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Evaluating the reinforcements efficiency of sawdust and corncob wastes in structural concrete: A comprehensive review

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Abstract. Sawdust (SD) and Corncob (CC) wastes possess up to 89.4% and 83.03% pozzolanic properties with a high impact on the mechanical properties required for high concrete strength reinforcement respectively. Applications of SD and CC wastes in concrete increased the concrete workability by 8.75% and 27.9% respectively. In addition, the use of SD in concrete eased its aggregates' compatibility rate by 4.4%. The consistency of cement paste with corncob ash (CCA) decreased with an increase in the percentage of CCA included. In addition, the final and initial setting times of paste with sawdust ash (SDA) decreased by 28.2% and 20% with increasing use in the percentage of SDA included, while that of CC increased with an increase in the percentage of CC. The densities of SDA-concrete and CCA – concrete observed were from 300 to 1800kg/m3 and 1998 kg/m^3 to 2302kg/m^3, and these were classified as lightweight concrete. The review showed that CCA had a high potential for increasing the concrete compressive strength by 34.5%. The blending of CC waste with other admixtures was observed to have increased concrete's tensile properties by 3.9%. CC waste possessed high potential for composite tensile property enhancement up to 68%. The CCA-concrete's flexural strength observed was low; the blending of CC with other admixtures has increased the concrete's flexural strength. SDW-Concrete suggested to high temperature showed an increase in compressive strength until 600^{0}C is reached, after 600^{0}C, there was a reduction in strength. The CCA reduced concrete's modulus of elasticity by 27%. From the X–ray result, quartz (SiO2) shows an essential and main mineralogical content of CCA. The concrete's rate of water absorption increased by 74% with the inclusion of SD. The ANN model is efficient and possesses good features for CCA and SD – concrete models. In conclusion, SD and CC wastes possess a good potential for the enhancement of structural concrete, which can be processed into types of cement and concrete composites.

Keywords: sawdust waste, corncob waste, concrete reinforcement, structural properties

1. Introduction

In recent years, the application of natural fibres in form of admixtures or as an aggregate substitute in concrete will improve the durability properties of the concrete and reduce its rate of CO2 and green house gases (GHGs) emissions from concrete. One of the best methods of reducing GHGs emissions from concrete is to replace some percentages of Ordinary Portland Cement (OPC) with Pozzolanic Materials (Felman, 2005). Sawdust is the waste material obtained from the wood routing, planning, milling and sawing operations. It is made up of small wood chippings. Wood dust can be obtained when hand tools, power tools and machinery operate on wood. Some animals were feeding on wood such as carpenter ants and woodpeckers. Many daily used materials were manufactured from wood dust such as wood pulp, particleboard, and icehouses for cooling in the summer. It is also used for models and railroad formation. In the factories, sawdust is used in making pykrete, charcoal briquettes, and cutler's resin (International Agency for Research on Cancer, IARC, 1995). In the year 2000 to 2003, the estimation made by European Union with 25 states members (EU-25) shows that up to 3.6 million individual industrial workers were exposed to wood dust inhalation, especially, in furniture industries and construction sectors. The populations of people inhalable to sawdust were up to 2.0% of EU-25 employee populations (Green, 2006; Kaupineen et al. 2006). Figure 1 shows the picture of common sawdust generated from wood from saw industries.

(I) **(II)**

Fig 1. (I) Zaagsel Saw dust (II) Chainsaw from wood shaving (IARC) (Green, 2006; Kaupineen et al. 2006)

A corncob is a material at the core ear of the corn called maize, and it is obtained after the removal of the corn kernel from the cob. At their mature age, the corn kernels were consumed raw or taken after processing. Cobs were used as moisture-absorbing material in animal feeding processing. Cobs were used for charcoal production, as bio-fuel, and for the production of abrasive materials. They were used as fibre in making ruminant livestock fodder andused as furfural in chemical industries. The corncobs generated from agricultural farms, and the treatment of corncobs into ashes respectively (Aston 2010; Murthi et al. 2020). Many wastes were generated from wood. These wastes could be from processing and logging activities. The quantity of wood waste generated from sawmills globally is about 3.87 million metre-cubic. The increase in the number of sawmills in Nigeria has increased the quantities of waste generated from saw industries. According to the authors, about 20% of these wastes were estimated to be sawdust in the year 1981. Also, the growth in saw industries is to about 1200 which is twice the estimated value (over 500) in the year 1975 has increased the quantity of dust production from the mills. Authors stated that more than 1.7 million metre cubic of waste from wood were generated from sawmills globally in a year (Olafusi et al. 2017).

Almost 32.45 million metres cubic of wood waste were produced around the globe yearly. Its bulk density was estimated to be 160kg/m3. In a year, about 5.2 million tonnes of sawdust were produced in Nigeria. In support of this statement, more than 3.89 million metres cubic of dust from sawmills was generated yearly in Nigeria (Omochie et al. 2018). As estimated by the author, up to 0.66kg of waste municipal was generated in Nigeria yearly. Out of the municipal wastes generated, about 1.8 metric tonnes of sawdust were produced. In the years 2019 to 2020, the United States was observed to be the largest exporter and producer of corn together with its cob with about 346 million metric tonnes in quantities (World Agricultural Production (Ogwueleka, 2009; Oluoti et al. 2014).

(I) Sun - dried corncobs

(II) Crushed corncobs

(III) Burning of crushed corncobs in muffle furnace

(IV) Crushed corncobs carbonized

Fig 2 (I-IV). Incineration of corncobs (Ogwueleka, 2009; Oluoti et al. 2014).

About ninety million acres of land in America were used for the cultivation of corn. In addition, as estimated, the quantities of corncobs generated from Brazil are about 102 million metric tonnes in a year. With this estimation, Brazil is referred to as the third largest producer of corn in the globe. In the recent corn production estimate, about 51 million metric tonnes of corncobs were generated from Argentina while in Ukraine and India, about 35.9 and 25 million metric tonnes of corncobs were generated every year respectively. Likewise, in the 27 European Union countries, about 66.74 million metric tonnes of corncobs were generated. These countries were known as the fourth–largest corn producers in the globe from the year 2019 to 2020 (Kukogho et al. 2011).

The global rate of generating sawdust and corncob wastes is high these days. A strategic means of disposing of them to inform of processing to meet the other industrial demand have to be developed. The application of agricultural wastes as construction materials in cement and concrete industries has been gaining appreciation. Their effectiveness in concrete needs constant evaluations, to improve their usage in concrete industries. This review focus on evaluating the efficiency of using saw dust (SD) and corncob (CC) wastes in concrete. It covers the evaluation of the level of quality reinforcement developed by applying SD and CC waste to concrete. The effect of SD and CC wastes on some structural properties of concrete such as setting time, consistency, concrete workability, flexural strength, density, durability, tensile strength, and compressive strength. This review aims at evaluating the reinforcement efficiency using SD and CC wastes in concrete, identifying the undeveloped areas, and making suitable suggestions for their enhancement (George & Braide, 2014; Hussien et al. 2018; Ikenyiri et al. 2019).

2. Experimental Program

This review explains the physical and chemical properties of sawdust and corncob fibres; the fresh and hardened properties, thermal and durability properties, and micro-structural properties of concrete reinforced with both sawdust and corncob fibres. In addition, the responses of the SD and CC fibres to the concrete structural properties were modeled, and appropriate recommendations were made based on the reviewed properties.

2.1 Properties and efficiencies of sawdust and corncob fibre in concrete

2.1.1 Physical properties of sawdust fibre

Sawdust possesses some properties needed for the smooth reinforcement of concrete. The physical properties of sawdust suitable for the reinforcement of concrete are presented (Table 1). In addition, the moisture content of sawdust is up to 10.8%, which implied that much water is not needed to make use of sawdust fibre in concrete. There will be appropriate compaction of aggregates mixed with sawdust ash (SDA) due to its low specific gravity (Hussien et al. 2018; Oguche et al. 2021). SDF has 50% capacity of retaining water, therefore, its application in concrete should be preceded by proper treatment to prevent the high rate of water retention. With 84% porosity of SDA, there is a tendency of absorbing high percentage of water meant for the hydration process in concrete. This high porosity might be because of small variations in SDF's particle size with distribution sizes ranging from 0.075 (9 mm) to 4.75 (100 mm).

Table 1. Physical properties of Sawdust (Ash) fibre (Hussien et al. 2018)

Properties	Value	Properties	Value	
Water Drainage (m/s)	282.0	Particle size	0.075	9
Water Retention (%)	50	Distribution (mm)	0.21	30
Porosity (%)	84		0.425	48
Apparent Specific Gravity	0.14		0.6	81
Moisture Content	10.8		2.0	95
			4.74	100
		Specific Gravity		2.05

Considering the properties of SDF, dust fibre needs proper treatment, especially, on the rate of water absorption and drying, before its application for concrete reinforcement. A highwater-cement ratio is required to make use of SDF in concrete. With good physical properties of SDF observed in table 1, SDF possesses high reinforcing physical properties for concrete reinforcement.

2.1.2 Chemical properties of sawdust and corncob fibre

The chemical properties and composition of the sawdust wastes observed were shown in Table 2. As shown in Table 2, the percentages of pozzolanic constituents (SiO_2, Al_2O_3, and Fe_2O_3) of sawdust observed were high. The combination of silicon oxide, aluminate and ferrous oxide, which are the major component of pozzolanic properties,either specified for materials to be used as suitable supplementary material,in form of cement substitute or as partial replacement of aggregates in concrete were up to 76.0% to 89.4% respectively (Oguche et al. 2021). SDF possess a higher pozzolanic constituent than the specified standard for supplementary of aggregates in concrete (70%). This proves that SDF possesses good chemical properties for the reinforcement of structural concrete. Besides the good chemical constituent of SDF, it was made up of 61.58% of carbon content (Nnochiri, 2018). This carbon content is high and it can delay the setting of the concrete when use in concrete.

