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Influence of Waste Metalized Plastic Fibers and Guinea-Corn Husk Ash on Strength Properties of Self-Compacting Concrete

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Abstract

Green concrete is a form of eco-friendly composite material that is manufactured using waste material as one of its components. Guinea corn husk ash (GCHA) and waste metalized plastic (WMP) are all by-products that are nuisance to the environment. It is important to understand their influence on workability and mechanical properties of self-compacting concrete (SCC). In this study, the influence of waste metalized plastic fibre (WMPF) and Guinea corn husk ash (GCHA) on workability and mechanical properties of SCC was investigated. The concrete was designed to attain a characteristic strength of 40 N/mm^2. The chemical composition of the GCHA was determined by X-Ray Fluorescence (XRF) method. Properties studied include slump flow test on fresh concrete in addition to compressive strength, direct tensile strength and microstructure of the hardened concrete. Seven concrete mixtures containing 0% - 1.5% WMPF of size 2mm width by 20mm length were cast. A second batch of concrete mixes containing the same fibre dosages and 5% GCHA as substitute of Ordinary Portland cement (OPC) were also cast. All concrete cast were cured and tested for 7-days, 28-days and 91-days for both compressive and direct tensile strengths. The result show that there was a reduction of slump flow due to inclusion of WMPF and GCHA in all the concrete mixes. Also, the compressive strength of both mixes reduced with the increase in the fibre content. There was an enhancement of the direct tensile strength due to inclusion of WMPF. The compressive strength of 5% GCHA-based concrete reduced at 7 and 28 days curing period and witnessed a high gain of strength at 91-days curing period. In conclusion, the compressive strength of both OPC-based and 5% GCHA-based concretes without fibre were found to be 52.42 N/mm^2 and 58.27 N/mm^2 respectively at 91 days of curing.

1.0 Introduction

Concrete, as a composite construction material, possesses a firm structure akin to stone when appropriately cast and cured. Its name derives from the Latin term "concretes," signifying the act of joining. This material comprises a blend of finely and coarsely distributed aggregates intricately bound within a solid cement or binder matrix. The cement fills the interstitial spaces among the aggregate particles, effectively bonding them together (Zongjin, 2011). Achieving adequate strength and durability in concrete typically requires thorough compaction. Inadequate compaction leads to the inclusion of air voids, diminishing compressive strength and jeopardizing the protection of embedded reinforcement bars within the hardened concrete (Newman and Seng, 2003). Compressive strength stands as a critical property in most structural applications, given concrete's primary role in withstanding compressive stress. Existing codes prioritize concrete strength or grade as the fundamental parameter from which other properties such as tension, shear strength, and modulus of elasticity are derived. Over time, researchers and engineers have aimed to enhance concrete strength and properties to position it as a robust competitor to steel in structural elements (Elreedy, 2016).

Beginning of 1983, Japan began to focus extensively on addressing the durability of concrete structures. Constructing resilient concrete structures requires meticulous compaction performed by skilled workers. However, the diminishing number of skilled laborers in Japan's construction sector has resulted in a decline in construction quality. One potential remedy to ensure durable concrete structures despite varying construction quality is the adoption of self-compacting concrete (SCC). SCC possesses the capability to uniformly fill every crevice of a formwork solely under its own weight, obviating the need for vibration compaction. The concept of this concrete type was initially introduced by Okamura and Ozawa in 1995 (El-Reedy, 2016). SCC, as its name suggests, is a variant of concrete that flows effortlessly without the need for external vibration, efficiently filling designated formwork and achieving complete compaction while avoiding any bleeding or segregation of its constituent materials.

The components employed in SCC are meticulously selected from the array of materials utilized in traditional concrete, encompassing coarse aggregate, fine aggregate, cement, mineral admixtures (such as fly ash, guinea corn husk ash, rice husk ash, and ground-granulated blast furnace slag), and chemical admixtures (such as superplasticizers and viscosity-modifying agents) (Rawat and Khan, 2022). The utilization of SCC obviates the necessity for vibration during placement, offering various benefits such as reduced noise, heightened productivity, and the creation of a robust, enduring, and impermeable structure following appropriate mix design, mixing, placing, and curing processes (Rawat and Khan, 2022).

Self-compacting concrete, distinguished for its exceptional flowability and stability, possesses the unique capability to effortlessly spread and occupy designated spaces within formwork without requiring consolidation or significant segregation (Hardik et al., 2011). This innovative blend, commonly termed Self-Compacting Concrete, effectively expels entrapped air through a vibration-free process and adeptly maneuvers around obstacles, including reinforcement, to achieve optimal filling within the formwork (Neville & Brooks, 2010). With the advent of rapid industrialization and technological progress, a considerable amount of waste materials, notably non-biodegradable plastic waste, is generated. These waste materials pose challenges in terms of reprocessing or reuse. A notable issue arising from the food packaging industry is the substantial production of metalized plastic waste. These metalized plastic sheets, comprising polymers with thin aluminum coatings, exhibit an extremely slow degradation rate, thus posing long-term environmental concerns (ChallaGifta et al., 2021).

Plastic's inception dates back to 1838 when A. Parker first synthesized it. However, it wasn't until World War I that its production experienced a significant upsurge, largely due to substantial research investments made by the chemical and petrochemical industries in the exploitation of polymeric materials (Songyan, 2019). Metalized plastic waste (MPW) and automotive plastic waste (APW) emerge as two of the most intricate types of plastic waste generated in contemporary society. Their intricate composition, comprising various polymeric materials, metals, plastic additives, and contaminants, poses challenges for recycling through conventional means (Songyan, 2019).

Metalized plastic films are composed of a polymer substrate coated with a thin layer of metal, typically aluminum. These films replicate the glossy metallic appearance of aluminum foil but with reduced cost and weight. Widely employed across diverse applications, such as food packaging, insulation, electronics, and decorative purposes, metalized plastic films offer versatility (Hossein et al., 2018).

In 2020, records indicate that Nigeria generated approximately 1.25 million tonnes of plastic waste. The mismanagement of this waste poses a significant nuisance, contaminating ecosystems and posing threats to biodiversity when released into marine environments. Utilizing Waste Metalized Plastic (WMP) stands out as a crucial avenue for promoting cleaner production, waste reduction, conservation of natural resources, and mitigation of greenhouse gas emissions, thereby fostering the establishment of a sustainable environment (Alyousef et al., 2020). Given the substantial volume of pre- and post-consumer solid waste generated by industrialization, innovative alternative approaches are imperative for achieving sustainable development. Consequently, sustainability principles within the construction sector advocate for the use of waste materials as substitutes for natural resources such as cement, aggregates, and fibers. This strategy not only promotes environmentally friendly construction practices but also reduces costs (Hossein and Mahmood, 2018).

Fiber-reinforced cementitious composites offer a solution to the brittleness often associated with concrete. In this study, waste metalized plastic fiber will be employed to enhance the properties of self-compacting concrete.

