

Augmentation of Coconut Fiber with Ground Granulated Blast Furnace Slag Reinforced Light Weight Aggregated Concrete: A Review

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Abstract

Natural fibers are environmentally friendly, cost-effective, lightweight, renewable, and have high thermal stability with corrosion resistance capabilities. The addition of natural fibers with ground granulated blast furnace slag (GGBS) in light weight aggregate concrete (LWAC) will be a long-term step toward improving mechanical properties and encouraging green construction. Coconut fibers are the least expensive of all-natural fibers and are widely available in a several developing countries. This study describes the impact of using coconut fibers in LWACs for sustainable construction. The effect of coconut fiber and GGBFS on the mechanical strength of LWACs including compressive strength, split tensile strength, and flexural strength, is reported. The effect of varying coconut fiber length and content on the mechanical strength of LWACs has been described, and optimum coconut fiber length and content have been reported. The current research initiative aims to increase understanding of the issues and challenges encountered during the production of coconut fiber reinforced GGBS with LWACs. In this study, it was determined that incorporating coconut fibers with GGBS can improve the strength properties of LWACs when used in shorter lengths and lower volume contents, whereas higher volume contents of coconut fibers degraded the strength properties of LWACs. Furthermore, current research on the practical applications of coconut fiber reinforced LWACs is quite limited, and more research is required in the future to determine their applications in civil engineering construction. Moreover, this review will aid in the promotion of the use of coconut fiber in the green construction of LWACs with the addition of GGBS.

Keywords: Coconut Fiber, Ground Granulated Blast Furnace Slag, Light Weight Aggregated Concrete

Introduction

Coconut fibers (CFs) are basically obtained from husk of coconut fruit [1]. These fibers are cheap, low density, strong, biodegradable, sustainable, have a higher energy absorption capacity, and are abundant in nature [2]. It is well known that lignin, hemicellulose, and cellulose are the major components of CF, and the mechanical properties of these fibers are primarily determined by the amount of cellulose and lignin content. A high cellulose and lignin concentration are desired to strengthen a fiber in various polymer composites. Coconut is the cheapest, most useful, and can be easily accessible fiber among all the NFs. Coconut fibers (CFs) consist of around 25–30% cellulose, 17.2–18.4% hemicellulose and 40.8–41.1% lignin [3]. A Coconut tree can reach a height of 22 m and has a base stem diameter of 9 m [4]. In comparison with different other NFs, Coconut fiber has several convenient features, such as high tensile strength, sustainability, reusability, and mostly important being environmentally friendly. Because of these characteristics, it is preferable to other types of NFs

[5]. Depending on the type, shape, and size of the CF composite, several methods were used to create it. The composite, with mixing 15% coconut composition with other derivatives has proven to produce greater tensile strength since the other derivatives content can be higher by weight. A composite of 50% jute and 50% coconut fiber has a semi-brittle and ductile effect that was discovered to be most effective when Coconut fiber was used [6]. According to the results of the literature review, the majority of the studies provide a good evaluation of the mechanical properties and potentials of NF uses. As a result, the material used in this study has a high potential for use in purpose for construction [7].

Fibers either be it a natural or artificial have been used in different composites of concrete to enhance their performance [8, 9]. As we know Environmental pollution, a major issue for the mother earth, is increasing by every second and poses a significant threat to humanity. Carbon dioxide and other greenhouse gases are major contributors to global warming. It is estimated that one tonne of cement produced results in one tonne of CO₂ production [10]. Different researches are going on to minimize the production of CO₂ by addition various natural fibers which needs minimal energy to extract and provide strength as well as provide less harm to environment [11]. NFs include jute, coir, sisal, bamboo, date, cotton, malva, hemp, banana, sugar cane, flax, and palm. CF, among them, may have relatively good LWAC strengthening [12]. Various NFs may be utilized to strengthen LWACs to overcome their inherent limitations. Because of its higher tensile strength and distinct microstructure, CF is a better option for replacing synthetic fibers in composite materials than all other types of NFs [13]. Significant research is being conducted on NFs for use in LWACs because of its compressive strength as mentioned in (Figure 1) particularly as reinforcement fibers in construction materials such as jute, akwara, sisal, bamboo, sucrose bagasse, and cocoon husk [14]. The present aim of research is to build sustainable and green construction materials [15, 16]. Thus, incorporating NFs into construction materials, particularly light weight aggregated concrete, would be a sustainable approach [17]. Because CFs are biocompatible, they can be successfully used to create advanced, non-toxic, biodegradable materials like synthetic matrix composites. In recent years, some research has been conducted by incorporating CFs into concrete [18].

