

Investigation into the Properties and Structure of Ternary blends of Saw dust ash and sponge Gourd ash in Mortar

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ABSTRACT: This study explores the utilization of ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) as partial replacement of cement in mortar. Comprehensive characterization of SDA and SGA, including their chemical composition, specific gravity, particle size distribution, and pozzolanic activity, were carried out. Also, the fineness, soundness, and setting times of mortar containing the ternary blend of SDA and SGA were investigated. Further, microstructural investigations using X-ray diffraction (XRD), X-ray fluorescence (XRF), and scanning electron microscopy (SEM) were also conducted. The results showed that; the fineness of ternary blends of SDA and SGA increases with SGA from 262.56 m²/kg to 459.81 m²/kg, the soundness of SDA and SGA blends decreases from 5.90 mm to 4.50 mm, the consistency decreased from 28.1 mm to 26.0 mm with increasing SGA, the initial and final setting times decreased from 98/216 minutes to 80/194 minutes with increasing SGA, SDA and SGA exhibit high silica and alumina content, as indicated by XRF results. The SEM analysis reveals particle sizes ranging from 0.1 μm to 100 μm for SDA and 10 μm to 100 μm for SGA. Compositionally, SDA consists of Graphite, Urea, Silicon Dioxide, and Englishite, while SGA comprises Quartz, Hanksite, Davyne, and Woodhouseite, displaying varying particle morphologies.

Keywords: Sawdust ash (SDA), Spongegourdash (SGA), Ternary blends, Pozzolanic activity, Microstructure, Compressive strength, Splitting tensile strength, Flexural strength.

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1. Introduction

According to Ahmed (2024), the construction industry is a significant consumer of natural resources and producer of greenhouse gas emissions. Cement production, a primary component of concrete, contributes substantially to these environmental concerns. Researchers have explored using supplementary cementitious materials (SCMs) to reduce the environmental impact of concrete production. Sawdust ash (SDA), a waste product from the timber milling industry, poses an environmental

hazard due to improper disposal. Several studies have investigated using SDA as a partial replacement for cement in structural concrete. These studies include those by Afolabi (2019),

Olugbenga (2019), Jubril, *et al.* (2024), and Ayuba, *et al.* (2023). These studies concluded that SDA is a suitable pozzolan for producing structural concrete. The Sponge gourd (Fig. 1), also known as *aegyptiaca* is a plant that is native to Asia and Africa, but found all over the world as in Table 1.



Table 1: Worldwide distribution of Sponge gourd (Harwick,2017)

Continent	Percentage of Saw dust produced per annum (million m ³)					
	2019	2020	2021	2022	2023	2023
Asia Pacific	300	435	165	321	321	322
North America	240	320	365	340	543	156
Europe	225	200	553	664	322	354
South America	233	270	643	432	453	435
Middle East and Africa	300	446	675	981	534	441

The usage of sponge gourd as a construction material is in two states, which are as fibre and as ash.

Researchers who have explored the use of sponge gourd as ash include Quadri, *et al* (2020), Li, *et al* (2024), and Garcia, *et al* (2024). Others, such as Raghda, *et al* (2022), Mithra, *et al* (2012), Querido, *et al* (2019), and Mithra, *et al* (2022), have also investigated sponge gourd ash. Sponge gourd, whether as ash or fibre, has potential as a construction material. However, the quality of some agro-based pozzolans, including SDA, can be inferior, limiting their application. To address this issue, researchers have conceived ternary blends as a strategy to compensate for inferior pozzolans. Ternary blends combine cement with two other pozzolans and Portland cement to form a binder in structural concrete, as shown in Equation 1.

$$\text{binder} = \text{Portland cement} + 2 \text{ pozzolanic materials} \quad 1$$

Equation 1 was based on the possibility of obtaining a combined chemical composition from the two (2) pozzolanic materials that will yield cementitious paste capable of impacting adequate strength and durability properties to the resulting concrete. A comprehensive review was carried out by Fapohunda *et al.*, (2023) on usage of agro-based pozzolans in ternary blends. The agro-based ternary blends reviewed, with encouraging results, included ternary blends of: Saw dust ash (SDA) and rice husk ash (RHA), rice husk ash (RHA) and corn cob ash (CCA), rice husk ash (RHA) and wheat straw ash (WSA) and others.

