International Journal of Engineering &Technology, 7 (4) (2018) 6735-6740

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.19391
Research paper

Flexure behaviour of foamed concrete incorporating BSP and POFA strengthened with CFRP

Khalidah Aziz[1], Noridah Mohamad[1*], Muhammad Tahir Lakhiar[2], A. A. A. Samad[1], Suriani Jusoh[3], Anis Sofia[4]

[1]Faculty of Civil and Environment Engineering Universiti Tun Hussein Onn Malaysia, 86400, Batu Pahat, Johor, Malaysia
[2] Department of civil engineering National University of Science and Technology Quetta Campus, Pakistan
[3] School of Ocean Engineering Universiti Malaysia Terengganu, 21300 Kuala Nerus, Terengganu, Malaysia
[4] School of Materials Engineering Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
**Corresponding author E-mail: noridahmohamad@gmail.com*

Abstract

This paper investigated the flexural behavior of lightweight foamed concrete (LFC) incorporating banana skin powder (BSP) and palm oil fuel ash (POFA), strengthened with carbon fiber reinforce polymer (CFRP) plate. The BSP and POFA are added in the LFC mixture at various percentages as cement and sand replacement, respectively. LFC cubes incorporating BSP and POFA, LFC-BSP-POFA, were cast and tested under compression to determine its compressive strength. LFC-BSP-POFA prisms strengthened with 100 mm and 150 mm length of CFRP plates glued on its bottom mid-span surface were cast and tested under four point bending load to determine its flexure behaviour. From the results obtained, compressive and flexural strength increased when percentages of BSP and POFA incorporated in the LFC increased. Meanwhile, CFRP plate managed to strengthen the LFC prism further where higher ultimate load recorded when longer CFRP plate was used.

Keywords: *Lightweight Foamed Concrete; Agricultural Waste; Compressive Strength; Ultimate Flexure Load; Crack Pattern.*

1. Introduction

Concrete is a brittle material used in the construction field, hence, the concrete mixture has been refitted with various kind of additive materials either as cement and sand replacement, or as filler, to enhance its physical, chemical, and mechanical properties. By-product materials from agricultural wastes, such as palm oil fuel ash (POFA), rice husk ash (RHA), and banana skin powder (BSP), have been investigated on their potential to replace cement and sand in a concrete mixture. Various researches were conducted where concrete was incorporated with POFA as cement replacement [1-3]. From these researches, it was found that with proper amount of super plasticizer added, the concrete's compressive strength increased when content of POFA added as cement replacement increased up to 40%. A research was conducted on concrete with RHA at 0%, 10% and 20% as cement replacement [4]. It was observed that 10% RHA as cement replacement recorded higher compressive strength by 4%. However, higher percentage of RHA added showed a reduction of strength by 6% [5]. Meanwhile, it was also reported that incorporating banana skins in foamed concrete, due to its fibrous properties increased the bonding in the cement mixture; thus, enhanced its compressive strength and impact resistance [3]. Afif et al. [6] conducted an experimental study on the incorporation of banana skins in the foamed concrete mixture. It was found that the compressive strength of this foamed concrete was higher compared to control foamed concrete.

Alternatively, the usage of fibres in strengthening the concrete has also been explored. The type of fibers that could be incorporated in various types of concrete mixture include both artificial and natural fiber. In a report by Awang et al. [7], a density of 1000 kg/m^3 foamed concrete prism were incorporated with polypropylene and kenaf fiber and tested under flexure. It was shown that addition of fibers had contributed to the higher peak flexural strength achieved by the specimens before failure. On the contrary, specimens without fibers experienced immediate failure and broken into two parts after the peak flexural strength was reached. This finding is in agreement with the work conducted by previous researchers [8-10] where it was found that when concrete cracks, the fibers prevents the micro-cracks from spreading and breaking into two parts. Ahmad et al. [11] conducted a research on added polypropylene fibers in a concrete mixture and observed that these fibers had created bridging across the concrete matrix which help to control shrinkage cracking during plastic stage and matrix micro cracks that occurred as the concrete was loaded. It was also found that fibers can control the crack propagation and prevent the occurrence of large cracks widths.

