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Review Article

Evaluating the effects of agricultural wastes on concrete and composite mechanical properties: a review

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Abstract

Wastes generation and emission of greenhouse gases are the major concerns of the contemporary world. Concrete's cements companies in the globe are producing up to 2.8 billion tons of cements annually. This contributed to the emission of anthropogenic substances into the atmosphere which destroys the ozone layers. The incessant disposal of these agricultural wastes has detrimental effect on the environmental and human health. Thus, utilizing these wastes as secondary resources in concrete is a reasonable consideration in sustainable waste management in the circular economy. The use of agricultural wastes in concrete production has been gaining attraction in recent years, however, their effectiveness and performance in concrete need evaluation. This study presents an overview of the effects of some agricultural wastes: Bagasse, Coconut shell, Cotton, Oil palm and Hemp fibers on concrete and composite's mechanical properties. As reviewed, Sugar-Cane Bagasse Ash (SCBA) and Coconut Shell Ash (CSA) are rich in cementitious (pozzolanic) properties (SiO2, Fe2O3 and Al2O3) for cement production up to 70%. Sugar-cane bagasse and oil palm-fiber ashes improved concrete workability. SCBA and CSA highly increased the concrete compressive strengths. The concrete tensile strengths were increased up to 97% with the inclusion of cotton and bagasse ashes. The SCBA, hemp-fiber and treated oil palm - fiber ash increased the concrete and composite's flexural strengths up to 11.3%, 26.2% and 50.7% respectively. In conclusion, the output of this review will supply full data of the research gaps yet to cover on the use of agro-wastes in concrete for future investigations.

1. Introduction

Concrete is a composite material that consists of course and fine aggregates closely bonded together with hydraulic cement paste which solidify over time without or with admixture [1]. Also, concrete is defined as a chemical reaction that occurred within its material components to generate the targeted strength suggested for the structural construction. It is a conventional material with desirable properties namely: excellent durability, moldability, secondary uses as byproducts in the production of other materials, lower energy input, and readily available in our environments. These characteristics made it globally acceptable for the construction purposes [2]. Apart from water, concrete is the most commonly used material on Earth. Only the United State of America (USA) and China were producing up to 2.8 billion tons of concrete cements globally. These countries are the most emitter of carbon dioxide in the globe [3]. In the year 2020, as estimated, the total volumes of cements produced globally amounted to 4.1 billion tones.

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While in the year 1995, the total volumes of cements produced amounted to 1.39 billion tonnes. There was a significant difference of 2.71 billion tonnes of cement produced from the year 1995 to 2020. This proofs that there was an upsurge in industrial growth within the years 1995 and 2020 [4]. The amount of agricultural biomass generated in a year were about 5 billion metric tonnes. These wastes were highly generated due to the increase in the rate of producing agricultural products. Accumulations of the dumped agro-wastes have caused a lot of gas emission like leachate and methane, resulting in air pollution (Rahimah et al. [78]). Figure 1 presents the global statistics of the cement produced from 1995 to 2020

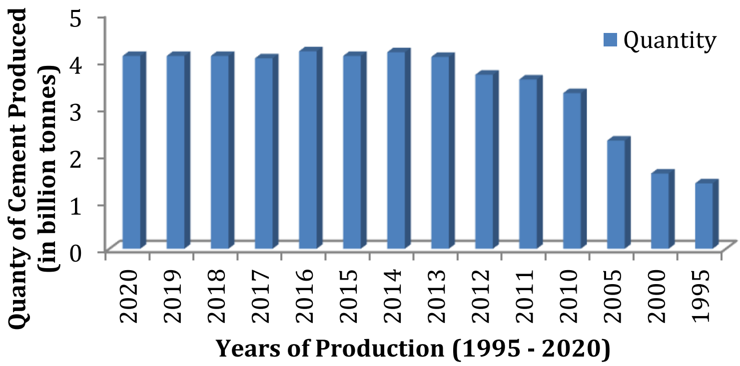


Fig. 1 Quantity of Cement Produced from 1995 to 2020 [4]

As shown in figure 1, the quantities of cement production were increasing as the years were increasing from 1995 to 2020. The amount of concrete and cement products in the global markets were estimated to raise to about $̣365.58 billion in the year 2021 from $̣333.26 billion estimated in the year 2020 using the annual growth compound rate (AGCR) of 9.7%. The cement and concrete companies' operations need rearrangement so as to recover from COVID-19 impact that had caused the earlier social distancing, closure of commercial activities and remote working. Come 2025, with the estimation rate of 7% AGCR , the cement and concrete products market is expected to reach $481.23 billion [5].

Cement and concrete are the globally acceptable construction materials for the production of concrete structures like dams, roads, buildings and bridges. Due to the frequent rate of production, a lot of harmful effects have been caused by many cements and concrete industries to the environments like: releasing of large quantity of carbon dioxide (CO_2) into the atmosphere, destroying of the ozone layers. Countries like United State of America (USA) and China experienced major emissions of carbon dioxide in the globe as at year 2020 [3]. In construction industries, over 4 billion tonnes of CO_2 were generated from cement and concrete companies globally every year. As it was known, the production of concrete is from the mixture of cement and aggregates (coarse and fine) with water. In the hydration process of the mixture, large volumes of carbon dioxide were released to the environment due to presence of certain percentage of carbon in cement composition. At the time of using these cements for concrete productions globally, it was observed that, the concrete industries generated up to 8% of overall global emissions of CO_2 and 12% of CO_2 emissions in New Jersey as indicated in Table 1.

Table 1. 2020 Global categories of CO_2 emissions [3]

Source	Emission Percentage (%)
Transportation	29.0
Industry	14.0
Electricity	28.0
Commercial & Residential	12.0
Concrete	8.0
Agriculture	9.0

In the process of producing cement from materials like clay, limestone and others in a kiln, the energy used to fire the mixture was causing the emission of CO_2 from the composition. According to the National Reality Mixed Concrete Association (NRMCA), it was discovered that, one pound of concrete releases about 0.93 pounds of carbon dioxide [7]. Lafarge Holcim Company, the largest concrete production company in the globe, had lowered the emission of carbon by 25% since 1990 and had a goal to reach net – zero emission soon. This was done to lead way in green constructions. The National Building Materials Organization (NBMO), which was into British Solar Renewable of about $1.4 billion, and cemex, also have the target of reducing carbon dioxide emission by 35% by 2030. This was implemented by following Lafarge Holcim's path in improving their foot print. Also, by converting the waste carbon dioxide into the valuable products, Thales Nano Energy company has reduced the effect of CO_2 emission in the globe [7].

The management of the huge quantity of agricultural wastes (AW) has become the major concern of the contemporary world owing to the environmental consequences connected to its disposal. The incessant disposal and illegal dumping of these have resulted into so many unprecedented effects on environmental quality and human health wastes. Emission of greenhouse gases, health hazards, environmental pollution, attraction of pests and reduction in values of economics importance of the land occupied by the waste materials are some of the harmful effects caused by these wastes in the societies [8]. The wastes from agricultural products occupy more than 50% of the agricultural biomass in the world [9]. Among the countries where these wastes have been generated globally were the ten top countries with large volumes of these wastes. Also, these countries were emitting large amount of carbon dioxide (CO_2) into the atmosphere as shown in Table 2.

Table 2. The ten top countries that Generate Large Amount of CO_2 from Agro-Wastes from 2010 – 2017 [9]

Countries	Amount of Carbon dioxide (CO_2) Generated from Agro-Wastes (g)
Bangladesh	400
Pakistan	400
Thailand	500
Mexico	500
Indonesia	750
Russian Federation	750
Brazil	1500
United States of America	3000
India	3500
China	4500

Among these countries; China, India and the United State of America (USA) were the countries where agricultural wastes (AW) were emitting large quantities of CO_2 (4500g, 3500g and 3000g of CO_2) respectively. Most of these wastes were burnt by farmers, causing air pollution. Some were used as fuel to generate energy for domestic uses. The treatment of these wastes made them useful as construction materials either as partial replacement of cement (in form of ash), aggregate, or as admixture in concrete. During the time of wastes treatment, the issues of CO2 emission, broken particles and harmful chemical in the wastes have been removed. The conversion of wastes into construction materials required low – energy consumption. The extracted fibers from agro–wastes possessed good properties like high efficiency in thermal insulation, good stiffness and toughness balance. With these properties, agro–wastes were useful for the industrial growth globally and for the sustainability of structural concrete. This will really benefit the future generations in term of clean environment and provision of standard solutions for natural problems. [10-11]. The perfect and effective ways of reducing the emissions of greenhouse gas (GHG) were by recycling, reusing and reducing the municipal wastes. The discarded waste materials were served as alternative source of material for concrete production in companies where they were recycled. The use of agro-wastes in concrete reduced the rate of demand for concrete virgin materials whose processing, transportation and extraction contributed majorly to the emissions of GHG. Virtually, in all the extractive industries such as: petroleum, agriculture, forestry and mining industries; their recycling of waste contributed to the reduction in the emission of GHG. Up to 3 or 5 times of the energy used for the incineration burning of cement aggregates can be saved through the use of recycled wastes in concrete.