Table 2. Chemical properties and composition of sawdust fibre (George & Braide, 2014; Hussien et al. 2018; Ikenyiri et al. 2019; Oguche et al. 2021)

Chemical Composition	Value			Chemical Properties	Value
	Oguche et al. (2021) (%)	Hussein et al. (2018) (%)	George and Braide (2014) (%)		Ikenyiri et al. (2019) (%)
SiO_2	68.7	76.3	85	Nitrogen (N)	0
Al_2O_3	5.1	5.8	2.7	Oxygen (O) (%)	33.04
Fe_2O_3	2.21	2.9	1.7	Hydrogen (H) (%)	5.32
CaO	5.2	4.7	3.5	Carbon (C) (%)	61.58
SO_3	2.1	1.6	-	Hollo-cellulose (%)	83.8
MgO	1.7	1.2	0.25	Lignin	29.3
Specific Gravity	-	2.02	-	Extractives	3.3
Moisture Content	1.53	1.37	-		
Fineness	-	75μm	-		
Others	-	2.5	-		
Loss of Ignition	-	-	4.3		
Pozzolanic Properties	76.01	85	89.4		

For perfect reinforcement, SDF required standard treatment before use in concrete. Furthermore, SDF consists of 83.8% of cellulose content, and with the high percentage of cellulose, the structural properties of the concrete will be highly improved. According to Kilani et al. 2022; cellulose is referred to as the firm property well-built of plants. The application of a material with high percentage of cellulose in concrete will highly enhance the concrete properties. Also, more improvement is expected on concrete reinforced with SDF as 29.3% of its lignin property will supplement the strength yielding capacity of cellulose of SDF (Table 2). All these properties show the chemical fitness and stability of SDF for concrete reinforcement. The chemical composition of concrete with corncob ash (CCA) as investigated by different research scholars was presented as shown in Table 3.

Table 3. Chemical composition of corncob ash

LOI	K_2O	Na_2O	MgO	CaO	Fe_2O_3	Al_2O_3	SiO_2	Source
	4.23	0.43	2.08	10.24	4.75	10.79	64.90	Nnochiri (2018)
	12.12	-	2.91	4.13	3.95	4.01	63.91	Suwanmaneechot (2015)
-	3.89	0.36	1.86	10.57	4.40	6.25	62.30	Desai (2018)
-	4.20	0.39	1.82	10.29	3.74	7.34	67.33	Akila et al (2018)
-	-	-	3.01	12.0	5.12	9.42	64.56	Komalpreet et al (2017)
5.95	1.05	0.90	1.99	16.23	4.03	6.48	64.50	Oyebisi et al (2017)
-	1.98	1.91	0.98	11.47	9.07	17.57	56.39	Oluborode & Olofintuyi (2015)
10.8	3.83	0.0003	1.46	8.97	0.64	0.98	79.29	Udoeyo & Abubakar (2003)
-	4.92	0.41	2.06	11.57	4.44	7.48	66.38	Adesanya and Raheem (2009)
≤ 10%	-	≥ 0.70	≤ 4%	-	$SiO_2 + Al_2O_3 + Fe_2O_3 > 70\%$			Oyebisi et al (2017)

The percentage composition of the pozzolanic elements ($SiO_2 + Al_2O_3 + Fe_2O_3$) of corncob ash (CCA) investigated by research scholars was far more than that of the specified limit (70%) stated for material to function as a supplement of cement in the concrete according to ASTM C618 specification. This property makes CCA a suitable material for concrete reinforcement, either as supplementary material or as a replacement for aggregates (Murthi et al. 2020).

2.2 Fresh properties of mortar/concrete with sawdust fibre

2.2.1 Workability of concrete with sawdust fibre

Gibi Miriyam et al. (2017) investigation shows that the workability of concrete reinforced with sawdust fibre was gradually decreasing with the increase in the percentage of SDF included. In the investigation, 2.5% to 12.5% of SDA was substituted with certain percentages of cement with 2.5% increase interval. The workability of the concrete was measured through a slump test. As observed by the author, the concrete with 0% of sawdust ash (SDA) developed a slump loss of 80mm. The rate of slump loss was gradually reduced with the replacement of cement with 2.5% and 5.0% of SDA. The reduction range from 80mm to 70mm and from 80mm to 77mm respectively. Also, with the application of 7.5% to 12.5% of SDA to concrete's mortar, the concrete workability increased by 8.75% with the reduction in slump fall from 80 to 76mm, and 80 (control) to 73mm (concrete with 12.5% of SDA) (Table 4). As observed by the authors, SDA has great potential for enhancement of concrete workability.

It was observed that, SDA has high water retaining capacity, so, to obtain good concrete workability with SDA, high water cement ratio is suggested for SDA-concrete mixing to prevent absorption of large amount of water from the mixed aggregates, and to prevent production of harsh concrete due to poor hydration process in the aggregates. Likewise, application of SDA in concrete has reduced it compaction factor (CF) from 0.921 (control) to 0.87 (CF) of concrete with 12.5% of SDA) which up to 4.4% reduction. The reduction in CF observed might be as a result of good surface property and low specific properties of SDA which improve the rate of concrete aggregates' compatibility. To improve the concrete workability, application of SDA in concrete should be up to 12.5% to improve the concrete workability greatly.

Table 4. Workability of concrete with SDA (Gibi Miriyam et al. 2017)

Percentage of SDA (%)		0	2.5	5	7.5	10	12.5
Workability	Slump Loss (mm)	80	79	77	76	75	73
	Compaction Factor	0.91	0.90	0.89	0.89	0.88	0.87

In support of Gibi et al. 2017), the experimental result of Ruhai et al. (2017) likewise indicates that, the concrete reinforced with SDA showed a decrease in its slump fall values. According to the authors, the values of slump fall observed were within the range of 30 – 60mm. The increase in the ratio of SDA in concrete paste (from 1:1 to 1:3) has caused decrease in slump flow of SDA-concrete mortar from 40 mm (with 1:1 ratio) to 30 mm (with 1:3 mix ratios) (Figure 3). Therefore, the authors concluded that application of SDF in concrete has a great influence on the reduction of concrete workability.

The report of Ambika and Sabita (2015) proves that; addition of SDA to concrete has decreased the concrete workability significantly. This was applicable when the percentages of SDA applied in the cast concrete were increasing in the mix (Figure 4a). Thus, the use of SDA in concrete will go in a long way in controlling the segregation in freshly cast concrete. More thick concrete may be produced with the use of SDA in concrete mix, and the hydration of the concrete might not be effective. The compaction factor (CF) of the SDA-concrete was observed as 0.94 at the inclusion of 15 and 20% of SDA in concrete. The Value was reduced from 0.94 to 0.93 (Figure 4b). Having observed this CF, SDA was classified as a good aggregates-binder for smooth compatibility. According to observation, the SDA have a good surface area and low specific gravity for concrete compassion.

According to Haveth et al. (2017), sawdust wood wastes (SWW) have high moisture absorption capacity. As observed, the pastes samples tested with the inclusion of sawdust, the rate of water absorption of the SWW recorded was up to 8.72 ± 0.4% (which is too high).

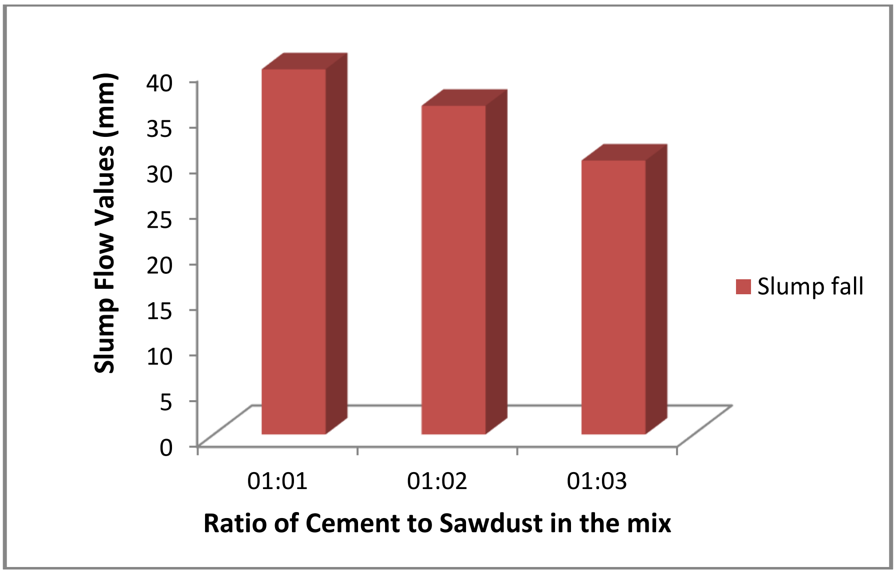

Fig 3. Slump falls of concrete mortar with SDA (Ruhai et al., 2017)