Meanwhile, the use of Fibre Reinforced Polymer (FRP) materials for the repair and strengthening of reinforced concrete structures and for other types of construction has become common practice. As a material, FRP offers outstanding combination of physical and mechanical properties such as its high tensile strength, light weight, high stiffness properties, high fatigue strength and excellent durable properties [12], [13]. It was reported that the application of the FRP composites has been proven to increase the service life contributing to the structures longevity [14-16].

It has been proven that certain additive materials could enhance the strength and properties of foamed concrete. This makes foamed concrete possible to be used as structural element, provided it is strengthened with reinforcement. This research investigated the flexural behaviour of lightweight foamed concrete (LFC) prisms incorporated with banana skin powder (BSP) and palm oil fuel ash (POFA), strengthened with carbon fiber reinforce polymer (CFRP)

Copyright ©2018 Noridah Mohamad et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

which was glued at its mid-span. The LFC developed in this study is considered as sustainable and environmental friendly material because no natural coarse aggregate used, while BSP and POFA were added as partial cement and sand replacement.

2. Materials and methods

2.1. Materials preparations

The materials for casting LFC include cement, sand, water, foam, BSP and POFA. The type of cement used is Ordinary Portland Cement (OPC) which complied with BS 12:1996 or BS EN197: Part 1: 2000 [17]. Fine sands used in LFC mixture complied with BS 882:1992, with sizes up to 5mm [18]. For this research, banana skin were produced into a powder form where it was dried in the oven at temperature 105°C ± 5°C for 24 hours. The dried banana skins were then grinded and sieved under 150 µm sieve. POFA was obtained from Ban Dung Palm Oil Industries Sdn. Bhd. at Parit Sulong, Batu Pahat, Johor. Fig. 1 and Fig. 2 show the BSP and POFA, both in powder form. Foam agent which was used to produce foam was from a synthetic type, which was mixed with water at the ratio of 1 to 40. The foam was generated from this mixture by using foam generator connected to air compressor where the concentrated foaming agent was added with water. The foam generated was a form of stable bubbles which were added to the LFC-BSP-POFA mixture in stages to control its density.



Fig. 1: Banana Skin Powder (BSP).



Fig. 2: Palm Oil Fuel Ash.

2.2. LFC-BSP-POFA mixture

The suitable lightweight foamed concrete mixture incorporating BSP and POFA (LFC-BSP-POFA) was determined from several trial mixing processes. The mixture proportion of LFC-BSP-POFA was investigated by adding various percentages of BSP and POFA as cement and sand replacement in all the trial mixtures as shown in Table 1. The percentages of BSP added as cement replacement are 0% to 2%. These values were chosen based on the investigation conducted by Afif et al., 2017[6] which reported that both compressive and tensile strength increased by more than 100% at 2% of added BSP. However, more cracks were observed in concrete with BSP prisms compared to plain concrete prisms. Meanwhile, the percentages of POFA used are 0% and 15%. These percentages were chosen based on the observation by UI Islam et al., 2016 [19] and Tangchirapat et al., 2009 [3]. UI Islam et al. investigated the effect of 0%, 10% and 20% POFA added as cement replacement and reported that 10% added POFA increased the concrete's strength up to 11%. Tangchirapat et al., on the other hand, had proven that 20% of POFA added resulted with 24% of strength increased in concrete. From these trial mixtures, the actual mixture to cast the LFC-BSP-POFA prism was determined, which is the mixture that produced the targeted density of 1800 kg/m^3. The mixture of LFC-BSP-POFA chosen is M1 as shown in Table 2. Control prism was cast form LFC with 0% BSP and 0% POFA.