According to the United States Department of Agriculture, global sorghum production totals 59.35 million metric tons, with Nigeria ranking as the second-largest producer contributing 6.55 million metric tons. Sorghum cultivation primarily occurs in Nigeria's northern region. Post-harvest processing involves winnowing or the use of combined harvesters, resulting in the generation of significant quantities of waste husks, which constitute the protective outer shell of the sorghum seed. Proper incineration of sorghum husks yields Sorghum Husk Ash (SHA) (Tijani et al., 2018).

The husk of guinea corn, an agricultural byproduct encompassing the corn kernel, is notable for its high cellulose content. This resource finds various applications, including bioethanol and biogas production, as well as utilization as animal feed. However, despite its versatility, guinea corn husk contributes to environmental pollution. In many developing nations, the common practice involves disposing of corn husks alongside corn stalks and leaves, either through burning or incorporating them into the soil (Marfo et al., 2018).

Pozzolans, also referred to as pozzolanic materials, are substances that occur naturally or are artificially created and contain reactive silica. In their natural state, pozzolans do not possess significant cementitious properties. However, through finely grinding and introducing moisture, they undergo a chemical reaction with calcium hydroxide, resulting in the formation of compounds with adhesive properties (Newman and Seng, 2003).

According to Marfo et al. (2018), pozzolanic materials, when finely divided and in the presence of moisture, react with calcium hydroxide released during cement hydration to produce stable, insoluble silicates known as Calcium-Silicate-Hydrate (C-S-H). This compound serves as an excellent bonding material, as demonstrated in equations 1 and 2.

$$C_2S/C_3S + H_2O \text{ (cement hydration) } C\text{-}S\text{-}H + H_2O \quad (1)$$

$$CH + Silica + H_2O \text{ (pozzolanic reaction) } C\text{-}S\text{-}H \quad (2)$$

GCHA is characterized by a notable silica content, which categorizes it as a high-quality pozzolanic material. However, substituting a portion of cement with GCHA in concrete does not improve the flexural strength of the concrete (Ndububa & Aburime, 2021).

2.0 Experimentation

2.1 Materials

For the purposes of this research, GCHA served as the pozzolanic material and WMPF as the fiber in the production of SCC. The materials included in the mixture comprised ordinary Portland cement (OPC), GCHA with particle sizes finer than 150 micrometers, fine aggregates, crushed rock, high-range superplasticizer, and potable water. Throughout the study, Dangote brand ordinary Portland cement was utilized. The chemical and physical characteristics of Dangote Portland cement are detailed in Table 1, sourced from Sadiq (2023). River sand sourced from river Wudil served as the fine aggregate in this investigation, with sieve analysis conducted following clause 7.2.2 of B.S 812: part 103 (1985).

Table 2 presents the outcomes of the sieve analysis conducted on both the fine aggregate and coarse aggregate utilized in this study. The specific gravity of the sand is recorded at 2.63, with a bulk density of 1653 Kg/m3. According to BS 882: 2004 grading criteria, the sand falls under the classification of zone 2 material. In this research, the coarse aggregate consisted of crushed stone with a maximum size of 20mm, boasting a specific gravity of 2.67 and a bulk density of 1515 Kg/m3.

The Guinea corn husk ash utilized in this study originated as post-harvest agricultural waste obtained from Guinea corn harvested in Bauchi local government of Bauchi state. Hand sorting was conducted to remove extraneous particles, and the Guinea Corn Husk (GCH) collected underwent burning at approximately 600°C in a kiln fueled by kerosene at the Industrial Design Programme of the Abubakar Tafawa Balewa University Bauchi. After a three-day cooling period, the ash was ground and sieved through a 150µm sieve, with particles passing through retained for use. The chemical composition analysis was conducted using Energy Dispersive X-Ray Fluorescence (EDXRF) at the central laboratory of Umaru Musa Yar'adua University, Katsina, Katsina state. Table 3 provides the oxide composition of the Guinea corn Husk Ash utilized in this research work.

High Range Superplasticizer (Master Glenium ACE 456) is a chemical admixture designed to reduce the quantity of mixing water required to achieve a specific consistency in concrete. It comprises a series of innovative superplasticizers formulated with newly developed polycarboxylate ether polymers. Master Glenium ACE 456 expedites cement hydration by increasing the surface area of cement grains exposed to water. The recommended dosage rate ranges from 0.3 to 2.0 L/100 kg of binder.

The waste metalized plastics utilized were post-consumer waste, collected, cleaned, and manually shredded into fibers measuring 2 mm by 20 mm using rulers and scissors. Figure 1 below illustrates the shredded waste metalized plastic fibers.

Table 1: Chemical characteristics of Dangote Portland Cement

S/No.	Oxide Composition	% Oxide Composition	BS EN 197-1 Limits %	NIS 444-1 Limits %
1	CaO	64.96	61-69	59-69
2	SiO_2	21.98	18-24	18-24
3	Al_2O_3	5.75	2.6-8.0	2.6-8.0
4	FeO_3	3.50	1.5-70	1.5-7.0
5	SO_3	2.45	3.5-4.0	$\leq$ 3.50
6	MgO	2.07	0.5-4.0	$\leq$ 4.0
7	$Na_2O + K_2O$	0.42	0.2-1.0	< 2.0
8	P_2O_5	1.11	0.1-0.2	0.1-0.2
9	TiO_2	0.40	0.1-0.4	0.1-0.4
10	LOI	1.5	0-5.0	$\leq$ 5.0

Table 2: Summary of Sieve Analysis

Fine Aggregate			Coarse Aggregate		
Sieve size (mm)	% Retained	% Passing	Sieve size (mm)	% Retained	% Passing
5.00	-	100	28.0	-	100
2.00	11.00	89.0	20.0	3.63	96.37
1.18	6.00	83.0	14.0	59.97	36.40
600µm	39,50	43.5	10.0	16.23	20.17
300µm	26.50	17.0	6.3	8.63	11.54
150µm	10.00	7.0	5.0	2.87	8.67
63µm	5.50	1.5	Pan	8.67	-
Pan	1.50	-	-	-	-

Table 3: Typical properties of Master Glenium ACE 456

Appearance and Form	Whitish to light brownish liquid.
Specific gravity at 25ºC	1.060 typical
PH Value	4.0-7.0
Chloride ion content	≤0.01%
Alkali content (Na_2O equivalent %)	<3%

Figure 1: (a) waste metalized plastics (b) shredded waste metalized plastic fibre

2.2 Mix Proportioning of WMPF, GCHA in Self-Compacting Concrete

The constituents of the mixes used in this study are presented in Table 4 below. Mix N1 to N7 with dosages of WMPF 0%, 0.25%, 0.50%, 0.75%, 1.0%, 1.25% and 1.5%, GCHA 0%, while mix P1 to P7 with dosages of WMPF 0%, 0.25%, 0.50%, 0.75%, 1.0%, 1.25% and 1.5%, and GCHA 5% as partial replacement of cement in all the mixes.