The interest of both industries and science are in the use of residues from agriculture (agricultural wastes) in concrete production to improve its Mechanical properties together with its sustainability. Concrete mechanical properties are properties possessed by concrete for its stability against cracking and deflection during loading [12]. Much damage has been done to concrete properties, especially, the mechanical properties; accidentally or intentionally, which have been affecting their structural performance at service. Many buildings have been collapsing as a result of intensive fire impact on buildings from the aircraft. This has also caused several damages to the concrete properties, especially, the mechanical properties [13]. Other factors like: tension, lack of uniformity in concrete loads shearing, concrete expansion, unfavorable climatic conditions, poor mix proportion, poor concrete design contributed to the damage of concrete (mechanical) properties [14]. The major properties affected by these factors were: modulus of elasticity, setting times, workability, flexural strength, compressive strength, consistency and tensile strength. As it has been known that, concrete reinforcement always improves its structural properties, and many structural civil engineers in the world today have made this their major concern at the earlier stage of designing and construction of concrete structures. As a result of this, many techniques have been adopted to reinforce the structural properties of concrete for better performance. Some of these adopted methods are on application of chemical admixtures (for example super-plasticizers) in concrete, use of different fibers (steel, glass) and natural plant fibers such as: coir, hemp, cotton, sisal, bagasse, flax for concrete reinforcement [15]. Most of this high strength yielding artificial fibers are very expensive in the market this day (for example, steel fiber), thus, the researchers need alternative fibers to replace the expensive one with less cost of purchase. Thus, this lead to the use of natural plant fibers in concrete to enhanced its mechanical properties [16]. Natural plant fibers are the fiber derived from the processed agricultural plant wastes that are harmful pollutants to the environments and societies [17]. From the history, the inclusion of natural plant fibers (NPF) in concrete has been long, their effectiveness in concrete need evaluations. Thus, this leads to the use of natural plant fibers in concrete to enhance its mechanical properties [16]. Natural plant fibers are the fiber derived from processed agricultural plant wastes that are harmful pollutants to the environment and societies [17]. From history, the inclusion of natural plant fibers (NPF) in concrete has been long, their effectiveness in concrete needs evaluations. Thus, this paper evaluates the effectiveness of some agricultural waste-fibers (APWF) used in the reinforcement of concrete's mechanical properties with the specializations on the physical and chemical properties of the fibers; effect of agricultural wastes on concrete fresh state properties such as consistency, setting times and workability; and harden state properties (mechanical properties) such as compressive strength, flexural strength, tensile strength, and modulus of elasticity. Also, this study evaluates the effects of some high-strength yielding fibers (according to literature) extracted from agricultural wastes for concrete strength enhancement. These fibers were: sugar cane bagasse, coconut (shell), Cotton, hemp and oil palm fibers. To achieve this aim, the following objectives were set: (i) to review the effects of physical and chemical properties of agricultural waste-fibers on reinforcement of concrete (ii) to know the qualities of reinforcement developed with the use of fibers from agricultural wastes in concrete (iii) to evaluate the amount of strengths yielded by the fibers from agro-wastes in concrete (iv) to identify fibers that are not yielding strength on concrete mechanical properties, and consider them for better enhancement (v) to recommend for research development, the discovery gaps on agro-wastes fibers enhancement in concrete.

2. Effects of Agricultural Wastes on Concrete Mechanical Properties

2.1 Sugar Cane Bagasse (Ash)

The bagasse from sugar cane is the solid residue gotten after the crushed stalk of sugar cane and juices were squeezed out [18]. Approximately, about 280kg of bagasse from wet stalks of sugarcane can be extracted from a tone of wet Brazilian canes. Figure 2 shows the image of fresh bagasse from sugarcane and its processed extracted fiber.

(a) (b)

Fig. 2 (a) Raw Bagasse fiber, (b) processed bagasse fibers [18]

The moisture content of bagasse from sugarcane falls between 45% and 50% (Rezende et al, 2011). Bagasse Ash of sugar-cane residue is an agricultural waste that contributed to the reinforcement of concrete properties as pozzolanic cementitious material [19].

2.1.1 Mechanical and Physical Properties of Bagasse Fiber

The Mechanical and physical properties of bagasse fiber are presented in Table 3. The average diameter of bagasse fiber is 22 μm and that of the length is 1.8mm (Table 3). The aspect ratio of a single bagasse fiber is 76, while the density and tensile strength of bagasse fiber were 80 kg/m^3 and 235MPa respectively. These properties were standard for high tensile strength yielding in concrete. Also, the bagasse fiber has good surface areas for quality reinforcement of structural concrete [20].

Table 3. Mechanical and physical Properties of bagasse fiber [20]

Physical Properties			Mechanical Properties	
S/N	Properties	Value	Properties	Value
1	Diameter (μm)	10 - 34	Young Modulus (GPa)	15 - 19
2	Length (mm)	0.8 – 2.8	Tensile Strength (MPa)	180-290
3	Aspect Ratio (l/d)	76	Density (kg/m3)	880-720
4	Moisture Content (%)	49	Failure Strain (%)	1 -5

2.1.2 Chemical Properties and Composition of Bagasse (Ash) Fiber

Table 4 shows the chemical properties and components of Bagasse (ash) fiber. According to [22]; the burning of bagasse fiber or wastes from sugar-cane factory at temperature of 600 - 800^{0}C produced ash with large content of amorphous silica (Al_2O_3 and SiO_2) which are good pozzolanic elements. These properties have the cementitious yielding elements for quality reinforcement of paste and concrete for better construction. In the investigation conducted by Muhd et al. [77], the pozzolanic properties in the ash from sugar-cane bagasse were improved by removing the amorphous – silica elements from the bagasse before burning it at 300^{0}C temperature to ashes. This was highly contributed to the content of pozzolanic elements in the ashes for concrete strength increment. Also, in the findings of [21]; it was discovered that, bagasse ash consists of: 73% of Silica (SiO_2), 6.7% of Alumina (Al_2O_3) and 6.3% of Ferric Oxide (Fe_2O_3) (See Table 4) which were cementitious properties that can improve the quality of cement in concrete.

Table 4. Chemical Properties and Composition of Bagasse fiber (Ash) [20-21]

Chemical Properties of Bagasse Fiber			Reference	Chemical Composition of Bagasse Ash Fiber		Reference
S/N	Properties	Value		Properties	Value	
1	Hemi-Cellulose (%)	20-25	[20]	Alumina(Al_2O_3)	6.7	[21]
2	Cellulose (%)	45-55		Silica (SiO_2)	73.0	
3	Pectin (%)	0.6-0.8		Ferric Oxides (Fe_2O_3)	6.3	
4	Lignin (%)	18-24		Magnesium Oxide (MgO)	3.2	
5	Extractives (%)	1.5-9		Calcium Oxide(CaO)	2.8	
6	Ash (%)	1-4		Potassium Oxide(K_2O)	2.4	
7				Sodium Oxide(Na_2O)	1.1	
8				Pentoxide (P_2O_2)	-	
9				Loss of Ignition	0.9	

The high content of Silica, Alumina and Ferric Oxide in sugarcane bagasse ash was up to 86% of its chemical constituent. These compounds have the major required elements for sugarcane bagasse to function as pozzolanic properties for reinforcement of concrete properties. They can also function as aggregate for cement production. According to the specified standard of ASTM C618 (2003) for raw or calcined natural pozzolan and fly ash materials to be use in concrete; the three major constituent compounds (Silica (SiO_2), Ferric Oxide (Fe_2O_3), and Alumina (Al_2O_3)) of pozzolanic material should be up to 70% for it to be used as mineral admixture in concrete. Since the addition of these pozzolanic compounds was up to 86% (> 70%), the sugar cane bagasse ash (SCBA) can be use as pozzolanic material in concrete for its reinforcement. As observed, the binding (cementitious) property of SCBA is by 56.94% greater than that of OPC (29.06%). This shows that, SCBA can be perfectly used for cement substitute in concrete up to 86% and perform more excellently than that of OPC by 50% [23]. Only Silica compound alone, possessed up to 73% of cementitious property of SCBA as indicated in Table 2. This proved that, bagasse ash is very rich in pozzolans for the enhancement of concrete. Also, as investigated by [20], the main chemical constituents of sugar cane bagasse fiber (SCBF) were: cellulose, hemi-cellulose, lignin and pectin. These four properties contributed greatly to the best performance of SCBF as partial replacement of aggregate or as cementitious material in concrete for its reinforcement. Mostly, cellulose tends to increase the mechanical properties of concrete structures by 50% (Table 4). With this characteristic, high quality of concrete will be produced when used as an admixture in concrete. Hemi-cellulose is the next in action to cellulose; it contributed to concrete strength development up to 23%. While, Lignin and pectin, are having strength yielding capacity of 21% and 0.7% respectively.

