Progress in Engineering Application and Technology Vol. 1 No. 1 (2020) 13–21
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PEAT

Homepage: https://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 0000-0000

A Study of Comparison of The Physical Characteristics of Lightweight Foam Concrete Additional Selected Natural Fiber

Ahmed Bilal Efifi Mustafa Daldal[1], Mohd Kamaruzaman Musa[2]*,

[1]Ahmed Bilal Efifi Mustafa Daldal,
UTHM Kampus Pagoh, Hab Pendidikan Tinggi Pagoh,
KM1, Jalan Panchor, 84600, Panchor, Johor, MALAYSIA

[2] Mohd Kamaruzaman Musa,
UTHM Kampus Pagoh, Hab Pendidikan Tinggi Pagoh,
KM1, Jalan Panchor, 84600, Panchor, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2020.01.01.002
Received 21 September 2020; Accepted 09 November 2020; Available online 02 December 2020

Abstract: Lightweight foam concrete (LFC) has the disadvantage of being brittle and to overcome this problem, natural fibers were added to the LFC design to produce lighter and stronger concrete bonds. This study aims to identify the type of natural fiber that is suitable to be used as an additive in LFC design by comparing its characteristics in terms of compressive strength and water absorption as well as comparing natural fibrous LFC with LFC without standard fiber British Concrete Association (BCA). This study uses the method of analyzing the findings of previous studies and a total of five selected journals that use different types of natural fibers as additives in KRB design namely kenaf fiber, jute fiber, oil palm fiber, sisal fiber and coconut fiber that has been treated using sodium hydroxide solution (NaOH) all of them. The potential of this fibrous LFC is studied based on a comparison of compressive strength and water absorption tests that have undergone a curing process for 28 days. The results of the study found that kenaf, palm and coconut fibers are able to increase the compressive strength of LFC compared to jut and sisal fibers. Proper fiber selection promises a longer LFC lifespan.

Keywords: Lightweight Concrete, Foam Concrete, Lightweight Foam Concrete, Natural fiber, Compressive Strength.

1. Introduction

Lightweight Foam Concrete (LFC) is known as cellular concrete or cellular material because of the presence of air cavities in this building material. Cellular materials have been found to have better impact resistance properties than ordinary concrete building materials [1]. The impact resistance

**Corresponding author: kamaruz@uthm.edu.my*

properties of lightweight foam concrete are related to the base material used to form the composite and the base materials used are cement, sand, water and foam [2]. The foam material used makes lightweight foam concrete different from ordinary concrete formations. The foam material has caused light foam concrete to have air cavities.

In addition, limestone is also not used in the formation of LFCs. In short, LFC has many advantages for the construction of futuristic structures that are lightweight, economical, easy in terms of construction work and most importantly environmentally friendly. However, LFC is not applied as a structural building material because this composite has the disadvantage of being fragile. LFC has brittle properties due to the cell structure found in the composite is scattered and the cell bond is less rigid [3]. To overcome this deficiency feature, fiber is added to the LFC design mix.

Nowadays, there are many uses of natural fiber including building materials, sound absorbing materials, animal feed and paper products. Researchers' awareness of environmental sustainability is increasing over time [4]. This awareness has opened a new field for researchers and development involved in the field of production of new composite materials, namely the production of natural fibers mixed with LFC to produce stronger concrete bonds. Fiber from natural plants such as kenaf, sisal, oil palm, jute and coconut which has many advantages such as strong, light, non-rust and cheap price, it can be used as an additive and binder in LFC production design mix [5].

This study aims to identify the type of natural fiber that is suitable to be used as an additive in LFC design by comparing its ability characteristics in terms of compressive strength and water absorption as well as comparing natural fibrous LFCs with British Concrete Association (BCA) fiber-free LFCs. With previous studies on the addition of natural fibers in the design mix of LFC, then comparative studies need to be conducted to identify the types of natural fibers that are suitable to be used to produce strong LFCs. Successful design is produced with optimum ratio rate as well as precise material selection promises longer lifespan and can indirectly reduce maintenance work in the future.

2. Method

This study uses a comparison method of the findings of previous studies. Figure 1 shows a flow chart of the methodology of this study which contains the process of data collection such as the collection of study journals along with the required parameters. There are two major physical potential comparisons studied in this study.