Table 4: Concrete mix details of both OPC and GCHA

MIX	CEMENT Kg/m^3	GCHA Kg/m^3	WMPF %	WATER Kg/m^3	W/C	C.A Kg/m^3	F.A Kg/m^3	SP %
				N – Concrete				
N1	445.00	-	0.00	178	0.38	710	979	0.86
N2	445.00	-	0.25	178	0.38	710	979	0.86
N3	445.00	-	0.50	178	0.38	710	979	0.86
N4	445.00	-	0.75	178	0.38	710	979	0.86
N5	445.00	-	1.00	178	0.38	710	979	0.86
N6	445.00	-	1.25	178	0.38	710	979	0.86
N7	445.00	-	1.50	178	0.38	710	979	0.86
				P – Concrete				
P1	445.00	0.00	0.00	178	0.38	710	979	1.8
P2	422.75	22.25	0.25	178	0.38	710	979	1.8
P3	422.75	22.25	0.50	178	0.38	710	979	1.8
P4	422.75	22.25	0.75	178	0.38	710	979	1.8
P5	422.75	22.25	1.00	178	0.38	710	979	1.8
P6	422.75	22.25	1.25	178	0.38	710	979	1.8
P7	422.75	22.25	1.50	178	0.38	710	979	1.8

2.3 Test Procedure

The slump flow test was performed on fresh concrete following EFNARC (2005) guidelines. Subsequently, the compressive strength tests of the cured concrete cubes were conducted according to BS EN 12390-3 (2009), while the tensile strength tests were carried out in accordance with BS EN 12390-6 (2000).

3.0 Result and Discussions

3.1 Chemical Composition of GCHA

The chemical composition analysis of the GCHA was performed using Energy Dispersive X-ray Fluorescence (ED-XRF), a nondestructive test utilized for determining the chemical composition of various materials, including liquids, slurries, solids, powders, films, and more.

Based on ASTM C618 the total amount of major chemical oxides in a pozzolanic materials should be equals to 70%; SiO_2 + Al_2O_3 + Fe_2O_3 =70%. The percentage of the three major oxides found in GCHA = 64.332+9.805+1.3431 = 75.48%.

The findings of the chemical composition analysis of GCHA are presented in Table 5, indicating that the GCHA utilized in this study meets the criteria for both chemical and physical properties expected of a pozzolanic material, it complied with ATSM C618 (ASTM, 2001) standards. The three major constituents of Silica Oxide, Aluminium Oxide and Iron Oxide has a total of 75.4801 which is greater than the minimum 70% provision in the ASTM C618 standard, SO_3, K_2O and Na_2O are all below 3% given in the standard. The strength activity index result at 28days curing period is 84.78% which is greater than the minimum 75% provision in the ASTM C618 (ASTM, 2001).

Table 5: Microstructural analysis of GCHA

Oxide Composition	% Oxide Composition
SiO_2	64.33
$Al2O_3$	9.81
Fe_2O_3	1.34
CaO	1.23
MgO	3.57
SO_3	0.22
Na_2O	-
K_2O	2.31
LOI	-

3.2 Slump Flow Test

Slump flow is a test on fresh mix concrete or mortar that designates the flowability of specimen in unconfined conditions. This a test for self-compacting concrete used in determining its filling ability, it entail measuring its flow spread and flow time. The testing apparatus comprises a sturdy base plate crafted from plywood, glass, or steel, an Abrams cone, a stopwatch, a cleaner, and a measuring tape. EFNARC categorizes slump flow into three classes, outlined in Table 6. The outcomes are detailed in Table 7, with measurements illustrated in Figure 2.

Table 6: Slump flow classes and diameters based on EFNARC guidelines

Slump Flow Classes	Slump Flow Diameter (mm)
SF1	550-650
SF2	660-750
SF3	760-850

Table 7: Slump flow tests of mix type N and P

Mix No.	Fiber Content (V)%	Flow (mm)	Time Flow 500mm (sec)
		N – Concrete	
N1	0.00	690	2.2
N2	0.25	660	2.8
N3	0.50	655	3.5
N4	0.75	650	4.0
N5	1.00	645	5.0
N6	1.25	630	5.8
N7	1.50	615	6.0
		P – Concrete	
P1	0.00	675	3.1
P2	0.25	660	3.8
P3	0.50	630	4.6
P4	0.75	625	5.3
P5	1.00	620	6.2
P6	1.25	615	7.2
P7	1.50	610	7.9

Figure 2: Slump flow of GCHA/WMPF concrete

Based on EFNARC classifications of slump flow 550-650mm is class 1, 660-750mm is class 2 while 760-850mm is class 3. From the results shown on Table 7 above N4-N7 samples are all class 1 mixes, while N1 and N2 are class 2 mixes. It shows that samples P3-P7 are all class 1 while mixes P1 and P2 are class 2. Slump flow-1 (SF1) is suitable for use in plain or lightly reinforced concrete structures, including slabs and casting via pump injection systems such as tunnel linings, piles, and certain deep foundations. Slump flow-2 (SF2) is well-suited for various structural applications, including columns and walls. Conducting a flow test aids in assessing the filling capacity of SCC (Self-Consolidating Concrete).

The test conducted on the fresh concrete was the slump flow test. In all the mixes that contained GCHA and WMPF the mixes were harsher than that of plain concrete thus increased the time of flow to the 500mm diameter. The flow for plain concrete was 690mm but with addition of fibres at 0.25%, 0.50%, 0.75%, 1.00%, 1.25% and 1.50% the flow decreases to 659mm, 652mm, 650mm, 644mm, 630mm and 615mm respectively. The flow for GCHA concrete was 674mm but decreases with addition of fibres at 0.25%, 0.50%, 0.75%, 1.00%, 1.25% and 1.50% to 658mm, 627mm, 623mm, 618mm, 614mm and 609mm respectively. Comparing the results of plain mixes and that of GCHA mixes it shows that there were drop in flow in GCHA concrete more than that of plain concrete at similar fibres inclusion as shown in Figure 3.