2.1.3 Fresh State Properties of Concrete

Concrete Workability

According to the cement and technology specification standard of America Concrete Institute (ACI116R-1990), concrete workability is defined as fresh property of mixed concrete that shows the homogeneity and ease at which concrete is mixed, consolidated, finished and placed [24]. The workability of structural concrete was determined by slump test. [22] burnt the bagasse fibers from sugar cane residues to ashes within the temperature range of 600^0C to 800^0C. The ashes produced were rich in aluminous and siliceous cementitious properties which can be used to perform the same function binding like that of cement in concrete. According to the authors, ashes from sugar cane bagasse were rich in pozzolanic compounds and were used as partial substitute some quantities of cement in concrete. The tested concrete showed high increment in concrete's strengths, and its workability. Also, [19] experimented on the effect of bagasse (from sugarcane) fibre ash on concrete structure. The experimental result showed that, inclusion of bagasse fiber ash in concrete improved its workability greatly. This might be as a result of high content of cementitious properties (pozzolanic elements) in bagasse fiber ash used, especially, aluminous and siliceous. Likewise, the outcome of the test conducted by [25] on concrete workability with the inclusion of SCBA were presented in Table 5

Table 5. Concrete Workability [25]

% SCBA	Workability	
	Slump (mm)	Compaction Factor
0	70	0.88
5	85	0.91
10	90	0.91
15	100	0.93
20	125	0.94
25	160	0.96

As shown in the Table 5, the concrete slump values were increasing as the percentage of SCBA in concrete mixed were also increasing from 70 mm (control) to 160 mm (concrete with 25% of SCBA). The increment in slump value was up to 56.25%. Likewise, the factor of concrete compaction increased from 0.88 (control) to 0.96 (concrete with 25% of SCBA) which is about 9.09% increment. In the same perspective, [26] replaced some percentages of cement (grade M25) with certain percentages of SCBA, and investigated the effect of replacement. The results showed that, the slump values of the concrete increased from 76mm (control) to 82mm (with 20% of SCBA). These results clearly show that, low water cement ratio is needed to achieve perfect concrete workability when SCBA is used in concrete.

2.1.4 Concrete Harden State Properties

Concrete Compressive Strength

The compressive strength of structural concrete is the capacity of the concrete to resist loads aiding to reduce its form and cause unnecessary lengthens [27]. [28] partially replaced some quantities of cement with BAM and BAMP for the production of concrete-mortar. From their investigation, it was observed that, the compressive strengths of concrete with 5% of bagasse ash mortar (BAM) with ordinary Portland cement (OPC) and that 10% of BAM with same OPC were higher than that of (control) by 3.8% and 2.8% after being cured for 28 days respectively. In another perspective, certain percentages of cement were replaced with Portland pozzolana cement – bagasse ash (PPC-BA). The result showed that, concrete – mortar compressive strength decreased from 43.71N/mm^2 (which is the control strength value) to 27.93N/mm^2 (which is the strength at 30% replacement of cement with PPC-BA). The strength reduction was about 36.1%, which implied that, the use of bagasse ash mortar with pozzolana (BAMP) cement in concrete has caused a lot of strength loss to concrete. Looking at the result from the research perspective, BAMP is not good for concrete reinforcement, and if it will be use in concrete, it can only be in low strength structures. Also, [26] partially substituted certain percent of cement with 5%, 10%, 15% and 20% of SCBA in order to observe their structural performance in concrete. The results showed great reductions in concrete compressive strength, especially, from 5% replacement of cement with SCBA up to 20% replacement. The optimum strength reduction was about 60.4%. Since, concrete compressive strength is one of the major components of its stress-bearing capacity (ability to withstand heavy load), a 60.4% reduction in concrete strength due to the inclusion of SCBA has rendered the concrete useless. With this percentage of strength reduction, their usage in concrete will cause a lot of failures to concrete structures. So, authors concluded that, SCBA is not good for concrete reinforcement. Comparing the concrete strength reduction (60.4%) observed by [26] with that of strength reduction observed by [28] (36.1%), then, it can be deduced that, application of SCBA inform of BAM, and BAMP in concrete will contribute many failures to construction industries. But, if the result of [28], with strength reduction of 36.1%, can be improved upon, there will be increase in strength yielding properties of concrete. Beside the above results, [25] used some percentage of SCBA in concrete as partial substitute of cement; their structural performance was observed and recorded as shown in Table 6. The result shows that, concrete compressive strength was increased up to M4 mix (with 20% of SCBA). The concrete compressive strength increment was about 12.6% at 10% replacement of cement with SCBA. The results of an investigation conducted by [25] proofed that, SCBA can be used for cement substitute in concrete, and it can function as strength reinforcing admixture in concrete. This finding negates the results of experiments conducted by [26] and [28] which show that, the inclusion of SCBA in concrete reduced its compressive strength up to 60.4%.

Table 6. Average Concrete Compressive strength [25]

Mix Designation	M0	M1	M2	M3	M4	M5
Average Compressive Strength (N/mm^2)	33.281	37.351	38.077	36.769	35.752	30.956
% SCBA	0%	5%	10%	15%	20%	25%

Concrete Tensile Strength

As shown in Table 7, both the tensile strengths of plain concrete and that of concrete with SCBA were low. Yet, the inclusion of SCBA in concrete increased its tensile strength by 31.7% up to 20% of replacing cement with SCBA. According to [25], the strength increment yielded (31.7%) by replacing 20% of concrete aggregates with SCBA was more than that of the strength generated by adding 10% of SCBA to concrete mix (1.26% increment). The gradual reduction in concrete tensile strengths began to set in from M3 to M5 mix. The reduction is up to 9.8% at M5 mix with 25% of SCBA. With critical observation of the results in Table 7, it could be deduced that, sugar-cane bagasse ash is rich in pozzolanic properties for concrete strength enhancement up to M2 mix. On the other hand, the average concrete tensile strength obtained by [26] in their investigation conducted by partially replacing certain percentages of cement with SCBA was very low. It was less than that of control by 32.5% (from 1.94 to 1.31 N/mm^2). This might result into shearing of concrete during tension and unexpected deflection at construction stage. It was suggested that, the inclusion of SCBA in concrete mix should not exceed 10% to avoid unwanted flaws.

Table 7. Average Concrete Tensile strength [25]

Mix Designation	M0	M1	M2	M3	M4	M5
Average Tensile Strength (N/mm^2)	2.102	2.822	3.077	2.938	2.683	1.897
% SCBA	0%	5%	10%	15%	20%	25%

Concrete Flexural Strength

According to [28], the flexural strength of concrete with BAO (control) and that of concrete with BAS yielded the same result (4.68 N/mm^2). In the investigation, the bending strengths of the concrete beams were reduced even after 28th day of curing when 10% of Bagasse Ash (BA) and 25% of BA were included in the concrete mix. The bending resisting strength of the concrete increased from 6.05 to 6.821 N/mm^2 when the certain quantities of cement were partially replaced with 10% of SCBA [25]. The strength increment is about 11.3%. This result negates the findings of [28] that show no increase in concrete flexural strength.

Concrete Modulus of Elasticity

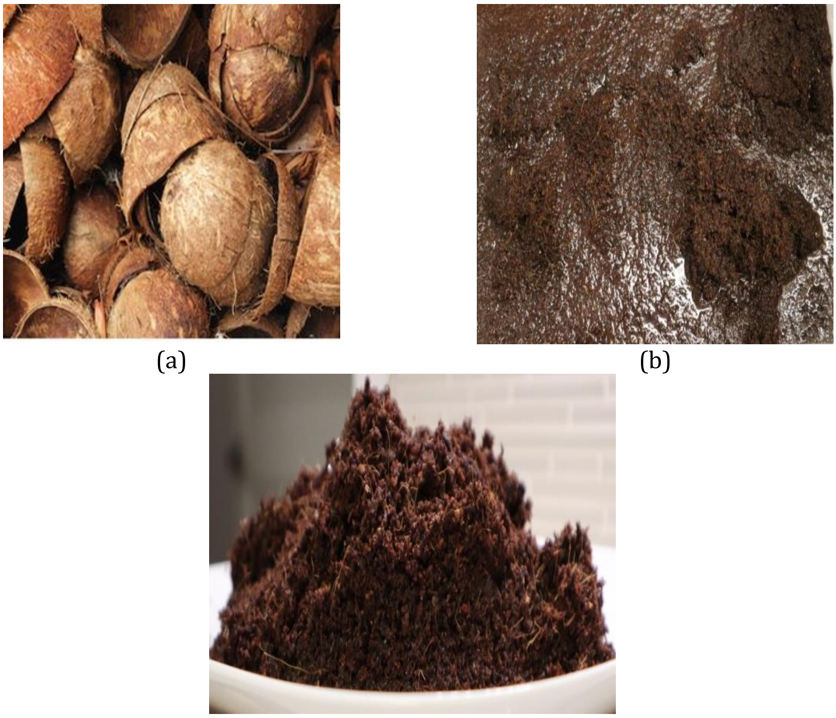
As shown in Table 8, the concrete modulus of elasticity increased up to M4 mix with the inclusion of 20% of SCBA. The highest concrete elasticity strength was observed at 10% inclusion of SCBA (Table 8) [25]. The elasticity strength of concrete increased a little (7.8%) with the addition of SCBA. Therefore, SCBA improved the sustainability and stability of concrete structures by reducing the concrete expansion limit by 7.8%.

