www.amlett.com, www.vbripress.com/aml, DOI: 10.5185/amlett.2015.5818 Published online by the VBRI Press in 2015

Investigation into the suitability of kenaf fiber to produce structural concrete

Noor Md. Sadiqul Hasan[1], Habibur Rahman Sobuz[2*], Abubakar Sharif Auwalu[1], Nafisa Tamanna[2]

[1]*School of Civil Engineering, Linton University College, Legenda Education Group, Mantin 71700, Malaysia*
[2]*Department of Civil Engineering, Universiti Malyaisia Sarawak, Kota Samarahan, Sarawak 94300, Malaysia*

[*]Corresponding author. Email. habibkuet@gmail.com

Received: 24 January 2015, Revised: 29 March 2015 and Accepted: 03 April 2015

ABSTRACT

This paper investigates of an experimental research that was conducted to study the effect of natural kenaf fiber on concrete production which implements in the sustainable construction industry as a low-cost material. Concrete produced with kenaf fiber reinforced concrete (KFRC) with fiber volume contents are increasing 0%, 1%, 3% and 5% in the mix proportions. The concrete fresh properties consisting slump and density are determined in the laboratory. The compressive strength, compacting factor test, modulus of rupture, surface strength, and direct shear test of KFRC specimens are investigated and compared to the properties of conventional concrete specimens. A total number of 36 concrete cubes with the size of 150 mm x 150 mm x 150 mm were tested for compressive strength, 36 Concrete beams with the size of 100 mm x 100 mm x 350 mm were tested for flexural strength, and also 36 concrete small beams with the size of 100 mm x 100 mm x 350 mm were tested for direct shear test. All of the specimens were cured for 7, 14 and 28 days before testing. The experimental results indicate that the mechanical and fresh properties of KFRC are decreased then the conventional concrete specimens with the increased of kenaf fiber content. It is also observed that the additions of fiber decreased the ultimate load of the concrete for compressive strength, modulus of rupture and direct shear test. However, kenaf fiber concrete enhanced more toughness and ductility behaviour compared with the conventional concrete. Finally, it concluded that kenaf fiber is a suitable material that could potentially be used to produce low-cost 'green' concrete which has higher toughness and reduce the cracking propagation in the concrete structural applications. Copyright © 2015 VBRI Press.

Keywords: Sustainable; toughness; kenaf fiber; compressive strength; flexural strength; direct shear; rebound hammer; ductility.

Introduction

Natural fibers are prospective reinforcing materials in concrete and their use has been more traditional than technical. The advantages of natural kenaf fiber reinforced concrete (KFRC) included increasing toughness, enhancing cracking behaviour, enhanced durability and improving fatigue and impact resistance have been well presented in the previous research [**1**]. Steel, polypropylene and synthetic fibers are the main materials used to control concrete cracks, weak bonds and spalling of concrete. As the needed for these materials is becoming higher and their cost is also rapidly increasing. Therefore, there is a need to explore alternative materials to ensure that the price of fibre is within an affordable limit for both small and large scale construction purposes.

Kenaf fiber comes from a plant named 'Kenaf' which is a plant in the Malvaceae family, is in the genus Hibiscus and is probably native to southern Asia although its exact natural origin is unknown. Kenaf denoted as industrial kenaf due to of its great interest for the production of industrial raw materials Kenaf is comparatively commercially available and economically cheap amongst other natural fiber reinforcing material **[2]**. Kenaf has been studied as a potential replacement for the diminishing tobacco farming industry in the south-eastern United States. Kenaf is a hardy, strong and tough plant with a fibrous stalk, resistant to insect damage and requires relatively fewer amount of or no pesticides **[2]**. Kenaf fiber consisting of following properties which includes its density is 1320 Kg/m^3, Tensile strength is 260 N/mm^2 and moist absorption is 10-12%, with the average diameter of fiber is 67.6 lm **[2]**. The kenaf plant can grow to heights of 3.5– 4.5 m within 4–5 months with annual fiber yields of 6 to 10 tons of dry fiber/acre, which is approximately four times greater than that of southern pine trees. Kenaf filaments consist of discrete individual fibers, generally 2–6 mm long **[3]**. Because of its high stiffness, strength values and also has higher aspect ratios which made it suitable to be used as reinforcement in polymer composites **[4]**. It has a best fiber which contains 75% cellulose and 15% lignin which offers the advantages of being biodegradable and environmentally safe material for producing structural concrete [**5**]. The use of kenaf fiber composites as reinforcements is currently one of the more interesting areas of research. Various sectors, especially from the research field involved in the use of natural materials as a reinforcement fiber, claim kenaf fiber, composite materials to be among the best available alternatives to replace synthetic fiber. Its excellent flexural and tensile strength made itself as a good candidate for many applications such as the reinforced material in concrete [**6**]. The use of natural plant fibers as a reinforcement in fiber-reinforced plastics (FRP) to replace synthetic fibers such as glass is receiving attention, because of advantages such as renewability, low density, and high specific strength. A large number of researches carried out on synthesis and characterization fibers based on different materials and their applications [**7-12**]**.**