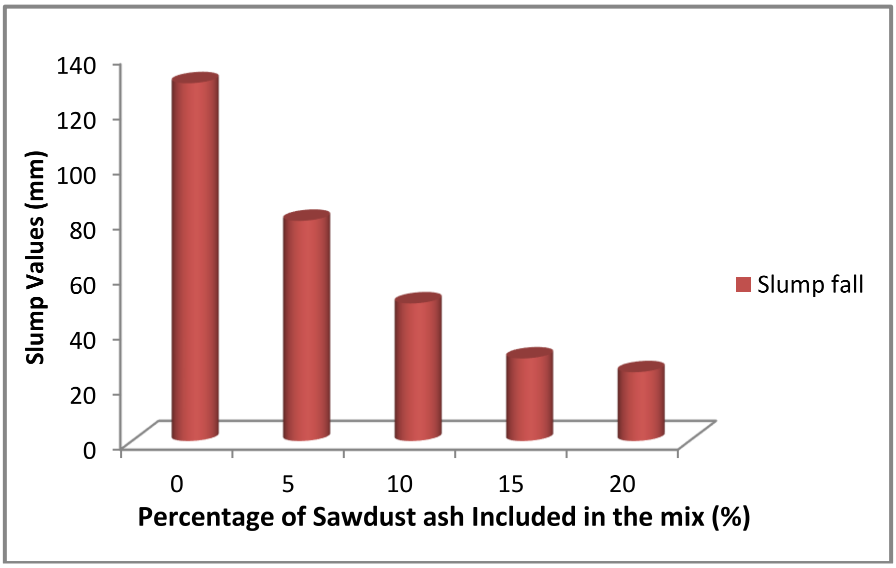

Fig 4a. Slump values of concrete with sawdust ash (Ambika and Sabita, 2015)

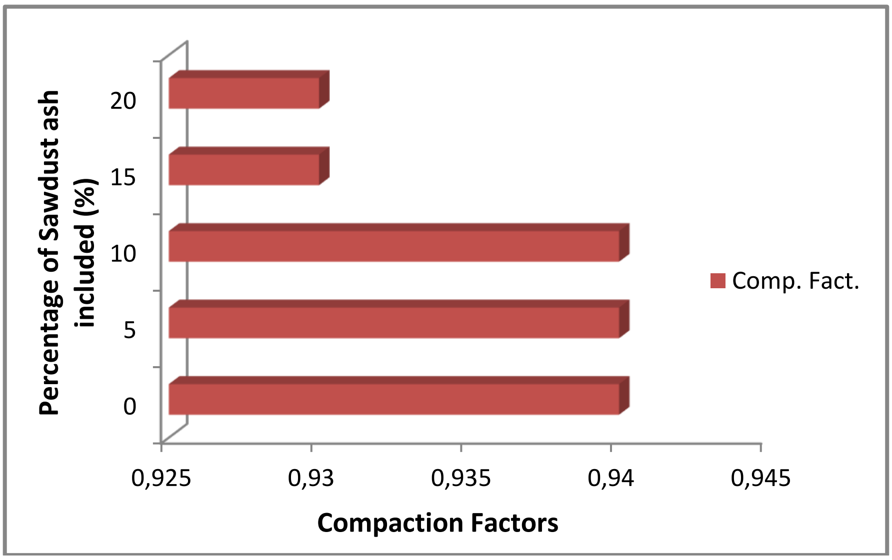

Fig 4b. Sawdust ash-cement concrete compaction factors (Ambika &Sabita, 2015)

2.2.2 Consistency of cement paste with sawdust fibre

In addition, the findings of Hisham et al. (2020) showed that, application of SWW in concrete demand for higher volume of water to form consistency with paste. The high viscosity of the aggregates mixed with SDF was noticed to have caused rapid hardening of cement during hydration. This was traced to the absorption of high percentage of an alkaline solution when the fibre was pretreated with the solution before used as a supplement of cement in concrete. With proper pretreatment of SDF before used in concrete, it will go a long way in controlling the high rate of water absorption in concrete which usually dehydrate much water from concrete mix and caused poor concrete-aggregate hydration. It was concluded that application of SDF in concrete required high water cement ratio to attain the standard consistency. Furthermore, the report of Darweesh and El-Suoud (2017) also support that, the use of sawdust wastes in concrete normally increases its consistency. According to the authors, application of SDA to concrete paste has brought slight decrease to the consistency of the paste. The reduction was observed to be gradual. As the SDA constituent percentage in concrete mix was increasing, the SDA-paste consistency was also decreasing (figure 5).

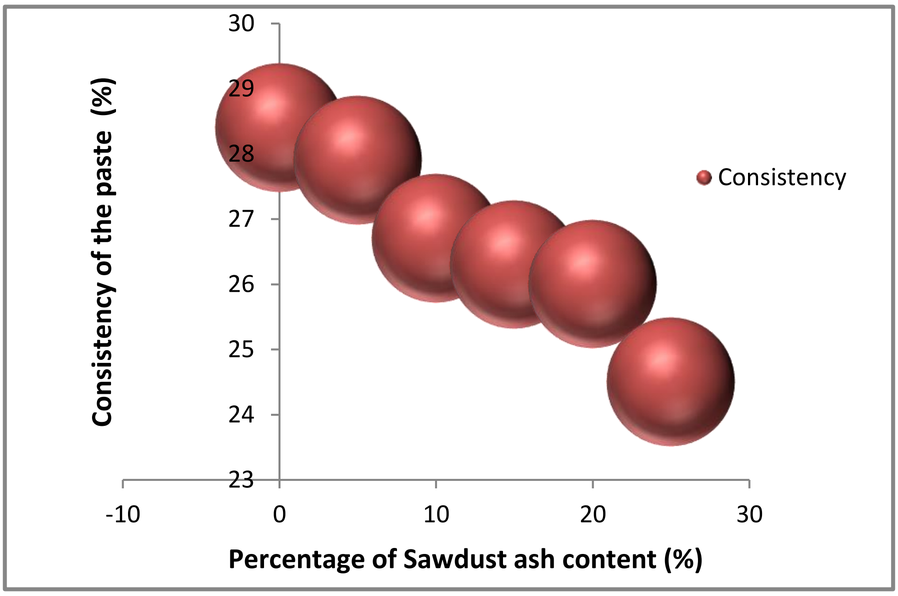

Fig 5. Consistency of cement - paste with sawdust ash (Darweesh and El-Suoud, 2017)

The major cause of this was traced to the presence of sod, high content of carbon and fines of SDA compared with that ordinary Portland cement (OPC). In addition, it was observed that a certain percentage of water meant for concrete mixing was absorbed by SDA included.

2.2.3 Setting time of concrete paste with saw dust fibre

As presented in figure 6, the setting time of paste with SDA decreased with the increase in the percentage of SDA included in the mix. As stated by Darweesh and El-Suoud (2017), the decrease in the setting time might be a result of the presence of lime in the SDA generated from tricalcium and dicalcium silicates hydration process with high pozzolanic compound of SDA and cement developed in the reaction (Mangi et al. 2017). The findings of Hisham et al. (2020) also support the decrease in the SDA-cement paste setting time reported by Darweesh and El-Suoud (2017). As investigated by the authors, both the final and initial setting of concrete paste with SD were decreasing with increase in the percentage of SD in the mix (Figure 7). As observed from Figure 7, the initial time of the concrete setting range from 39 to 28minutes, while the final one ranges from 60 to 48 minutes with increase in the percentage of SDA included (from 0% to 100%). Therefore, the increase in the percentage of SDT in concrete will reduce the time specified for its setting, leading to the production of harsh concrete. With this rate of SD-cement paste setting time reduction, the level of water used for paste setting was also increasing. With reduction for water meant for hydration by SD, the elements like: calcium and alumina-silicate might have been dissolved during geopolymerization process of the paste. In addition, the report of Ozdemir et al. (2022) supports that, application of SDF in concrete always reduced its setting times and also affected the hydration process of the concrete mix, especially, in the area of water absorption.

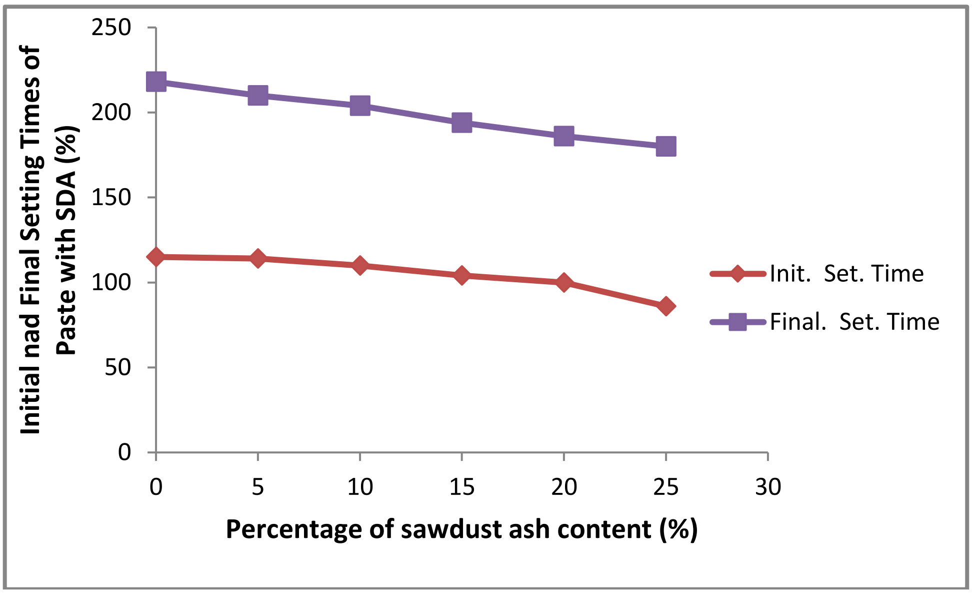

Fig 6. Initial and final setting time of paste with sawdust ash (Darweesh and El-Suoud, 2017)