Table 8. Modulus of Elasticity [25]

Mix Designation	M0	M1	M2	M3	M4	M5
Modulus of Elasticity x 10^4 (N/mm^2)	4.72	5.02	5.12	5.07	4.86	4.66
% SCBA	0%	5%	10%	15%	20%	25%

2.2 Coconut (Shell) Fiber

Coconut shell fiber is defined as fiber extracted from coconut husk through the crushing and combing method [29]. Also, according to [30], Coir is the threadlike material built within the outer skin of the coconut. The crushed shells of coconut were converted into ash after burning it in the combustion device at the temperature of 500^0C – 550^0C for two (2) hours. The burnt ash of coconut shell was sieved and used as partial replacement of cement in concrete [31]. Fig. 3 shows the images of coconut shells.



(a) (b) (c)

Fig.3 (a) Coconut Shells (b) Fresh Crushed Coconut Shells (c) Dry Crushed Coconut Shells (Source: [32, 76])

2.2.1 Properties of Coconut (Shell) Fiber

Physical Properties of Coconut (Shell) Fiber

Coconut fiber is a hollow and narrow fiber. It possesses a thick wall built of cellulose. A coconut shell is about 1mm in length and its diameter fall within the range of 10 - 20 µm. A raw fiber from coconut has length variation that fall within the range of 15 – 35 cm and the diameter variation of 50 - 300µm [29]. Some physical properties of coconut ash fiber compared with that of Ordinary Portland Cement (OPC) were presented in Table 9 according to the investigation conducted by [33].

The normal consistency of coconut shell ash (CSA) was greater than that of cement by 4% (Table 9). Also, the specific gravity of CSA was less than that of cement [33]. Therefore, CSA had been acting as an accelerator in concrete for quick paste setting, and thus, developed good surface area for quality concrete production (since 1.33% < 3.15%). Having developed good consistency properties, the rate of absorption of water of CSA was very high (25%, see Table 9). This might lead to the use of high water – cement ratio for the production of concrete with CSA.

Table 9. Physical Properties of Cement and Coconut Shell Ash (CSA) [33]

S/N	Properties	CSA (%)	Cement (%)
01	Normal Consistency	38	34
02	Specific Gravity	1.33	3.15
03	Water Absorption	25	-
04	Fineness Modulus	8	5

Chemical Properties of Coconut (Shell) Fiber

The chemical properties of matured nuts, young nuts and very young nuts of coconut fiber were presented in the Table 10.

Table 10. Composition of Coconut Fiber (Coir fiber – wt %) [34]

Maturity	Cellulose	Hemi-Cellulose	Lignin	Hot Water Soluble	Total water Soluble	Ash
Matured Nuts	43.44	0.25	45.84	3.00	5.25	0.13
Young Nuts	32.86	0.15	40.52	2.75	16.00	-
Very Young Nuts	36.11	0.25	41.02	4.00	15.50	-

As shown in Table 10, the matured coconut developed highest values of chemical properties such as Lignin-45.84%, Hemi-cellulose-0.25%, and cellulose-43.44%, which is up to 89.53%. These three properties contributed highly to the reinforcement of concrete up to 90% effectiveness. Therefore, the matured nuts of coconut are preferable to be use for concrete reinforcement than others [34]. Likewise, the chemical compositions of coconut shell ash were shown in Table 11. The three chemical components were very rich in pozzolanic properties (Silica, Aluminates and Iron oxides) to be able to function as cementitious material in concrete. Silica (SiO_2) is a pozzolanic compound, responsible for early development of mortar and concrete strength [35]. Silica occupies the largest percentage of pozzolanic properties of coconut shell ash such as 44.05% [36]; 43.50% [37]; 42.50% [38] and 37.97% [33,39] as shown in Table 11. Also, Aluminates and Iron oxides contribute to the effectiveness and performance of a material to function as a pozzolan in concrete. ASTM C618 (2013) stated that, for a material to be use as a pozzolan in concrete or mortar, either as partial substitution of cement or aggregates, its pozzolanic chemical compositions percentage, that is, the combination of Iron Oxide (Fe_2O_3), Silicon (SiO_2) and Alumina (Al_2O_3) should be up to 70%.

Table 11. Chemical Composition of CSA and Cement

Constituent	OPC [23]	CSA [36]	CSA [37]	CSA [38]	CSA [33]	CSA [39]
SiO_2	20.78	44.05	43.50	42.50	37.97	37.90
Al_2O_3	5.11	14.60	15.20	17.70	24.12	24.12
Fe_2O_3	3.17	12.40	12.60	8.17	15.48	15.48
CaO	60.89	4.57	3.25	4.30	4.98	4.98
MgO	3.0	14.20	15.01	0.71	1.89	1.89
Na_2O	0.25	0.45	0.47	0.93	0.95	0.95
K_2O	0.39	0.52	0.49	0.82	0.83	0.83
P_2O_5	0.26	-	0.40	-	0.32	0.32
SO_3	1.71	-	-	0.55	0.71	0.71
Loss of Ignition	2.31	8.89	8.39	6.51	11.94	11.94

As conducted by [23], the percentage constituent of the three major pozzolanic compounds of OPC (Fe_2O_3, SiO_2 & Al_2O_3) was 29.06% (< 30%) which is very low compared to the specified percentages stated by [40]. Certain percentages of cement were substituted with coconut shell ash (CSA) by [39]; and [33]. The total percentages of pozzolanic compounds observed in coconut shell ash (CSA) were 77.50% and 77.57% respectively. These percentages were more than that of OPC (29.06%) by 48.51%, which is about times 2 of OPC value. It was also more than the specified standard, 70%, stated by [40] by 7.5% and 7.57% respectively. Likewise, [37]; and [36] had similar results like that of [39] and [33] (71.3% and 71.05% respectively). Thus, the review of CSA chemical compositions showed that, CSA is very rich in Pozzolanic (cementitious) properties and can be use for concrete strengths reinforcement.

2.2.2 Fresh State Properties

Setting Time of cement with CSA Paste

The setting time of concrete-paste with CSA is presented as in Table 12. The setting time of cement-paste with CSA were increasing as the percentages of CSA substituted in the paste were increasing from 0CSA to 30CSA (Table 12). By considering the results of investigation made by [41] shown in Table 12, the initial setting of CSA-Paste occurred at a time beyond the specified time limit stated by [6] (40 minutes) especially at the time of including 5CSA to 30CSA in the pastes. It was observed that, CSA prolong the initial setting time of concrete. This will cause delay for concrete to achieve its initial setting strength. Besides, the final setting time of concrete with CSA were within the specified time limit (600 minutes) stated by [6] for the final setting of concrete paste. Though it took a lot of time to attain the initial setting of concrete with CSA, the finally setting of CSA - concrete took place within the specified final setting time (10 hours). With higher water – cement ratio, concrete with CSA cannot achieve good setting. The use of CSA in concrete requires low water - cement ratio in order to achieve accurate CSA - cement - paste setting.

Table 12. Setting Time of CSA [41]

S / No.	CSA Replacement (%)	Initial Setting Time (mins)	Final Setting Time (mins)
01	0CSA	74	96
02	5CSA	142	239
03	10CSA	262	345
04	15CSA	273	384
05	20CSA	295	458
06	25CSA	327	476
07	30CSA	346	492

Concrete Workability

In an experimental analysis conducted by [42], coconut hard-shells (CHS) were applied to structural concrete on the basis of increasing its workability. The outcome of the investigation showed that concrete with CHS developed slump value of 26mm and that of unreinforced concrete had slump value of 25mm. This implied that, the workability of unreinforced concrete was improved by 4%. That is, the rate of concrete flow was increased by 4% with the addition of CHS. Though, the best slump value was observed at the inclusion of 25% of CHS in the concrete mix, still, the use of CHS in concrete requires low water - cement ratio to achieve good workability.

2.2.3 Concrete Harden State Properties

Concrete Compressive Strength

The plain concrete was discovered to develop 20 – 30% compressive strength increment than that of concrete with CSA (Coconut Shell Ash) as reported by [43]. 25% of coconut shell fiber was used for partial replacement of certain percentages of concrete aggregates.

The result showed that, the concrete of which some of its aggregates were substituted with some percentages of coconut shell fiber showed reduction in compressive strength of concrete up to 5.75% compared with that of concrete without coconut fiber. This might be as a result of using longer length coconut shell fiber in the mix [42]. Also, certain quantities of cement were replaced with CSA in concrete by [44]. Among the samples tested, the concrete sample with 10% of CSA at M30 mix yielded the compressive strength of 42.89N/mm^2. This value (42.89N/mm^2) is greater than that of concrete with 0% of CSA (35.00N/mm^2). These values were observed after the concrete has been cured for 28 days. Other compressive test results also showed increment in concrete strength but that of 28th day result developed up to 99% strength increment. Actually, CSA-concrete developed maximum strength increment at inclusion of 15% CSA in concrete when used as partial replacement of cement. However, the report of [45] was different from that of Sharan and Raijiwala [44]. At the time of substituting certain percentages of concrete aggregates with some percentages of coconut (shell) fiber as conducted by [45], the concrete compressive strength observed was very low compared to that of control (Plain concrete). In another perspective, the results obtained by [46] were in line with that of Sharan and Raijiwala [44]. The substitution of cement with certain percentages of CSA (0%, 10%, 20% and 30) showed increase in the compressive strength of CSA – concrete. In addition to [46] report, report of [39] showed that, the inclusion of CSA in concrete increase its compressive strength. As indicated in Figure 3, concrete with CSA showed strength increment up to 10% replacement of cement. The compressive strength increments recorded were 7.52%, 8.79%, 8.23% and 7.47% at 7, 14, 21 and 28 days of curing respectively. [39] observed that, CSA increases the concrete compressive strength up to 9% (see Figure 4). Though, the strength increment is low, but application of other fibers with it improves its enhancement properties in concrete.