Kenaf fiber can be used as a joining material with minimal overlapping length and can be utilised to produce polymeric material to implement in rehabilitation techniques of structures [**13**]. Due to its physical properties of light weight, competitive tensile strength, stiffness, vibration damping properties, and also due to the fiber being a renewable and biodegradable resources, kenaf fiber is the most suitable natural fiber for producing lightweight structures. An investigation conducted on natural fiber concrete to overcome the brittle response and limiting post-yield energy absorption of concrete led to the development of fiber reinforced concrete using discrete fibers within the concrete mass.

A number of experimental studies have been conducted past to explore the potential of kenaf fiber as reinforcement in polymers [**1, 2, 14-16**]**.** Recently, a detail of the review on kenaf fiber is introduced by Saba *et al.* [**2**]**.** Although the commercial application of natural fibers into fiber-reinforced concrete composite is gradually increasing day by day, there is still a lack of understanding of specific issues regarding their properties and behaviour. Therefore, much research is needed for potential use of natural-fiber materials in green construction applications.

Elsaid *et al.* [**1**] investigated that KFRC generally exhibits more distributed cracking and higher toughness than plain concrete. They also found that cracking behaviour enhances the durability of concrete at relatively low cost compared to other types of fibers. They established that the optimum mixture proportions of KFRC are of 1.2% and 2.4% fiber contents. Ngo *et al.* [**14**] to investigate the effects of the addition of natural fibres (Kenaf and Oil Palm Fruit Bunch) on the mechanical properties of reinforced polymer composites. They found that tested composites showed improvement by adding natural fiber as reinforcement in both tensile and flexural strength. Moses *et al.* [**15**] investigated the compressive strength properties of kenaf fiber composite mortar with Fiber contents of 1%, 2% and 3 %. It is observed that the compressive strength decreased with increasing fiber volume and length. However, there was an increase in compressive strength of between 0.21% - 22.3% for composite mortar containing 1-3% volume of fiber with 10mm fiber length. Hafizah *et al.* [**16**] presented the experimental results of a series of tensile test conducted on continuous kenaf fiber with different types of thermoset resin. It is found that composites performance increased gradually with every increment of fiber volume fraction. Flexural properties of beams under static and cyclic loading conditions and behaviour of beam-column joints under cyclic loading have been carried out and it is concluded that rural fibers including coir and sugarcane natural fibers exhibit better performance than conventional concrete. Hence the past research activities on natural fibrous concrete focused on mechanical strength and microstructural studies at 28 days curing period only [**17-20**].

It is observed that a number studies has been conducted on kenaf reinforced fiber concrete, but still there is lac of findings of an experimental research on natural kenaf fiber reinforced concrete (FRC). The main focus of this paper is to investigate the mechanical properties of KFRC including the compressive strength, modulus of rupture, shear strength and surface strength of KFRC.The objectives include the determination of the optimum percentage of kenaf fiber in concrete; comparing the mechanical properties of KFRC with the conventional concrete and also to set the possibility in implication of KFRC as a sustainable construction green material for low-cost housing industry.

Experimental

Materials and sample preparation

The materials used in this research work to acquire the desired strength including kenaf fiber. Specimens were prepared by some moulds of the concrete with different shapes and sizes in different sizes in the laboratory. A total of 108 specimens were prepared in the laboratory to conduct the compressive strength, flexural strength and direct shear test for the corresponding size of 150mm x 150 mm x 150mm, 100mm x 100mm x 350mm and 100mm x 100mm x 350mm. All of the specimens were tested after curing times for 7, 14 and 28 days. The brief description of the material used in this research is given in below:

Water

Water is the chemical means by which cement is changed from a powder into a hardened material with strength and durability [**21**]. For a concrete to be form water must be added to the mixture in order to create a chemical reaction between water and cement to form a paste.