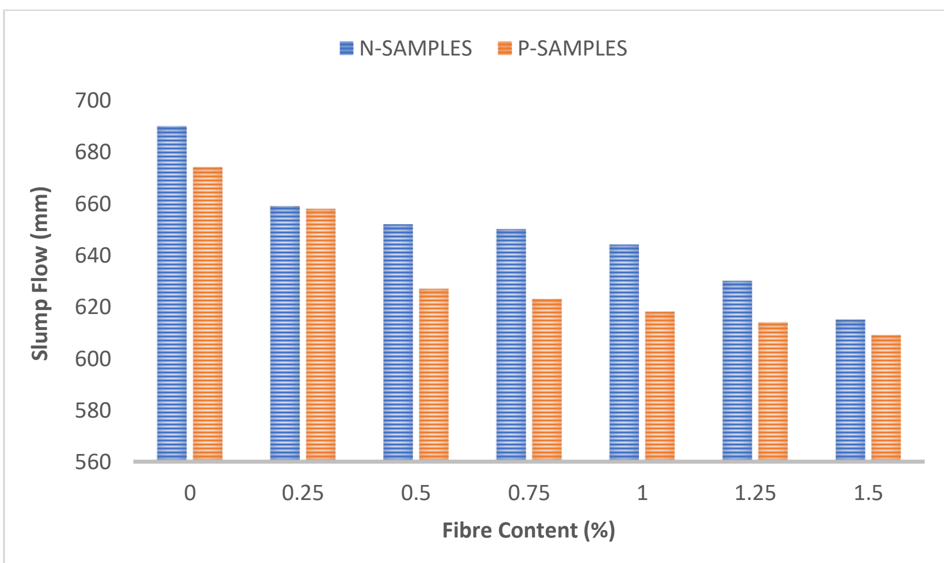

Figure 3: Disparity of Slump flow with different WMP fibre volume fractions

3.3 Compressive Strength Test

The compressive strength of concrete cubes test was carried in accordance to BS 1881: Part 116 (1983) as shown in Figure 4 (a), (b) and (c). Formula for used in calculating the values of compressive strength is given in equation (3) below.

$$Compressive\ Strength = \frac{Normal\ Load\ (N)}{Area\ of\ specimen(mm^2)}\ x\ 100 \quad (3)$$

A self-compacting concrete was prepared using water cement ratio of 0.38. Fourteen mixes labeled N1 to N7 and P1 to P7 were used with cement replaced by 5% of GCHA in the mixes P1 to P7 by weight. Total numbers of sixty-three cubes were cast using a mould size of 150mm x150mm x 150mm. The test specimen was removed from the mold after 24 hours and then cured in water at room temperature for durations of 7, 28, and 91 days. Three specimens underwent crushing using a motorized compression machine, and the average strengths are displayed in Table 8, Figures 5, and 6.

Figure 4: (a) Cast concrete cubes (b) Curing of concrete (c) Compressive strength test

Table 8: Compressive strength of concrete cubes specimen

Mix No.	Mean Compressive Strength (N/mm²)		
	7-Days	28-Days	91-Days
N – Concrete			
N1	38.98	49.09	52.42
N2	37.96	44.29	45.66
N3	37.20	41.45	44.53
N4	36.45	40.92	43.86
N5	35.61	40.22	42.39
N6	34.96	39.33	41.68
N7	34.54	37.72	41.60
P – Concrete			
P1	36.98	41.62	58.27
P2	36.49	37.85	54.68
P3	35.70	36.95	52.08
P4	34.76	36.68	47.25
P5	33.98	36.55	44.24
P6	33.11	36.41	43.59
P7	32.36	36.10	42.98

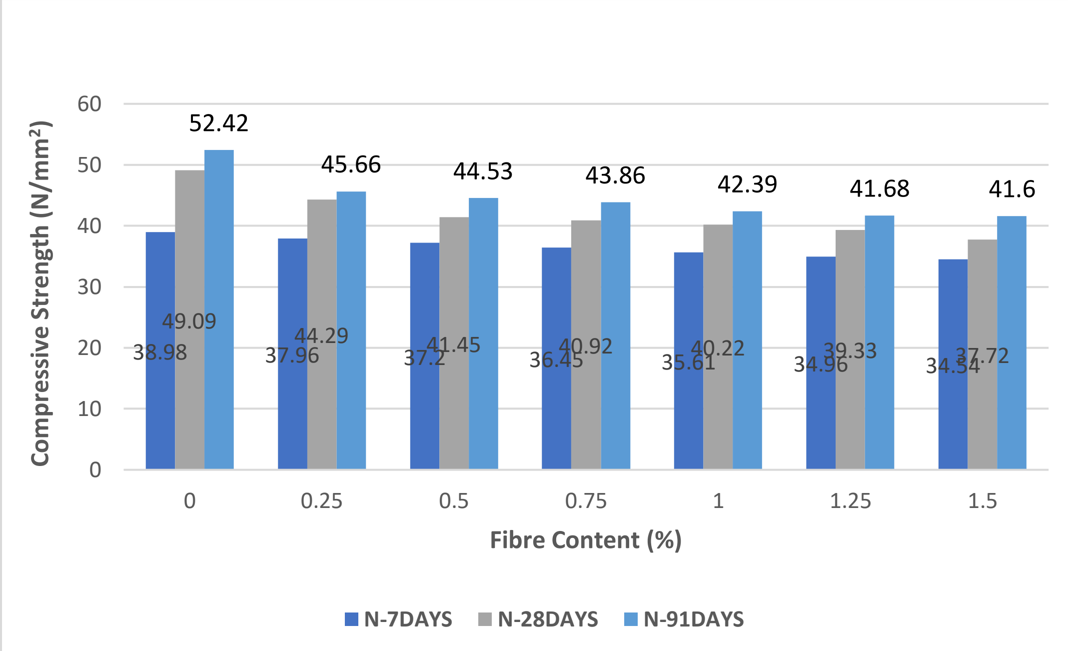

Figure 5: Disparity of compressive strength with different WMP fibre volume fraction at 7, 28 and 91 days curing period (N – Concrete samples)

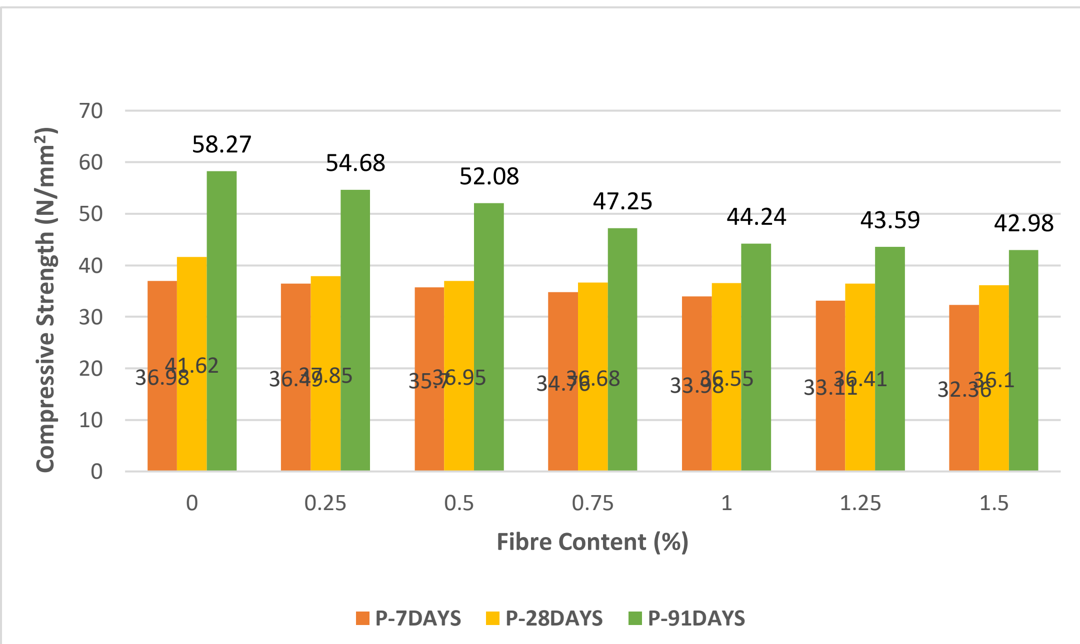

Figure 6: Disparity of compressive strength with different WMP fibre volume fraction at 7, 28 and 91 days curing period (P – Concrete samples)