However, the use of ternary blends of saw dust ash and sponge gourd ash in concrete is yet to be investigated. This study investigated the possibility of using ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) in concrete. The objectives are to investigate the structural characteristics of mortar containing the ternary blend of SDA and SGA; with respect to consistency, soundness, setting times, and morphological structure.

II. MATERIALS AND METHODS

2.1 Materials

The primary materials used in this investigation are: Portland limestone cement, fine aggregates, coarse aggregates, water, sawdust ash (SDA), and sponge gourd ash (SGA). The ordinary Portland cement used was Elephant Cement's Superset brand. It is a 42.5R rapid-hardening type, conforming to BS EN 197-1: (2011). The fine aggregates used were natural sand. This sand was sourced from the Ureje River in Ado-Ekiti, Ekiti State, Nigeria. The sand met the requirements outlined in ASTM C136: (2019) standards. Potable water was used. It met the requirements outlined in C1602/C1602M (2012). The water was sourced from the borehole facility located at the laboratory of the Planning Department, Ministry of Works, in Ado Ekiti. Sawdust ash (SDA) was sourced from the saw mills in Ado-Ekiti, Nigeria. Sponge gourd ash (SGA) was sourced from various bushes. These bushes were located in Ekiti and Ondo States, Nigeria.

2.2 Preparation of Saw dust ash (SDA) and Sponge gourd ash (SGA)

2.2.1 Saw dust ash (SDA)

The sawdust was processed through a series of carefully controlled steps, including 72 hours of sun drying to reduce moisture content. Calcination at a precisely controlled temperature of 600°C for 2 hours adopted to enhance reactivity, and sieving

to a uniform particle size of 63µm, ultimately yielding a highly reactive, finely divided ash with optimal physical and chemical properties; characterized by improved surface area, reduced impurities, and enhanced pozzolanic activity.

2.2.2 Sponge gourd ash (SGA).

The sponge gourds underwent a rigorous multi-step processing protocol. This protocol involved sorting and cleaning to remove impurities. The gourds were then sun-dried to reduce moisture content. After drying, they were crushed to facilitate burning. The crushed gourds underwent subsequent combustion to produce ash. The resulting ash was then collected and sieved to remove coarse particles. The ash was then calcined at 600°C for 2 hours to enhance reactivity. It was then ground to improve fineness. Finally, the ash was sieved to a uniform particle size of 63µm. This yielded a highly reactive, finely divided Sponge Gourd Ash (SGA) with optimal physical and chemical properties.

2.2.3 Mix Design and Proportion of the ternary blends of SDA and SGA

From the available literature as reported by Afolabi, (2019), the optimum level of SDA substitution in concrete was found to be 15%. This value was used as the base value for SDA, and thus used as constant. The ternary blends were obtained by progressive substitution of the 15% SDA with SGA at interval of 2.5%. The adopted nomenclature is as presented in Table 2

Table 2: Nomenclature of the proposed mix proportion

Mix	Composition
C _T	Control ₁ (No SDA)
T ₀	Control ₂ (85% Cement + 15% SDA + 0% SGA)
T ₁	(85% Cement + 12.5% SDA + 2.5% SGA)
T ₂	(85% Cement + 10% SDA + 5.0% SGA)
T ₃	(85% Cement + 7.5% SDA + 7.5% SGA)
T ₄	(85% Cement + 5% SDA + 10% SGA)
T ₅	(85% Cement + 2.5% SDA + 12.5% SGA)

2.3 Experimental Investigation

2.3.1 Evaluation of Pozzolanic Properties

The pozzolanic properties of sawdust ash (SDA) and sponge gourd ash (SGA) were evaluated according to ASTM C 618-19 (2019). This evaluation involved determining the chemical composition, loss on ignition, and pozzolanic activity index of the ashes.

The goal was to assess their ability to react with calcium hydroxide and form cementitious compounds, and to classify them appropriately. This included tests such as Autoclave expansion

test, Blaine air permeability test and Vicat needle test. These tests ensured that the ashes met the required standards for use as supplementary cementitious materials in concrete.

2.3.4 Determination of the effects of Ternary Blends of SDA and SGA on Fineness of Mortar

The effects of ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) on the fineness of concrete were evaluated. This was done using the Blaine air permeability test, according to BS 8500-2:2015+A1:2016 and ASTM C204-23 (2023). The

test involves measuring the rate of airflow through a compacted bed of cementitious material. This includes the ternary blends of SDA and SGA. The test determines the specific surface area of the material. It also assesses the fineness and particle size distribution of the ternary blends. The Blaine fineness value is determined through this test.

