ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(6), DOI: 10.17485/ijst/2016/v9i6/77483, February 2016* ISSN (Online) : 0974-5645

Hybrid Kenaf Fibre Composite Plates for Potential Application in Shear Strengthening of Reinforced Concrete Structure

Md Ashraful Alam[1*], Khalid Alriyami[1], Zakaria Che Muda[1] and Mohd Zamin Jumaat[2]

[1]Department of Civil Engineering, Universiti Tenaga Nasional, Malaysia;
ashraful@uniten.edu.my, alriyami510@hotmail.com; MZakaria@uniten.edu.my
[2]Department of Civil Engineering, Universiti of Malaya, Malaysia;
zamin@um.edu.my

Abstract

This paper presents the finding of an experimental study on kenaf fibre hybrid composite plates for potential application in shear strengthening of RC beam. In the experimental programme, hybrid composite plates had been fabricated using kenaf and carbon fibres with five different mixes i.e., 47% kenaf with 0% carbon; 45% kenaf with 2.5% carbon; 47% kenaf with 5% carbon; 45% kenaf with 7.5% carbon and 45% kenaf with 10% carbon. The physical and mechanical properties of the fabricated hybrid composite plates were then experimentally investigated. Results showed that carbon contents had an influence to enhance the tensile strength of the plates. Hybrid composite plate with 10% carbon content had shown 130% higher tensile strength as compared to that of plate without carbon fibre. The carbon content also had enhanced the modulus of elasticity of plates. Higher percentage of carbon had shown higher tensile strength and modulus of elasticity of hybrid composite plates. All fabricated plates had linear elastic properties under tension. The density of plates increased with the increasing of carbon content in composite plates. The research findings indicated that the developed hybrid composite kenaf could be used for shear strengthening of reinforced concrete beam.

Keywords: Carbon Fibre, Epoxy, Hybrid Composite, Kenaf, RC Structure, Shear Strengthening

1. Introduction

Nowadays, using of agricultural based natural fibres as reinforcement in the composite materials is getting more attention by researchers. The need for the world to become environmentally friendly made the natural fibre reinforced composites growing rapidly. The interest is due to the availability of natural fibres in bundles and also the advantages over traditional reinforcement materials in terms of low cost, low density, renewability, recyclability, abrasiveness and biodegradability which made the researcher more interesting worldwide to use eco-friendly material in engineering technologies[1]. This material shall warrant high specific strength and high specific stiffness of the structural materials provide a possible alternative to synthetic fibres[2–4].

Generally, natural fibres have been widely used for non-structural applications such as rope, binder twine, bag, broom, fish lines and filters[5]. Natural fibres can be defined as substances produced by plants, animals, and minerals. Plant fibres are the most common natural fibres used as reinforcement in fibre reinforced composites. Plant fibres exists in many varieties, such as kenaf, jute, bamboo, hemp, and flax extracted from stem of the plant, sisal, and abaca from leaf and coir and cotton from fruit of the plant[6]. Amongst them, kenaf has been widely used in composite plates recently. It is an herbaceous annual plant that can be grown under a wide range of weather condition, it grows to more than 3 m within 3 months even in moderate ambient conditions[7]. Kenaf has high environmental impact, absorbs nitrogen and phosphorus included in the soil and accumulates carbon dioxide at

** Author for correspondence*

a significantly high rate[8,9]. Kenaf fibres also offers the advantages of being available in large quantities, non-abrasiveness during processing, low density, it exhibits high specific mechanical properties, and biodegradability. It has a baste fibre which contains 75% cellulose and 15% lignin and offers the advantages of being biodegradable and environmentally safe[10,11].

There are factors have to considered which influence the performance of natural fibre reinforced composites. One of the factors is, the fibre ratio/content which has an influence to the properties of the natural fibre reinforced composites. The influence of the fibre content on the properties of natural fibre reinforced composites is predominantly significance as to achieve high performance of the composites required high fibre content. It is investigated that the tensile property increases with the increases in fibre content[12–14].