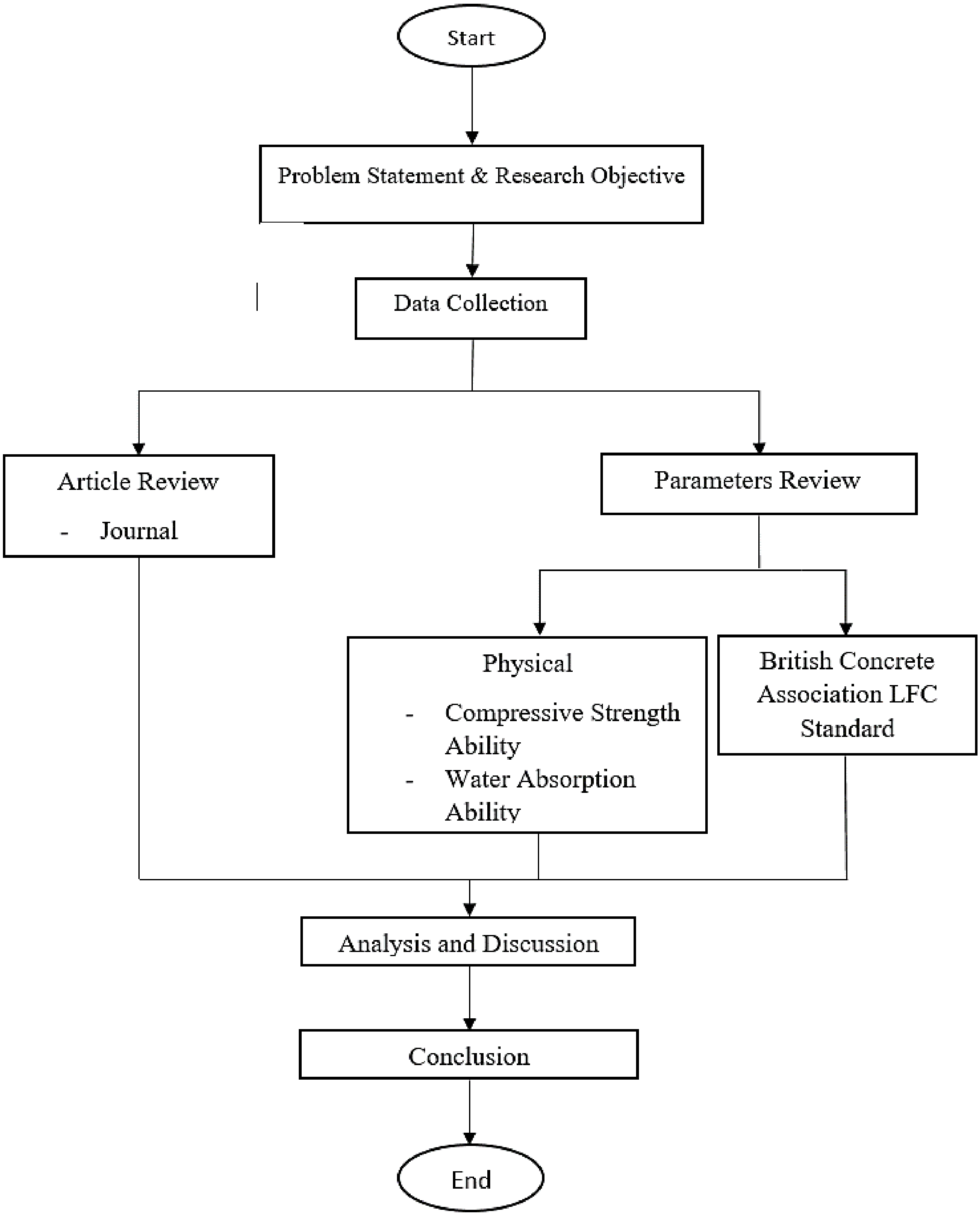

Figure 1: Methodology Flow Chart

2.1 Past Study Data Collection

Among the websites that publish quality resources for scientific research used in this study are science direct, academia, google scholars and research gate. There are five journals that have been obtained and successfully collected as the main reference material that will be used to achieve the objectives of this study.

Selected journals conducted a study on lightweight foam concrete (LFC) that uses natural fiber additives in their mixed designs. However, each journal uses different natural fibers in its experiments, among which are kenaf fiber, coconut fiber, jute fiber, oil palm fiber and sisal fiber.

Based on the five journals that have been selected, comparisons in terms of design mix, compressive strength and also water absorption are performed to identify the type of natural fiber that is suitable to be used as the best LFC binder.