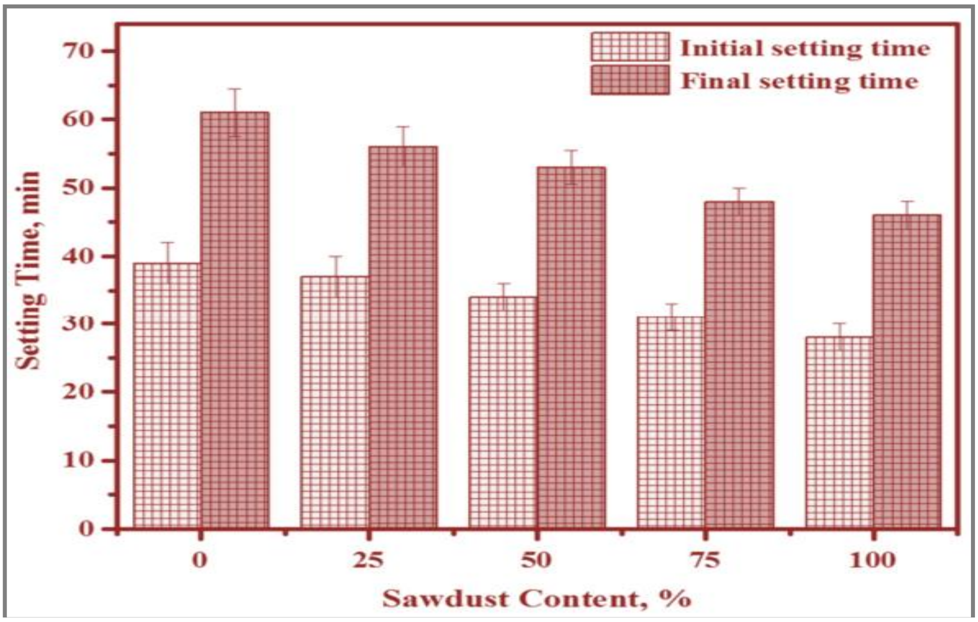

Fig 7. Initial and final setting time of paste with sawdust ash (Hisham et al. 2020)

More than 98% of concrete compressive strength results obtained were allowed to undertake full hydration process up to 90 days. At 90th day, the SD-concrete increased in its compressive strength. It was observed that, the SD-concrete compressive strength was appreciated when its curing age is increased. Likewise, application of sawdust in concrete required higher water/cement ratio for quality concrete production, with good workability and yield high compressive strength.

2.2.4 Tensile strength of concrete reinforced with sawdust fibre

Tensile properties of concrete is the properties possessed by a concrete to resist its tensile splitting and cracks, due to the tensional force (Kilani and Fapohunda, 2022). As conducted by Hisham et al. (2020), the average tensile strength of lightweight concretes (LWCs) was decreasing with increase in the percentage of sawdust content included. According to the authors, the test was carried out by replacing certain percentage of coarse and fine aggregates with sawdust, and cured for 28days. From the results of 28days curing, it was observed that, concrete tensile strength decreased from 4.2MPa to 3.9, 3.7, 3.4, and 3.0 MPa with increase in SD content of 0, 25, 50, 75 and 100%. As observed, up to 1.2MPa strength of normal concrete (control) was reduced with the inclusion of sawdust into the concrete mix (Figure 8). The reduction in strength was attached to the difference shapes of sawdust particle used, high rate of water absorption of SD and presence of organic substance in SD used. These were developed into formation of weak bonding interaction within the paste of cement, aggregates and sawdust fibre. This has led to the formation of low tensile strength bonding matrices within the concrete composite. So, raw SDF is not suitable for concrete tensile strength increment unless it is treated with chemicals for better improvement.

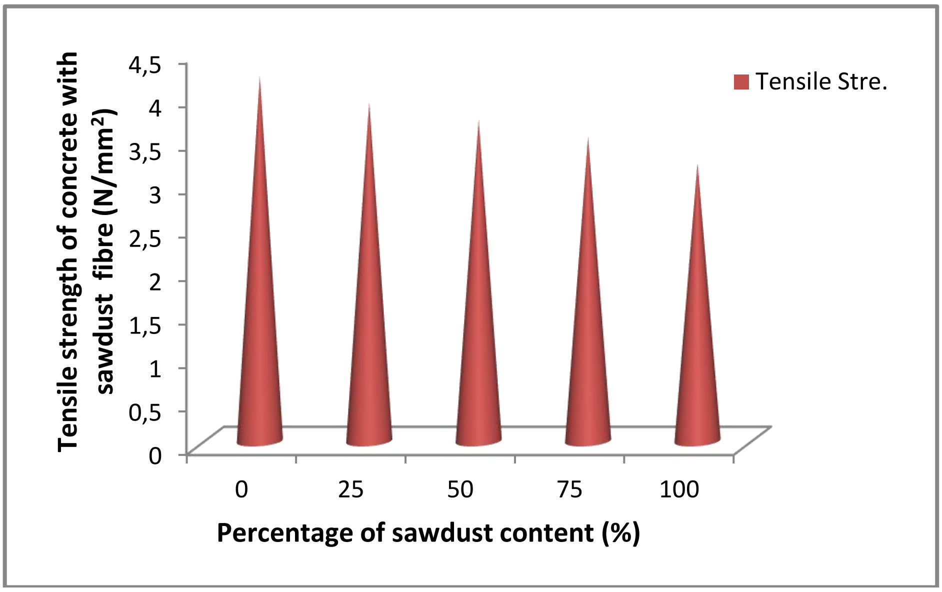

Fig 8. Tensile strength of concrete with sawdust fibre (Hisham et al. 2017)

Contrary to Hisham et al. (2020) report, the findings of Joy et al. (2016) proved that, the application of sawdust to concrete mix as contributed to the increase in the tensile strength of the concrete. This increment was observed at 15% of SD inclusion in structural concrete. The maximum tensile strength value observed was 3.58N/mm^2 compared with that of the control (3.49N/mm^2) was the strength increment of 0.09N/mm^2. The next tensile strength increment was observed at the inclusion of 30% of sawdust in concrete, which was 3.53N/mm^2 (Figure 9). With these, it was observed that, concrete with sawdust get appreciated in tensile strength with the inclusion of 15% and 30% of sawdust. However, the tensile strength increment observed was minimal (0.09N/mm^2), but it negates the results, which is based on concrete tensile strength reduction. This strength increment might be because of increase in concrete curing age to 90 days.

The concrete with SDA shows a little increment in its tensile, especially at its 56th curing day compared with that of the control. The result shows that concrete with 5% of SDA yielded 3.2N/mm^2 of tensile strength. The maximum strength yielded was more than that of control (2.5N/mm^2) by 0.7N/mm^2. The result showed that, extension of SDA-concrete curing days will increase the hydration process of SDA-concrete by forming standard bonding matrices among the concrete composite. Ruhal et al. (2017) uses the indirect method of concrete tensile strength testing to determine the tensile strength of SD-concrete. In the investigation, concrete samples were produced using cement to sand ratio of 1:1, 1:2, and 1:3 with water cement ratio of 0.65, 1.00, and 1.40 respectively. The test result shows that, SD-concrete produced developed low tensile strength to that of the tensile strength of normal concrete (control).

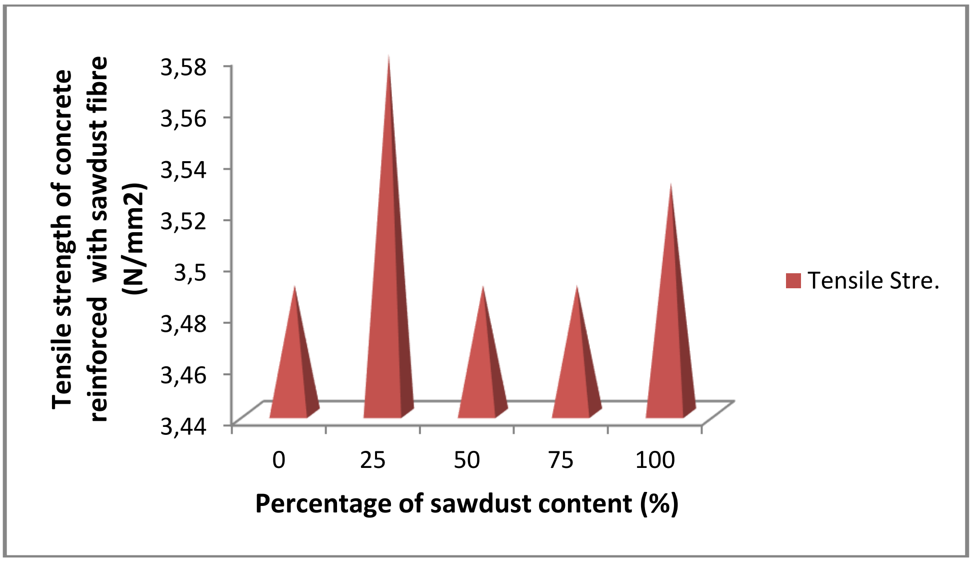

Fig 9. Tensile strength of concrete with sawdust fibre (Joy et al. 2016)

Still, concrete with 1:3 mixes with 0.65 water-cement ratio had the highest tensile strength (4.1MPa) compared with that of control. The finding shows that concretes with SDF could only gain increment in strength at their long curing ages during which maximum hydration might have been taking place. Due to slow in hydration process of sawdust – concrete, longtime of curing is suggested for its sufficient hydration process to really improve its tensile strength yielding capacity. This is achievable with proper treatment of sawdust before applying for concrete operation. Likewise, the cement to sawdust ratio in concrete should be limited to that of 1:1 to prevent reduction in its tensile strength.