Hybrid composites are fabricated by mixing two or more fibres to form a single matrix. It can be made up of artificial fibres, natural fibres or with a mixture of both artificial and natural fibres[15]. There is a great potentiality of hybrid composite materials in the field of engineering due to low cost, strength-to-weight ratio and ease of manufacturing[16]. Combining two or more fibre in a single matrix could offer a possibility of achieving combined properties such as increasing fatigue life, stiffness, ductility and strength, compared to single fibre reinforced composites[17].

Over the last few years, research works have been conducted to develop biodegradable hybrid natural fibre composite plates for automotive industry[18,19]. However, fabrication of high strength hybrid natural fibre based composite plates for strengthening of reinforced concrete structure is seldom found. Recently, few works are done on the development of natural fibre based composite plate for strengthening of structure[20,21]. In this study, natural fibre, kenaf had been used to fabricate a high strength hybrid composite plate with carbon fibre for the potential use in retrofitting of structure. The physical and mechanical properties of the composite plates were experimentally analyzed.

2. Experimental Programme

2.1 Specimen Preparation

To develop hybrid kenaf fibre composite plates, the specimen K0, KC1, KC2, KC3 and KC4 were fabricated using different carbon fibre contents as shown in Table 1. Three specimens were prepared from each batch. The specimens were fabricated by had lay-up technique using kenaf fibre, carbon fibre sheets and epoxy resin. The details of all specimens are shown in Table 1.

Table 1. Details of specimens

Specimen ID	Fibre content by weight (%)	
	Kenaf	Carbon
K0	47	-
KC1	45	2.5
KC2	47	5
KC3	45	7.5
KC4	45	10

2.2 Materials

The raw kenaf fibres, as shown in Figure 1 were dried, cleaned and combed. The composite plates were fabricated using kenaf fibre, carbon 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 Bintang Timur Sdn. Bhd.

Figure 1. Kenaf fibre.

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 weight. The first layer of the fibre was put in the mould

Table 2. Mix proportion of hybrid kenaf fibre composite plates

Specimen		Weight of fibre (g)		Weight of plate (g)	Fibre content (%)		Composition (Kg/m³)		
							Fibre		
ID	No.	Kenaf	Carbon		Kenaf	Carbon	Kenaf	Carbon	Adhesive
K0	1	160	-						
	2			341	47	0	606	-	686
	3								
KC1	1	160	8.9						
	2			355	45	2.5	606	34	706
	3								
KC2	1	160	17.8						
	2			343	47	5	606	67	626
	3								
	1								
KC3	2	160	27	353	45	7.5	606	102	629
	3								
	1								
KC4	2	160	36	358	45	10	606	136	612
	3								

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.

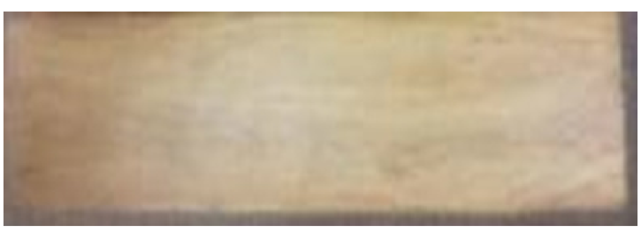
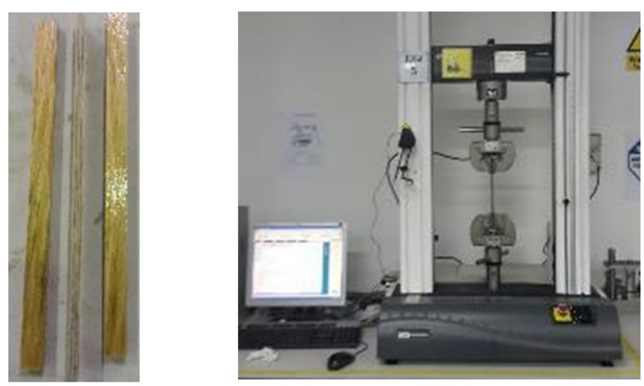


Figure 2. Fabricated composite plates.

2.5 Testing Procedure

The physical and mechanical properties of the composite plates were experimentally investigated as per ASTM standards. The densities of the hybrid composite plates were being determined as per Archimedes methods in the ASTM D3800. Water absorption and moisture contents of the hybrid composite plates had being conducted according to ASTM D5229/D2339M.

A total of 3 samples for each type of plates were selected for tensile test as shown in Figure 3(a). The samples were cut into 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 3(b).