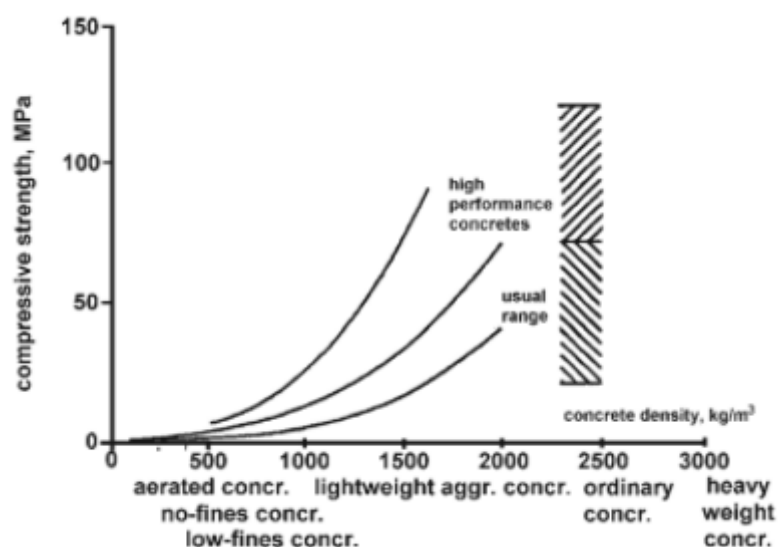


Figure 1: Strength and Various Ranges of Concrete

Ground granulated blast furnace slag (GGBS) is a by-product of the iron manufacturing industry, in which iron ore, coke, and limestone flux are combined in a furnace and heated to 1500 degrees Celsius for the manufacturing of pig iron. When molten slag is quickly quenched with water in a pond or cooled with powerful water jets, it forms a fine, granular, almost completely noncrystalline, glassy form which is known as granulated slag and this granulated slag is rich in silica, alumina, and calcium oxide. After that, the slag is dried and grinded into a fine powder. By adding GGBS in various types of concrete, the setting becomes quick, and strength achievement is higher, producing concrete which can be reason for the better development. In geopolymer concrete, the best strength is achieved by adding 40–50% GGBS [19]. In recent research it has been established that slag reactivity is influenced by slag properties such as glass content, chemical composition, mineralogical composition, fineness, and the type of activation provided. As a result, the current review aims at effectiveness of GGBS with coconut fibre reinforced Light weight aggregated concrete.

Light Weight Aggregated Concrete

Lightweight aggregated concrete is not a new development in the field of concrete technology. Since ancient times, aggregated concrete was made using natural aggregates such as pumice, scoria and different other light weighted materials. LWAC examples can be seen during Mayan period in Mexico which was used in the construction of pyramids as seen in (Figure 2) [20]. Concrete is commonly thought of as a grey material with high mechanical strength, but it can also be heavy and cold. Concrete is commonly understood to be more than just a heavy, sharp-edged grey block; it can take on any shape, colour, density, and strength. The low density of pumice aggregates reduces the weight of the structure and foundations while also saving money on thermal insulation. The density is primarily determined by the type of aggregate used. The type of aggregates used to make the concrete also has an impact on its strength [21].