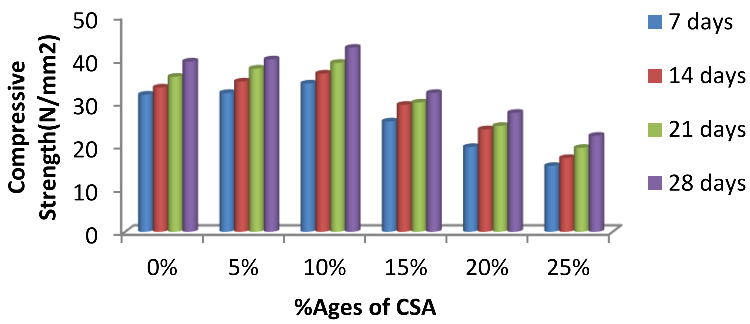


Fig. 4 Compressive Strength of Concrete with CSA [39]

Concrete Tensile Strength

Application of CSA as substitute for cementitious aggregate in concrete developed higher tensile strength than that of the control [47]. This might be as a result of present of high cementitious (pozzolanic) properties and filler component (like cellulose) in the CSA used [48]. Also, [39] stated that, the inclusion of CSA in concrete increased its tensile strength up to 10% substitute of OPC with CSA as indicated in Figure 5. Then, it could be deduced that, CSA is good for concrete tensile strength improvement but its application should not exceed 10% cement replacement.

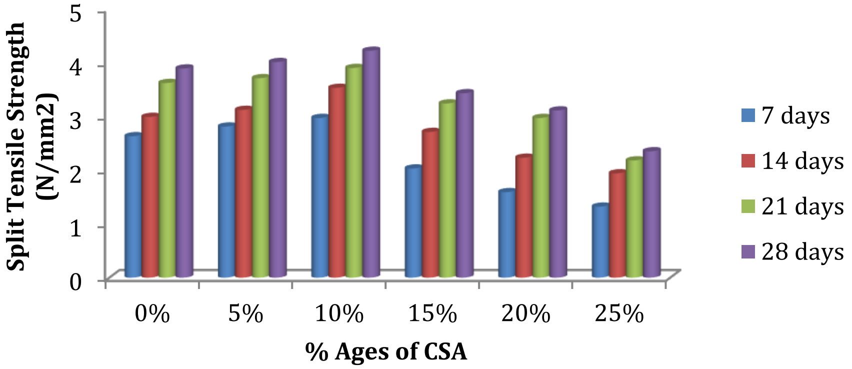


Fig. 5 Split Tensile Strength of Concrete with CSA [39]

Contrary to the above results, the investigation of [49] show that, the tensile strength of CSA-concrete was decreasing as the percentage of CSA included was increasing when CSA was applied as cement substitute in concrete. According to [42], the concrete tensile strength was decreasing until 36.8% strength reduction was reached at the inclusion of certain percentages of coconut fiber shell in concrete. This implied that, coconut shell fibre had poor reinforcement properties against concrete tensile failure. Its application in concrete can lead to several concrete failures relating to tensile stress. The report of [50] also supports the findings of [42] and [49]. According to the authors, the use of CSA as coarse aggregate substitute in concrete decreased the tensile strength of concrete. If the experimental procedures used by [47] and [48] were adopted in CSA-concrete experiment, and application of CSA to concrete is not exceed 10% of the weight of cement, there should be positive results of using CSA in concreting.

Concrete Flexural Strength

The concrete flexural strength formed from the mixture of 10% CSA, stone dust and OPC showed high concrete bending (flexural) strength increment up to 10% cement replacement with CSA material [51]. In addition to this, [39] used the combination of egg-shell ash (ESA) powder and CSA for the production of concrete instead of using Ordinary Portland Cement (OPC). According to the author, there was increase in the ESA-CSA-concrete flexural strength. The increment in strength might be as a result of high content of pozzolanic and filler properties in CSA and powder of egg-shell ash (ESA) used. On the contrary, [42] used coconut shell fiber for partial replacement of certain percentage of concrete aggregate. The result showed that, there was reduction in the flexural strength of concrete up to 25% inclusion of CSA in the mix. Due to this, the percentages of coconut fiber in the mix were minimized. Though, the percentage of CSA in mix was reduced, still, there were decreases in the concrete flexural strengths than that of concrete with highest percentage of CSA up to 19.4% (from 5.36MPa and 4.32MPa). According to the authors, coconut shell ash is not good for concrete reinforcement, especially, to improve its flexural strength. In addition to the above statements, according to [43], the higher the proportion of CSA in concrete, the more the decrease in its flexural strength.

Modulus of Elasticity of Concrete with CSA

With prolong curing age; the concrete modulus of elasticity (MOE) was increasing as the percentage of CSA used for the substitution of certain percentages of cement in concrete was increasing [51]. The finding of [47] also supports the results of [51] on concrete strength against unnecessary expansion that can cause cracking. In their investigation, 20% of cement was replaced by CSA. The concrete MOE was increased compared to that of control (Plain Concrete). Therefore, application of CSA in concrete will block a lot of pores in concrete where cracks can be developed as a result of constant elating and contracting of concrete due to temperature changes.

2.3 Cotton (Ash) Fiber

Cotton fiber is an unbleached fiber from plant family of mallows. It is a very light species. It can restrain water up to 27 times of its own weight. The length of a cotton fiber is normally indicated by its spinnability and physical characteristics. Each cotton fiber has a single long tubular cell [52]. Hosseini and [53] defined cotton fibers as soft hollow fibers that possessed absorbent and breathable properties. According to the authors, cotton fibers can be blended with other fibers to improve their structural properties. Cotton fibers are good in withstanding high temperature and abrasion wear, especially, in concrete elating and contraction due to temperature changes. Figure 6 shows cotton fiber and woven cotton fabric images.

(a)

(b)

(c)

Fig. 6 (a) Cotton Plants (b) Cotton waste fiber (c) Woven cotton fiber (Source: [32, 53])

2.3.1 Properties of Cotton Fibers

Physical Properties of Cotton Fiber

A cotton fiber has the length of 0.5^{11} to 2.5^{11} [67], and a length average of 10mm. It possesses up to 7 - 10% moisture regaining capacity. Its specific gravity falls within the range of 1.52 – 1.55 (see Table 13). A cotton fiber has 400MPa tensile strength, 0.2mm diameter and 4.8GPa Young modulus. Also, a cotton fiber has a density of 1.54g/cm^3 [54]. These characteristics made fiber from cotton plant suitable for research work and also physical fit for concrete reinforcement.

Table 13. Physical properties of Cotton fibers [52]

Properties	Values
Length	0.5¹¹ - 2.5¹¹
Moisture regains	7 - 10%
Strength, tenacity (gm per denier)	3 - 5
Specific gravity	1.52 - 1.55
Resiliency	Cream or Yellowish like Clean white
Color	Low

Chemical Composition of Cotton

Cotton fiber consists of 91% of cellulose [55] which is the best property of plant required for sufficient reinforcement of concrete as indicated in Table 14. All other properties were also good for concrete enhancement.

Table 14. Chemical properties of Cotton fibers [55]

Properties	Values
Cellulose (%)	91.00
Mineral Salt (%)	0.20
Water (%)	7.85
Protoplasm, Pectins	0.55

2.3.2 Fresh State Properties of Concrete with Cotton fiber

Concrete Workability

Partially replaced some percentage of OPC with cotton dust (CD) ashes [56]. The result of the investigation shows that, concrete with 5%, 10%, 15% and 20% of CD ashes showed reduction in workability compared to that of concrete with OPC only [42]. According to the authors, CD ash- concrete required high water – cement ratio to achieve a suitable workable.

2.3.3 Harden State Properties

Concrete / Composites' Compressive Strength

Reinforced geo-polymer composites with cotton – fabric fiber [54]. The mechanical properties of the composites were observed at the temperature of 200^0 - 1000^{0}C. The compressive strength of geo-polymer-composites was decreasing after the temperature range from 200^0 - 1000^{0}C. This was traced to constant deterioration in hydration process of geo-polymer-composites. It could also be as a result of increase composites porosity with increase in burning temperature. According to the authors, the geopolymer-composites suggested to heat under the temperature range of 800^{0}C - 1000^{0}C usually have high porosities than those heated at the temperature range of 200^{0}C to 600^{0}C. In support of this, [57] used woven fabric – cotton for composite reinforcement. The results showed that, there was decrease in compressive strength of composites with fabric woven – cotton than that of composite without woven fabric – cotton (control) as shown in Table 15.