Table 1: Trial Mixtures for LFC-BSP-POFA

Mixes	BSP (kg)	POFA (kg)	Cement (kg)	Sand (kg)	Water (kg)
Control 0%BSP 0%POFA	0	0	12.03	24.05	6.62
0%BSP 15%POFA	0	3.6	12.03	20.45	6.62
M1 0.2%BSP 0%POFA	0.02406	0	12.01	24.05	6.62
0.2%BSP 15%POFA	0.02406	3.6	12.01	20.45	6.62
M2 0.4%BSP0%POFA	0.04812	0	11.98	24.05	6.62
0.4%BSP 15%POFA	0.04812	3.6	11.98	20.45	6.62
M3 0.6%BSP0%POFA	0.07218	0	11.96	24.05	6.62
0.6%BSP 15%POFA	0.07218	3.6	11.96	20.45	6.62
M4 0.8%BSP 0%POFA	0.09624	0	11.93	24.05	6.62
0.8%BSP 15%POFA	0.09624	3.6	11.93	20.45	6.62
M5 1%BSP 0%POFA	0.1203	0	11.91	24.05	6.62
1%BSP 15%POFA	0.1203	3.6	11.91	20.45	6.62
Total materials	0.7218	21.6	143.64	267	79.44

Table 2: Trial Mixtures for LFC-BSP-POFA

Mixes	BSP (kg)	POFA (kg)	Cement (kg)	Sand (kg)	Water (kg)
Control 0%BSP 0%POFA	0	0	7.8	15.6	4.29
0%BSP 15%POFA	0	2.34	7.8	13.26	4.29
M1 1.0%BSP 0%POFA	0.078	0	7.72	15.6	4.29
1.0%BSP 15%POFA	0.078	2.34	7.72	13.26	4.29
Total materials	0.156	4.68	31.04	57.72	17.16

2.3. Casting of specimens

The specimens cast for LFC-BSP-POFA include cube and prisms tested under compression and flexure to determine its compressive strength and flexure behaviour. LFC-BSP-POFA cubes of 100 mm x 100 mm x 100 mm and prism with the size of 500mm x 100mm x 100mm in length, width and height were cast. The preparation to cast the LFC-BSP-POFA cubes are as shown in Fig. 3.



Fig. 3: Cubes Mould (Left), Wet Mix LFC-BSP-POFA in the Mould (Center), the LFC-BSP-POFA Once Demoulded (Right).

For LFC-BSP-POFA prism, CFRP was placed at the bottom of the prism with aim to control the crack propagation. Epoxy paste was first spread onto the prism bottom's surface. CFRP with 100 mm and 150 mm length were glued to the surface of different prisms and left to harden. The preparation for these prisms strengthened by CFRP are shown in Fig. 4.

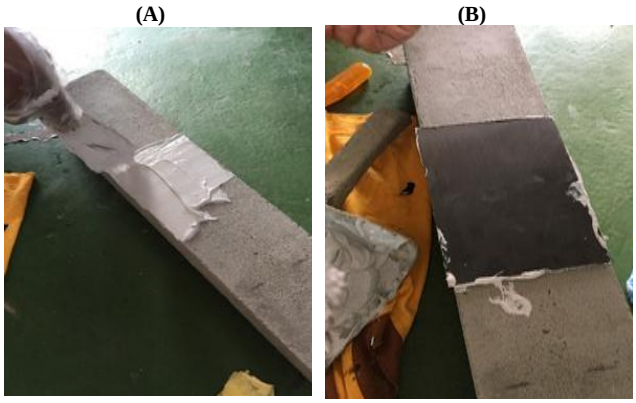


Fig. 4: (A) Epoxy Paste Spread onto the Prism Surface (B) CFRP Glued Onto the Paste at the Bottom Surface of the Prism.

3. Experimental programme

The experimental programme conducted were chemical test, compressive strength test and flexural test to determine the chemical properties of BSP and POFA, and mechanical properties of LFC-BSP-POFA. The mechanical properties include its compressive strength, flexural strength and crack pattern. The tests for obtaining the chemical properties of BSP and POFA was X-ray Fluorescence (XRF) test. To determine the mechanical properties of LFC-BSP-POFA, compressive strength test and flexural test were conducted.

3.1. XRF test

XRF test were conducted on BSP and POFA according to ASTM C618-17a [20]. The material were sieved between 50µm to 75µm (63µm) sieve which is to remove larger particles to avoid the failure of XRF. Hydraulic machine was used to compress the sample to become the pallet coin shaped as shown in Fig. 5. The pallet sample is then analyzed under XRF machine.



Fig. 5: Pallet Sample of POFA (Left) and BSP (Right).