Figure 2: Pyramid in Mexico Built during Mayan Period

Light weight aggregates can be of two types either can be natural or can be manmade. The majority of natural aggregates can be obtained from volcanic materials, whereas man-made or synthetic aggregates are produced in factories through the heating process.

Natural Aggregates

Natural aggregates main source is the lava erupted from the volcano which cools down and produces spongy well sintered mass. When lava reaches its boiling point, it contains air and gases, and when it cools, it solidifies into a spongy porous mass. In other words, it creates porous and reactive lightweight materials. This type of material is known as volcanic aggregates, pumice aggregates, or scoria aggregates, and aggregated concrete is produced by mechanically handling lava, which includes crushing, sieving, and grinding.

Natural aggregates can also be obtained from other sources like palm oil shells which is an organic aggregate. The use of organic waste as aggregates in the manufacture of construction materials has a number of practical and economic benefits. The use of organic waste as aggregates for the production of building materials has several practical and economic advantages. Some of the palm oil industry which are in Malaysia, Indonesia and Nigeria produces large amount of waste which can be utilised in the production of construction materials. Palm oil shells are produced in large quantities by the oil mills and can be used as aggregates for the production of Light weight aggregated concrete [22]. And after being so many of the advantages, production of LWAC from natural sources are yet to be commercialized and are mostly used locally. As it has same benefits and is cheaper as compared to synthetic aggregates so more research and development is needed to produce better quality.

Synthetic Aggregates

Synthetic aggregates are produced by the thermal treatment of the materials which have tendency to expand. Natural materials such as permit, vermiculite, clay, shale, and slate are included in the category of synthetic aggregates. Industrial products include glass and Industrial by-products such as fly ash, expanded slag cinder, bed ash, and others are examples of industrial products. Leca and Liapor are the two most common types of light weight aggregates made from expensive clay. Lytag, for example, is an aggregate made from fly ash [23]. The bulk density of the aggregates varies and is greatly depending on the raw materials used and their manufacturing process. The development of light weight aggregated concrete with a mixture of ground granulated blast furnace slag reinforced with coconut fibre or coir is reviewed below.

Significance of Research

High-performance engineering materials derived from natural resources are currently being developed for green construction. Nowadays, Steel and polypropylene which are two common synthetic fibres, are expensive and may raise the cost of the materials. Natural fibres provide a more cost-effective, environmentally friendly, and long-term solution for improving LWAC properties. In the recent year, researchers have been comparing natural fibre reinforced with various synthesised concrete and different artificial fibre reinforced synthesised concrete in order to develop the best materials for the engineering application in the term of mechanical properties as well as contributing environment friendly construction. This study summarises the impact of natural coconut fibre implicated with GGBS reinforced LWAC based on the available literature. Furthermore, the effect of CFs length and content on the mechanical properties of LWAC is discussed. Furthermore, the use of GGBS in conjunction with LWAC is discussed. Finally, future scope is suggested so that this study can help to identify gaps in current research so that future research can be better implemented toward the

application of coconut fibre in conjunction with GGBS reinforced LWACs in civil engineering applications for sustainable and green construction.

Properties of Coconut Fibers

Some individual reports are available on investigation of physical, mechanical and other properties of coconut fiber [24, 25] which have been given in (Table 1). Similar properties were compared with sisal [26]. The length of coconut fibers ranges between 8 and 337 mm. Fibers with lengths ranging from 15 to 145 mm is 81.95%. The weight of fibers with lengths ranging from 35 to 225 mm accounted for 88.34% of the total. The fineness of CFs is 27.94 tex on average [27]. Density of unrutted raw coconut fibre is reported to be 1.15 g/cm³.