2.2 Mixed Design Summary

Through the observations made on the previous studies that have been selected, a summary of the characteristics of the materials used in all the designs mix is shown in table 1.

Table 1: Mixed Design Materials of Past Studies

Material	Characteristics
Cement	Ordinary portland cement (OPC).
Sand	Sieve size between 0.60 mm - 1.20 mm.
Foam	Various synthetic foam materials.
Water	Uncontaminated tap water.
Natural Fiber	Dipotong antara 1-10 cm panjang. Has been treated with sodium hydroxide solution (NaOH)

The various water-cement ratios used range from 0.3 to 0.5. The manual mixing method is standardized by dry mixing of all ingredients. Next, water is added until the wet concrete reaches a uniform mixture. Finally, the foam material is added until it blends well. The wet concrete that has been mixed well is compacted into a cube mold. Concrete molds of various sizes were used in selected previous studies.

2.3 Compressive Strength

Through observations made on selected previous studies, compression strength tests were conducted on fibrous LFCs that had undergone a curing process after 28 days only. Concrete compression strength test in various selected studies is determined by using various compression machines in accordance with ASTM C39/C39M-18 [6], BS EN 12390-3 [7] and IS 4031(Part 6):1988 [8] standards.

2.4 Water Absorption

Through observations made on selected previous studies, this water absorption test was performed after the concrete cubes reached a curing age of 28 days only guided by ASTM C1585 -13 [9], BS1881: Bahagian 2:1983 [10] and ASTM C 642-82 standards [11].

2.5 British Concrete Association (BCA) LFC standard

Lastly, the best lightweight natural fibrous foam concrete compared to the British Concrete Association (BCA) fiberless LFC standard in terms of compression strength of the same density to identify whether the addition of natural fiber as an additive in LFC design produces stronger KRB or vice versa.

3. Results and discussions

3.1 Findings

Information on the findings of the compression strength and water absorption ability is needed to make a comparison of these capabilities on lightweight fibrous foam concrete to identify the type of fiber that gives strength to LFC. Table 2 shows the findings of the study for compression and water absorption.

Table 2: Findings of Compression and Water Absorption Study

Type of Fiber	Sample	Compressive Strength (MPa)	Water Absorption (%)
KENAF	LFC-K0.40	16.50	7.70
	LFC-K0.45	14.56	9.30
JUTE	J-03	2.30	10.80
	J-04	2.20	11.30
OIL PALM	OPF25	13.70	9.0
	OPF40	11.90	9.50
SISAL	MIX4	1.60	9.50
	MIX5	1.70	11.0
COCONUT	FC-D15	14.60	7.20
	FC-E20	13.40	8.60

Table 2 shows two different fiber content samples for each fiber type. Based on the results of observations that have been made, LFC-K0.40 with kenaf fiber content of 0.40 % has been selected as the optimal design because it records the highest compressive strength value.

3.2 Physical Characteristics of Natural Fiber LFC

Two comparisons are made to determine the main physical characteristics of a fibrous LFC, namely the comparison of compression strength and water absorption ability.

3.2.1 Compression Ability Comparison

In this study, a comparison in terms of compressive strength was conducted to identify the types of natural fibers that act as good binders for LFCs.