Aggregate

In this research, crushed aggregate which have been prepared from quarry were used with the normal size of 10mm. The coarse aggregate were air dried for obtaining saturated surface dry (SSD) condition for ensuring that the water cement ratio will not be affected. Fine aggregate are usually known as sand which must comply with coarse, medium or fine grading requirements of [**22**]. The fine aggregate act as a filler in concrete and it was air dried to acquire SSD condition to ensure that the water cement ratio does not affected, it is also refers to the particles that passed 600µm sieve.

Cement

The cement which has been used in this research is locally producing Ordinary Portland Cement (OPC). Portland cements are hydraulic cement, which means they harden and set by the action of water only. OPC is made of finely powdered crystalline minerals which are composed primarily of aluminium silicate and calcium.

Kenaf fiber

The kenaf fibers used in this investigation were obtained from MARDI, Selangor, Malaysia. The fibers were extracted from the bast through retting bacteria process. The existing moisture content in kenaf fiber was less than 6%.The fiber used in the experiment was kenaf fiber which is added at different percentages of 0% (for control specimen), 1%, 3%, and 5% respectively; **Fig. 1(a)** has shown the type of kenaf fiber used in this experiment which is at a mixture of 2cm and 5cm in length.

Test set-up and procedure

An experimental program was conducted to evaluate the basic material properties and mechanical behaviour of KFRC. Compaction and slump test were accomplished to examine the workability of the fresh concrete while compressive strength, flexural strength, rebound hammer test, direct shear test and density test were done on the hardened concrete to identify the mechanical properties of the fiber. The details of the experimental program are described in the following sections.

Slump Test

The slump test was developed by C.M. Chapman in 1913 from the United States [**23**]. One of the basic attributes of concrete is its workability or consistency; the slump test is done to ensure the concrete mix is workable. There are three characteristics of slump test; true slump, shear slump and collapse slump.

Compacting factor test

The compacting factor test gives the behaviour of fresh concrete under the action of external forces. It measure the compatibility of concrete which is an important aspect of workability by determine the amount of compacting achieved for a given amount of work.

Flexural strength test

A total number of 36 prisms with the sizes of 100mm x 100mm x 350mm were tested for evaluating the flexural parameters. Flexural strength test is based on two important parameters. The first parameter is well recognized as first crack strength is primarily controlled by the matrix. The second parameter can be defined as the ultimate flexural strength or the modulus of rapture, which is determined by the maximum load that can be reached.

Rebound hammer test

The rebound (Schmidt) hammer is an easy to use instrument; it provides a quick and simple non-destructive test to determine an immediate indication of concrete strength in different part of a structure. The minimum verifiable strength is 10 MPa and can be carried out under the guidance of [**24**] to assess the general quality, uniformity and relative strength of concrete members.

Direct shear test

A total number of 36 prisms with the sizes of 100mm x 100mm x 35mm long were used However, in comparison of these two different failures, it discovered that the prism with 1% KFRC has more toughness than that with 0% KFRC, thus the prism that has 0% KFRC failed totally after reaching the maximum load while the 1% KFRC detained after reaching the ultimate load.

Density test

In this research, density test was based on dried density method. Before crushing, the samples were weighted; the weight of the concrete is recorded to be used in the density formula. The density test is one of the important factors that used to determine the properties of concrete.

Compressive strength test

A total number of 36 concrete cubes with the size of 150mm x 150mm x 150mm were used for the compression tests. This test was performed according to the differences in the ages of the samples for both modified and unmodified concrete which included 7, 14 and 28 days of curing respectively.

Results and discussion

This section is presenting the various tests that have been conducted in the concrete laboratory; the results were recorded and discussed critically. The specimens were cured and tested at 7, 14 and 28 days. However, a total number of 108 specimens were tested for both cubes and prisms, and also they were analysed by comparing the results of KFRC with the results of plain concrete specimens.

Slump test

According to the BS code [**25**], the design slump of the experiment is 30-60 mm but when the percentage of fiber increases from 1% to 5%, the mix becomes stiffer in workability results and shown low slump value compared to the slump of 0% (control) fiber. Low slump value may have great impact on the workability of the concrete. However, 1% KFRC (optimum percentage) slump value represents the designed range of the slump test by providing 32 mm (refer to **Table 1**).