Table 1: Physical and Mechanical Properties of Coconut Fibres

	Coconut Fiber	Sisal Fibers (A. Sisalana)
Dimension of Ultimate Cell		
Length (mm)	0.8–1.06 [25, 28]	2.5-5.3 [29]
Width ($\times 10^{-3}$) (mm)	14–16 [27, 28]	21.5-25.3 [30]
Length/width	95–536 [27, 28]	310 [31]
Area of cross section of cell (10^{-4} mm ²)	1.6 [25]	---
Lumen (%)	38 [28]	144 [32]
Dimension of Fibre		
Length (mm)	8–337 [33]	60-120 [30]
Fibre fineness (Linear density) (tex)	25–50 [34]	---
Fibre diameter (μ m)	69–870 [34, 35]	122-144 [36]
Coefficient friction	---	0.18-0.30 [37]
Fibre Density (g/cm³)		
True density (g/cc)	1.40 [38]	1.45 [30]
Apparent density (g/cc)	1.15–1.32 [33, 38]	1.20 [30]
Tensile Properties		
Single fibre tenacity (g/tex)	10.0–15 [28, 38]	30.9-35.4 [39]
Bundle tenacity (g/tex)	10–15 [38]	23-26 [39]
Single fibre breaking elongation (%)	15–3 [25, 28]	11.5-15.9 [39]
Torsional modulus ($\times 10^{10}$ dyn/cm ²)	0.2–1.5 [40]	---
Flexural modulus (dynes-cm ²)	150–250 [40]	---
Initial modulus (g/denier)	38.3 [40]	350-355 [39]
Young's modulus (Gpa)	4–6 [25]	3.8-4 [41]

The tenacity of coconut fibre (10–15 g/tex) is low when compared to other popular rope-making lignocellulosic fibres. Coconut fibres with shorter fibre lengths are stronger than those with longer fibre lengths. At 65% relative humidity, moisture regain of coconut fibre was reported to be 8–12.5%. The transverse swelling of coconut fibre in water has been observed to be about 15% in diameter, and

it increases noticeably up to 34% after 15 minutes. After 15 minutes of wetting, longitudinal swelling was reported to be 0.9% [25]. Untreated coconut fibre samples showed up to 61% water uptake [27].

Augmentation of Coconut Fiber with Light Weight Aggregated Concrete

Effect on the Length of Fiber

CFs have been shown in numerous studies to improve the compressive strength (C-S), split-tensile strength (S-T-S), and flexural strength (F-S) of LWACs. The change in the C-S of CF reinforced concrete with varying length and w/c has been shown by [42]. The C-S was mostly enhanced when the fiber length was increased to 25 mm with a 1.5% increase in fiber content, and then decreased when the fiber content was increased to 2%. However, for 50 mm and 75 mm long fibers, the C-S decreases as the fiber content increases. The decrease in C-S may be due to: (i) the workability of fresh concrete decreasing due to the higher content and longer length of fibers, as well as improper compaction during specimen casting, resulting in the formation of air voids; or (ii) the dilution of the cement matrix/hardened cement paste due to the addition of fibers. The improvement in σ due to the addition of fibers is also reported by [43]. S-T-S increased with increasing fiber length and 0.5% and 1% fiber contents, while at 1.5% and 2%, S-T-S improved briefly before deteriorating slightly. The S-T-S decreases as fiber content increases. In the case of 50 mm fiber length, however, the S-T-S has a maximum value of 1.5% fiber content. For shorter fiber lengths, the S-T-S of coconut fiber reinforced light weight aggregated concrete was less than that of LAWC because of insufficient embedment length to bridge the cracks. The S-T-S of reinforced aggregated concrete was reduced at higher fiber contents due to the formation of voids in the matrix and improper compaction caused by higher fiber contents, resulting in less workability. A similar trend in CFRC is also described by [43]. The improvement in S-T-S due to the addition of fibers in concrete is also reported in the literature [44].