(a) (b)

Figure 3. (**a**) Test specimens. (**b**) Testing of specimens using UTM.

3. Experimental Results

3.1 Properties of Kenaf Fibre Hybrid Composite Plates

The mechanical and physical properties for the five different types of kenaf fibre composite plates are summarized in Table 3 and Table 4 respectively. From the result summary it can be observed that the KC4 with the 10% carbon have the highest average tensile strength of 301 MPa as compared to K0, KC1, KC2 and KC3, with average tensile strength of 131 MPa, 155 MPa, 200 MPa and 287 MPa respectively. The hybrid composite plate, KC4 with 10% carbon has approximately 83% higher tensile strength than the yield strength of steel plate. Results showed that the amount of carbon fibre considerably influenced the tensile strength properties of hybrid composite plates. The tensile strength of the hybrid composite plate increases with the increase of the percentage of carbon. The average modulus of elasticity of kenaf without carbon, K0 was 13.19 GPa. While, hybrid kenaf, KC1, KC2, KC3 and KC4 were 14.11 GPa, 18.33 GPa, 17.91 GPa and 18.37 GPa, respectively.

The average density from the five testing samples, K0, KC1, KC2, KC3 and KC4 were found to be 1.18 g/cm^3, 1.15 g/cm^3, 1.17 g/cm^3, 1.22 g/cm^3 and 1.23 g/cm^3 respectively. In general the density of the natural fibre based composite plates were lower than steel plate (7.8 g/cm^3) and CFRP laminate (1.6 g/cm^3)[22]. It could be due to low density of nature fibre. The highest moisture content was observed in K0 with 4.92% whereas the lowest was for KC3 and KC4 4.33% and 4.34% respectively. The moisture content for KC1 and KC2 were 4.88% and 4.80% respectively. The moisture content increases with the increase of fibre content. The water absorption is defined as the ability of the composite materials to absorb water. The water absorption rate of K0 was 4.79%, whereas, the water absorption rate of KC4 was 3.70%. The more fibre content, the higher percentage of water absorption is.

3.2 Stress-Strain Behaviour of Kenaf Fibre Hybrid Composite Plates

A selected failure tensile mode of the composite plate is shown in Figure 4. It was observed that the natural fibre composite plates failed with adhesive rather than debonding of fibre or fracture of the composite along the direction of the fibre. Whereas, slight debonding of fibres were noticed in case of hybrid composite plates. The debonding of fibre initiated at the interface of kenaf and carbon fibre. The stress strain behaviour of K0, KC1, KC2, KC3 and KC4 kenaf composite plates are shown in Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9 respectively. All the plates had shown almost linear elastic pattern until it would fail. From the pattern, it can be understood that the composite are brittle composite materials. The results of all three samples in each group were found to be compatible.

Figure 4. Failure mode of composite plates due to tensile force.

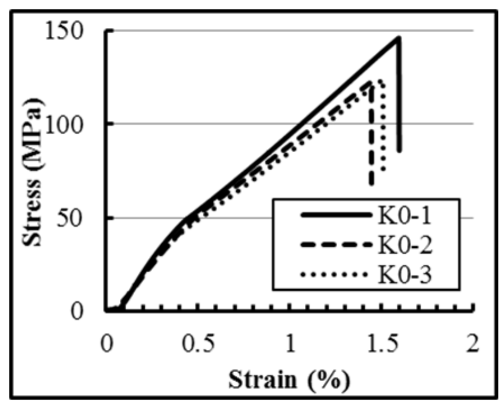


Figure 5. Stress-strain behaviour of K0 composite plate.

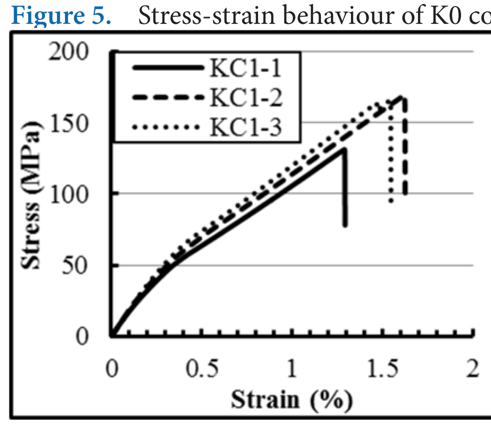


Figure 6. Stress-strain behaviour of KC1 hybrid composite plate.