3.2. Compressive strength

Compressive strength test was conducted on LFC-BSP-POFA cube samples of 100 mm x 100 mm x 100 mm according to BS EN 12390-3:2009 [21]. The test was conducted on cube samples (100 mm x 100 mm x 100 mm) of LFC-BSP-POFA at 7 and 28 days. The cube samples were placed at the center of the plate of the testing machine and the load was applied on the cross section are of the cube samples.

3.3. Four point bending test

Four-point bending test on LFC-BSP-POFA prisms was conducted by using Universal Testing Machine according to ASTM D6272 [22]. Prisms with the dimension of 500 mm x 100 mm x 100 mm was placed on this machine which was supported by pin at one end and rolled at the other end as shown in Fig. 6. Two axial loads from the top were applied on the prism at distance from the end supports as shown in Fig. 6.

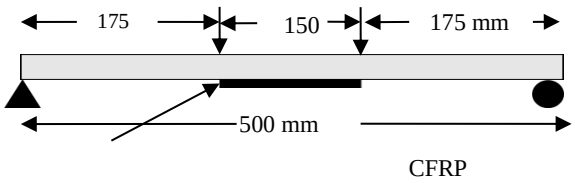


Fig. 6: Four Point Bending Load Test.

4. Results and analysis

The results recorded from the experiment include chemical composition of BSP and POFA, and mechanical properties of LFC-BSP-POFA mixture. The mechanical properties of LFC-BSP-POFA obtained include its compressive and flexural strength.

4.1. Chemical properties of BSP and POFA

The chemical composition of BSP and POFA were obtained from the XRF test, as shown in Table 3. From the table, it is seen that BSP and POFA contain high silicon dioxide, which are 55.98% and 51.83% in BSP and POFA, respectively. Both materials contain small amount of aluminium oxide which are 2.71% and 2.32%, for BSP and POFA, respectively. Therefore, both materials could be considered as pozzolanic. A pozzolan is defined as siliceous and aluminous materials which contain little cementitious value, which in finely divided form, will chemically react with calcium hydroxide at ordinary temperature to form compound possessing cementitious properties [23].

Table 3: Trial Mixtures for LFC-BSP-POFA

Chemical Composition	BSP (%)	POFA (%) 8.10
Calcium Oxide, CaO	8.95	51.83
Silicon Dioxide, SiO_2	55.98	0.17
Carbon, C	-	2.32
Aluminium Oxide, Al_2O_3	2.71	2.23
Sulphur Trioxide, SO_3	0.10	7.60
Ferric Oxide, Fe_2O_3	1.36	3.13
Magnesium Oxide, MgO	1.08	13.72
Potassium Oxide, K_2O	28.75	4.30
Phosphorus Pentoxide, P_2O_5	-	

4.2. Mechanical properties of LFC-BSP-POFA

4.2.1. Compressive strength

From the data gathered, it is obvious that the compressive strength was found to increase with the increase of BSP and POFA. This is due to high content of SiO_2 and CaO in BSP and POFA. Some studies have reported the possibility of a successful replacement of artificial powder to cement required molar ratio of 0.5 [24-26].

However, in Table 3, the calculated molar ratio is less than 0.5 for both BSP and POFA. Interestingly, the existence of these two chemical compositions in the mixture had caused pozzolanic reaction which is shown in the high compressive strength achieved even though molar ratio used was less than 0.5. This could be due to the distribution of finer particle size of BSP and POFA used. Pozzolanic reaction which perform better with finer particles [27].
In a pozzolanic reaction, the final products were not eliminated from the cement hydrations; hence, built up their own contribution to the strength and other mechanical properties of the hardened cement paste and concrete mixture[28]. This is clearly indicated in the chemical reaction that took place in the pozzolanic reaction as presented in Equation (1). When calcium hydroxide in cement, $Ca(OH)_2$, reacts with silicon dioxide (SiO_2), calcium silicate hydrate, $3(CaO)2(SiO_2)3(H_2O)$, or known as C-S-H gel is produced. This gel increased the bonding between particles of various materials in the LFC, resulted with higher compressive strength achieved.