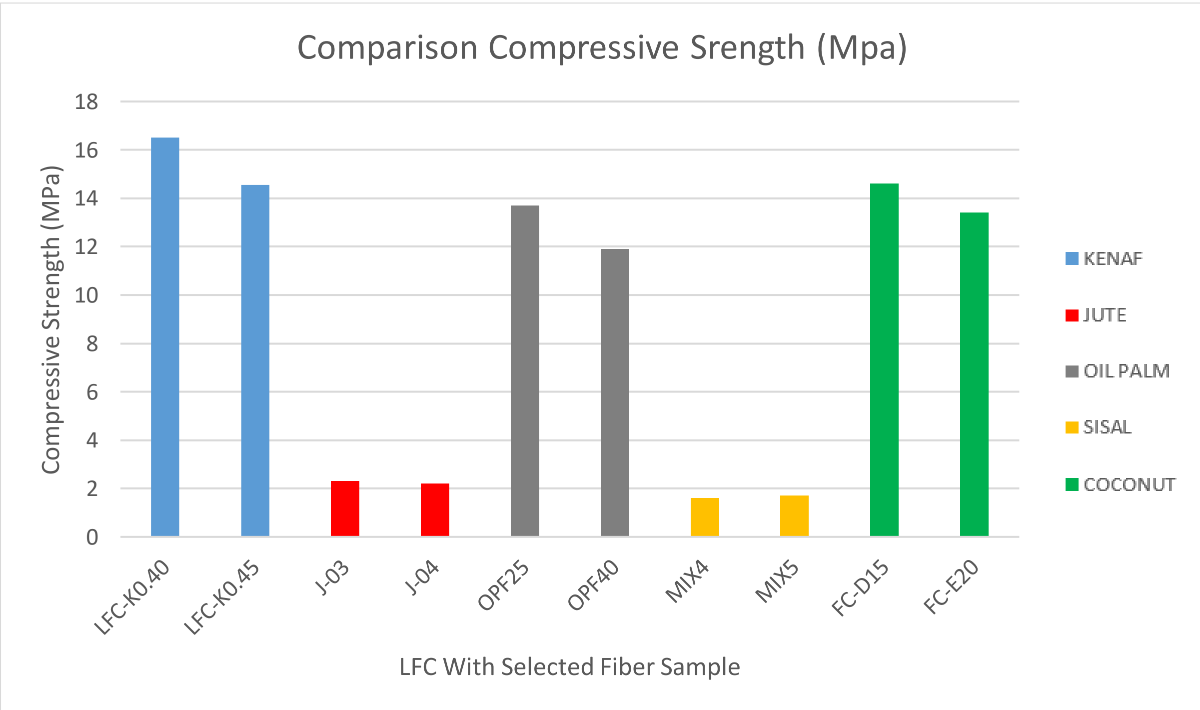

Figure 2: Comparison of Compression Strength

Figure 2 shows the comparison of LFC compression strength ability with varying addition of natural fibers. Samples of LFCs using kenaf, palm, and coconut fibers as additives showed higher compressive strength compared to LFCs with the addition of jute fiber and sisal fiber.

LFC samples containing kenaf fiber recorded compressive strength values of 16.50 MPa and 14.56 MPa while palm fiber recorded 13.70 MPa and 11.90 MPa. While, coconut fiber recorded 14.60 MPa and 13.40 MPa. These three types of fiber are proven to be suitable as an additive in LFC design because they can contribute to the increased compressive strength of an LFC without the addition of natural fibers. This is because these fibers have a high strength and less brittle than other natural fibers.

Different for jute and sisal fibers where these two fibrous KRBs recorded a much lower compressive strength with readings of 2.30 MPa and 2.20 Mpa for jute fiber as well as 1.60 MPa and 1.70 MPa for sisal fiber. This is due to the fiber content that is too little in its design of 0.09 % and 0.12 % for jute fiber samples. On the other hand, sisal fiber has the characteristics of fine and brittle fiber, which is also the reason why this sisal fiber LFC is not able to withstand high compressive forces.

3.2.2 Water Absorption Comparison

In this study, a comparison in terms of water absorption is conducted to identify the best types of natural fibers that act as good additives for LFC.