The incorporation of GCHA and WMPF led to a decrease in the compressive strength of concrete at 7 days. Introducing WMPF at varying percentages (0.25%, 0.5%, 0.75%, 1.00%, 1.25%, and 1.50%) resulted in reductions in the 7-day compressive strength of OPC-based concrete specimens by 2.62%, 4.57%, 6.49%, 8.65%, 10.31%, and 11.39%, respectively. Similarly, adding 5% GCHA and WMPF at the same percentage increments led to decreases in the 7-day compressive strength of GCHA-based concrete specimens by 1.33%, 3.46%, 6.00%, 8.11%, 10.47%, and 12.49%, respectively.

At 28 days, the compressive strength of concrete also exhibited a decrease with the incorporation of GCHA and WMPF. Adding WMPF at various percentages (0.25%, 0.5%, 0.75%, 1.00%, 1.25%, and 1.50%) resulted in reductions in the 28-day compressive strength of OPC-based concrete specimens by 9.78%, 15.56%, 16.64%, 18.07%, 19.88%, and 23.16%, respectively. Similarly, including 5% GCHA and WMPF at the same percentage increments led to decreases in the 28-day compressive strength of GCHA-based concrete specimens by 9.06%, 11.22%, 11.87%, 12.18%, 12.52%, and 13.26%, respectively.

By the 91st day, the compressive strength of concrete declined with the addition of WMPF. Introducing WMPF at varying percentages (0.25%, 0.5%, 0.75%, 1.00%, 1.25%, and 1.50%) resulted in reductions in the 91-day compressive strength of OPC-based concrete specimens by 14.88%, 15.05%, 16.33%, 19.13%, 20.49%, and 20.64%, respectively. Similarly, including WMPF at the same percentage increments led to decreases in the 91-day compressive strength of GCHA-based concrete specimens by 2.83%, 7.45%, 16.03%, 21.38%, 23.53%, and 23.62%, respectively.

These findings suggest that GCHA exhibits slow pozzolanic activity during early curing stages, resulting in a less significant influence on strength development. However, at 91 days of curing, GCHA provides more nucleation sites for hydration, thereby increasing the compressive strength of concrete through its pozzolanic reaction, facilitated by the presence of additional C-S-H gels and the filling ability of fine GCHA particles. The results of GCHA-based mixes at a 5% replacement level, cured for 91 days, demonstrate a significant effect on the compressive strength of concrete. These findings are consistent with those of Tijani et al. (2019), Oyedemi et al. (2020), Oyedemi et al. (2022), and Aliyu et al. (2023).

3.4 Split Tensile Strength Test

The tensile test was carried out using either the split test or Brazilian test method. For this procedure, cylindrical concrete samples measuring 150 mm in diameter and 300 mm in height were cast. These specimens were removed from the molds after 24 hours and then subjected to curing for 7 days, 28 days, and 91 days in a curing tank. The cylinders were loaded along its length in compression for tensile strength with universal testing machine. Tension was created along its diameter and the cylinder splits into two halves, but some of the samples were not fully split due to the presence of waste metalized plastic fibres.

Tensile strength = compression load along axis/Area in tension

$$= \frac{2P}{\pi DL} \quad (4)$$

Where:

P = Ultimate load at failure

D = Diameter of the cylinder

L = Length of the cylinder

Three specimens were crushed using a Universal Testing Machine as shown in Figure 7 (a) and (b) and the mean strengths are presented in Table 9 and Figures 8 and 9.

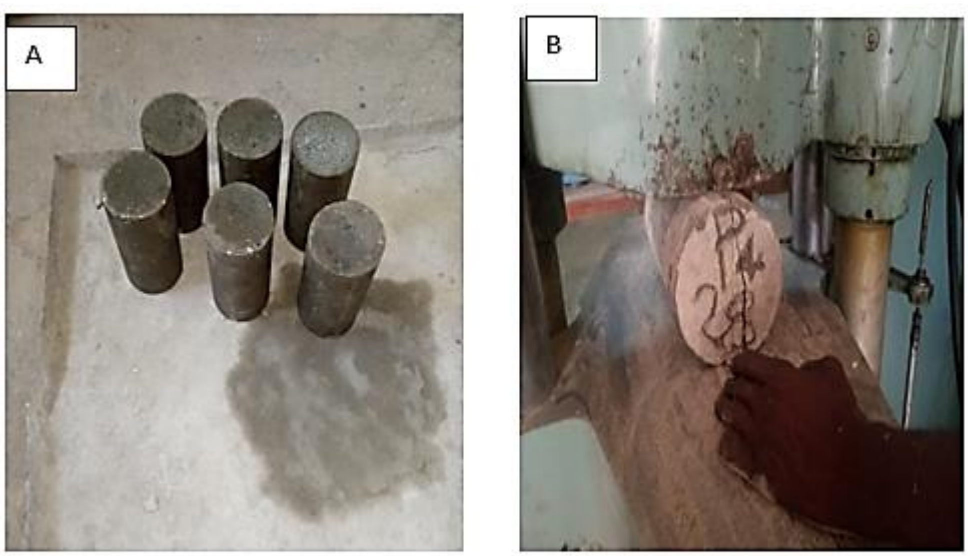

Figure 7: (a) Cast concrete cylinders (b) Split tensile test

Table 9: Tensile strength of concrete cylinders specimens

Mix No.	**Mean Tensile Strength (N/mm²)**		
	7-Days	**28-Days**	**91-Days**
N – Concrete			
N1	2.53	2.92	3.63
N2	2.62	3.03	3.68
N3	2.68	3.14	3.87
N4	2.84	3.39	4.04
N5	2.78	3.23	3.72
N6	2.69	3.10	3.67
N7	2.61	2.92	3.54
P – Concrete			
P1	2.53	3.28	4.12
P2	2.76	3.31	4.24
P3	2.85	3.43	4.48
P4	2.70	3.36	4.34
P5	2.63	3.30	4.29
P6	2.50	3.27	4.22
P7	2.45	3.25	4.17