2.3.5 Determination of the effects of Ternary Blends of SDA and SGA on Soundness of Mortar

The effects of ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) on the soundness of concrete were investigated by using the autoclave expansion test method, according to ASTM C 151-18 (ASTM, 2018) and BS 8500-1:2015+A2 (2019). The test involves exposing mortar bars containing the ternary blends to high-pressure steam in an autoclave. The expansion of the mortar bars is then measured. This assesses the potential for deleterious expansion due to reactive minerals or other components in the ternary blends. The autoclave expansion value is determined through this test. This value measures the potential for soundness problems in the concrete.

2.3.6 Determination of the effects of Ternary Blends of SDA and SGA on Consistency of Paste

The effects of ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) on the consistency of concrete were evaluated. This was done using the Vicat needle test method,

according to BS EN 196-3:2016. The test involves measuring the time it takes for a Vicat needle to penetrate a certain distance into a mortar specimen. The specimen contains the ternary blends. The test assesses the consistency and workability of the concrete. It determines the initial and final setting times, and measures the needle penetration depth. It determines the optimal dosage of SDA and SGA for achieving the desired consistency and workability.

2.3.7 Determination of the effects of Ternary Blends of SDA and SGA on Setting Times of Paste

The effects of ternary blends of sawdust ash (SDA) and sponge gourd ash (SGA) on the setting times of concrete were evaluated. This was done using the Vicat needle test method, according to BS EN 196-3:2016. The test involves measuring the time it takes for a Vicat needle to penetrate a certain distance into a mortar specimen. The specimen contains the ternary blends. The test determines the initial and final setting times of the concrete. This includes measuring the time for the needle to penetrate 25mm and 10mm into the mortar specimen. The test assesses the effects of the ternary blends on the hydration kinetics and setting behavior of the concrete. It also evaluates the potential for the ternary blends to influence the construction schedule and early-age properties of the concrete.

2.3.8 Microstructural Investigation of SDA and SGA

The microstructure of Sawdust ash (SDA) and Sponge gourd ash (SGA) was investigated. This was done using Scanning Electron Microscopy (SEM) machine model Phenom ProX, by phenom World Eindhoven, shown in Fig. 2.



Fig. 2: Scanning Electron Microscopy Machine

X-Ray Diffraction (XRD), shown in Fig. 3 was also used to determine the mineralogical composition. The

analyzed material was finely ground, homogenized, and average bulk composition is determined.



Fig. 3: X-Ray Diffraction Machine

The powdered sample was then prepared using the sample preparation block and compressed in the flat sample holder to create a flat, smooth surface that was later mounted on the sample stage in the XRD cabinet. The sample was analyzed using the reflection-transmission spinner stage using the Theta-Theta settings. Two-Theta starting position was 4 degrees and ends at 75 degrees with a two-theta step of 0.026261 at 8.67 seconds per step. Tube current was 40mA and the tension was 45VA. A Programmable Divergent Slit was used with a 5mm Width Mask and the Gonio Scan was used. The intensity of diffracted X-rays is continuously recorded as the sample and detector rotate through their respective angles. The goal was to gain a

comprehensive understanding of the physical and chemical properties of SDA and SGA.

III. RESULT AND DISCUSSION

3.1 Evaluation of Pozzolanic Properties

The results of investigation conducted to evaluate the pozzolanic potentials of sawdust ash (SDA) and sponge gourd ash (SGA) are presented in Tables 3 and 4. From Table 3, it can be seen that The results indicate that SDA and SGA have high silica and alumina contents, low loss on ignition and high pozzolanic activity.

Table 3: Chemical Properties of Sawdust ash (SDA) and Sponge gourd ash (SGA)

S/No	Formula	Composition of SDA (%)	Composition of SGA (%)
1	CaO	13.9	10.94
2	SiO ₂	62.90	63.70
3	Al ₂ O ₃	15.15	10.34
4	Fe ₂ O ₃	8.7	0.31
5	Mn ₂ O ₃	1.06	0.06
6	MgO	2.07	1.20
7	K ₂ O	1.07	0.90
8	Na ₂ O	0.22	0.17
9	SO ₃	1.92	0.92
10	MC	0.62	0.32
11	CO ₂	1.17	0.05
12	P ₂ O ₅	1.84	1.48
13	TiO ₂	0.84	0.04
14	LOI	9.42	9.86
15	RI	0.62	0.92

From Table 3, it can be seen that the combined total of SiO₂+Al₂O₃+Fe₂O₃ exceeded 70% for both

the SDA (86.75%) and SGA (74.35%). The basis of classification, according to ASTM-C618 (2019) is

presented in Table 4. It is obvious from the Table 4 that

both SDA and SGA met the requirements for classification as reactive pozzolans.