$$3[Ca(OH)_2] + 2[SiO_2] = [3(CaO)2(SiO_2)3(H_2O)] \quad (1)$$

From Fig. 7, for every percentage of BSP added (0% to 1.0%), the compressive strength increased about 3% to 10% for both LFC with 0% and 15% POFA. Meanwhile, for mixture of LFC-BSP-POFA incorporated with 15% POFA, the compressive strength achieved at every percentage of BSP added was about 5% higher than the compressive strength achieved in mixture of LFC-BSP-POFA with 0% POFA. This shows that effect of incorporating BSP on the compressive strength of LFC is greater than the effect of incorporating POFA. This may be due to higher content of pozzolanic materials in BSP compared to POFA. From Table 3, it is seen that BSP contain silicon dioxide of 55.98% compared to 51.83% in POFA. Both materials contain small amount of aluminum oxide which are 2.71% and 2.32%, for BSP and POFA, respectively.

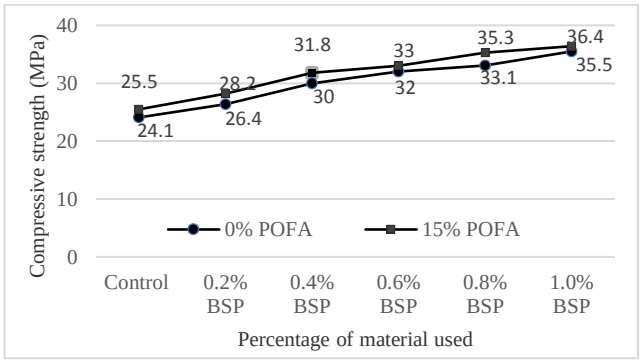


Fig. 7: Compressive Strength of LFC Versus Percentage of BSP and POFA at 28 Days.

4.2.2. Ultimate flexure load

Under four point bending load test, the ultimate load of LFC-BSP-POFA prisms and LFC-BSP-POFA prisms strengthened with CFRP were recorded and presented in Table 4 and Fig. 8. It is noticed that the flexural strength of LFC-BSP-POFA were likely to increase with the increasing portion of cement replacement with BSP. It is noticed to increase even more with the existence of 15% POFA as sand replacement. From Table 4, it is shown that LFC prisms incorporating both BSP and POFA achieved highest ultimate flexure load of 7.82 kN. It is also shown that LFC-BSP-POFA strengthened with CFRP plate achieved higher ultimate flexure strength compared to LFC-BSP-POFA prisms without CFRP glued to it. From the table, it is also noticed that the longer the CFRP plate, the higher the ultimate flexure load achieved. LFC-BSP-POFA with 100 mm and 150 mm length CFRP plate glued at its bottom surface achieve ultimate load of 8.46 kN and 8.74 kN, respectively.

Table 4: Ultimate Load of LFC-BSP-POFA W/O CFRP, 100 MM AND 150 MM Length CFRP

Foamed concrete incorporating with banana skin powder and palm oil fuel ash	Ultimate flexure load (kN)		
	Without CFRP	CFRP (100mm)	CFRP (150mm)
0.0% BSP 0% POFA	5.06	6.45	6.90
0.0% BSP 15% POFA	6.10	7.69	8.10
1% BSP 0% POFA	6.86	8.20	8.74
1% BSP 15% POFA	7.82	8.46	8.74

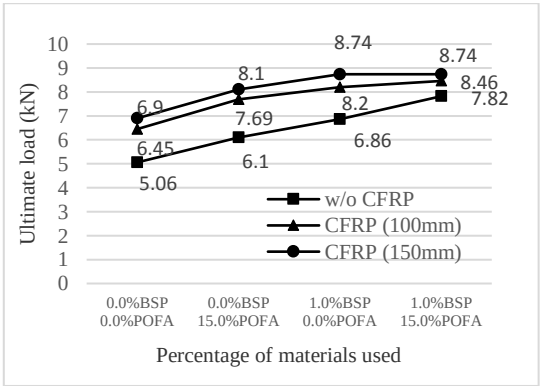


Fig. 8: Ultimate Flexure Load versus the Percentage of BSP and POFA Incorporated for LFC-BSP-POFA Prisms with and without CFRP.