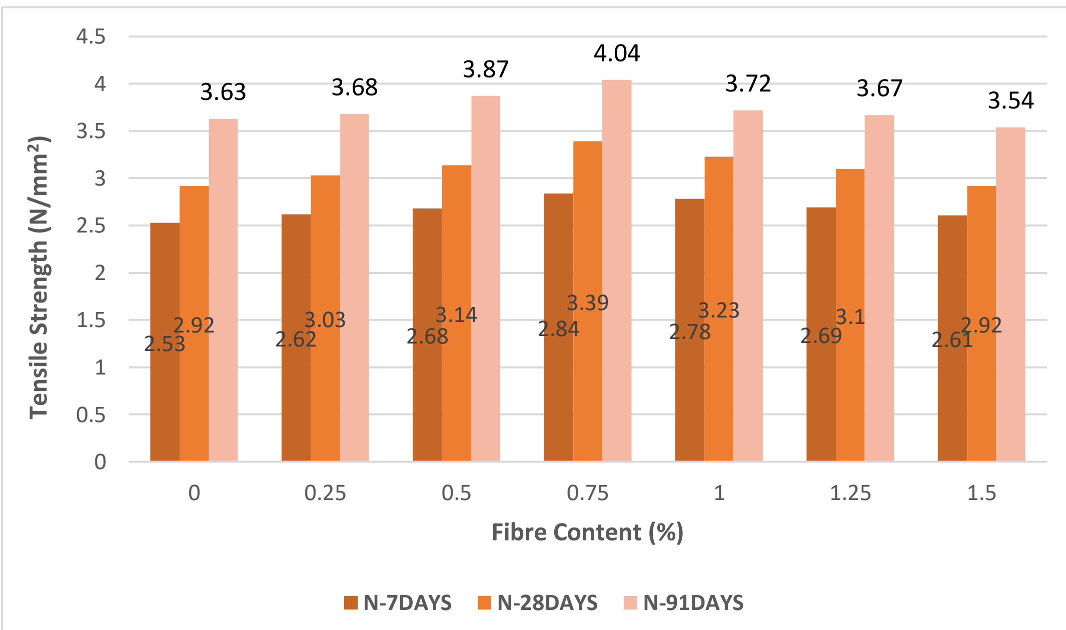

Figure 8: Disparity of split tensile strength with different WMP fibre volume fraction at 7, 28 and 91 days curing period (N – Concrete cylinder samples)

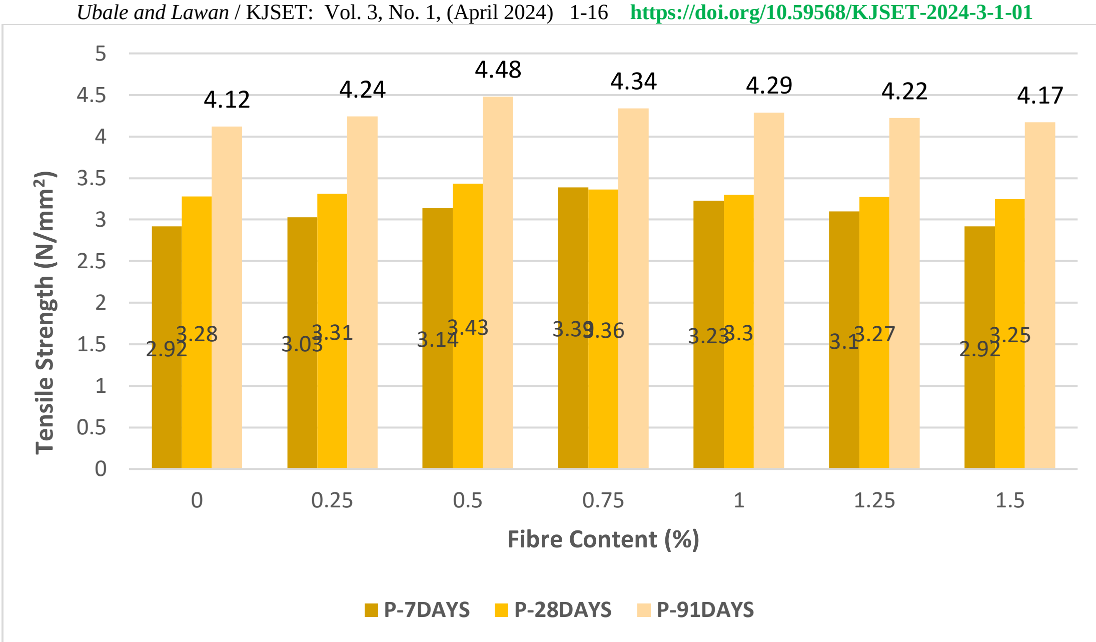

Figure 9: Disparity of split tensile strength with different WMP fibre volume fraction at 7, 28 and 91days curing period (P – Concrete cylinder samples)

The inclusion of WMPF led to an increase in the direct tensile strength of all concrete specimens cured for 7 days, 28 days, and 91 days, both in OPC-based and GCHA-based concrete. Additionally, the addition of GCHA in the concrete contributed to the rise in direct tensile strength due to the filling ability of its finer materials. The optimal fiber contents for N-Samples were observed in mix N4, exhibiting the highest improvement in tensile strength of 4.04 N/mm2 at the 91-day curing period, which represents an 11.29% increase compared to conventional concrete N1. Similarly, for P-Samples, the optimal fiber content was found in mix P3, showcasing the highest improvement in tensile strength of 4.48 N/mm2 at the 91-day curing period, representing an 8.74% increase compared to the control specimen P1.

These findings align with those of Prageeth and Mohan (2023), Oyedemi et al. (2022), Hossein et al. (2020), ChellaGifta et al. (2021), and Alyousef et al. (2021), who investigated the behavior of Metalized Plastic Waste Fiber Reinforced in Green Concrete. They found that the inclusion of Waste Metalized Plastic Fibers at various percentages (0.25%, 0.50%, 0.75%, 1.00%, and 1.25%) enhanced the direct tensile strength of concrete cured at different ages.

3.5 Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) proves valuable for examining fractured concrete specimens. Given that cement paste or concrete typically exhibit non-conductive properties, a thin layer of electrically conductive material is applied as a coating. Subsequently, the specimen is mounted onto a metal or graphite stub using rapid-hardening glue for examination. It's worth noting that the larger the sample, the longer it takes for SEM electrons to be reflected or absorbed, thus producing various signals (Ramachandran and Beaudion, 2001). The Scanning Electron Microscopy Analysis was conducted at the Central Laboratory of Umaru Musa Yar'adua University, Katsina. Below, Figure 10 showcases images of OPC-based and GCHA-based mixes.