Table 1. Average results of slump test and compacting factor test.

Percentage of KFRC	Slump height (mm)	Compacting factor
0	35	0.96
1	32	0.945
3	20	0.925
5	13	0.89

Compacting factor test

This test was conducted on the fresh concrete to investigate the workability of the concrete and corroborate the outcome achieved by slump test. The results indicated that 1%

KFRC has the highest workability of 0.945 compared to the other two specimens. Hence, it is ensured that the addition of fiber to the mix make it more stiffer and provided low workability, which means the compacting factor will becomes less as a result of the distribution of fiber that interrupts the movement of concrete particles.

Concrete density

Average density of both modified and unmodified concrete were obtained and illustrated in this section, the designed concrete density for this experiment is 2375 kg/m^3. After 28 days, the concrete reached the highest density as well as the highest strength for both modified and unmodified concrete. However, when 1% of kenaf fiber (KF) contents was added to the concrete mix, the density and the strength decreases a bit in the same manner for 7, 14 and 28 days respectively with fulfilling the desired by having the average density of 2368.753 kg/m^3, 2421.333 kg/m^3 & 2448.102 kg/m^3 respectively.

Hence, this lower density caused by the light weight of the fibre. From **Fig. 1(b)**, it can be noted that the 28 days of curing for both modified and unmodified concrete has the highest strength and density. Moreover, KF can be used to make light weight concrete that has less density as a result of light weight of the fiber. Hence, the addition of KF in concrete reduces the spalling of concrete and 1% KFRC will be the optimum percentage that can be used in order to provide a sustainable structure.

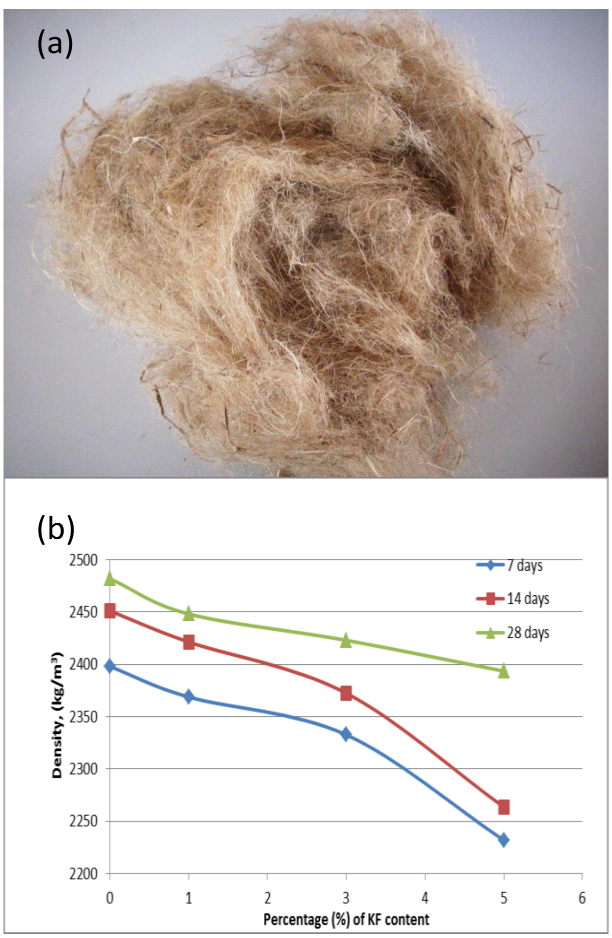

Fig. 1. (a) Kenaf fiber used (b) Density for different percentages (%) of KFRC.

Schmidt hammer best

The Schmidt hammer test was conducted in order to determine the surface strength of the concrete samples. From **Fig. 2(d)**, it can be seen that the strength of 14 and 28 days are higher than 7 days curing specimen which implies that when a concrete samples get more cured, the more the strength of the concrete gained. Hence, **Fig. 2(d)** has shown that at 28 days of curing, 0 % KF has the average value of 29.91 N/mm^2; however the test reached the desired value when approximated. Thus, due to the high strength of 1% KFRC compared to 3% and 5%, 1% KFRC will be more desirable to choose for applying in structure since it will provide a significant toughness to that particular structure.