Effect on Content of Fiber

It was discovered that adding CF to a specific quantity improved the C-S and S-T-S of concrete [42]. The use of CF aids in the improvement of mechanical properties of concrete with specific fiber content and length [45]. Several findings show that the incorporation of CFs has a significant impact on concrete tensile resistance. The S-T-S improved as fibre content increased. For instance, the S-T-S of composites containing 0.5% and 1% CF content was improved by 1.5% and 2%, respectively. The STS of CFR-LWAC was found to be reduced at higher fibre contents due to the formation of voids in the matrix and improper compaction caused by higher fibre contents, resulting in less workability [46]. Previous research has shown that including fibres in LWACs reduces drying time and shrinkage [47, 48]. The results of literature research on various CF-containing specimens clearly illustrated that the specimen's ductility, energy absorption capacity, stiffness, and load-bearing capability had been improved. C-S and S-T-S tests on concrete with varying percentages of CFs, such as 0.5%, 1.0%, and 1.5%, revealed that only 1.5% of CF in relation to cement content produced the best results. Strength and stiffness improved with a 1% increase in CF content, after which the impact of CF reinforcement had some negative effects. The CF inclusions, on the other hand, consistently increased the ductility and toughness of the composite. When compared with normal concrete, Adding CFs to normal concrete and high-fluidity concrete increased the S-T-S by about 5% and 10%, respectively [49, 50]. Higher CFs content had a negative impact on composite properties due to non-uniform distribution in the matrix and increased porosity [46].

Addition of Ground Granulated Blast Furnace Slag with Light Weight Aggregated Concrete Ground Granulated Blast Furnace Slag (GGBS)

GGBS is obtained from the steel-making process when molten iron slag is quenched from a blast furnace in water to form granules and ground to specified fineness. GGBS is commonly a self-cementitious and pozzolanic material as the typical composition consists of CaO, SiO₂, Al₂O₃ and MgO, which range about 30–42%, 35–38%, 10–18% and 5–14%, respectively. As well as GGBS has a specific gravity of 2.85–2.95 and a specific surface area of 400–600 m²/kg. High-pressure water jets are used to cool the slag, and rapid cooling causes granular slag particles to form. Following that, the slag is dried and ground into a fine powder. By incorporating GGBS into LWACs concrete, the setting time is reduced and the strength achieved is increased, resulting in concrete that is suitable for ambient curing.

Effect of GGBS on Fresh Properties

Generally, the use of GGBS could improve the workability of LWAC by up to 30% [51]. According to study by [52] it was not as effective as compared to the use of fly ash. The lower effectiveness was primarily due to the GGBS's shape and rougher surface [51]. According to [53], Exceeding 30% GGBS reduced the workability of oil palm shell LWAC and increased the viscosity of the mix. In terms of Vebe time there was little difference between oil palm shell LWAC with 20% and 70% GGBS as partial cement replacement [53]. In neither of the studies there was no significant effects of GGBS on the expanded clay LWAC's fresh density [51].

Effect of GGBS on Hardened Properties

When GGBS was used as partial cement replacement in LWAC, Because of its lower specific gravity when compared to ordinary cement, the density of the resulting concrete was reduced [54, 55]. When 20% GGBS was used as a cement replacement, the thermal conductivity of expanded perlite lightweight mortar was reduced by up to 13% due to its lower density [56]. Normally, the compressive strength of LWAC in the presence of GGBS is lower at early ages than that of concrete without GGBS, but it gradually increases at later ages. The delayed hydration of GGBS causes a reduction in strength and gain in later life [54]. In one study, it was discovered that using up to 40% GGBS in expanded clay LWAC at the ages of 7 and 28 days increased compressive strength [57]. Similarly, in the case of expanded perlite lightweight mortar, incorporation of 10% and 20% GGBS increased the 28-day compressive strength [56]. Accelerated curing at 60° C was found to be beneficial in increasing early age strength and reducing compressive strength loss with the use of high volume GGBS in oil palm shell LWAC [53], whereas steam curing and concealed curing had no effect on the reduction in strength loss in GGBS-blended coconut shell LWAC [57]. It was discovered that the inclusion of GGBS reduced the strength loss of expanded perlite lightweight at elevated temperatures of up to 800° C. In general, researchers discovered that when GGBS exceeded 20% or was used at a high level of replacement, the mechanical properties of LWAC were reduced. For example, the flexural tensile strength of expanded perlite lightweight mortar increased with 10% GGBS, but at a higher replacement level of 20% GGBS, the flexural strength was slightly reduced [56]. In one study, Akcaozoglu and Atis [58] found that using 50% GGBS as a cement substitute reduced the flexural tensile strength of PET lightweight mortar. The decrease in tensile strength could be attributed to an insufficient interfacial transition zone bond between the aggregate and the cement matrix. The weaker interfacial transition zone caused by GGBS was also discovered to contribute to the reduction of the modulus of elasticity of oil palm shell LWAC. When 70% GGBS was blended in oil palm shell