4.2.3. Crack pattern

From the flexural strength test, the prisms with CFRP and without CFRP illustrated the difference in a crack pattern which affected from the placement of CFRP. For LFC-BSP-POFA prisms without CFRP strengthening, failure in the prisms was accompanied by rupture after reaching its ultimate load as shown in Fig. 9(a) and Fig. 9(b). From the figures, it is noticed that the crack line occurred in the control prism and prism with 1% BSP inclined at an angle of 4°. The crack was noticed to initiate from the middle span of the bottom surface. For the prisms with added POFA, the crack line developed line of crack with slightly higher degree and propagated to the top surface as shown in Fig. 10 (a) and Fig. 10(b).

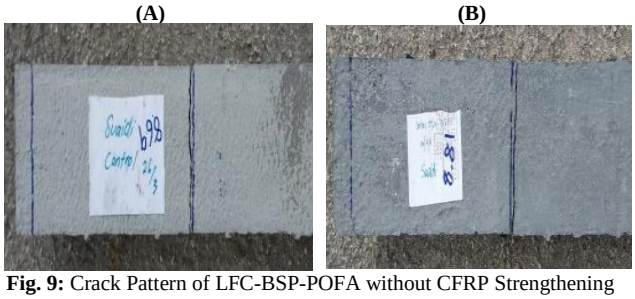


Fig. 9: Crack Pattern of LFC-BSP-POFA without CFRP Strengthening with (A) (0% BSP 0% POFA), and (B) (1% BSP 0% POFA).



Fig. 10: Crack Pattern of LFC-BSP-POFA without CFRP Strengthening with (A) (0% BSP 15% POFA), and (B) (1% BSP 15% POFA).

The additional of CFRP in the mid-span of bottom surface was intended to arrest the debonding cracks that were observed to propagate in the middle of the prisms. CFRP wrapped along the entire beam length were used to anchor the longitudinal laminates since it develops the maximum strength of the composite in tension [29].

Hence, it is agreed with this finding that the longer the CFRP used, the higher the flexural load achieved. For LFC-BSP-POFA strengthened with CFRP, in all prisms the crack was noticed to initiate at a point outside the CFRP region at its bottom surface and propagate to the upper surface and splitted into two parts at failure load as shown in Fig. 11 and Fig. 12. LFC-BSP-POFA prisms with 100 mm CFRP cracked instantly with line of crack developed at an angle less than 8°. Meanwhile, in LFC-BSP-POFA prisms with 150 mm CFRP developed line of crack at an angle about 12°.

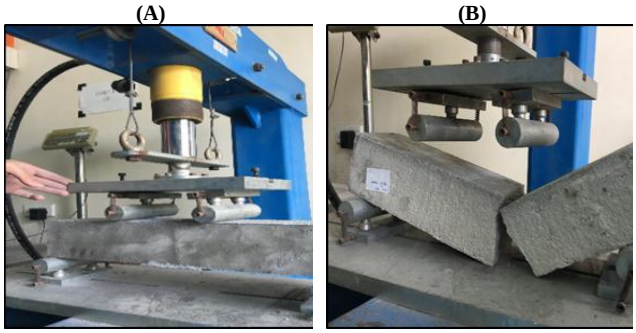


Fig. 11: Four Point Bending Load Test on Prism Strengthened with CFRP

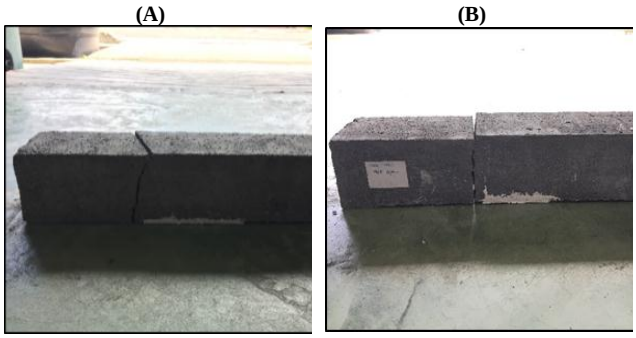


Fig. 12: Crack Pattern for LFC-BSP-POFA Prisms with (A) 100 MM, and (B) 150 MM CFRP.