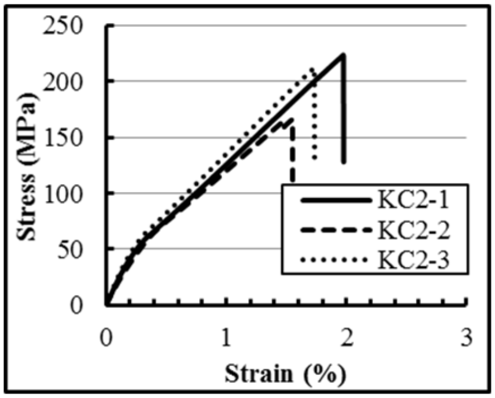


Figure 7. Stress-strain behaviour of KC2 hybrid composite plate.

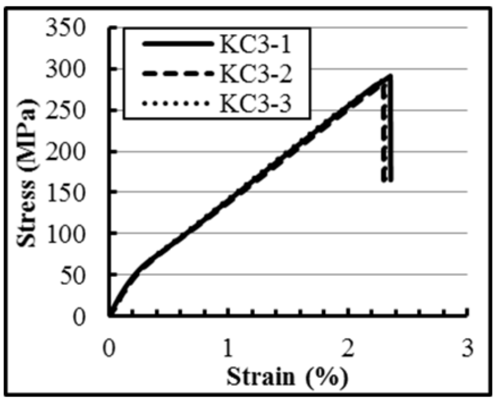


Figure 8. Stress-strain behaviour of KC3 hybrid composite plate.

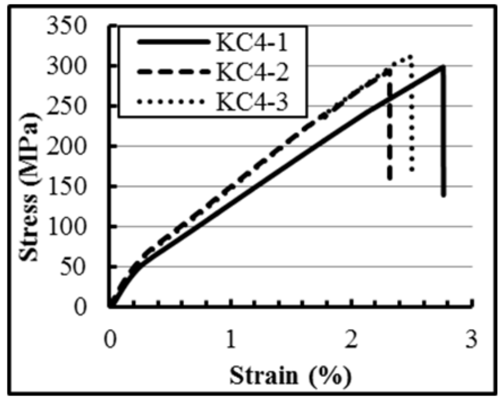


Figure 9. Stress-strain behaviour of KC4 hybrid composite plate.

3.3 Effect of carbon fibres in kenaf fibre composite plates

There are many factors that could affect the mechanical and physical properties of the natural fibre composite plate. In general, the higher fibre content resulted the higher properties and performance of composite plate. Table 3 and Table 4 showed that the physical and mechanical properties of the hybrid kenaf fibre composite plates was enhanced with the increasing in carbon fibre content. The enhancement in the tensile strength of the hybrid kenaf fibre composite plate with respect to the carbon fibre content was 18.3%, 52.7%, 119% and 129.8% for KC1, KC2, KC3 and KC3 respectively. The enhancement is

Table 3. Mechanical properties of hybrid kenaf fibre composite plates

Specimen ID	No.	Tensile strength (Mpa)	Average tensile strength (Mpa)	Modulus of elasticity (Gpa)	Average modulus of elasticity (Gpa)
	1	146		14.55	
K0	2	123	131	12.29	13.19
	3	124		12.72	
	1	131		15.58	
KC1	2	169	155	16.27	14.11
	3	166		10.44	
	1	223		17.47	
KC2	2	166	200	17.57	18.33
	3	211		19.94	
	1	291		17.43	
KC3	2	281	287	17.68	17.91
	3	288		18.63	
	1	298		16.33	
KC4	2	294	301	19.88	18.37
	3	311		18.90	

