre and kenaf fibre based composite plates were found to be minimal. However, jute rope composite plates had shown significantly lower tensile strength as compared to kenaf and jute fibre composite plates. The treated fibre based composite plates had a bit higher tensile strength as compared to those of untreated plates. All the plates had linear elastic nature. The density of all untreated kenaf, jute and jute rope composite plates were found to 1.04 g/cm^3 to 1.07 g/cm^3. However, the composite plates with treated fibre had shown bit higher density as compared to untreated composite plates. The chemical treatment showed significant decrease in the moisture content and water absorption of the composite plate compared to untreated fibres. Finally, it could be conclude that the alkali treatment had enhanced the mechanical and physical properties of the natural fibre composite plates.

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6. References

1. Wambua P, Ivens J, Verpoest I. Natural fibres: can they replace glass in fibre reinforced plastics. Compos Sci Technol. 2003 Jul; 63(9):1259–64.
2. Kozlowski R, Mieleniak B. Flame resistant lignocellulosic-mineral composite particleboards. Polym Degrad and Stability. 1999 Jun; 64(3):523–8.
3. Rai B, Kumar G, Diwan RK, Khandal R K. Study on effect of euphorbia coagulum on physico-mechanical and fire retardant properties of polyester-banana fiber composite. Indian Journal of Science of Technology. 2011 Apr; 4(4):443–6.
4. Srinivasababu N, Murali Mohan Rao K, Suresh Kumar J. Experimental determination of tensile properties of okra, sisal and banana fiber reinforced polyester composites. Indian Journal of Science and Technology. 2009 Jul; 2(7):35–8.

5. Saba N, Paridah MT, Jawaid M. Mechanical properties of kenaf fibre reinforced polymer composite: a review. Constr Build Mater. 2015; 76:87–96.
6. Nitta Y, Noda J, Goda K. Effect of alkali-treatment on tensile properties of kenaf long fibers. 18th International Conference on Composite Materials.
7. El-Shekeil YA. Influence of chemical treatment on the tensile properties of kenaf fiber reinforced thermoplastic polyurethane composite. Express Polym Lett. 2012 Sep; 6(12):1032–40.
8. Sever K. The Improvement of mechanical properties of jute fiber/ldpe composites by fiber surface treatment. J Reinf Plast Compos. 2009 Jul; 29(13):1921–9.
9. Meon MS, Othman MF, Husain H, Remeli MF, Syawal MSM. Improving tensile properties of kenaf fibers treated with sodium hydroxide. Procedia Eng (Iris). 2012 Jan; 41:1587–92.
10. Glass C. Effect of alkali treated jute fibres on composite properties. 2001; 24(2):129–35.
11. Keshk S, Suwinarti W, Sameshima K. Physicochemical characterization of different treatment sequences on kenaf bast fiber. Carbohydr. Polym. 2006 Jul; 65(2):202–06.
12. Yousif BF, Shalwan A, Chin CW, Ming KC. Flexural properties of treated and untreated kenaf/epoxy composites. Mater Des. 2012; 40:378–85.
13. Sen T, Reddy HNJ. Pretreatment of woven jute frp composite and its use in strengthening of reinforced concrete beams in flexure. AMSE Adv Mater Sci Eng. 2013; 2013.
14. Edeerozey AMM, Akil HM, Azhar AB, Ariffin MIZ. Chemical modification of kenaf fibers. Mater Lett. 2007 Apr; 61(10):2023–5.
15. Ray D, Sarkar BK, Rana AK, Bose NR. Effect of alkali treated jute fibres on composite properties. Bull Mater Sci. 2001 Apr; 24(2):129–36.
16. Li X, Tabil LG, Panigrahi S. Chemical treatments of natural fiber for use in natural fiber-reinforced composites: a review. J Polym Environ. 2007 Jan; 15(1):25–33.
17. Miah MJ, Khan MA, Khan RA. Fabrication and characterization of jute fiber reinforced low density polyethylene based composites: effects of chemical treatment. J Sci Res. 2011 Apr; 3(2):249–59.
18. Williams T, Hosur M, Theodore M, Netravali A, Rangari V, Jeelani S. Time effects on morphology and bonding ability in mercerized natural fibers for composite reinforcement. Int J Polym Sci. 2011; 2011.