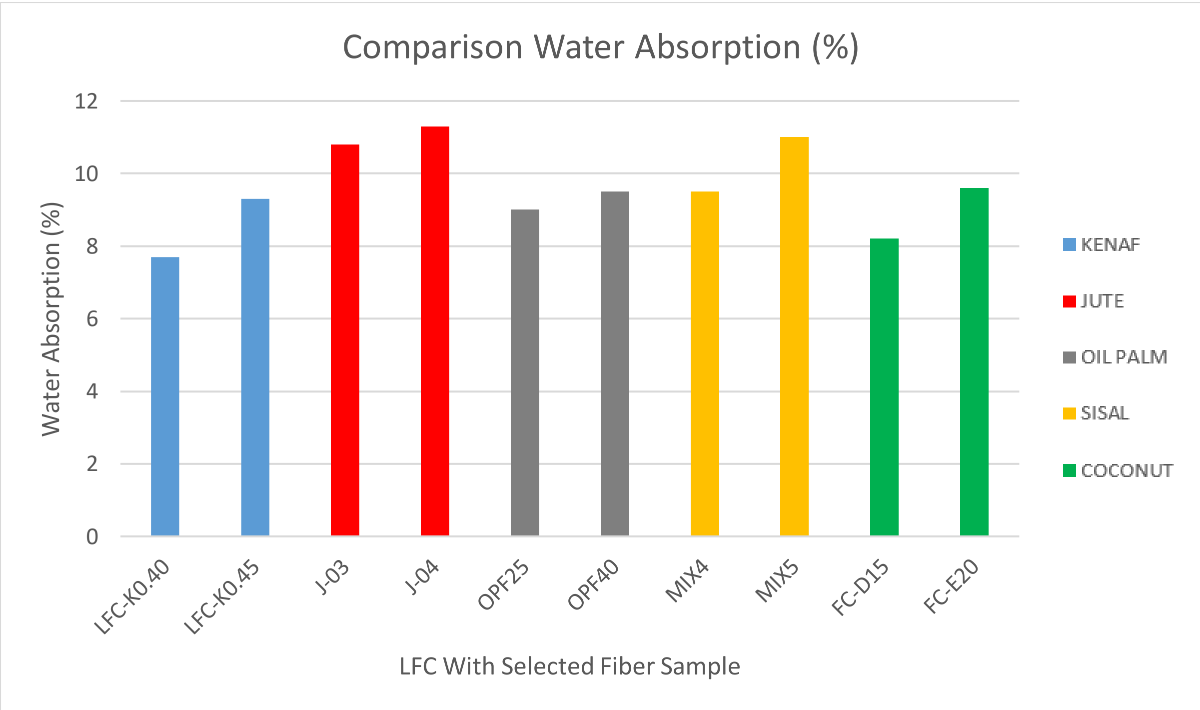

Figure 3: Comparison of water absorption

Figure 3 shows the results of comparing the water absorption ability of five LFC samples with the addition of various natural fibers. On the observations that have been examined, LFC samples containing jute fiber and LFC samples containing sisal fiber recorded high water absorption compared to other LFC samples containing kenaf fiber, oil palm and even coconut.

LFC samples competing with jute fiber recorded water absorption of 10.80 % and 11.30 % despite having a low fiber content. This shows that jute fiber is not suitable as an additive in LFC design because jute fiber has the highest water absorption among other natural fibers, as well as LFC samples containing sisal fiber which recorded the second highest water absorption of 9.50 % and 11.00 %. High water absorption rate will weaken the strength of a light foam concrete.

For LFC samples containing kenaf fiber, oil palm and coconut recorded a moderately high percentage of water absorption percentage of 7.70 % and 9.30 % for kenaf fiber LFC, 9.00 % and 9.50 % for oil palm fiber LFC, 8.20 % and 9.60 % for LFC coconut fiber. However, the sample of these three fibers is considered the best because it has a low percentage of water absorption compared to the LFC sample which contains natural jute fiber and also sisal sample even though all these fiber samples go through the same curing process for 28 days. This shows that kenaf, oil palm and coconut fiber have high resistance despite the relatively high water absorption rate, but are considered suitable to be used as an additive in LFC mix design.

3.3 British Concrete Association (BCA) LFC Standard Comparison

Based on research conducted at BCA, the compressive strength of LFC is relatively low. Specimen size and shape, pore formation method, age, water content, material properties used and curing method are reported to affect LFC strength. The lower the density, the higher the foam material content is introduced and thus the further reduction of the compressive strength. The combination of using foam agents and lightweight aggregates is a technology developed in LFC to offset the reduction in compressive strength of foam concrete.

Table 3: Compressive Srength LFC (BCA)

Dry Density (kg/m^3)	Estimated Compression Strength (tested dry) (MPa)
400	0.5 – 1.0
600	1.0 – 1.5
800	1.5 – 2.0
1000	2.5 – 3.0
1200	4.5 – 5.5
1400	6.0 – 8.0
1600	7.5 – 10.0

Table 3 shows the estimated compressive strengths of dry density LFCs based on the British Concrete Association (BCA). Lightweight foam concrete with a density of 1000 kg/m^3 can be expected to reach compressive strengths between 2.50 MPa to 3.00 MPa, which are acceptable for precast building blocks in British Standard BS2028.