Table 4: Pozzolanic Properties of produced SDA and SGA with ASTM (C 618-2019)

Chemical Requirement	ASTM CLASS			SDA	SGA
	N	F	C		
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃ , Min., %	70	70	70	86.75	74.35
SO ₃ , Max, %	4.0	5.0	5.0	1.92	0.92
Moisture content, Max. %	3.0	3.0	3.0	0.62	0.32
Loss on ignition, Max %	10.0	6.0	6.0	9.42	9.86
Alkali content (Na ₂ O), Max., %	1.5	1.5	1.5	1.29	1.07

3.3 Effect of ternary blends of SDA and SGA on the Fineness Mortar

Table 4 presents the effects of ternary blends of Sawdust Ash (SDA) and Sponge Gourd Ash (SGA) on the fineness of the resulting mix. The results are compared to the control mix (pure cement).The results show a consistent increase in fineness with the addition of SGA in the ternary blends of SDA and SGA. The highest fineness

value was achieved with the 2.5% SDA + 12.5% SGA + OPC mix. This increased fineness can enhance the packing density of the mix, affects hydration rate, workability, strength development, durability, bleeding, and segregation. This leads to improved workability and strength. The structural implications of this includes enhanced workability, increased strength and reduced permeability. These findings are supported by Ayuba *et al* (2022).

Table 4: Nomenclature of the effects of Ternary blends of SDA and SGA on Fineness

Mix	Composition		Fineness (m ² /kg)
C _T	Control	Control ₁ (No SDA)	9.06
T ₀	B _{0SGA}	Control ₂ (85% Cement + 15% SDA + 0% SGA)	262.56
T ₁	T _{2.5SGA}	(85% Cement + 12. 5% SDA + 2.5% SGA)	295.44
T ₂	T _{5.0SGA}	(85% Cement + 10% SDA + 5.0% SGA)	328.31
T ₃	T _{7.5 SGA}	(85% Cement + 7.5% SDA + 7.5% SGA)	361.19
T ₄	T _{10SGA}	(85% Cement + 5% SDA + 10% SGA)	394.06
T ₅	T _{12.5 SGA}	(85% Cement + 2.5% SDA + 12.5% SGA)	426.94

3.4 Effect of ternary blends of SDA and SGA on the Soundness of Mortar

Table 5 presents the effects of ternary blends of Sawdust Ash (SDA) and Sponge Gourd Ash (SGA) on the soundness of the resulting mix.

Table 5: Nomenclature of the effects of Ternary blends of SDA and SGA on Soundness

Mix	Composition		Soundness(mm)
C _T	Control	Control ₁ (No SDA)	5.90
T ₀	B _{0SGA}	Control ₂ (85% Cement + 15% SDA + 0% SGA)	5.50
T ₁	T _{2.5SGA}	(85% Cement + 12. 5% SDA + 2.5% SGA)	5.30
T ₂	T _{5.0SGA}	(85% Cement + 10% SDA + 5.0% SGA)	5.10
T ₃	T _{7.5 SGA}	(85% Cement + 7.5% SDA + 7.5% SGA)	4.90
T ₄	T _{10SGA}	(85% Cement + 5% SDA + 10% SGA)	4.70
T ₅	T _{12.5 SGA}	(85% Cement + 2.5% SDA + 12.5% SGA)	4.50

The results are compared to the control mix (pure cement).The results show a consistent decrease in soundness with the addition of SGA in the ternary blends of SDA and SGA. The lowest soundness value was achieved with the 2.5% SDA + 12.5% SGA + OPC mix. Concrete with reduced soundness is more prone to cracking, disintegration, and decreased durability due to compromised volume stability, durability, and strength. This importance of soundness is highlighted by Kabir, *et al* (2020), which specifies a maximum soundness limit of 0.8% expansion (or 10mm for pozzolanic materials) to ensure the material's durability and performance.

3.5 Effect of ternary blends of SDA and SGA on the Consistency Paste

Table 6 presents the effects of ternary blends of Sawdust Ash (SDA) and Sponge Gourd Ash (SGA) on the consistency of the resulting paste.