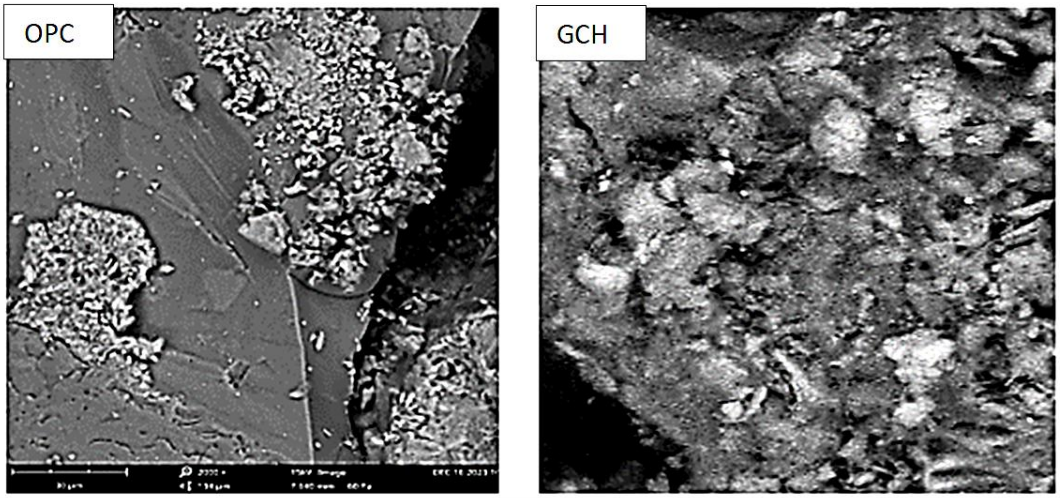

Figure 10: SEM of hydration products in OPC and GCHA concrete matrices

Figure 10 depicts the magnification of both OPC-based and GCHA-based mixes. In the GCHA-based concrete, a conspicuous formation of C-S-H gels is observable, uniformly dispersed across the specimen. This consistent distribution of C-S-H contributes to the substantial consumption of Calcium Hydroxide, which prompts the formation of corresponding C-S-H gels and consequently yields higher concrete strength, a phenomenon also highlighted by Mohammadhosseini et al. (2020). The pozzolanic reaction of GCHA and the formation of secondary C-S-H gels enhance the paste-aggregate interface and reduce the capillary porosity of the cement paste, thereby achieving a greater degree of hydration and resulting in strength development at 91 days of curing surpassing that of the control specimen.

4.0 Correlation Among the Strength Parameters

In this segment, empirical equations are formulated to establish the connections between the compressive strength and tensile strength of concrete specimens incorporating WMP fiber, utilizing the outcomes of experimental tests. These equations are derived through regression analysis. Figure 11 displays these empirical equations, illustrating the correlation between compressive strength and tensile strength. The linear regression technique was utilized to scrutinize the data, yielding an R^2 value of 0.5632 across all mixtures. These R^2 values suggest that 56.36 percent of the variability in Y can be anticipated from X.

$$f_t = 0.07439 f_{cu} + 0.2601 \quad (5)$$

$$R^2 = 0.56$$

f_t is the Splitting Tensile Strength of Concrete

f_{cu} is the cube Compressive Strength of Concrete

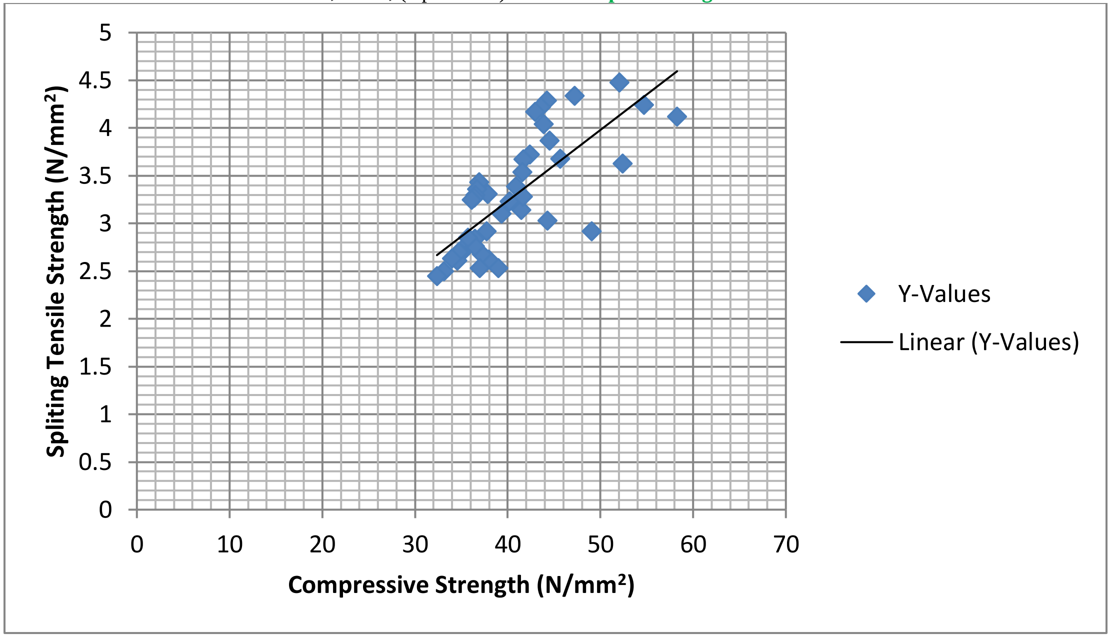

Figure 11: Tensile-compressive strength relationship

5.0 Conclusions

Based on the results of this study, the following conclusions can be drawn:

1. The chemical composition of Guinea Corn Husk Ash was found to have the total of major oxides of 75.5% which is above the specification of ASTM C618-78 clause 17.2 and therefore GCHA is a good pozzolana.
2. The mixes with GCHA and WMPF were harsher than the control mixes, and in turn the workability of concrete decreased upon their addition in concrete.
3. The optimum fibre content in OPC-based mix was at N4 (0.75% fibre content) with tensile strength of 4.04 N/mm^2 at 91 days curing period, while that of GCHA-based mix was at P3 (0.50% fibre content) with tensile strength of 4.48 N/mm^2 at 91curing period.
4. The Scanning Electrons Microscopy result shows that the presence of GCHA and WMPF in N1 and P1 respectively at 91 days curing had uniformly distributed supplementary C-S-H gels, which owed to the consumption of calcium hydroxide which in turn caused higher strength of concrete specimens.

In addition to the above conclusion, it was also established in this study as follows:

i. There was an increase in compressive strength of GCHA concrete at 91days curing age. The compressive strength obtained was 58.27 N/mm^2 while the compressive strength of control specimen at 91 days curing period was 52.42 N/mm^2. The compressive strength of GCHA was 11.16% greater than that of the control specimen.

ii. There was an increase in tensile strength due to inclusion of fibre in both OPC-based and GCHA-based concrete for all the curing ages. All the mixes incorporating fibres were found to maintain their original appearance without much strain at the ultimate loading.

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Declaration of conflict of interest

No conflict of interest among the authors.