Table 4. Physical properties of hybrid kenaf fibre composite plates

Specimen ID	No.	Density (g/cm³)	Average Density (g/cm³)	Moisture content (g/cm³)	Average Moisture content (g/cm³)	Water absorption (%)	Average Water absorption (%)
	1	1.13		5.21		4.79	
K0	2	1.21	1.18	3.81	4.92	4.46	4.79
	3	1.20		5.74		5.14	
	1	1.17		4.84		3.89	
KC1	2	1.16	1.15	4.86	4.88	3.90	3.82
	3	1.10		4.94		3.68	
	1	1.23		4.57		3.42	
KC2	2	1.09	1.17	4.82	4.80	3.63	3.52
	3	1.20		5.01		3.50	
	1	1.22		6.39		3.56	
KC3	2	1.24	1.22	2.81	4.33	4.19	3.83
	3	1.21		3.79		3.73	
	1	1.13		4.99		3.95	
KC4	2	1.28	1.23	3.75	4.34	3.04	3.70
	3	1.26		4.27		4.12	

mainly due to high strength of carbon fibre compared to the low strength of kenaf fibre.

Figure 10 represents the effect of carbon contents on tensile strength of hybrid composite plate. The tensile strength of natural composite plates depends on the fibre and carbon contents. The higher carbon contents, the higher tensile strength. The results in Table 4 shows that the water absorption and moisture content of the hybrid kenaf composite plate with carbon are noticeably lower compared to kenaf composite plate without carbon. The content of carbon fibre on the kenaf composite plates has shown a significant effect and enhancement on its properties. The enhancements are in the mechanical and physical properties of the composite plate. Therefore, the effect of carbon fibre content in kenaf fibre composite plate is particularly significance.

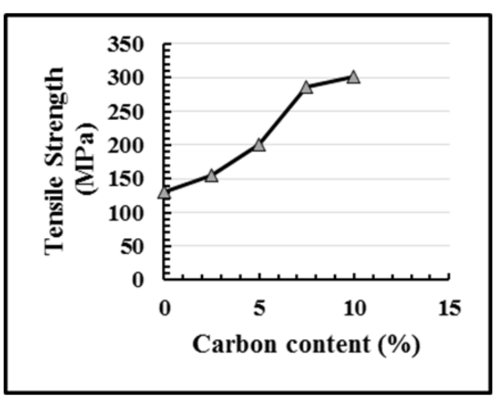


Figure 10. Effect of carbon content on tensile strength of hybrid composite plate.

3.4 Optimal Ratios of Carbon Fibre for Shear Strengthening of RC Beam using Hybrid Kenaf Fibre Composite Plate

The hybrid kenaf fibre composite plate K0, KC1, KC2, KC3 and KC4 were fabricated using different carbon fibre contents of 0%, 2.5%, 5%, 7.5% and 10% respectively. During the fabrication process of the hybrid kenaf fibre composite plate, it was noticed that the more carbon fibre content, the less adhesive is required as shown in Table 2. Furthermore, the 10% carbon fibre was the maximum ratio to maintain the minimum 6mm thickness and no more fibre could be added into the steel mould. Results shows that the ratio of 10% carbon fibre content had shown the highest tensile strength as compared to other ratios. Thus, 10% carbon fibre would be the optimal ratio to fabricate the hybrid kenaf composite plate for shear strengthening of RC beam.

4. Conclusion

Hybrid kenaf fibre composite plate with 10% carbon content had shown the highest tensile strength of 301 MPa as compared to kenaf fibre composite plate without carbon of 131 MPa. It is approximately 83% higher than the yield strength of steel plate. Changing various carbon contents had shown significant increases in tensile strength of the hybrid composite plate. The composite plate's behaviour had shown linear elastic pattern until it fail. The water absorption rate of K0 had shown higher percentage as compared to KC4 of 4.79% and 3.7% respectively. The more kenaf fibre contents, the higher percentage of water absorption is. The modulus of elasticity of K0 was found to be 13.19 GPa, whereas for KC4 was 18.37 GPa. From the experimental results, it could be conclude that the hybrid kenaf composite plate can be used for shear strengthening of reinforced concrete beam.

5. Acknowledgment

The work of this research had been conducted at the Department of Civil Engineering, University Tenaga National, authors would like to express their thanks to the Department. Thanks are also due to the Research Management Centre (RMC) of UNITEN for providing fund under grant J510050525 to carry out the research.