Table 6: Nomenclature of the effects of Ternary blends of SDA and SGA on Consistency on Paste

Mix	Composition	Consistency on Paste
C _T Control	Control ₁ (No SDA)	28.1
T ₀ B _{0SGA}	Control ₂ (85% Cement + 15% SDA + 0% SGA)	27.5
T ₁ T _{2.5SGA}	(85% Cement + 12. 5% SDA + 2.5% SGA)	27.2
T ₂ T _{5.0SGA}	(85% Cement + 10% SDA + 5.0% SGA)	26.9
T ₃ T _{7.5 SGA}	(85% Cement + 7.5% SDA + 7.5% SGA)	26.6
T ₄ T _{10SGA}	(85% Cement + 5% SDA + 10% SGA)	26.3
T ₅ T _{12.5 SGA}	(85% Cement + 2.5% SDA + 12.5% SGA)	26.0

The results are compared to the control paste (pure cement).The results show a consistent decrease in consistency with the addition of SDA and SGA. The incorporation of supplementary cementitious materials (SCMs), such as SDA and SGA, significantly affects the consistency of blended cement paste. Among the tested mixes, the combination containing 2.5% SDA and 12.5% SGA with ordinary Portland cement (OPC) demonstrated the lowest consistency value. This reduction in consistency may enhance the workability and flowability of the ternary blended paste. However, achieving optimal concrete performance requires a careful balance of various

properties, including strength, durability, shrinkage, and air content. As noted by Ayuba et al. (2022), maintaining optimal consistency is critical for producing high-quality concrete. Therefore, meticulous attention to mix design and the proportioning of constituent materials is essential to achieve the desired properties and ensure overall performance in concrete applications

3.6 Effect of ternary blends of SDA and SGA on the Setting Times of paste

Table 7 presents the effects of ternary blends of Sawdust Ash (SDA) and Sponge Gourd Ash (SGA) on the setting times of the resulting mix.

Table 7: Nomenclature of the effects of Ternary blends of SDA and SGA on Setting time

Mix	Composition	Initial setting times	Final setting times
C _T Control	Control ₁ (No SDA)	98	216
T ₀ B _{0SGA}	Control ₂ (85% Cement + 15% SDA + 0% SGA)	93	206
T ₁ T _{2.5SGA}	(85% Cement + 12. 5% SDA + 2.5% SGA)	90	203
T ₂ T _{5.0SGA}	(85% Cement + 10% SDA + 5.0% SGA)	88	201
T ₃ T _{7.5 SGA}	(85% Cement + 7.5% SDA + 7.5% SGA)	85	198
T ₄ T _{10SGA}	(85% Cement + 5% SDA + 10% SGA)	83	196
T ₅ T _{12.5 SGA}	(85% Cement + 2.5% SDA + 12.5% SGA)	80	194

From Table 7, it can be observed that decrease in both initial and final setting times were recorded with the addition of SGA in the ternary blends of SDA and SGA. This decrease in setting times indicates accelerated hydration and improved early-age strength development in the ternary blended concrete. This demonstrates the potential of ternary blends to enhance the early-age properties of concrete, such as strength and durability. It also improves constructability and

reduces construction timelines. However, reduction in setting times mean that the risk or reduced workability exists if the concrete is to use at a long distance from the place of production.

3.7 Microstructure Investigation

3.7.1 X-Ray Diffraction (XRD) Analysis of SDA

The mineralogical composition through XRD of SDA is shown in Fig. 4

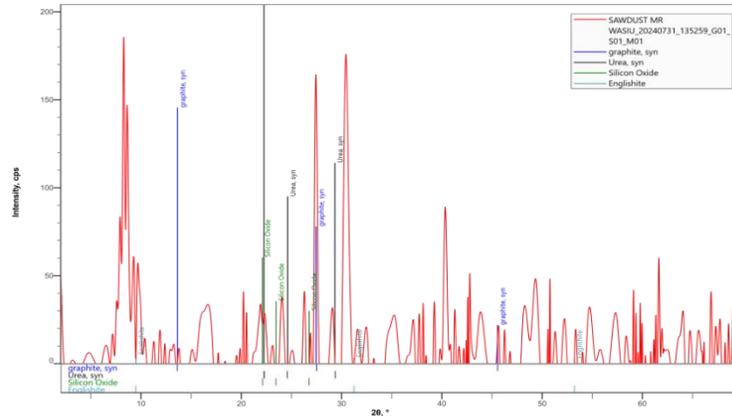


Fig. 4: Fig. showing X-Ray Diffraction (XRD) Analysis of Sawdust Ash

The XRD pattern of SDA (Fig. 4) reveals a mineralogical composition dominated by Graphite (46%), Urea (33%), Silicon Dioxide (16%), and Englishite (5%). Graphite improves workability and air-entrainment but reduces strength. Urea accelerates setting time but reduces strength and