2.2.5 Concrete flexural strength reinforced with sawdust fibre

The results of tests on flexural strength of concrete with sawdust fibre (SDF) proofed that, application of SDF to concrete decrease its strength against bending and deflection. As investigated by Ruhal et al. (2017), the concrete strength capacity with sawdust fibre were observed using three different mixing ratio of 1:4, 1:3, and 1:1 (cement to sawdust ratio) with different water cement ratios of 1.40, 1.00 and 0.65 respectively. The specimens produced were cured in water for 56, 28, and 7days for proper hydration to take place. From the results obtained, the highest flexural strength of 5.77MPa was observed with the mixing ratio of 1:1, while the least flexural strength (0.77MPa) was obtained at the 56th day of curing in water with 1:3 missing ratio. The result implied that, the percentage of sawdust content in concrete have the great influence on its flexural strength yielding capacity. In other perspective, sawdust fibre was applied for composite reinforcement, which was observed to be a good strength-yielding admixture in composites. According to Heckadka et al. (2018), during the experiment, resin composite was produced with different percentages of sawdust fibre as substitute of some percentage of the aggregates. The composite- material replacements were by 3, 6, and 9% with sawdust, which was referred to as filler. The flexural strength of the composite reinforced with sawdust showed maximum strength increment at the inclusion 3 and 6% of sawdust fibre as presented in figure 10.

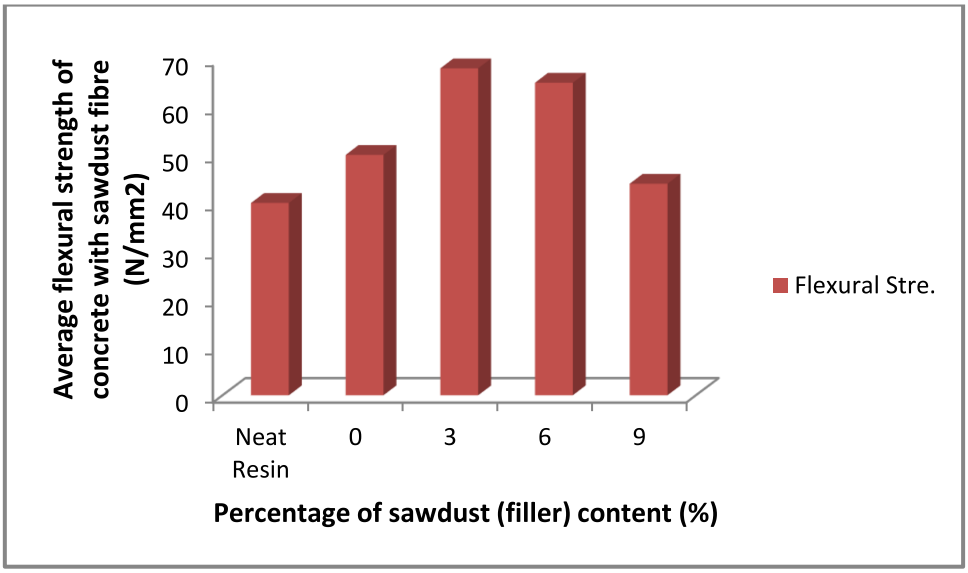

Fig 10. Average flexural strength of concrete with sawdust fibre (Ruhal et al. 2017)

The percentage of strength yielded by including sawdust fibre in composite was by 68% compared with that of control. This was achieved at the inclusion of 3% of SDF in the composite mixing. The least composite flexural strength (44MPa) was observed at the addition of 9% of SDF (filler) in the composite. Thus, sawdust waste has the maximum strength yielding capacity for composite reinforcement up to 68% strength increment. So, application of SDF to composite material will make it stronger in resisting the bending, cracking and deformation defects when in usage. In addition, Hisham et al. (2020) replaced some percentages of fine and coarse aggregates with sawdust waste (SDW). As investigated by the authors, certain percentages of coarse and fine aggregates were substituted with 25, 50, 75 and 100% of SDW and flexural test was conducted on the SDW-concrete beams produced. The result of the test shows that, SDW-concrete flexural strength decreased from 6.8MPa (control) to 6.2, 5.7, 5.1, and 4.9MPa in order of the increase in the percentages of SDW included in concrete as shown in Figure 11. As the percentage of SDW in the concrete mix was increasing from 0% to 100%, the concrete flexural strength was decreased by 27%. With this output, it was observed that concrete flexural strength does not appreciate with the inclusion of SDW.

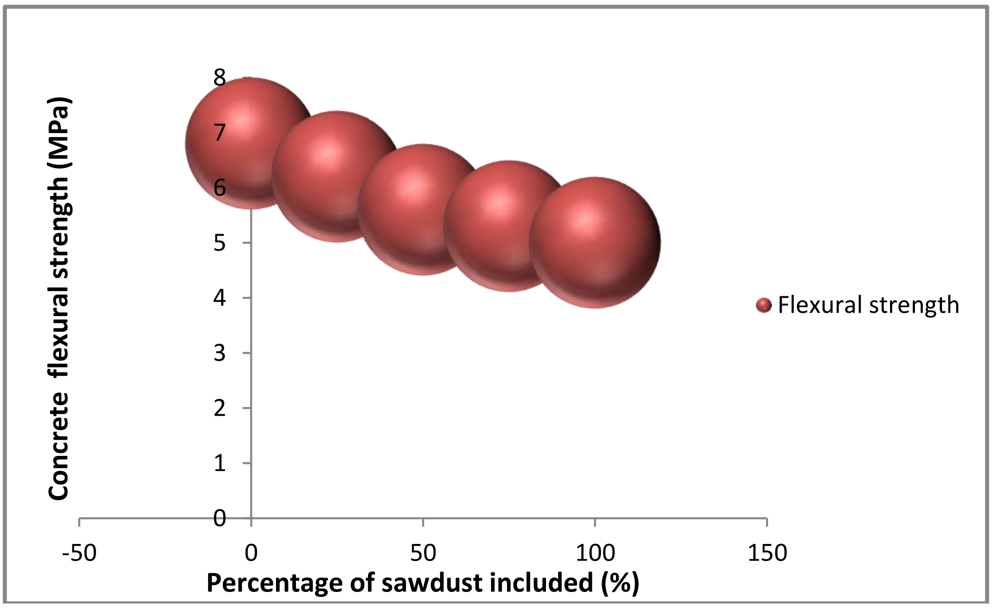

Fig 11. Concrete's flexural strength with sawdust fibre (Hisham et al. 2020)

The experimental result of using sawdust wastes in concrete by Joy et al. (2017)proved the findings of Hisham et al. (2020) wrong. As reported by the author, there was an increase in the concrete flexural strength from 4.38 N/mm^2 (control) to 4.50 N/mm^2 at the inclusion of 30% of sawdust fibre as shown in figure 12. However, the flexural strength yielded by substituting some percentages of concrete aggregates with sawdust might be minimal (0.12 N/mm^2), yet, concrete strength was developed against deformation.

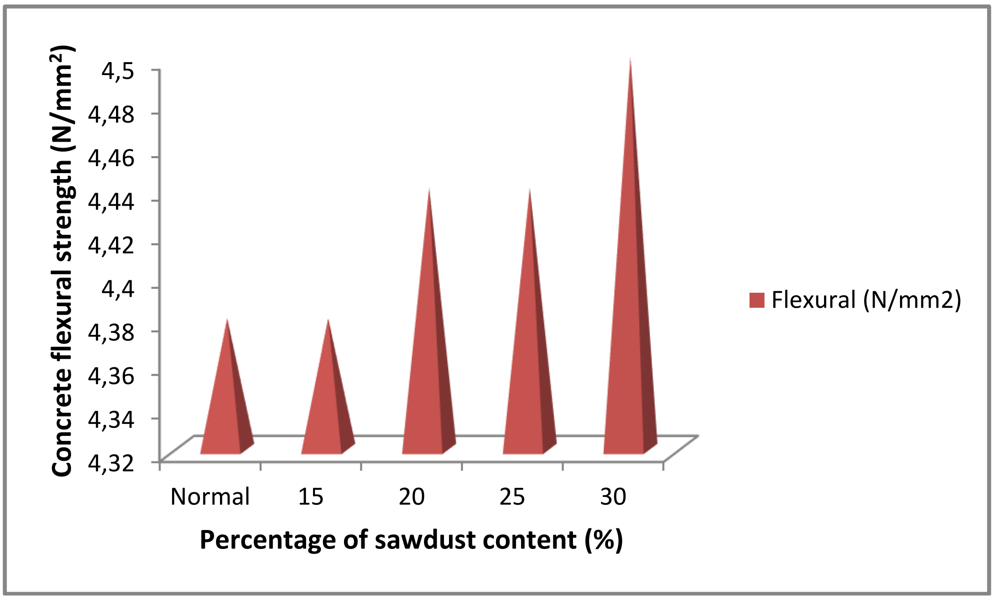

Fig 12. Flexural strength of concrete with sawdust (Joy et al. 2017)

Furthermore, the report of Sasah and Kankam (2018) was in agreement with Hisham et al. (2020) report. As investigated by the scholars, the brick's standard mortar flexural strength decreased from 2.54N/mm^2 to 0.47 N/mm^2 with the increase in percentage of sawdust included from 5 to 50% (figure 13). From the results of the samples prepared from modified brick mortar, it was observed that, the mortar's flexural strength decreased from 2.56 N/mm^2 to 0.85 N/mm^2 with the increase in the percentage of sawdust included. Therefore, it was observed that, concrete strength against deformation can be increased, if it is reinforced with the treated sawdust fibre, and the little percentage of sawdust should be added to concrete to avoid decrease in strength.