The normal compressive strength of composite with ordinary cement-paste indicated that, there was a very strong high bonding relationship within its grain-particles. Thus, addition of layers of cotton fabrics to the cement pasted has caused a lot of decrease to the grain-particles bonding of the composite which led to its compressive strength reduction. In the reinforcement of geopolymer composite with fabric fiber, the cotton-fabric was acting as an isolator. [56] used ash made from cotton dust (CD) to partially replaced certain percentages of cement in concrete.

Table 15. Compressive Strength of Geopolymer Composites (N/mm²) (Source: [57])

No. of Layers	Compressive Strength (N/mm²) (Source: [57]) control	Twill 2/2	H8-Satin	Weft Rib 2*2	Crepe	Warf Rib 2*2	Weft Rib 4*4	Honey comb
0	60							
1	-	40.80	35.49	34.96	42.93	34.89	33.76	29.47
2	-	37.80	34.73	31.48	35.80	28.67	30.28	21.47
3	-	27.67	27.67	31.20	35.67	24.80	25.76	19.87

The proportions of cement replacement were in 5%, 10%, 15% and 20%. In the investigation, the concrete produced were immersed in water for 3, 7, 14, 28 and 60 days for proper curing. The values of strengths yielded at concrete different curing ages were presented in figure 7. As shown in Figure 7, the values of concrete compressive strength developed were less than that of control at days of curing. Concrete compressive strengths were decreasing as the percentage of CD ash in concrete and its curing age were increasing up to 28 days of curing. The extension of concrete curing age up to 60 days increased the concrete compressive strength up to 10% cement replacement with CD ash. The percentages of strength increment were: 1.20% for 5% CD ash and 2.67% for 10% CD ash replacement with cement. Here, it could be deduced that, the more the curing ages of concrete reinforced with CD ash, the more the concrete compressive strength yielded.

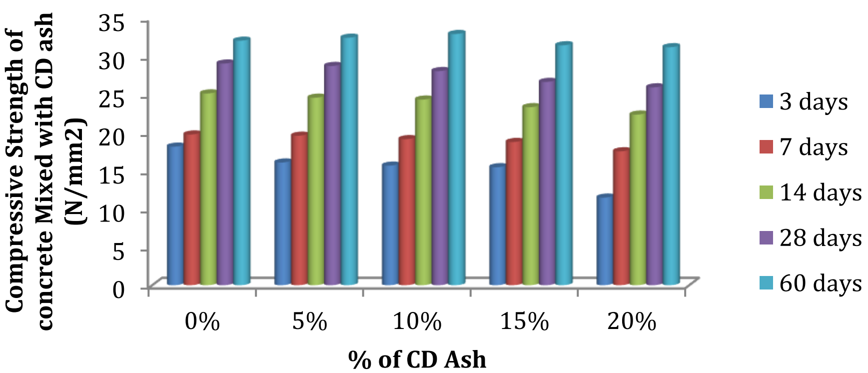


Fig. 7 Compressive Strength of Concrete Mixed with CD ash (N/mm²) (Source: [56])

Tensile Strength of Cotton Fiber Concrete

In the investigation conducted by [56], 5%, 10%, 15% and 20% of cement aggregates were replaced with CD ash in concrete to determine their tensile strengths capacities. The results of the test showed that, as the percentages of CD ash in concrete was increasing; the concrete tensile strengths were also increasing up to 28 days of curing. In other perspectives, the concrete tensile strengths were increasing as their curing ages were prolonging until 60 days was reached. These increments were observed up to 10% replacement of cement with CD ash in concrete. 1.34% and 8.47% strength increments were observed for concrete with 5% and 10 % of CD ash respectively as shown in figure 8.

As indicated in figure 8, authors concluded that, the reinforcement of concrete with CD ash will continues to be gaining more strength for its stability against shearing as long as its curing ages were prolonging. In addition to this, [57] also investigated on the use of woven cotton fabric in composites to improve its shearing strength due to tension. The investigation was conducted on the specimens up to three different layers of composites. The result showed that, the cotton fabrics improved the tensile behavior of fabric – cement composites. At every layer, the tensile splitting strength of fabric – cement composites observed were 7MPa and 9 MPa which were more than that of the controls (the three controls). Also, as the quality of design of fabric – cement composites were increasing, the composites tensile strengths were also increasing up to 82% at layers 2 (2 layers) with increment range of 74% to 97%.

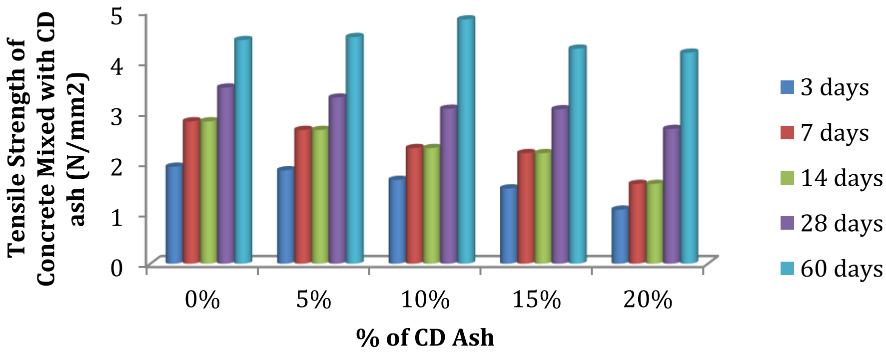


Fig. 8 Tensile Strength of Concrete Mixed with CD ash (N/mm^2) (Source: [56])

Flexural Strength of Cotton Fiber concrete

There was increase in the flexural strength of composite reinforced with fabric woven cotton cement composite as investigated by [57]. According to [57], the structural performances of fabric-composites were very high against bending stresses of the composites. As the number of layers of fabric applied to cement composite was increasing, the composite flexural strength was also increasing. Author concluded that, woven cotton fabric highly increased the cement composites strengths against any future bending at service. On the contrary, the investigation of [54] showed that, the geopolymer composites reinforced with cotton fabric fiber had decrease in their flexural strength with increase in temperature. These strengths were at the composite's temperature range of 800^{0}C to 1000^{0}C which were higher than those of composites at 200^{0}C, 400^{0}C and 600^{0}C. The degradation in cotton fiber content in the composites influenced the decrease in the flexural strength of the composites. Likewise, the concrete produced from the mixture of cement and certain percentages of cotton dust (CD) ash showed strength reduction at 3, 7, 14 and 28 days of water curing. As it was observed by [56]; even though, the bending strength of structural concrete was reinforced with 5%, 10%, 15% and 20% of CD ash for cement replacement, but still, instead of concrete to increase in strength, its flexural strength was decreasing up to 28 days of curing in water. On the other hand, the prolonging of curing age of CD ash – concrete to 60 days increased its flexural strength up to 1.22% and 2.75% for 5% and 10% CD ash replacements respectively.

2.4 Oil Palm Fiber

Palm fiber is defined as the waste resources extracted from palm trees. Examples of these waste resources are: empty bunches of oil palm fruits, shells of oil palm fruits, press of oil palm fruits and palm fronds. Press of oil palm fruit is defined as the coarse residue obtained after the removal of palm oil from the fruits of the oil palm [58]. Ash of Empty Fruit- Bunch of Oil Palm-Fiber (AEFOPF) is the ash obtained after the burning of oil palm-empty fruit bunches in incineration device at high temperature of 700^{0}C for 90 minutes. AEFOPF is commonly used to enhance its concrete properties. Its straw –fiber will control pore formation when use in concrete [59]. Figure 9 shows the images of empty bunch of oil palm, a single of oil palm-empty fruit bunch and the processed oil palm-empty fruit-bunches.

(a)

(b)

(c)

fig. 9 (a) Heap of oil palm-empty fruit-bunches {60] (b) a single empty fruit bunch of oil palm (c) processed empty fruit bunches of oil palm fiber [61]

2.4.1 Properties of Oil Palm-Empty Fruit-Bunch- Fiber

Mechanical and Physical Properties of Oil Palm-Empty Fruit-Bunch-Fiber

The tensile strength of OP-EFB fiber, its density and other properties were suitable for the production of quality concrete as indicated in Table 16.

Table 16. Mechanical and Physical Properties of Oil Palm-Empty Fruit-Bunch-Fiber

(OP-EFB-F) (Source: [62 – 64])

Properties	Tensile Strength (MPa)	Diameter (μm)	Density (g/cm^3)	Young Modulus (GPa)	Elongation at Break (%)
OPE-FB-Fiber	60 - 81	250-610	0.7-1.55	1-9	8-18

Chemical properties of Oil Palm Empty Fruit Bunch Fiber (OP-EFB-F)

As shown in Table 17, the constituent of pozzolanic properties (SiO_2, Fe_2O_3 and Al_2O_3) of AEFOPF is 25.77% and that of OPC is 29.71%. The percentage of pozzolanic properties of AEFOPF is less than that of OPC by 3.94%. Also, the percentage of pozzolanic properties of

AEFOPF is less than that of specified percentage stated by [65] for a material to be use as a pozzolan for substitution of cement in concrete which is 70%. Therefore, AEFOPF is not suitable to be used as pozzolanic material for replacement of cement (OPC) in concrete for better performance of concrete. With these low cementitious properties of AEFOPF, it cannot be used only for concrete strength improvement, but, blending it with other fibers or treating it with chemical will make it performs better in concrete.