durability. Silicon dioxide increases strength and durability but reduces workability. Englishite (a rare phosphate mineral; its presence in concrete suggests phosphate-rich or waste materials were used, impacting strength and durability) may improve strength and durability but its effects are

uncertain as reported by Al-Bayati, *et al* (2020). This composition suggests that SDA can enhance concrete's thermal conductivity acted upon by Fayissa, *et al* (2020) and Tlegenov, *et al* (2024), and mechanical properties accomplished by Ahmed, (2024), Majeed, (2024) and (Osuya, & Mohammed, (2017)). As a supplementary cementitious material, SDA offers a sustainable alternative to silica fume and fly ash, reducing greenhouse gas emissions and conserving natural resources completed by Bendezu Romero, *et al* (2024) and Jhatial, *et al* (2023).

The results of mineralogical composition SGA through XRD is shown in Fig. 5

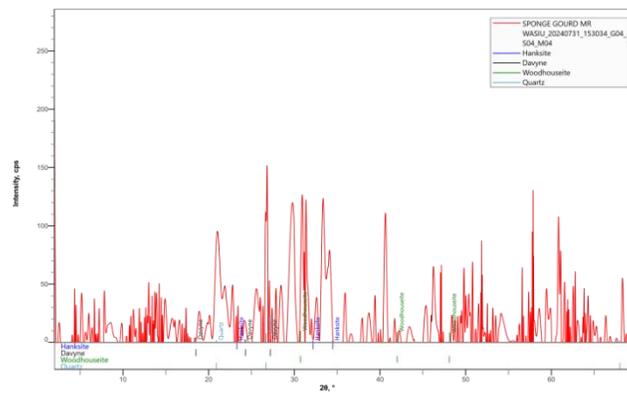


Fig. 5: Fig. showing X-Ray Diffraction (XRD) Analysis of Sponge gourd Ash

The XRD pattern of SGA, as shown in Fig. 5, reveals a mineralogical composition primarily consisting of Quartz (SiO₂) (40%), Hanksite (Na₂₂ K Cl (CO₃)₂ (SO₄)₉) (25%), Davyne (K₂ Na₄ Ca₂ Al₆ Si₆ O₂₄ Cl₂) (20%), and Woodhouseite (Ca Al₃ (PO₄) (SO₄) (OH)) (15%). The presence of Quartz (SiO₂), Hanksite (Na₂₂ K Cl (CO₃)₂ (SO₄)₉), Davyne (K₂ Na₄ Ca₂ Al₆ Si₆ O₂₄ Cl₂), and Woodhouseite in concrete can have varying effects, including improved mechanical properties from Quartz, potential sulfate attack and alkali-silica reaction (ASR)

from Hanksite and Davyne, and uncertain influences from Woodhouseite, highlighting the need for careful consideration of mineralogical composition in concrete mix design. These minerals contribute to the ash's pozzolanic activity, potentially enhancing concrete's mechanical properties as demonstrated by Ogunyemi, *et al* (2020). The sponge gourd ash's mineralogical composition suggests its suitability as a supplementary cementitious material. It offers a sustainable alternative to traditional materials, with benefits including reduced greenhouse gas emissions and conserved natural resources, enacted by Jhatial, *et al* (2023).

3.7.2 Scanning Electron Microscopy (SEM)

The results of morphological structure of SDA and SGA are shown in the micrographs in Figs 6 - 9