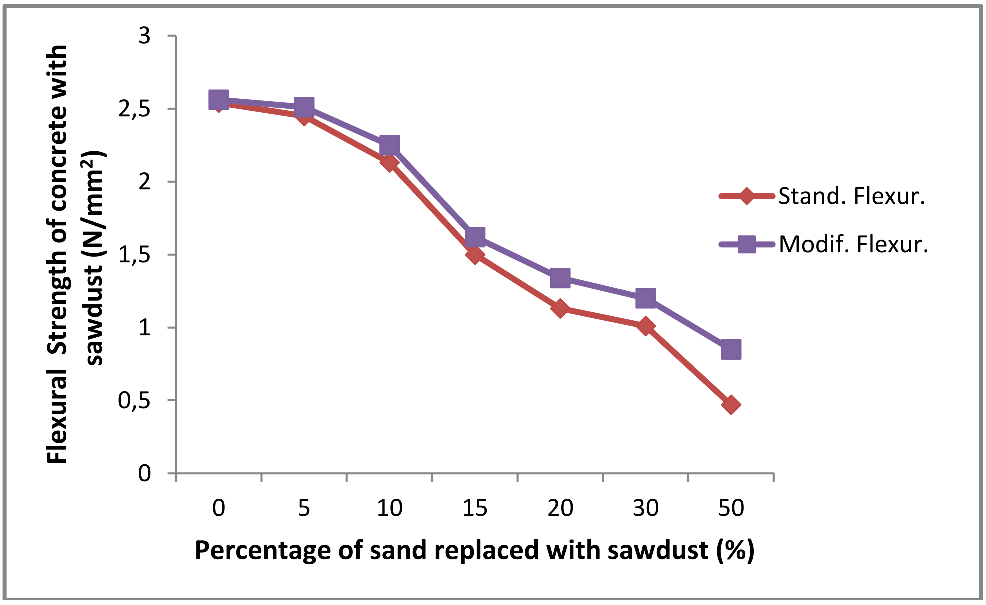

Fig 13. Standard and Modified Flexural Strengths of Concrete with sawdust Hisham et al. (2020)

2.2.6 Modulus of elasticity and temperature transmission of concrete reinforced with sawdust fibre

Concrete modulus of elasticity (ME) as the ratio of stress applied to a concrete structure to its corresponding strain. The structural concrete has to develop good strength against any deformation because of the stress applied on it with substituted 15, 20, 25, and 30% of coarse and fine aggregates with sawdust fibre for the production of concrete. This was carried out to ascertain the capacity of concrete against expansion and contraction conditions, which could lead to deformation and cracking of concrete structures. The result shows that, the elasticity resisting capacity of concrete was decreased from 2.5 x10^4 N/mm^2 (control) to 2.0 x10^4 N/mm^2 with 15% of sawdust content. The inclusion of other percentages of sawdust fibre (20 to 30%) in concrete yielded more strength increment than that of the concrete with 15% of sawdust, 2.22 x10^4, 2.38 x10^4 and 2.27 x 10^4 N/mm^2 with 20, 25 and 30% of SDF. But, still less to the strength developed by normal concrete (control) to withstand elasticity defects due to the applied stress on concrete (figure 14). Therefore, the application of SD in concrete could lead to increase in its shrinkage, cracks, deformation and creeping. The application of sawdust waste in concrete does not good for the reinforcement of its structural properties against deformation as a result of constant modulus elasticity due to the applied stress.

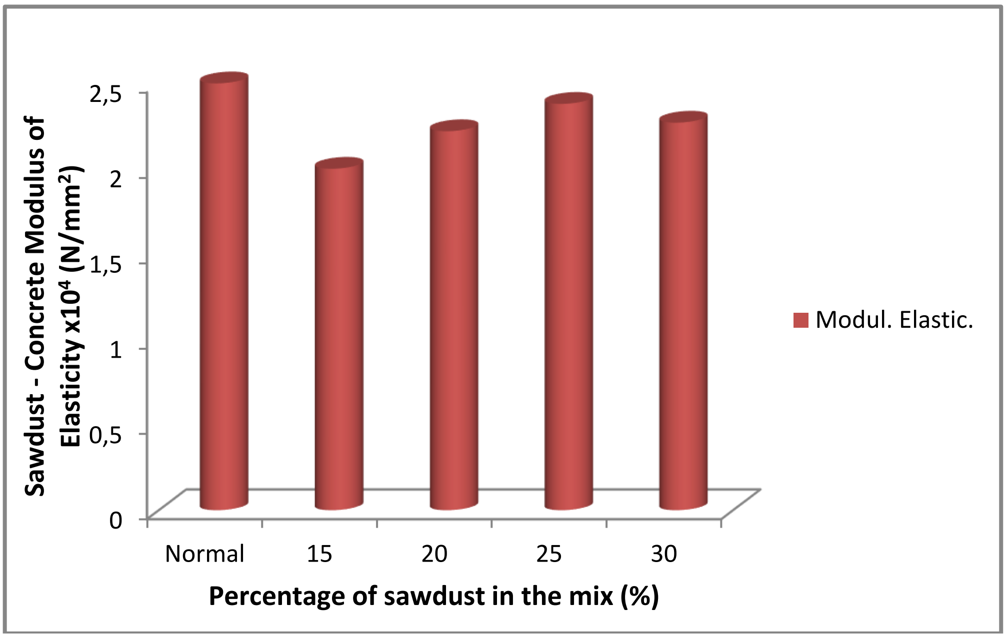

Fig 14. Sawdust – Concrete Modulus of Elasticity (Joy et al., 2017)

The result of modulus of elasticity test conducted on sawdust – quarry dust composite followed the same trend with the finding of Joy et al. (2017). From the result, it was observed that, the statics modulus of elasticity of sawdust – quarry dust composite decreased from 9.41N/mm^2 of the composite produced from 1:1:1 (Cement Sawdust: Quarry dust) to 6.56 N/mm^2 with 1:3:3 mix design. The observed reduction in strength was due to the increase in the content of sawdust and quarry dust included in the mix, which is about times three of that of cement mix proportion. With the consideration of average shear modulus of sawdust – quarry dust composite, it was observed that, composite shear strength decreased from 3.90 GPa (of 1:1:1 mix) to 2.43 GPa (from 1:3:3 mix ratio). From authors' observation, statics and average shear modulus strength of sawdust – quarry dust composite were reduced by 30.3% and 37.7% with application of sawdust in the composite's mix. (Table 5). From the result output, it was concluded that, sawdust waste is not good for the reinforcement of both composite's and concrete's modulus of elasticity to prevent unwanted cracks, deflection, shrinkage and shear that might developed from the reinforcement process.

Table 5. Statics and Average Modulus of Shear & Elasticity of sawdust – quarry dust composite (Ibearugbulem et al. 2018)

Cement : Sawdust : Quarry Mix ratio	1:1:1	1:2:2	1:3:3
Static Modulus of Elasticity (N/mm²)	9.41	8.75	6.56
Average Shear Modulus (GPa)	3.90	3.68	2.43

The concrete transmission temperature is defined as degree of hotness or coldness at which heat is being transferred within the composites of the concrete. It can be measured using thermometer or thermos-guage. The blending of concrete material with 10% substitute of sawdust waste investigated by Nimyat and Tok (2013) show that, concrete with the blended sawdust waste (SDW) increase in compressive strength with increase in applied temperature. During the investigation, the compressive strength of the concrete with 0% of SDW (control) increased with increase in temperature until 400^0C was reached. It was also decreasing until 800^0C was reached. While the concrete with 10% of SDW increased in compressive strength until 600^0C was reached. Its decrease in strength was observed at 800^0C temperature (see Table 6).

Table 6. Different Concrete Compressive Strengths under Different temperatures (Nimyat and Tok, 2013)

Percentage of Sawdust content (%)	Concrete Compressive Strength (N/mm²)					Water / Cement Ratio
	Room Temp.	200^0C	400^0C	600^0C	800^0C	
0	20.15	23.31	24.42	18.44	12.22	0.6
10	15.06	15.73	16.09	18.67	14.20	0.6

From Table 6, it could be observed that, exposure of sawdust – concrete to thermal expansion increased its compressive strength by 23.97% with 10% inclusion of sawdust fibre up to 600^0C. This proof that, sawdust fibre is a good thermal absorption in concrete against splitting, cracking and deformation till 600^0C is reached when suggested to thermal transmission. With this result, it was observed that, sawdust –concrete has capacity of withstanding heat transfer within the composites constituent of the concrete up on till 600^0C temperature is reached without trace of decrease in temperature. As shown in Table 7, normal concrete (with 0% of SD) showed decrease in concrete compressive strength from room temperature of 200^0C to 400^0C from 1.16 to 1.05 N/mm². Also, the compressive strength of plan concrete was decreased from 1.05N/mm² (at 400^0C) to 1.32 N/mm² (at 600^0C) and 1.51N/mm² (at 800^0C) respectively. While the compressive strength of concrete with 10% of sawdust showed reduction in strength from 1.04N/mm² of 200^0C (Room temperature) to 1.02 N/mm² at 400^0C: 200^0C and later increased to 1.31N/mm² at 800^0C temperature (Table 6).

Table 7. Concrete compressive strength with thermal gain and loss (Nimyat and Tok, 2013)

Percentage of aggregate placed Sawdust (%)	Strength Gain / Loss				Average percentage loss (%)	Average percentage Gain (%)
	800^0C: 600^0C	600^0C: 400^0C	400^0C: 200^0C	200^0C: Room Temperature		
0	1.51	1.32	1.05	1.16	29.11	10.22
10	1.31	1.16	1.02	1.04	23.94	7.59

Though, the increase in the level of heat transfer within the SD-concrete caused increase in its strength until 800^0C, the rate of heat loss /gain shown in the Table 7 proofed that, only little increment in concrete strength was observed when suggested to heat. Therefore, it was suggested that, concrete with sawdust should not be exposed to high thermal transmission. As presented in Table 8, the result of sawdust – concrete thermal sock resistance at 800^0C were presented. The concrete with SDW showed good result than that of control. It can be deduced from the investigation that, application of SDW in concrete is good for concrete thermal shock resistance up until 800^0C of heat transfer.