Table 17. Chemical composition of AEFOPF [61]

Material	Oxides (%)								
	SiO_2	Fe_2O_3	Al_2O_3	CaO	Na_2O	MgO	K_2O	SO_3	LoI
OPC	20.68	3.62	5.41	64.37	0.51	1.81	0.47	1.03	0.39
AEFOPF	6.62	6.64	12.71	19.01	7.25	4.10	1.86	1.42	40.60

2.4.2 Fresh - State Properties

Concrete Workability

Use oil palm fiber to improve the workability of concrete [66]. The results of the test showed that, oil palm fiber reduced the unreinforced concrete workability (slump) value from 155mm to 70 mm which is slump value of concrete reinforced with the oil palm fiber. According to the authors, the oil palm fiber in concrete has absorbed much excess of water within the prepared concrete-mortars, thus, making concrete more workable. Additionally, as the content of oil palm fiber in concrete was increasing, the mixed concrete became thicker and emanated into concrete with a low slump which is a good quality of structural concrete. Authors included that, oil palm fiber improved the concrete workability up to 54.8% and its efficiency emanated into the production of quality concrete.

2.4.3 Harden - State Properties

Composite Mean Compressive Strength

Figure 10 shows the compressive strength of composite reinforced with AEFOPF as indicated [68]. This strength was achieved by combining AEFOPF and cement paste to form composite. There were decreases in the compressive strength of composite as the percentage of AEFOPF in the mix was increasing. This showed that, AEFOPF has low cementitious properties and cannot be use for concrete reinforcement composite.

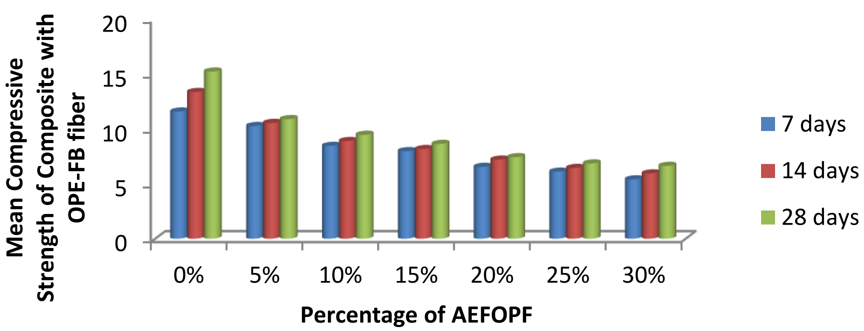


Fig. 10 Compressive strength of composite reinforced with AEFOPF [68]

Density, Modulus of Rupture and Elasticity (MOR and MOE) of Composite

AEFOPF was treated with NaOH and its effectiveness was observed on AEFOPF- composite by [68] as presented in Table18. The densities of the composite treated with NaOH were more than that of control up to 10% treatment. Besides, the densities of composite produced were less than that of normal weight of concrete or composites. The densities of composite produced fell within the range of light weight composite (less 2200 Kg/m^3 as specified by [69]. Also, as the percentages of OPE-FB fiber treated with NaOH was increasing; the composite MOR and MOE were increasing up to 8% NaOH treatment. The maximum strengths increment observed were: 38.2% for MOE, 50.7% for MOR, and 8.5% for Density respectively. It was concluded that, the treatment of OPE-FB with NaOH increased the bonding matrix within the composite for better performance, especially in terms of strength yielding [68]. So, treatment of OPE-FB fiber with NaOH will improve the concrete or composite tensile strength by building the good matrix bonds in between the aggregates of the concrete or composite.

Table 18. Density, MOR and MOE of Composite Treated with NaOH [68]

NaOH Content (%)	MOE (GPa)	MOR (MPa)	Density (Kg/m^3)
0	5.5	3.6	1550
2	6.2	3.9	1575
4	6.3	4.5	1580
6	7.7	5.1	1654
8	8.9	7.3	1694
10	4.1	3.8	1683

2.5 Hemp Fiber

Hemp fibers are fibers with 100 percent textile properties. Hemp fibers are always performed better in concrete or composite when blended with other natural fibers like silk, cotton, flax, and lime for concrete or composite's reinforcement. They were commonly used for the construction of buildings. Blending of the mixtures of lime and hemp fiber together is suitable for plastering of building internal [70 – 72].

2.5.1 Properties of Hemp fiber

Mechanical / Physical Properties of Hemp fiber

The mechanical and physical properties of hemp fiber which made it suitable for composites and concrete reinforcement were presented in Table 19. These properties were good for better concrete or composite quality production.

Table 19. Mechanical / Physical Properties of Hemp fiber [73]

Fiber Type	Density (g/cm^3)	Moisture Absorption (%)	Tensile Strength (MPa)	Young Modulus (MPa)	Elongatio n at Break
Value	1.4	8	690	30 - 70	1.6

Chemical - Properties of Hemp fiber

As shown in Table 20, hemp fiber had high content of 77.5% of cellulose, 10.0% of hemi-cellulose and 6.8% of Lignin with total percentage of 94.3 of hemp reinforcing properties. With these properties, concrete or composite properties will be improved perfectly.

Table 20. Chemical - Properties of Hemp fiber [67]

Properties	Lignin (%)	Hemi-Cellulose (%)	Pectin (%)	Cellulose (%)	Fat and Wax (%)	Water Soluble Materi al (%)	Ref.
Values	6.8	10.0	2.9	77.5	0.9	1.8	[67]

2.5.3 Fresh State Properties

Concrete workability

The use of hemp fiber in concrete led to the production of concrete with a very stiff and unworkable nature. As investigated by [74], the normal concrete (plain) slump fell was recorded to be 30mm. The concrete reinforced with hemp fiber had no fall (0 mm). Thus, concrete produced with hemp fiber were too stiff and unworkable, with the application of super-plasticizer, the concrete produced with hemp fiber will be workable.

Consistency

Consistency of hemp-cement paste increased more that of control. This implied that, concrete with hemp fiber required high water cement ratio for its production [74].

2.5.4 Harden - State Properties

Compressive and Tensile Strengths of Hemp – Concrete

The compressive Strength of concrete with hemp-fiber was higher than that of control (plain concrete) up to 1.5% of hemp fiber inclusion at both 7 and 28 days of curing. As shown in figure 11, the rate of compressive strength yielded by hemp fiber in concrete was about 7.78%. Also, the concrete tensile strength was increasing as the percentage of hemp fiber included in the mix was increasing up to 1.5% of hemp fiber inclusion. The highest concrete tensile strength observed was 31.44% as shown in figure 12 with inclusion of 0.5% hemp fiber at the 28th day. of curing. Author concluded that, hemp-fiber had high tensile reinforcement properties in concrete or composite up to 31% in strength yielding [76].

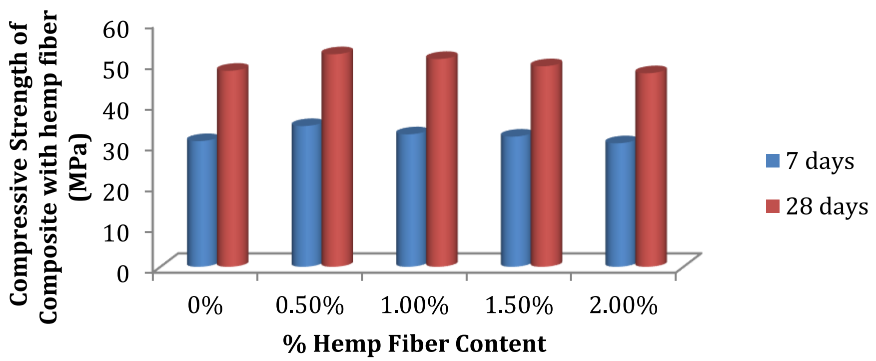


Fig. 11 Compressive Strengths of Hemp-Concrete [75]

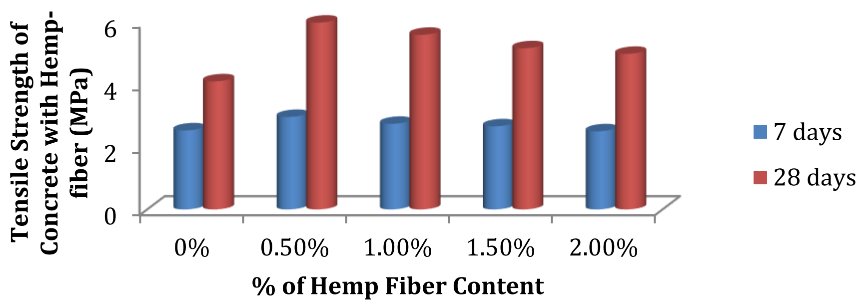


Fig. 12 Tensile Strengths of Hemp-Concrete [75]

Concrete Flexural Strength

The flexural strength of concrete with hemp fiber showed strength increment up to 1.5% of adding hemp – fiber in concrete compared to that of control. As presented in Figure 13, the maximum strength increment recorded at the inclusion of 0.5% of hemp – fiber in concrete was 26.2%. This increment was observed due to highly strength yielding properties of hemp fiber which was earlier recorded as 94.3%. Authors concluded that, hemp fiber is good for the reinforcement of concrete strength against deflection [75].