5. Conclusion

This paper concludes that when the percentages of BSP and POFA incorporated as cement and sand replacement increased, the higher the compressive strength and flexural strength obtained. From the chemical test, it was found that BSP and POFA each contained pozzolan materials, which were 55.98% and 51.83% silicon dioxide, and 2.71% and 2.32% aluminum oxide, respectively. From the mechanical property tests, compressive strength increased when percentages of BSP and POFA incorporated in the LFC increased. Higher ultimate load under flexure was also recorded for LFC prisms with higher percentages of BSP and POFA. Meanwhile, CFRP plate managed to strengthen the LFC prism further where higher ultimate load recorded when longer CFRP plate was used. Unlike LFC without CFRP, LFC strengthened with CFRP experienced crack outside the CFRP region, initiated from the bottom surface and propagated to the upper surface until the prism splitted into two.

6. Conflict of interest

The authors declare no conflict of interest".

7. Author contributions

ABC conducted the research; BDEF analyzed the data; ABC wrote the paper; all authors had approved the final version.

Acknowledgment

The authors thank Universiti Tun Hussein Onn Malaysia for its financial support (GPPS H393)

References

[1] N. M. Altwair, M.A. Megat Johari, and S.F Saiyid Hashim, "Flexural performance of green engineered cementitious composites containing high volume of palm oil fuel as,"Construction and Building Materials, 37, 518-525, 2012. https://doi.org/10.1016/j.conbuildmat.2012.08.003.

[2] S. M. A. Awal and S. I. Abubakar, "Properties of Concrete Containing High Volume Palm Oil Fuel Ash: A Short - Term Investigation," Malaysian Journal of Civil Engineering, 23(2), 54-66. 2011.

[3] W. Tangchirapat, C. Jaturapitakkul, and P. Chindaprasirt, "Use of palm oil fuel ash as a supplementary cementitious material for producing high-strength concrete," Construction and Building Materials, 23(7), 2641-2646, 2009. https://doi.org/10.1016/j.conbuildmat.2009.01.008.

[4] G. Rodríguez de Sensale, "Strength development of concrete with rice-husk ash," Cement and Concrete Composites, 28(2), 158-160, 2006. https://doi.org/10.1016/j.cemconcomp.2005.09.005.

[5] R. Madandoust, M. M. Ranjbar, H. A. Moghadam, and S.Y. Mousavi, "Mechanical properties and durability assessment of rice husk ash concrete," Biosystems Engineering, 110(2), 144-152. 2011. https://doi.org/10.1016/j.biosystemseng.2011.07.009.

[6] N. Mohamad, A.A.A. Samad, M. T. Lakhiar, A. Sofia, and S.A. Efendi, "Effects of incorporating Banana Skin Powder (BSP) and Palm Oil Fuel Ash (POFA) on mechanical properties of LFC," International Journal of Integrated Engineering, 10(9), Pp. 169- 176. 2018. https://doi.org/10.30880/ijie.2018.10.09.013.

[7] H. Awang, M. H. Ahmad and M. Z. Al-Mulali, "Influence of kenaf and polypropylene fibres on mechanical and durability properties of fibre reinforced lightweight foamed concrete," Engineering Science and Technology, 10(4), 496-508. 2015.

[8] Elsaid, M. Dawood, R. Seracino and C. Bobko, "Mechanical properties of kenaf fibre reinforced concrete, Construction and Building Materials," 25(4), 1991-2001, 2011. https://doi.org/10.1016/j.conbuildmat.2010.11.052.

[9] J. Hadipramana, A. A. A. Samad, A. M. A. Zaidi, N. Mohamad, Wirdawati, "Influence of Polypropylene fiber in strength of foamed concrete," Advanced Material Research, 488-489, Pp. 253-257, 2012. https://doi.org/10.4028/www.scientific.net/AMR.488-489.253.

[10] A.R. Hazlin, A. Iman, N. Mohamad, A.A.A. Samad, N. Ali, "Microstructure and tensile strength of foamed concrete with added polypropylene fibers," MATEC web of conference, 103, 01013, 2017. https://doi.org/10.1051/matecconf/201710301013.