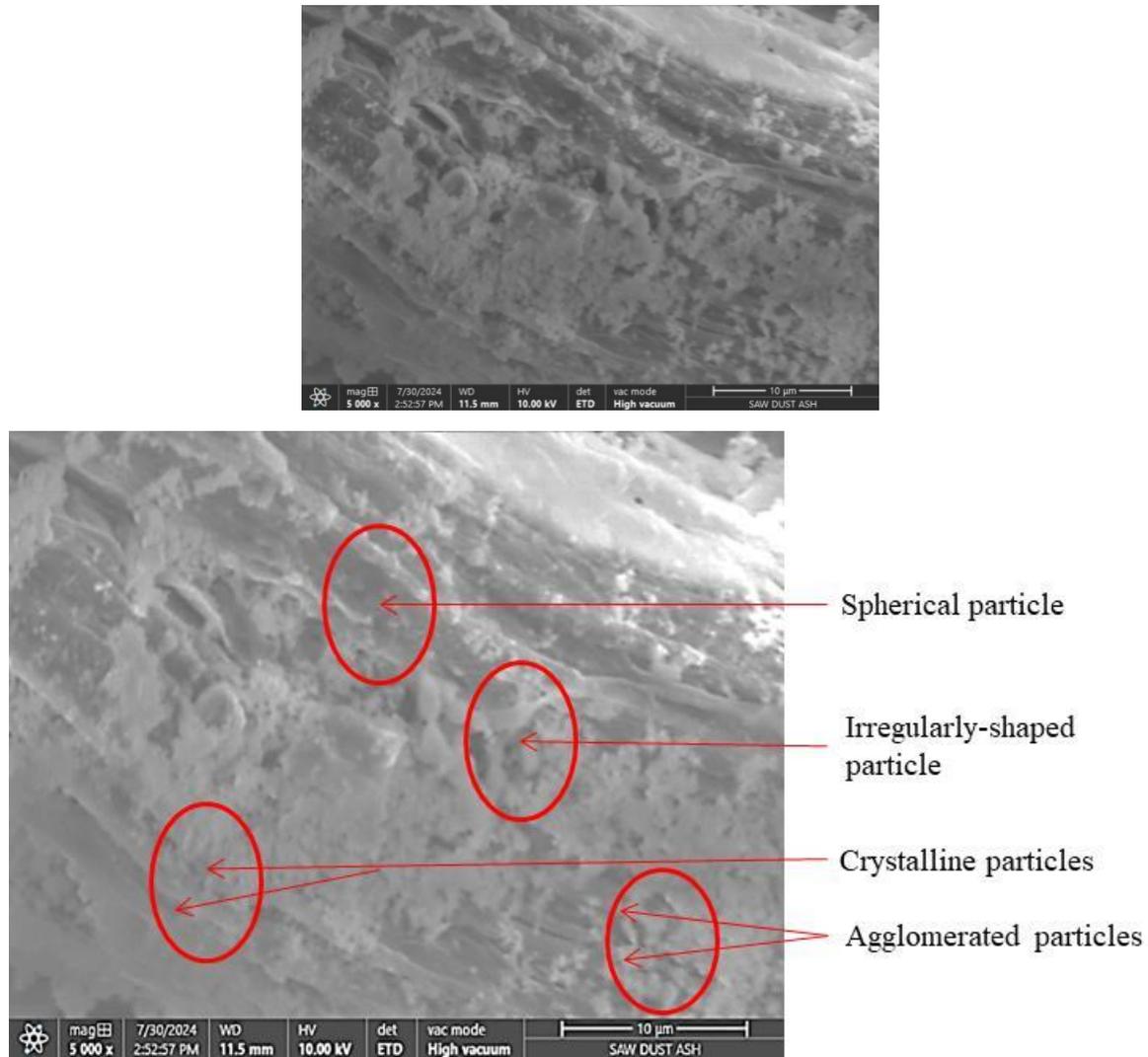


Fig. 6: Fig. showing SEM results for SDA (10 μm)

The Scanning Electron Microscopy (SEM) image of sawdust ash (Fig. 6) at 10 μm resolution reveals a detailed morphology featuring spherical particles (~1-5 μm), irregularly shaped particles with rough textures, crystalline structures, and agglomerated smaller particles. This morphology

suggests enhanced pozzolanic activity due to increased specific surface area, potentially improving concrete strength and durability, performed by Guhl, *et al* (2020). The micrographs at 100 micro is shown in Fig. 7.