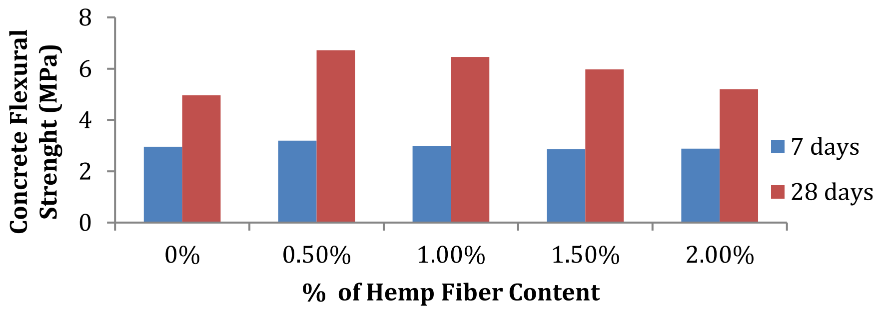


Fig. 13 Concrete Flexural Strength [75]

3. Discussions

Wastes generations, especially from agricultural products, have become the problem of the world today. The issues of environmental pollutions such as emissions of carbon dioxide into the atmosphere which gradually destroyed the ozone layers and exposed us to hot Sun rays together with occupying the lands that should have been use for other purposes for dumping heap were factors contributed to poor environmental hygiene in the globe. Likewise, the issue of generating up to 8% of overall global emissions of CO_2 from concrete and cement industries is also one of the factors multiplying the effect of greenhouse gases globally. The use of agricultural wastes in concrete and composites need to be increase in order to erase the effect of CO_2 emissions from concrete industries and agro-wastes, wrongly disposed to the environments globally. Creation of more cement and concrete production companies and uses of agro-wastes for concrete reinforcement are the solutions to the effect of CO_2 emission and reduction in the cost of concrete production material globally.

All the fibers reviewed had up to 70% compositions of pozzolan properties (SiO_2, Fe_2O_3 and Al_2O_3) except that of oil palm fiber. As stated by [40], 70% of cementitious properties of waste materials is enough for them to function as binding aggregate in concrete. So, the treatment of these wastes and their application as aggregate for cement production up to 70% constituent will go a long way in reducing the price of cement in the global market, and also less the use of greenhouse gases generating material in the world.

As shown in the review, majority of the concrete's mechanical properties reinforced with five agro-wastes need improvement to enhance their structural performances. Some of these properties such as: workability, setting time, tensile strength, modulus of elasticity, flexural strength, consistency and compressive strength need more enhancement more than the one done by the five fibers reviewed in concrete. The solutions to these can be achieved through constant researches on the new methods of improving them.

Some mechanical properties of concrete such consistency, workability, compressive and flexural strengths, have been efficiently reinforced with the inclusion of bagasse, coconut shell, cotton, oil palm and hemp fibers as reviewed. But major improvement is required in the areas of concrete - paste setting time with coconut shell ash fiber. The concrete tensile strength: especially, with the use of ash from empty fruit bunch of oil palm fiber needs improvement for the more enhancement of concrete. Cotton dust ash and hemp – fiber required water – cement ratio for better concrete strength reinforcement. The treatment of oil palm and hemp fibers with chemical like NaOH will really go in long way to improve the concrete structural properties.

4. Limitations of Using Agricultural Wastes In Concrete

As reviewed, the limitations of using these five agricultural wastes (Bagasse, Coconut shell, Cotton, Oil palm and Hemp fibers in concrete) for concrete reinforcement were presented as follows:

Agricultural wastes, especially, the five wastes reviewed, have not been used for cements production, since the majorities of these fibers reviewed had over 70% of cementitious properties, their application for cement production need quick investigation, especially, the use of sugar-cane bagasse and coconut (shell) ashes. The future scholars have to work on the production of cement with 70% of the constituent from agro-wastes.

More investigation is required on the use of oil palm fiber for the reinforcement of concrete's tensile strength. It should be treated with chemical (like NaOH) before use in concrete to improve its bonding matrix. Also, it could be blend with other fibers (like bagasse and sugar-cane fibers) together with lime, to improve its physical and chemical properties for better performance in concrete.

The concrete (paste) reinforced with coconut – ash needs improvement in the area of setting times. The concrete produced with hemp fiber have poor workability, application of super-plasticizer to it will make it workable. This is suggested for future improvement. High water – cement ratio is needed for the production of concrete with hemp and CD ash fibers to achieve good concrete workability. The tensile strength of the cotton – fabric concrete will increase with increase in curing age. The reinforcement properties of oil palm fiber can be improved by blending it with SCBA (which is very high in cementitious properties) for high concrete strength improvement. Combination of Sugar-cane bagasse fiber with other fibers, with high cementitious properties will greatly improve its tensile strength. These were suggested for future investigations.

5. Conclusions

The effects of Bagasse, Coconut shell, Cotton, Oil palm and Hemp fibers in concrete and composites have been critical evaluated in this study. The review covered the physical and chemical properties of agricultural wastes together with their effectiveness in reinforcing the concrete mechanical properties such as: setting times, consistency, workability, compressive strength, modulus of elasticity, flexural strength, and tensile strength. With evaluation of the effects of agricultural wastes in concrete, these were the valuable conclusions made from the review:

Application of agricultural wastes in concrete and composites will really prevented the emissions of carbon dioxide (CO_2) from concrete into the atmosphere usually destroy the ozone layers. Also, effect of CO_2 emission from the heap of agricultural wastes in our global environment can be avoided by exploring the agricultural waste as construction material. Agricultural wastes had good surface areas and specific gravities for concreting. Sugar-cane bagasse ash and coconut (shell) ash had up to 78% and 77.5% of pozzolanic (cementitious) properties (SiO_2, Fe_2O_3 and Al_2O_3) to function as cement binder in concrete and composites. Agricultural wastes can be used as major material for the production of cement up 70% replacement of cement pozzolanic composite's compounds (SiO_2, Fe_2O_3 and Al_2O_3) based on the reviewed outcome. The sugar-cane bagasse, coconut (shell), cotton, and hemp fibers were very high in textile properties such as Cellulose, Hemi-cellulose and Lignin with the percentages of 94%, 89.53%, 91% and 94.3% respectively. Among them, hemp fiber has the highest percentage of textile properties (94.3%). With these good qualities, the mechanical properties of concrete could be enhanced greatly. The pozzolanic properties of oil palm fiber requires chemical treatment for concrete tensile strength enhancement.

Application of sugar-cane bagasse and oil palm-fiber ashes in concrete really improved its workability by reducing its slump falls. On the contrary, cotton dust and coconut shell ashes increased the concrete slump falls, thus reduced the concrete workability. The concrete reinforced with hemp fibers requires the use of super-plasticizer to make its workability. The coconut shell ash in concrete paste quick the setting time of the paste. This could result into early crack of the concrete. Also, the coconut shell ash increased the consistency of concrete – paste, thus, lead to the production of harsh concrete with poor setting. To achieve good workability of concrete, low water – cement ratio is required to make use of bagasse, coconut shell and oil palm ash - fibres in concrete. But, concrete with cotton dust ash and hemp fiber required high water cement ratio to achieve quality workability.

The concrete compressive strength reinforced with sugar-cane bagasse – ash (SCBA) show increment in strength up to 12.6%. Also, the coconut shell ash improved the concrete compressive strength up to 9%. But SCBA reduced the concrete compressive strength by 60.4%. Application of coconut shell and oil palm –fiber ashes in concrete reduced its compressive strength a little. Despart the flaw, cotton and hemp – fibers highly increased the concrete and composite compressive strengths. The concrete and composite tensile strengths reinforced with cotton and bagasse ashes were improved greatly up to 97% and 31 .7% respectively. Besides the above results, the concrete tensile strength reinforced with SCBA showed strength reduction up to 32.4%. CSA and hemp-fiber showed higher strength increment at concrete tensile zone. SCBA, hemp-fiber and treated oil palm - fiber ash increased the concrete or composite flexural strength (or MOR) by 11.3%, 26.2% and 50.7% respectively. Likewise, cotton and coconut shell fibers highly enhanced the concrete flexural strengths. The concrete reinforced with SCBA, CSA and AEFOPF yielded high crack resisting strengths during the internal elasticity of the concrete due to unstable climatic condition.

As reviewed, all the fibers reviewed had good concrete reinforcing and pozzolanic properties. Therefore, they can be used for the production of cement in the cement industries globally up to 70% component of cement aggregates. Also, oil palm fiber should be treated with chemical (like NaOH) before use in concrete to improve its bonding matrix for the reinforcement of concrete tensile strength. The concrete (paste) with coconut – ash needs improvement at its setting times. The workability of concrete with hemp fiber needs improvement to produce quality concrete. The cotton – fabric concrete tensile strength will be increased with long curing age. If oil palm fiber is blended with SCBA, it will go in long way to increase concrete mechanical properties. Also, the combination of SCBA with other fibers will really improve the concrete mechanical properties, especially, the tensile strength. These were the gaps suggested for future investigation for the enhancement of concrete mechanical properties.

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