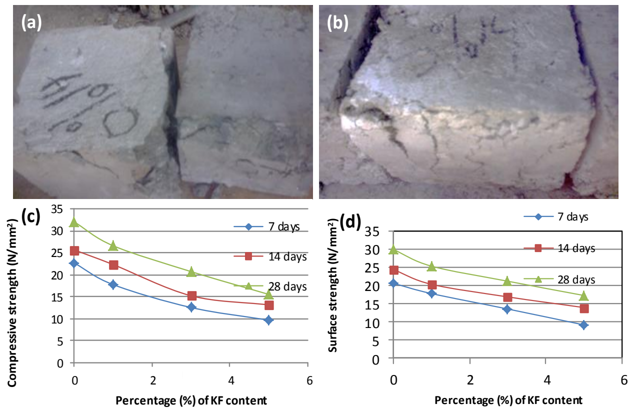

Fig. 2. (a) Mode failure of 0% (control) KFRC, (b) Mode failure of 5% KFRC, (c) Compressive strength for different percentages (%) of KFRC and (d) Surface strength for different percentages (%) of KFRC.

Compressive strength

Compressive strength tests was conducted in order to determine the strength of both modified and unmodified concrete at the age of 7, 14 and 28 days by using cube mould with the dimension of 150x150x150 mm according to the **[26]**. The average results and the behaviour of 0% KFRC was determined and compared with the average results and behaviour of 1% KFRC, 3% KFRC and 5% KFRC respectively. The control cube shown minor cracked then suddenly failed as soon as reaches its maximum load during testing.

The failure happened typically in a stiff way by spalling the concrete near the edges of the cubes as shown in **Fig. 2(a)**. After testing the KFRC, it classically showed a more yielding failure mode with well spread cracks which formed progressively prior to the cubes failure and the concrete cube after tested showed a columnar failure indicated by the formation of vertical cracks at the side edges as shown in **Fig. 2(b)**.

Fig. 2(c) illustrated that at 28 days, the concrete cubes reached the highest strength of the compressive tests while at the age of 7 days after the compressive test the cubes has a lowest values among the other curing ages. Furthermore, from **Fig. 2(c)**, it can be seen that the inclusion of KFRC to the concrete mixture adds an improvement of yield plateau after the occurrence of concrete cracking and the presence of fiber interferes with the sudden explosion of concrete matrix ingredients during failure thereby reduces the rate of rapid failure as shown in the **Fig. 2(b)** and the stress also transferred across the cracks and the fibres arrests the rapid crack propagation and prolongs the strain life to continue beyond the ultimate. However, according to the method [**15**], the designed strength of the control cube is 30 N/mm^2 at 28 days of curing, hence from the inspection of the results it discovered that Schmidt hammer results are very close to the designed values with the average strength of 29.91 N/mm^2, while from the compressive strength the average values of control samples is 32.111 N/mm^2 at 28 days of curing. Moreover, the addition of kenaf fiber to the concrete slightly changed the behaviour of the concrete by decreasing the strength of it. In general, 1% will be the best optimum percentage that could be used in structural construction purposes.

Flexural strength

A series of flexural tests were conducted to identify the effect of the KF on the flexural strength and toughness of KFRC prisms compared to the control prisms, the main effect of the kenaf fiber is to prevent and control the crack propagation. **Fig. 3(a)** represents the flexural strength of KFRC at various curing periods. In addition, **Fig. 3(b), (c), (d)** and **(e)** shows the measured mid span-load deflection of tested prisms concrete at the ages of 7, 14 and 28 days with 0% (control), 1%, 3% and 5% KFRC prisms respectively.