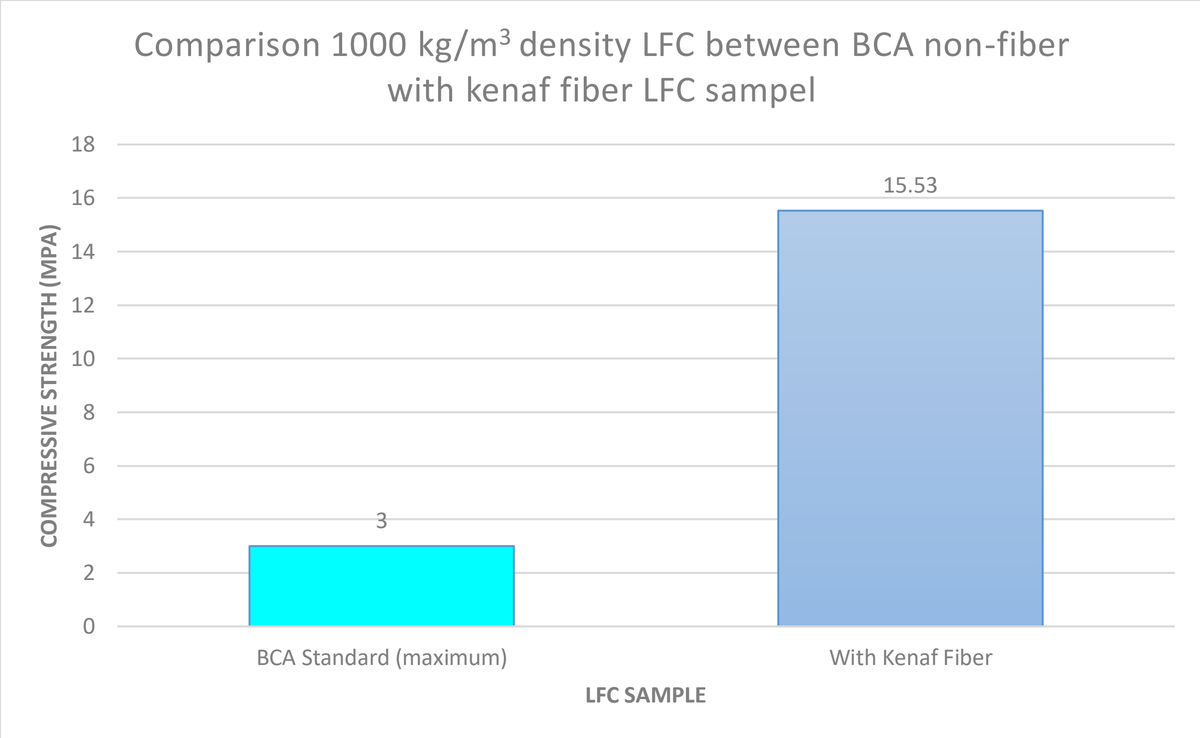

Figure 4: Comparison LFC 1000 kg/m^3 density between BCA non-fiber with kenaf fiber LFC sampel

Figure 4 shows a comparison between the estimated compressive strengths of a dry density LFC of 1000 kg/m^3 based on the British Concrete Association (BCA) along with the average compressive strength of LFC samples containing kenaf fiber which acts as an binder and an effective additive in LFC design. This sample was selected as the optimal design sample in this study based on the comparisons that have been conducted.

This selected sample has a density of 1000 kg/m^3 with a averange compressive strength of 15.53 KPa. This proves that natural fibers are able to have a significant impact in adding to the existing fragile deficiency characteristics of LFCs. The increase in compression force of 12.53 MPa is not a small increase in value for 1000 kg/m^3 density LFC, but is able to breathe new life that is more environmentally friendly in the building materials manufacturing sector in producing a stronger and much cheaper LFC.

4. Conclusion

The results of this study are expected to be applied in the construction sector in malaysia. The ability of LFCs with natural fiber content as an additive such as kenaf fiber can indirectly help reduce reliance on non-renewable sources such as sand which is widely used in LFC design mix. With the existence of natural fibers that act as LFC binders, the content of sand consumption can be slightly reduced from normal use. However, each different fiber gives a different impact as an LFC additive caused by the physical properties of the fiber itself. The reaction of the LFC base mixture to the fiber is also a factor making it brittle and unable to be a good binder in the LFC design for some types of natural fibers. The selection of the right type of natural fiber plays an important role in shaping a strong LFC design.

The three objectives of this study are to dentify the type of natural fiber that is suitable for use as an additive in LFC design, to comparing the characteristics of natural fibrous LFC in terms of compressive strength and water absorption ability, and to comparing natural fibrous LFCs with British Concrete Association (BCA) fiber-free LFCs has been successfully achieved. The results show that all the objectives of this study were achieved after the appropriate type of natural fiber as an additive in LFC design was identified. Successful design is produced with optimum ratio rate as well as accurate selection of natural fiber additives promises longer life span and can indirectly reduce maintenance work in the future.

Acknowledgment

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

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