6. References

1. Saba N, Paridah MT, Jawaid M. Mechanical properties of kenaf fibre reinforced polymer composite: A review. Constr Build Mater. 2015; 76:87–96.
2. Athijayamani BPA, Thiruchitrambalam M, Manikandan V. Mechanical properties of natural fibers reinforced polyester hybrid composite. International Journal of Plastics Technology. 2010; 14(1):104–16.
3. Ku H, Wang H, Pattarachaiyakoop N, Trada M. A review on the tensile properties of natural fiber reinforced polymer composites. Compos Part B Eng. 2011 Jun; 42(4):856–73.
4. Malkapuram R Kumar V. Recent development in natural fiber reinforced polypropylene composites. J Reinf Plast Compos. 2008 Nov; 28(10):1169–89.
5. 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.
6. Kozlowski R, Mieleniak B. Flame resistant lignocellulosic-mineral composite particleboards. Polym Degrad. 1999 Mar; 64(3):523–8.
7. Rowell RM, Sanadi A, Jacobson R, Caulfield D. Properties of kenaf/polypropylene composites. Kenaf Prop Process Prod; 1999. p. 381–92.
8. Abe K, Ozaki Y. Comparison of useful terrestrial and aquatic plant species for removal of nitrogen and phosphorus from domestic wastewater. Soil Sci Plant Nutr. 1998; 44(4):599–607.
9. Amaducci S, Amaducci MT, Benati T, Venturi G. Crop yield and quality parameters of four annual fibre crops (hemp, kenaf, maize and sorghum) in the North of Italy. Industrial Crops and Products. 2000; 11(2–3):179–86.
10. Zainuddin SYZ, Ahmad I, Kargarzadeh H, Abdullah I, Dufresne A. Potential of using multiscale kenaf fibers as reinforcing filler in cassava starch-kenaf biocomposites. Carbohydr Polym. 2013 Feb; 92(2):2299–305.
11. Rashdi A, Sapuan SM, Ahmad MMHM, Khalina A. Water absorption and tensile properties of soil buried kenaf fibre reinforced unsaturated polyester composites (KFRUPC). J Food Agric Environ. 2009; 7(3–4):908–11.
12. Amel BA, Paridah MT, Sudin R, Anwar UMK, Hussein AS. Effect of fiber extraction methods on some properties of kenaf bast fiber. Ind Crops Prod. 2013 Apr; 46:117–23.
13. Hafizah N. Strengthening reinforced concrete beams using kenaf fiber reinforced polymer composite laminates. 3rd International Conference on Sustainable Construction Materials and Technologies.
14. Alam MA, Hassan A, Muda ZC. Development of kenaf fibre reinforced polymer laminate for shear strengthening of reinforced concrete beam. Mater Struct. 2016; 49(3):795–811.
15. Nunna S, Chandra PR, Shrivastava S, Jalan A. A review on mechanical behavior of natural fiber based hybrid composites. J Reinf Plast Compos. 2012 Jun; 31(11):759–69.
16. Gururaja MN, Rao ANH. A review on recent applications and future prospectus of hybrid composites. Int J Soft Comput Eng. 2012; 1(6):352–5.
17. Shahzad A. Impact and fatigue properties of hemp-glass fiber hybrid biocomposites. Journal of Reinforced Plastics and Composites. 2011; 30(16):1389–98.
18. Jeyanthi S Rani JJ. Improving mechanical properties by KENAF natural long fiber reinforced composite for automotive structures. 2012; 15(3):275–80.
19. Venkateshwaran N, Elayaperumal A, Sathiya GK. Prediction of tensile properties of hybrid-natural fiber composites. Compos Part B Eng. 2012 Mar; 43(2):793–6.
20. Busel JP, Bank LC, Brown VL, Campbell TI, Fam AZ, Lee MW. Guide for the design and construction of structural concrete reinforced with FRP bars reported by ACI committee 440; 2006.
21. Alam MA, Alriyami K, Jumaat MZ, Muda ZC. Development of high strength natural fibre based composite plates for potential application in retrofitting of RC structure. Indian Journal of Science and Technology. 2015 Jul; 8(15):1–7.
22. Alam MA, Alriyami K, Jumaat MZ, Noori K. Development of hybrid jute rope composite plates for potential application in shear retrofitting of RC structure. Indian Journal of Science and Technology. 2015 Nov; 8(30):1–7.