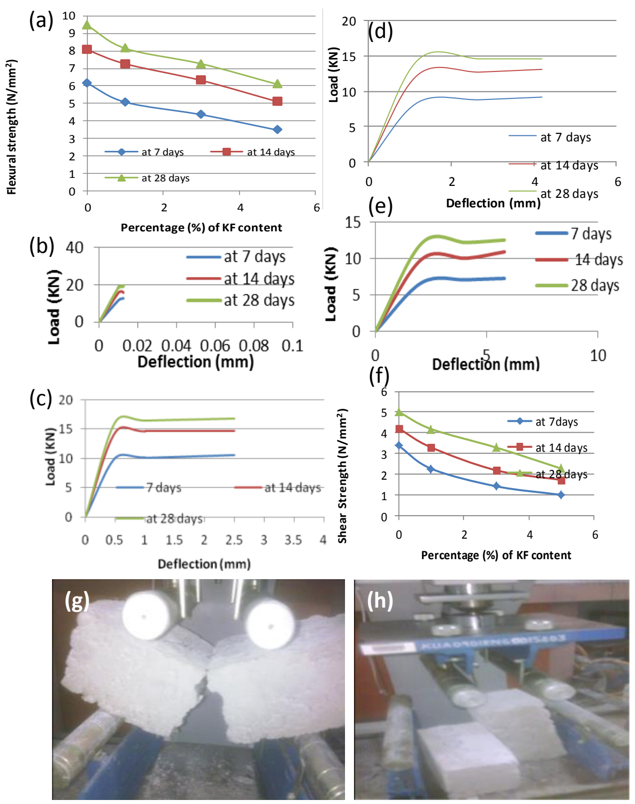

Fig. 3. (a) Flexural strength at 7, 14 and 28 days, (b) deflection of 0% KFRC, (c) deflection of 1% KFRC, (d) deflection of 3% KFRC, (e) deflection of 5% KFRC, (f) dhear strength of KFRC at 7, 14 and 28 days, (g) mode failure of modified concrete and (h) Mode failure of 0% KFRC.

The critical examination of **Fig. 3** ensured that inclusion of KF to the mixtures to some extent reduced the ultimate flexural strength of the concrete and simultaneously increased the residual flexural strength and toughness of the prisms which is distinctive for fiber reinforced concrete (FRC). **Fig. 3(g** & **h)** represent the different mode failure of the tested control and KFRC prisms respectively.

The control prisms failure arisen as a result of forming a single crack within the central part of the prism which headed to sudden brittle failure of the prism. Also a similar pattern of failure occurred in the KFRC prisms, but the presence of kenaf fiber helped to bond the crack as shown in the **Fig. 3(g)** which led to a more ductile failure mode with a greater toughness and enduring strength. The contribution of the kenaf fiber is rather observed on the ability of KFRC composite to maintain the ultimate load through further deflection without sudden deflection. Nonetheless, from the inspections of the results ensured that 1% KFRC can be used in structure to maintained the strength and provide a well toughness to the structure.

Direct shear test

A total of 36 concrete prisms were tested to evaluate the direct shear test of KFRC behaviour compared to plain concrete prisms. The tested 0% KFRC prisms characteristically showed single cracking prior to failure. The failure typically occurred suddenly in a brittle manner by separating the concrete from the centre of the prisms shown in the **Fig. 4 (a** & **b)**. In compared and contrast, the tested KFRC typically exhibited ductile mode failure. The prisms typically exhibited a single failure at the centre. Evaluation of the failed prisms indicated a better toughness of the fibres in the prisms.

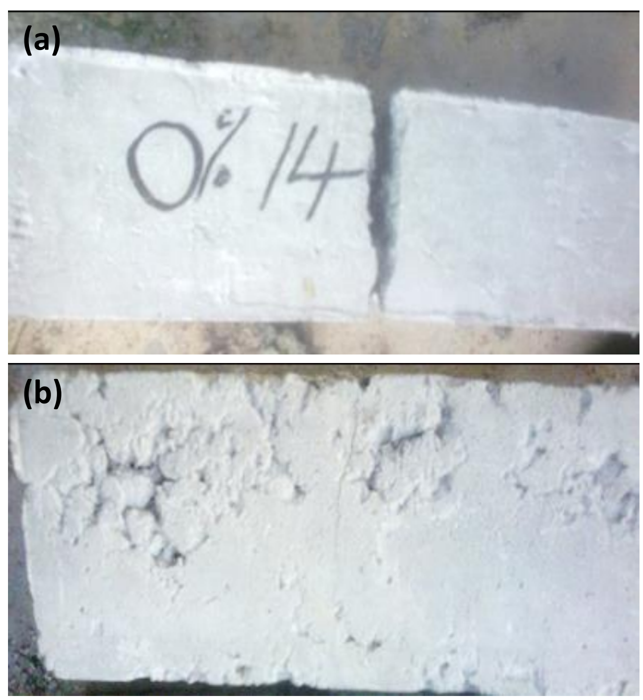

Fig. 4. (a) Mode failure of 0% (control) KFRC and (b) Mode failure of 1% KFRC.