LWAC, the modulus of elasticity was reduced by 28% [54]. When 50% GGBS was added to coconut shell LWAC, the reduction was found to be 8% [59].

Effect of GGBS on Durability Performance

In one study, Gao et al. [60] discovered that, similar to fly ash, including 20% GGBS increased the carbonation depth of shale LWAC after 14 days, but the carbonation depth was lower than the control concrete after 14 days. This was attributed to the delayed hydration of GGBS, which had a pore refinement effect, blocking and isolating water and air penetration channels. However, it was found that incorporating 25–40% GGBS increased the carbonation depth of expanded clay LWAC by four times when compared to control concrete after a 28-day accelerated carbonation test. Similarly, when GGBS was blended up to 40% cement replacement, there was a reduction in water absorption of oil palm shell LWAC. This was attributed to GGBS's pore refinement effect, which may have reduced pore size and pore connectivity in the concrete [61]. Mo et al. [61] also observed that the addition of GGBS provided a pore refinement effect that was more significant in the enhancement of the cement matrix. According to the findings, the effect of a 50% GGBS replacement level on the drying shrinkage of lightweight aggregates was minimal and comparable to that of aggregates without GGBS for up to 90 days. The drying shrinkage of GGBS-blended lightweight aggregates was lower after 90 days [58]. When different levels of GGBS were used to replace cement in reinforced oil palm shell LWAC structural beams, namely 20% and 60%, no significant effect was observed in terms of loadbearing capacity, failure mode, and moment-deflection relationship [55].

Applications of Coconut Fiber Reinforced Light Weight Aggregated Concrete

The research on CF reinforced LWACs is in its early stages, and their practical applications require further investigation. Some researchers, however, investigated their viability for specific applications. In one study, for example, alkali-treated (NaOH and Na_2SiO_3) solution CF reinforced concrete was used for geopolymer concrete as it was revealed that increasing the molarity of NaOH increases the strength and modulus of elasticity [62]. It was concluded that the use of GGBS as a source material resulted in environmentally friendly geopolymer concrete as use of all waste materials resulted in useful material and strength properties can also be increased by adding up to 0.2% coconut fibre. Furthermore, the cost of producing CF reinforced geopolymer concrete was comparable to that of high strength concrete. According to the findings, the use of CF reinforced concrete would result in the development of a wide range of commercial products with high added value for a variety of applications. Due to the fact that coconut is an NF, NF composites have a wide range of applications in building and construction, aerospace, and sports, such as partition boards, ceilings, boats, office products, and machinery. Because of their susceptibility to environmental attack, NF composites are primarily used in non-load-bearing indoor civil engineering components [63]. Besides this, the other applications for NF reinforced LWACs are restricted to areas that require energy absorption or are susceptible to impact damage. As a result, NF reinforced LWACs are ideal for shatter-resistant and earthquake-resistant construction, factory machinery foundation floors, lightweight cement-based roofing and ceiling boards fabrication, wall plaster, and low-cost housing construction materials [64]. The current study concludes that more research is needed before practical applications of CF reinforced LWACs can be made. As of now, the research on CF reinforced LWACs and their basic material properties is very limited. As a result, extensive research into the acceptability of CF reinforced LWACs in these applications is required.