Table 8. Thermal sock resistance's result at 800⁰C (Nimyat and Tok, 2013)

Number of resistance in cycle				Percentage of replacement with sawdust (%)
Test 1	Test 2	Test 3	Average cycle	
3	5	4	4	0
12	14	12	13	10

In addition, Hisham et al. (2020) investigated the thermal conductivity properties of concrete with sawdust. In the investigation, the influence of sawdust in concrete was determined by calculating its time of heat transfer after being cured for 28 days in water. According to the author, as the percentage of sawdust included in concrete was increasing, the concrete thermal conductivity properties were decreasing. As observed by the authors, the concrete samples with highest percentage of sawdust had the highest time (188mins) for heat transfer among the lightweight composites produced with sawdust than that of the control (36 minutes). While the time of heat transfer among the concrete samples with 25, 50 and 75% of sawdust in replacement of aggregates were observed to be 61, 108 and 149 minutes respectively (see Figure 15).

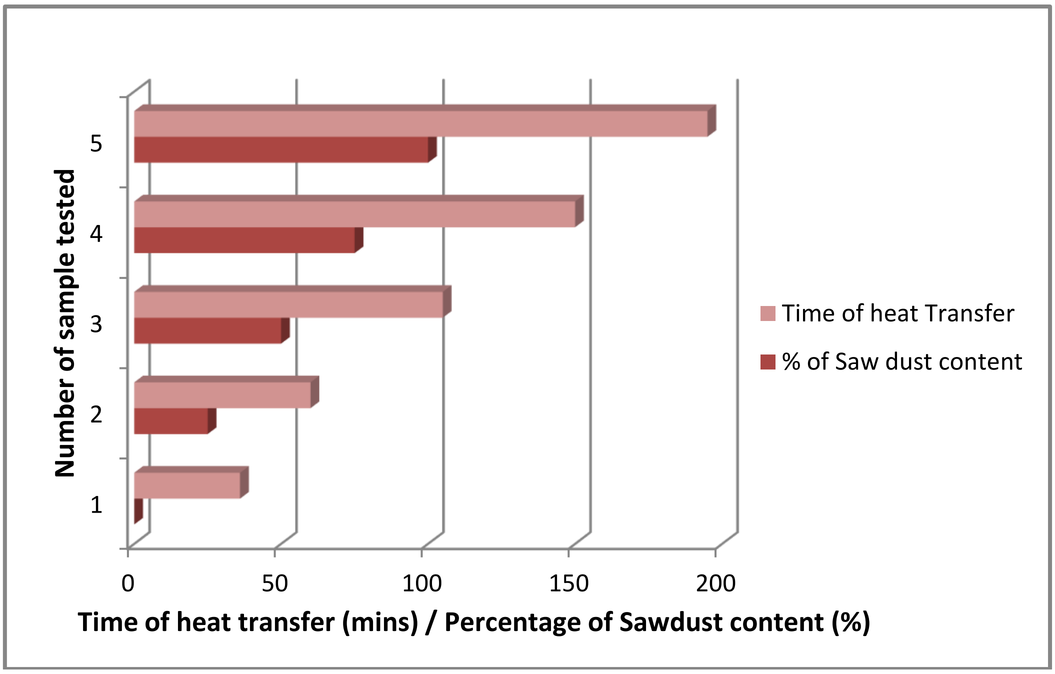

Fig 15. Thermal conductivity of concrete with sawdust (Hisham et al. 2020)

In addition, the results of experiment conducted on concrete reinforced with sawdust to enhance its coefficient of thermal conductivity were presented as shown in figure 15. The experimental results showed that, the thermal conductivity coefficient of concrete was decreasing as the percentages of sawdust included were increasing. The decrease in concrete coefficient of thermal conductivity observed were from 0.39 to 0.24, 0.19, 0.13, and 0.09 W/m. K with the increase in the percentage of sawdust content from 0 to 25, 50, 75, and 100% (See figure 16). This result is in agreement with Liu et al. (2020) findings stated that, concrete thermal conductivity is lower with increase in the percentage of sawdust content. Thus, application of sawdust in concrete is good in controlling the rate of thermal conductivity within the concrete composites, which can improve the durability of concrete.

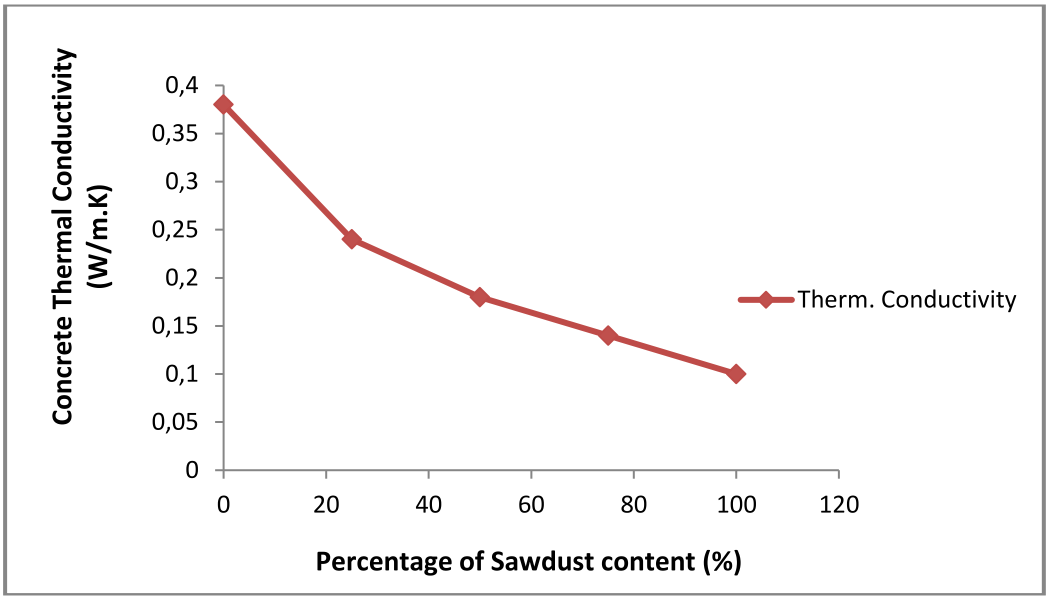

Fig 16. Coefficient of thermal conductivity with various percentages of sawdust (Hisham et al. 2020)

2.2.7 Durability of concrete reinforced with sawdust waste

Durability is the ability possess by a material or substance to stain long without developing a significant deterioration. While concrete durability is defined as the ability of a concrete to resist abrasion, chemical attack and weathering action in order to maintain its standard engineering properties (Kilani et al. 2022). Hisham et al. (2020) observed the rate of water absorption in concrete. The result showed that, concrete with sawdust developed high rate of water absorption into the concrete than those of normal concrete. The replacement of 0, 25, 50, 75 and 100% of coarse and fine aggregates with sawdust had caused the increase in the level of water absorption (W.A) in concrete by 9.7, 10.1, 13.4, 15.2 and 16.9% respectively. Considering the replacement of concrete aggregates with sawdust fibre, there was increase in the rate of water absorption by 74% while that of 25% of sawdust inclusion was by 4.1% (Figure 17). This increment has proofed that, concrete with sawdust waste possess structural porosity and non – reacted silica (Hisham et al. 2020). This result is in line with the findings of Juarezat (2015) and that of Tong et al. (2013). The high rates of water absorption of SD-concrete have to be corrected to improve its durability property.

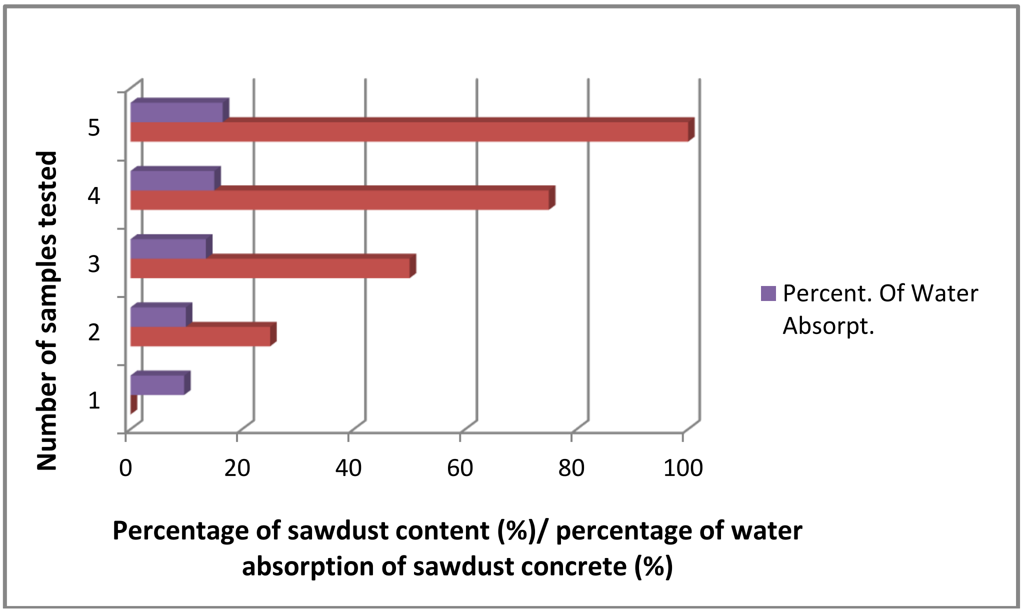

Fig. 17 Rate of water absorption in concrete with sawdust (Hisham et al. 2020)

3. Discussions

The high rate of global cement production has contributed highly to the emission of CO_2 and greenhouse gases (GHGs) in the world, causing the destruction of ozone layers. It was observed in the review that application of clinker to the production of cement was found suitable for the reduction of high rate of CO_2 and GHGs emission up to 52.4%. These emissions were minimized by applying natural admixture to concrete mix. This is a great potential for production of quality concrete, and concrete with very less percentage of CO_2 and GHGs emissions. The review showed that, there was accurate compaction of concrete aggregates mixed with saw dust ash (SDA) due to its low specific gravity and good surface area. Also, the percentages of pozzolanic constituents (SiO_2, Al_2O_3, and Fe_2O_3) of sawdust waste were observed to fall within the range of 76.0% to 89.4% which is greater than that of the limit stated by ACI 1999 for supplementary material to be use in concrete. Therefore, SD waste was observed to have rich in pozzolanic properties for concrete reinforcement. Also, the percentage compositions of the pozzolanic elements (SiO2 + Al2O3 + Fe2O3) in corncob ash (CCA) were observed to be within the range of 71.87% to 83.03% which is more than the specified standard stated by ACI 1999. Likewise, the result of CCA X-ray analysis showed that quartz (SiO_2) is the essential and main mineralogical content of CCA, and the next to it is potassium chlorate ($KClO_3$).