Fig. 4 (a and **b)** shown that the direct shear strength of all concrete prisms concrete increased according to the increase of curing period. It also shows that at each period of curing, 0% KFRC has the highest strength. At 7 days of curing, 1%, 3% and 5% KFRC decreased the strength with 1.106 N/mm^2, 1.953 N/mm^2 and 2.366 N/mm^2 compared to their corresponding control prism strength respectively. Also at 14 days of curing, 1%, 3% and 5% KFRC decreased the strength with 0.916 N/mm^2, 2.019 N/mm^2 and 2.485 N/mm^2 compared with 0% KFRC. Moreover, at 28 days of curing, 1%, 3% and 5% KFRC also decreased the strength of the concrete prisms with 0.827 N/mm^2, 1.721 N/mm^2 and 2.733 N/mm^2 compared to the control prisms strength. The inspection of the results specified that the KFRC prisms typically exhibit lower shear strength but higher toughness than the plain concrete prisms according to their observed results and failure modes. **Fig. 3(f)** also indicated that presence of the kenaf fiber decreased the elastic modulus of the concrete, even though a trend with the increased of fiber contents is not apparent. Also the increased of w/c ratio than the control specimen might also cause the decreased of the direct shear strength. However, 1% KFRC exhibit more toughness in concrete with providing high strength compared to other percentages of KFRC, thus 1% KFRC will be very crucial when applied to a structure.

Conclusion

This section presents the conclusion of the whole experimental research that were conducted for identifying the characteristics of KFRC for both fresh and hardened stages and a suitable mixture proportions were taken into account for KFRC with fibres contents of 1%, 3% and 5%.

1) This study reveals that increment of kenaf fiber contents in the mixture decreased the workability of concrete and this is due to the water absorption characteristics of kenaf fiber. Besides that, the water absorption with higher fiber contents made the mixture more stiffen which will finally produces lower workability concrete which may lead to consider choosing the optimum percentage of kenaf fiber content.
2) The results of density tests verified that an increase of fibers in the concrete mixture decreased the density of the concrete. However, additions of fiber contents in concrete reduced the density of the concrete and provided light weight concrete.
3) This study of KFRC cubes based on compression test ensured that adding kenaf fiber to the concrete mix slightly reduced the ultimate load of the concrete cubes. It discovered that the lower amount of fiber content, the increased strength of KFRC which will be very close to the plain concrete strength. Also when the fiber content increased high, the results also decreased compared with the plain concrete. However, KFRC exhibited more ductile behaviour with greater energy absorption and more well power of attacking the cracking pattern compared with the 0% KFRC cubes. The more concern of this study is about the strength of concrete with additions of fiber contents. Hence, 1% will be very sufficient to use in the structure as a result of having a high strength with a vital toughness to concrete at the same time.
4) Schmidt hammer test at 28 days of curing, 1% KFRC has the average value of 25.21 N/mm^2 and the test result falls from the designed range. Moreover, Schmidt hammer test can be used to estimate the compressive strength of a given concrete and it can provide the surface strength of concrete which termed as a nondestructive test.
5) The results of flexural strength indicated that KFRC exhibited a more ductile failure mode when compared with the 0% KFRC mode failure, after the deflections of the KFRC prisms, the toughness of the prisms are higher than that of the control concrete samples. Similarly, under the direct shear strength test, the behaviors of KFRC prisms are quite similar with those of flexural tests. They showed similar mode of failure, and ensured that KFRC prisms has a high toughness compared to the conventional concrete.

This study reveals that 1% of KFRC has achieved a very good strength compared to 3% and 5% KFRC, and also has an excellent toughness and ductility capability when compared with 0% KFRC. So, 1% KFRC will be suitable to that type of structure where higher toughness and high strength will be needed simultaneously. Natural Fibers are cheaper than synthetic fiber therefore; it is more convenient to choose kenaf fiber for construction of light weight concrete structures because of its excellent crack minimization and toughness capabilities compared to use synthetic, steel or polypropylene fibers.

Acknowledgements

This study was conducted at the Heavy Structures Laboratory, School of Civil Engineering, Linton University College, Legenda Education Group, Malaysia and the authors would like to thank the technicians in the laboratory for providing assistance in specimen fabrication and testing.