References

Aliyu M.M., Bishir Kado, Sikiru Siyanbola Abdulganiyu (2023). Mechanical Properties of Mortar Incorporating Guinea Corn Husk Ash (GCHA) as Partial Replacement of Cement. Iconic Research and Engineering Journals (IRE), 7(4), 109-114, ISSN: 2456-8880.

American Society for Testing and Materials. Standard Specification for Testing Pozzolanas. ASTM International, ASTM C618. USA. 2001.

Alyousef Rayed, Hossein Mohammadhosseini , Fahed Alrshoudi, Mahmood Md. Tahir, Hisham Alabduljabbar and Abdeliazim Mustafa Mohamed R. et al. (2020). Enhanced

Performance of Concrete Composites Comprising Waste Metalized Polypropylene Fibres Exposed to Aggressive Environments. Department of Civil Engineering, College of Engineering, Prince Sattam bin Abdulaziz University, Alkharj 11942, Saudi Arabia.

BS EN 12390-3 (2009). Testing Hardened Concrete - Compressive Strength of Test Specimens. British Standards, London, W4 4AL, UK, Standards Policy and Strategy Committee.

BS EN 12390-6 (2000). Testing Hardened Concrete - Tensile Splitting Strength of Test Specimens. British Standards, London, W4 4AL, UK, Standards Policy and Strategy Committee,(Amended 17th November, 2004).

ChellaGifta C, Christal Sophia R and R Ramya (2021). Characterization of Strength and Toughness Properties of Metalized Plastic Waste Fibres Reinforced Concrete. IOP Conference Series: Materials Science and Engineering, 1060, 12011.

EFNARC: Specifications and guidelines for self-compacting concrete, February, 2005.

Elreedy M.A. (2016). Advanced Materials and Techniques for Reinforced Concrete Structures. CRC Press, Tylor and Francis Series, Second Edition.

John Newman and Ban Seng Choo. (2003), Advanced Concrete Technology, Elsevier, Burlington.

Hardik Upadhyay, Pankaj Shah and Elizabeth George, (2011). Testing and Mix Design Method of Self-Compacting Concrete. National Conference on Recent Trends in Engineering & Technology.

Marfo S.A., Owusu W.A. and Amarfio E.M. (2018). Evaluation of Guinea Corn Husk Ash as Oil Well Cement Slurry Extender. International Journal of Petroleum and Petrochemical Engineering (IJPPE), 4(4), 1-7, DOI: http://dx.doi.org/10.20431/2454-7980.04-04001

Mohammadhosseini Hossein, Mahmood Md. Tahir, Abdul Rahman Mohd Sam (2018). The feasibility of improving impact resistance and strength properties of sustainable concrete composites by adding waste metalized plastic fibres. Institute for smart Infrastructure and Innovative Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), 81310, Johor Malaysia, Construction and Building Materials, 169, 223-236.

Mohammadhosseini Hossein , Rayed Alyousef , Nor Hasanah Abdul Shukor Lim, Mahmood Md Tahir , Hisham Alabduljabbar , Abdeliazim Mustafa Mohame, Mostafa Samadi (2020). Waste metalized film food packaging as low cost and eco-friendly fibrous materials in the production of sustainable and green concrete composites. Institute for smart Infrastructure and Innovative Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), 81310, Johor Malaysia, Journal of cleaner production, 258, 120726.

Mohammadhosseini H. and Mahmood Md T. (2018). Durability performance of concrete incorporating waste metalized plastic fibres and palm oil fuel ash. Institute for smart Infrastructure and Innovative Construction (ISIIC), Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), 81310, Johor Malaysia, Construction and Building Materials, 180, 92-102.

Ndububa E.E.and Aburime P.I. (2021). Flexural strength of concrete made from guinea corn husk ash as partial replacement for cement. Nigerian Journal of Engineering, Vol. 28, No 1, ISSN (Print):0794-4756, ISSN (Online): 2705-3954.

Neville A.M and Brooks J.J. (2010). Concrete Technology. Longman, London, 2nd Edition.

Odeyemi S.O., Atoyebi O.D., and Ayo E.K. (2020). Effect of Guinea Corn Husk Ash on the Mechanical Properties of Lateritic Concrete. IOP Conference Series: Earth and Environmental Science 445 012034, 10.

Odeyemi S.O., Atoyebi O.D., Kegbeyale O.S., Anifowose M.A, Odeyemi O.T., Adeniyi A.G., Orisadare O.A. (2022). Mechanical Properties and Microstructure of High-Performance Concrete with Bamboo leaf ash as additive. Cleaner Engineering and Technology, 3, DOI: 10.1016/j.clet.2021.100352.

Prageeth P.G. and Kavya Mohan. (2023). Study on Flexural and Shear Behavior of Metalized Plastic Waste Fibre Reinforced Concrete. International Research Journal of Engineering and Technology (IRJET), Volume: 10 issue 06/June 2023, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

Ramachandran V. S. and Beaudoin J. J. (2001. Handbook of Analytical Techniques in Concrete Science and Technology: Principles, Techniques, and Applications. Noyes Publications / William Andrew Publishing, LLC Norwich, New York, 57-79, 233, 240,241.

Rawat I.V.S and Khan M.Z. (2020). Self-compacting concrete. International Journal of Creative Research Thoughts (IJCRT), Volume 10, issue 6, ISSN: 2320-2882: 722, 726.

Sadiq A. (2023). Physicochemical and Strength Assessment of Portland Limestone Cement in Nigeria, Research Square, 16/22, DOI: https://doi.org/10.2103/rs.3rs-3195665/VI.

Yassine Senhadjia, Gilles Escadeillas, Hamid Khelafi, Mohamed Mouli and Ahmed Soufiane Benosman (2012). Evaluation of natural pozzolan for use as supplementary cementitious material. European Journal of Environmental and Civil Engineering, Volume 16, No. 1, 90.

SongyanYin.(2019).Sustainable Approach to Transform Metalize d Plastic Packaging Waste and Automotive Plastic Wast e into Value-added Resources. A thesis in fulfillment of the requirements for the degree of Doctor of Philosophy, School of Materials Science & Engineering Faculty of Science, The University of New South Wales, Sedney.

Tijani, M. A., Ogunlade, C. A., Ajagbe, W. O., Olawale, S. O. A., Akinleye, M. T. and Afolayan, O. D. (2018). Development of Green Concrete Using Agricultural and Construction Wastes in Nigeria: A Review. Adeleke University Journal of Engineering and Technology [AUJET] Vol. 1, No 1, 40 – 50.

Tijani M.A, Ajagbe W.O., Ganiyu A.A. and Agbede O.A. (2019). Sustainable Pervious Concrete Incorporating Sorghum Husk Ash as Cement Replacement. IOP Conference Series: Materials Science and Engineering 640-012051, 5-6.

Zongjin Li. (2011). Advanced Concrete Technology. John Wiley & Sons Inc, Hoboken, New Jersey.