Conclusion

Light weight aggregated concrete (LWACs) based on coconut fibre (CF) are gaining popularity due to their low cost, lightweight, high strength, long-lasting, renewable, thermal properties, and corrosion resistance. Because of their unique abilities to strengthen and repair concrete structures, fiber-reinforced LWACs or any concrete are a revolutionary development in the history of structural engineering innovation. Thus, the aim of this study was to evaluate the mechanical properties of CF reinforced concrete. Relevant data were retrieved and categorised from available publications and after thorough review, the following conclusions were reached:

- Coconut fiber (CF) addition in LWACs may enhance their mechanical performance significantly when used in optimum quantity, provided that fibres are distributed uniformly throughout the mix. The uniformly dispersed CFs improve the microstructure of the matrix by decreasing porosity and provide crack resistance during loading via the bridging effect, thereby improving the strength properties of LWACs. But beyond the optimal limit, the addition of CFs has minimal effect on concrete performance due to non-uniform dispersion and the creation of empty space.
- Based on the literature review, it was determined that the incorporation of CFs in concrete in shorter lengths (up to 25 mm) and lower proportions (up to 1.5% volume fraction) provided the best overall performance. At higher CF content, the water demand of the mix increases and the formation of voids in the matrix and improper compaction weakens the concrete matrix, reducing the mechanical strength of the concrete.
- In addition to increasing strength, the addition of CFs reduces brittleness and increases toughness and ductility by improving the response of the mixture.
- If higher levels of cement replacement or a more cost-effective alternative are desired in LWAC, the use of GGBS is also a viable option, provided a sufficient curing period is provided.
- In addition to improving the material's mechanical properties, the incorporation of natural CFs in LWACs will promote environmentally friendly construction.
- This study concludes that the current study is very limited for the practical applications of CFs reinforced LWACs, and more in-depth research using various other supplementary cementitious materials such as Rice husk ash (RHA), Palm oil fuel ash (POFA), pumice powder and volcanic ash in LWAC is still in an early stage is required in future for their acceptability in civil engineering construction.

Scope of Future Study

The following recommendations for future research are required to improve the affectability of CF reinforced LWACs:

- Despite the fact that some research has been done on the compressive strength and durability properties of CF reinforced concrete. The long-term durability of CF reinforced aggregates must be investigated in order to gain a better understanding of the effectiveness of CF in LWACs and their applicability in civil engineering construction.
- It is necessary to investigate the proper mixing process for uniform fibre dispersion in the matrix. Although some researchers have reported on the mixing process, a standard procedure for large-scale fibre mixing in concrete must be developed.
- Machine learning should be used to examine the presence of fractures, likely crack propagation paths, and crack shape in existing research in order to predict mechanical behaviours of various types of CF reinforced concrete in scientific and technical applications.

- While much research has been done in the field of natural fibre reinforced concrete, much more work is required to determine the commercial utility of natural fibre reinforced LWACs.
- Further investigation of the mechanical properties of CF reinforced LWACs under different curing conditions, such as heat and steam curing, is required.
- So far, only a few studies on the strength properties of CF reinforced aggregates under acidic conditions have been reported, with a significant reduction in the strength of the concrete. More research is needed to better understand and predict the behaviour of CF reinforced LWACs in the presence of GGBS in an acidic environment.
- The influence of supplementary cementitious materials, such as different quantity of silica fume (SF), fly ash (FA), metakaolin (MK), Palm oil fuel ash (POFA) and various other cementitious materials like crushed natural pozzolan, perlite, glass paper, sludge ash and calcined pyrophyllite using CFs in a mix and a combination of CF with other kinds of fibers in a mix on the mechanical properties, is still limited, which needs to be investigated.
- Currently, there is insufficient research on the performance of CF reinforced aggregated concrete at elevated temperatures. As a result, it is recommended that the fire resistance of CF concrete for structural applications is needed to be investigated.

Conflict of Interest

Author does not show any conflict of interest.

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