Reference

1. Elsaid, A.; Dawood, M.; Seracino, R.; Bobko, C.; *Construction and Building Materials*, **2011**, *25*, 1991. **DOI**: 10.1016/j.conbuildmat.2010.11.052
2. Saba, N.; Paridah, M.T.; Jawaid, M.; *Construction and Building materials*, **2015**, *76* , 87. **DOI**: 10.1016/j.conbuildmat.2014.11.043
3. Sen, T; Jagannatha, H. N.; Reddy; *International J of Innovation, Management and Technology*, **2011**, *2*, 192.
4. Sanadi, A. R.; Caulfield, D. F.; Jacobson, R. E.; Rowell, R. M.; *Industrial & Engineering Chemistry Research*,**1995**, *34*, 1889. **DOI:** 10.1021/ie00044a041
5. Mansur, M.A.; Aziz, M. A.; *Int. Cement Composites and lightweight Concrete*, **1883**, *5*, 165. **DOI:** 10.1016/0262-5075(83)90003-9
6. Aji, I. S.; Sapuan, S. M.; *International J of Mechanical and Materials Engineering*, **2009**, *4*, 239.
7. Yalçınkaya, Çağlar.; Sznajder, J.; Beglarigale, A.; Sancakoğlu, O.; Yazıc, Halit; *Adv. Mat. Lett.* **2014**, *5*, 345. **DOI:** 10.5185/amlett.2014.amwc.1021
8. Singh, S.; Kumar, P.; Jain, S. K.; *Adv. Mat. Lett*. **2014**, *5*, 345. **DOI:** 10.5185/amlett.2014.amwc.1021
9. Shoude, W.; Lingchao, Lu. Xin, C.; *Adv. Mat. Lett*. **2011**, *2*, 12. **DOI:** 10.5185/amlett.2010.9163
10. Le, H. G.; Huang, S. C.; Nguyen, V. S., Dao, T. P.; *Adv. Mat. Lett*. **2014**, *5*, 593. **DOI:** 10.5185/amlett.2014.6587
11. Kandpal, J.; Yadaw, S. B.; Nagpa, A. K.; *Adv. Mat. Lett*. **2013**, *4*, 241. **DOI:** 10.5185/amlett.2012.8403
12. Singh, C., V.; Yunus, M.; Sankararamakrishnan, N.; *Adv. Mat. Lett.* **2010**, *1*, 225. **DOI:** 10.5185/amlett.2010.6135
13. Ribot, N.; Ahmad, Z.; Mustaffa, N. K.; *Int. J. Eng. Sci. Technol.* **2011**, *3*.
14. Ngo, W.L.; Pang, M.M.; Yong, L.C.; Tshai, K.Y.; *J. Appl. Sci. Agric.*, **2014**, *8*, 2742.

15. Moses, O. T.; Samson, D.; Waila, O. M.; *Adv. Mat.* **2015**, *4*, 6.
 DOI: 10.11648/j.am.20150401.12
16. Hafizah, N.A. K.; Hussin, M.W.; Jamaludin, M.Y.; Bhutta, M. A.R.; Ismail, M.; Azman, M.; *JCement and Concrete Compositesournal Teknologi*, **2014**, *69*, 11.
17. Sivaraja, M.; Kandasamy, S.; *Bull Mater Sci.* **2010**, 33.
 DOI: 10.1007/s12034-011-0149-6
18. Savastano, Jr. H.; Warden, P. G.; **2005**; *27*, 517.
 DOI: 10.1016/j.cemconcomp.2004.09.014
19. Ramakrishna, G.; Sundararajan, T.; *Cement and Concrete Composites*, **2005** a, *27(5)*, 517.
 DOI: 10.1016/j.cemconcomp.2004.09.006
20. Ramakrishna, G.; Sundararajan, T.; *Cement and Concrete Composites*, **2005** a, *27(5)*, 575.
 DOI: 10.1016/j.cemconcomp.2004.02.0082
21. Taylor, G. D.; Materials in construction.3rd ed., **2000**.
22. BSI (British standards Institute), **1992**; Specification for aggregate from sources for concrete. London: BSI, 882:1992.
23. Somayaji, S.; Civil Engineering Material, 2nd ed. Prentice-Hall, Upper Saddle River, New Jersey: Prentice Hall; **2001**.
24. BSI British standards Institute), **2009**, Testing hardened Concrete Compressive strength of test specimens. London: BSI, EN 12390-5:2009 1881:103:1983.
25. BSI (British standards Institute), **1983**, Method for making test beams from fresh concrete. London, UK.
26. BSI (British standards Institute), **1983**, Method for making test cube from fresh concrete. London, UK.