This showed that, corncob ash possesses both crystalline and amorphous form for standard concrete reinforcement. The results of SEM images showed that, application of CSA in concrete will really blocks pores, and smoothly mingle with other aggregates for quality concrete production with good durability property. Likewise, the application of sawdust in concrete was observed to have reduced the concrete slump fall from 80 to 76mm, and from 80 (control) to 73mm; and thus, increased the concrete workability by 8.75%. While the application of CCA in concrete showed increase in concrete workability by 27.9% and 23.5% respectively, and reduced by 1.59%. The review showed that, application of SD in concrete has increased the rate of concrete aggregates' compatibility 4.4% which is a good quality for strong concreting. The mixing of SDA with CCA for concrete reinforcement really enhanced the concrete aggregates compatibility. The average slump value of concrete with CCA was observed to have decreased to 2mm with 30% of CCA from 5mm with 0% of CCA. It was also observed that application of SDF in concrete required high water - cement ratio to attain the standard consistency. The consistency of cement paste with corncob ash was decreasing with increase in the percentage of CCA included. In addition, the rate of water absorption of the pastes with CCA was reducing with increase in CCA – concrete curing ages. The final and initial setting times of paste with SDA were decreasing with the increase in the percentage of SDA included by 28.2% and 20%, thus increased the rate of water absorption in concrete and caused poor setting of concrete. Concrete paste with CCA shows low hydration and setting processes before acquire the desirable hardening state. The densities of SDA-concrete were within the limit of 300 to 1800kg/m^3 which is classified as light weight concrete. Thus, the use of SD fibre in concrete is good for the production light weight concrete. The modified brick mortar's density observed was increased by 15% with the application of SD waste to its composites. The increase in concrete curing age could lead to the increase in concrete's compressive strength up to 7.94%. The weight of block with CCA was decreasing with the increase in its CCA content. The reduction was traced to the reaction of pozzolanic elements with calcium hydroxide ($Ca(OH)_2$) which lead to the production of less dense of C-S-H in the mix block composite.

The concrete compressive strength with SD was reducing at the initial stages of curing but its strength yielding capacity got increased with increase in curing ages. The more increase in the volume of SD included in concrete, the less is its yielding compressive strengths. The concrete reinforced with CCA increased in compressive strength up to 34.5%. Concrete with 15% and 30% of sawdust showed increase in concrete tensile strength. The presence of organic substance and difference size particles of SD had caused the formation of weak bonding interaction within the paste of cement, aggregates and sawdust fibre, thus, leading to reduction in concrete's tensile strength. The application of CCA in concrete for cement replacement has shown low tensile strength yielding capacity in concrete. Sawdust waste has the maximum strength yielding capacity for composite reinforcement up to 68% strength increment but it application in concrete and brick productions lead to the decrease in flexural strength. The use of sawdust waste in concrete does not support reinforcement of its structural properties against deformation from modulus elasticity due to the applied stress. The concrete's modulus of elasticity reduced from 35809.8 to 26043 (27%) with the inclusion of CCA. Thus, increased its strength against constant expansion that could result into cracks and deformation. Concrete with SD has the capacity to withstand heat / thermal transmission until 600^0C after which reduction in strength can take place. Concrete with CCA showed strength increment until 300^0C. The modeling result shows that, at the interaction process, the best neuron number was observed to be 14 in the hidden layers. The result proofed that, ANN model used was efficient and had good strength predicting feature, since 0.991 was almost the same with that of experimental result (0.9878).

4. Conclusion

According to the review on the reinforcement properties and quality of sawdust and corncob wastes for enhancement of concrete properties, the following conclusion was made in according to the earlier stated objectives; from the review, it was observed that more minimized by applying natural admixture to concrete mixing. This leads to the production of concrete with less percentage of CO_2 and GHGs emissions. In addition, the percentages of pozzolanic constituents (SiO2, Al2O3, and Fe2O3) of sawdust and corncob wastes reviewed were within the range of 76.0% to 89.4% and 71.87% to 83.03%, which were high qualities of supplementary materials for concrete reinforcement. Therefore, SD and CC wastes possess high pozzolanic potential for concrete structural strength reinforcement. In addition, the review indicates that the application of SD and CC wastes in concrete has increased the concrete workability by 8.75% and 27.9% respectively. With this increment, the qualities of concrete production were globally appreciated. In addition, the application of SD in concrete has increased the rate of concrete aggregates' compatibility by 4.4% which is a good for quality concrete production. The consistency of cement paste with corncob ash was decreasing with an increase in the percentage of CCA included. In addition, the rate of water absorption of the pastes with CCA was reduced with increase in CCA – concrete curing ages. The final and initial setting times of paste with SDA were decreased with the increase in the percentage of SDA included by 28.2% and 20%, thus increasing the rate of water absorption in concrete and caused poor setting of concrete.

From the review, it was observed that, densities of interlocking blocks, composite and concrete produced with the inclusion of CCA and SD were observed to fall within the limit of light weight concrete, block and composite. Therefore, it was concluded that, application of sawdust and corncob wastes in concrete is good for the production of light weight concrete, bricks and composites. Like wise from the review, it was observed that, concrete with CCA has the potential of increasing its compressive strength by 34.5% while the strength yielding capacity of CC in concrete is very low. The blending of CC with other supplementary material like sawdust in concrete was observed to have increase the concrete compressive strength by 3.9%. Concrete with 15% and 30% of sawdust showed increase in concrete tensile strength. The application of CC waste in concrete lead to reduction in concrete tensile strength but increase the composite's tensile strength by 68%.

Therefore, it was concluded that, use of CC good for composite's tensile reinforcement. The CCA-concrete's flexural strength was low. The blending of CCA with other admixture in concrete was observed to have increased the flexural strength of concrete. The review showed that, SD is poor in reinforcing the concrete and composites' properties against modulus elasticity, statics and average shear modulus. So, CCA is appreciated when blended with other material for quality strength yielding in concrete. Concrete with CCA have capacity of strength increment until 300^0C. Thus, increase in CCA-concrete's temperature beyond 600^0C could result into cracks and deformation. The inclusion of SDW in concrete is good for concrete thermal shock resistance up until 800^0C of heat transfer. Application of sawdust in concrete is good in controlling the rate of thermal conductivity within the concrete composites. Application of corn cob ash (CCA) to cement – concrete has led to the increase in its workability. It was observed from the review that, ANN model used was efficient and had good strength predicting feature, since 0.991 gotten was almost the same with that of experimental result (0.9878).

The reinforcing potential of Cob corn (CC) in concrete is low, especially on its compressive strength,blending it with other materials like sawdust will make it perform better in concrete. The concrete with SD and CC wastes should be allowed to undergo long hydration process with extension of curing ages to 120, 180 and 210 days. These gaps need quick investigations. Application of sawdust in concrete should be preceded with proper treatment to prevent the high rate of water absorption. Saw dust fibre needs proper treatment, especially, its rate of water absorption and drying, before its application for concrete reinforcement. The high water cement ratio is required for the use of SDF in concrete. The review shows that SDF were made up of about 61.58% of carbon content, to prevent the delay of SD-concrete setting, proper treatment should be applied to remove carbon effect before use in concrete. High water cement ratio is suggested for SDA-concrete mix to prevent the absorption of water meant for hydration process. The addition of SD to concrete should not be more than 12.5% to prevent reduction in concrete workability. It was observed that, low water cement ratio is required to make use of CCA in concrete for accurate concrete reinforcement and for quick setting of the paste. Applications of other supplementary material together with SD will really minimized the reduction in SD-concrete setting time, then, increase the hydration process of cement – SD – aggregate composites. CCA-concrete requires enough time for accurate setting to prevent the production of harsh concrete. It was suggested that, concrete with CSA should undergo long hydration process to attain strength yielding of at least 3.75 N/mm^2, most especially, from 28 days of curing upward.

Application of sawdust in concrete required higher water/cement ratio for quality concrete production and high compressive strength yielding. It could be deduced from the experimental results that CCA is good for the production of light weight concrete. Application of CCA in concrete will be well appreciated for the reinforcement of concrete's tensile strength if it is blended with other admixtures like sawdust. As observed in the review, due to the slow hydration process of sawdust – concrete, long curing age is suggested for sawdust – concrete hydration to really improve its tensile strength yielding capacity. It was recommended that, concrete with sawdust should not be exposed to high thermal transmission. In addition, the exposure of CCA – concrete to thermal transmission should not exceed 300^{0}C to avoid weakening and great reduction in concrete strength. The high rates of water absorption of SD-concrete have to be corrected to improve its durability property. Engineers and contractors before implementation or before reaching construction stages suggest ANN software model for the prediction of sawdust – concrete compressive strength and other strength properties for accurate planning and design. Blending of CCA with other admixture for concrete reinforcement is recommended for maximum strength yielding against concrete's deformation and deflection. In addition, its application will improve the concrete properties against chemical attack and serves as water permeability resistance in concrete.

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