[11] O. A Ahmad and M. Awwad, "The effects of polypropylene fibers additions on compressive and tensile strengths of concrete," Int. J. of Civil and Environmental Engineering, 37(1), 1365-1372. 2015.

[12] Khalifa and A. Nanni, "Improving shear capacity of existing RC T-section beams using CFRP composites," Cement and Concrete Composites, 22(2), 165-174. 2000. https://doi.org/10.1016/S0958-9465(99)00051-7.

[13] Khalifa and A. Nanni, "Rehabilitation of rectangular simply supported RC beams with shear deficiencies using CFRP composites," Construction and Building Materials, 6, 135-146. 2002. https://doi.org/10.1016/S0950-0618(02)00002-8.

[14] M. B. S. Alferjani, A. A. Abdul Samad, B. S. Elrawaff and N. Mohamad, "Experimental and theoretical investigation shear strengthening of RC precraced continuous T-beams using CFRP strips," Int. J. of Engineering, Transactions B: Applications, 28(5), 671-676. 2015. https://doi.org/10.5829/idosi.ije.2015.28.05b.04.

[15] N. Ali, A.A. Abdul Samad, N. Mohamad and J. Jayaprakash, "Shear behaviour of precracked continuous beams repaired using externally bonded CFRP strips," Procedia Eng., 53, 129-144, 2013. https://doi.org/10.1016/j.proeng.2013.02.019.

[16] S. Shahidan, S. Salwa, M. Zuki, C. K. Keong and J. Jayaprakash, "Repaired of firedamaged concrete-filled double skin steel tubular (CFDST) columns with fiber reinforced polymer (FRP)," ARPN J. Engineering of Applied. Sciences, 11(6), 3718-3725. 2016.

[17] EN197: Part 1: 2000. Cement Composition, specifications and conformity criteria for common cement. British Standard. 2000.

[18] BS 882:1992. Specification for aggregates from natural sources for concrete. British Standard.1992.

[19] M. M. UI Islam, K. H. Mo, U. J.Alengaram, and M. Z. Jumaat, "Durability properties of sustainable concrete containing high volume

palm oil waste materials," Journal of Cleaner Production, 137, 167-177. 2016. https://doi.org/10.1016/j.jclepro.2016.07.061.
[20] ASTM C618-17a. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. ASTM International. 2017.
[21] BS EN 12390-3. Testing hardened concrete: compressive strength of test specimens. British Standard Institution. 2009.
[22] ASTM D6272. Standard Test Method for Flexural Properties of unreinforced and reinforced plastics and electrically insulating materials by a four-point bending test. Material Testing Technology. 2016.
[23] V. H. Dodson, "Pozzolans and the pozzolanic reaction. Concrete Admixtures," Pp 159- 201. Springer. 1990. https://doi.org/10.1007/978-1-4757-4843-7_7.
[24] R. J. Thomas, S. Peethamparan S., "Alkali-activated concrete: Engineering properties and stress–strain behavior," Constr. Build. Material, 93, Pp. 49–56. 2015. https://doi.org/10.1016/j.conbuildmat.2015.04.039.
[25] Bilodeau, V. M. Malhotra, "High-Volume Fly Ash System: The Concrete Solution for Sustainable Development," CANMET/ACI, Séminaire International; Lyon, France. 2000.
[26] V. Malhotra, "High-performance high-volume fly ash concrete," Concrete International, Vol. 24, Pp 30–34. 2002.
[27] K. Wunchock, S. Theerawat and J. Chai, "Effect of Palm Oil Fuel Ash Fineness on Packing Effect and Pozzolanic Reaction of Blended Cement Paste," Procedia Engineering, Vol 14(2011), Pp 361-369. 2011. https://doi.org/10.1016/j.proeng.2011.07.045.
[28] O.E.A Eldagal, "Study on the Behaviour of High Strength Palm Oil Fuel Ash (POFA) Concrete," Master Thesis, Universiti Teknologi Malaysia. 2008.
[29] H. V. S. GangaRao and P.V. Vijay, "Bending Behavior of Concrete Beams Wrapped with Carbon Fibre," Journal of Structural Engineering, Vol. 124, No. 1, pp.3-10, 1998. https://doi.org/10.1061/(ASCE)0733-9445(1998)124:1(3).