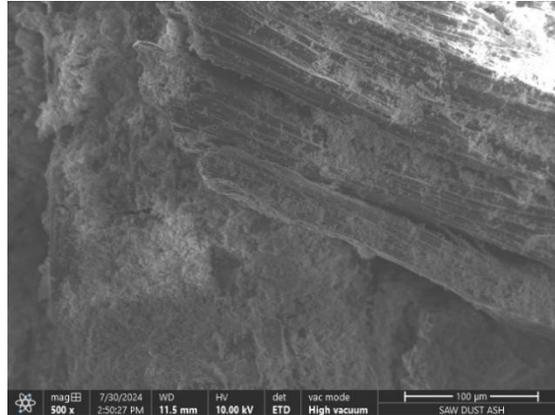


Fig. 7: Fig. showing SEM results for SDA (100 μm)

The Scanning Electron Microscopy (SEM) image of sawdust ash (Fig. 7) at 100 μm resolution reveals irregularly shaped particles with varying sizes and morphologies, indicating high surface roughness and irregularity. The image also shows porous and rough surface textures, agglomeration of smaller particles, and spherical particles,

suggesting improved flowability and workability. This morphology indicates enhanced pozzolanic activity, potentially improving concrete strength and durability, realized by Tunell, *et al* (2023).

The SEM micrographs for SGA at 10 and 100 micro is shown in Figs 8 and 9.

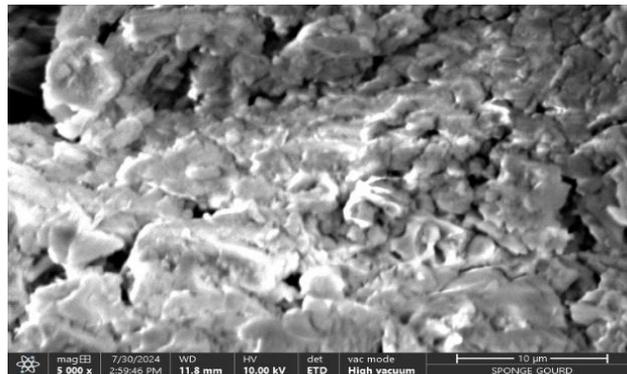


Fig. 8: Fig. showing SEM results for SGA (10μm)

From Fig. 8, it can be observed that SEM image of sponge gourd ash at 10 μm resolution reveals irregularly shaped, porous particles with rough textures, indicating high surface roughness and

irregularity. Varied particle sizes (10-20 μm to 100 μm) and high surface area suggest improved concrete performance and enhanced pozzolanic activity, accomplished by Guhl, *et al* (2020).

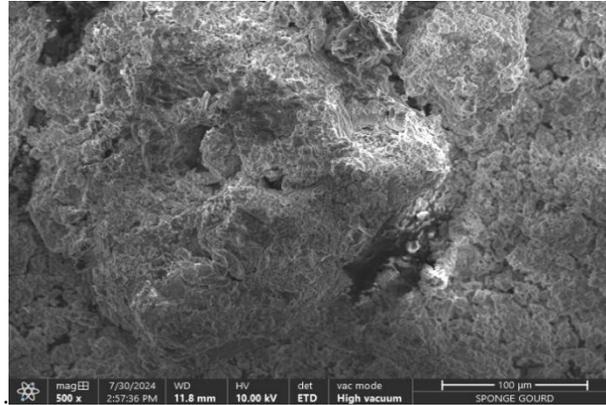


Fig. 9: Fig. showing SEM results for SGA 100 micro

However, at 100 μm at resolution, SEM image of sponge gourd ash (Fig. 9) reveals porous, irregular particles (10-100 μm) with rough, textured surfaces and visible pores. The agglomeration of particles and high specific surface area suggest enhanced pozzolanic activity and reactivity (Fadhil, *et al.*, 2019).

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusions

From the results of this investigation, the following conclusions are made.

- i. The fineness of the ternary blends of SDA and SGA increased with addition of SGA from 262.56 to 459.81 m^2/kg .
- ii. The soundness of the ternary blends of SDA and SGA decreased with addition of SGA from 5.90 mm to 4.50 mm
- iii. The consistency of the ternary blends of SDA and SGA decreased with addition of SGA from 28.1 to 26.0 mm.
- iv. The setting times of the ternary blends of SDA and SGA decreased with addition of SGA from 98/216 to 80/194 minutes,
- v. The SEM of SDA ranges from 0.1 μm to 100 μm and for SGA ranges from 10 to 100 μm
- vi. The result for the XRF indicates that SDA and SGA have high silica and alumina content,

4.2 Recommendations

The present work dealt with limited parameters. There are still other properties that are necessary to be investigated for full capture of structural responses of the ternary blends of SDA and SGA in structural concrete. These properties include compressive strength, tensile strength,

durability properties, bending performance, and many more. These are recommended for further investigation.

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