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Original Article

Physicochemical Characterization of Carbide Ash Wastes Collected from Ikorodu and Ajegunle Local Automobile Mechanic Workshops in Lagos State

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Abstract - *Some local government areas in Lagos State, Nigeria, revealed that the careless disposal of Carbide Ash Waste (CAW) produced by the local auto industry has raised serious environmental concerns because it has an impact on nearby humans and ecosystems. Examining and evaluating the wastes made of calcium carbide ash is the goal of this. Fourier transform infrared (FTIR) spectroscopy, Thermogravimetric Analysis (TGA), scanning electron microscopy (SEM), X-ray fluorescence (XRF), and X-ray Diffraction (XRD) were used to characterize the samples. Three distinct mineral phases (Portlandite, Portlandite Calcite, and Calcite) were identified by X-ray Diffraction (XRD) results for the carbide ash wastes from Ajegunle (CAW2) and Ikorodu (CAW1), measuring 0.3 nm and 0.2 nm, respectively. The elemental composition of calcium oxide (CaO), which ranges from 91.62% to 91.78%, was determined by XRF analysis to be the main metal oxide component in both CAW samples. In contrast, silicon oxide was found to be between 5.20% and 5.24% and aluminum oxide to be between 2.04% and 2.2%. All of the samples' IR spectrum absorption peaks pointed to CaO bond stretching. The carbide ash samples CAW1 and CAW2's SEM morphological characteristics showed irregular particle sizes and shapes with agglomeration. The broad band at ranges of 3534.6 - 2713.5 cm-1 for O-H, 2064.9 - 1587.9 cm-1, 1174.1 - 1047.4 cm-1, and 846.1 - 723.1 cm-1 for C=O, C-O, and CaO, respectively, was found in the FTIR analysis of the CAW samples. Both CAW samples exhibit high thermal stability. \ In conclusion, the CAW samples have a high quantity of CaO, which also adds to its high pozzolanic properties. It can be used as a substitute material in cement production.*

Keywords - *Automobile workshop, Carbide ash Waste, Disposal, Characterization.*

1. Introduction

Carbide Ash Waste (CAW) is a byproduct of acetylene gas (C2H2) production from the hydrolysis of calcium carbide (CaC2) [1]. Calcium carbides (CaC2) is a binary compound composed of carbon, which acts as an electronegative element and calcium acting as the electropositive element. CAW is an aqueous slurry composed of calcium hydroxide [$Ca(OH)_2$] with little amounts of calcium carbonate ($CaCO_3$), silica oxide (SiO_2), unreacted carbon with other metal oxides and during the process of acetylene gas production [2]. Different carbides have different uses; tungsten carbide is used in machine tooling [3] and [4], while silicon carbide is used as a diode [5]. These carbides are categorized as follows: carbides that resemble salt, covalent carbides, interstitial carbides, and carbides made of intermediate transition metals [6]; [7]. The chemical industry uses salt-like carbide, which has numerous industrial applications as feedstock. When calcium carbide and water react, acetylene gas is created. Acetylene is then used in oxygen-acetylene welding, which produces CAW as a byproduct [8]; [9]. The carbide lime is incredibly finely ground and has a greyish color.

$$CaC_2\,(s) + 2H_2O\,(l) \longrightarrow Ca(OH)_2\,(s) + C_2H_2\,(g) \quad (1)$$

The CAW generated is usually disposed of by landfilling, which may eventually create problems of leaching harmful compounds like alkali to the groundwater with a change in the physicochemical properties. Agricultural and industrial wastes generated are best used as alternative materials in the construction industries as pozzolanas in order to replace cement as additives in concrete or mineral admixtures [10]. Recycling of carbide lime waste can be favourable due to its physical and chemical properties, which can be reused for different purposes such as industrial processes, mining activities, sewage treatment plants, agriculture, construction, plastics industries, textile industries, and water treatment plants. The use of these wastes can significantly reduce the environmental impact of waste disposal. Acetylene is used to speed up the ripening of fruit just as ethylene is used [11]; [12]. Concrete is made by the use of the cementing medium, by the reaction between hydrated cement and water. Ndububa & Omeiza, 11] investigated the effect of CAW as a partial replacement of cement in concrete. Ndububa and Omeiza [11] investigated the properties of the compressive strength and flexural strength of CAW, consistency, setting times and specific gravity of cement replacement levels of 5%, 10%, 15%, 20% and 25% by weight compared with plain concrete (0% CAW) as control. The CaO estimated by Wang and Handy [13] was detected to be 72%. In a similar research conducted by Sun *et al*. [14], their outcome shows 92% calcium hydroxide, 2.9% calcium carbonate, 1.32% silica, 0.94 % ferric oxide and 0.06% alumina [15]. The high content of calcium hydroxide in CAW indicates it can react with pozzolanic material to produce a cementitious material [16]. The purpose of CAW is to help improve the soil's physical and mechanical qualities by compaction or mechanical stabilization with the addition of stabilizers or admixtures of calcium hydroxide [17]; [18]; [1]. A huge amount of acetylene was used as industrial fuel in China, and it is cheaper to make and use domestically than to import petroleum gas for the same purpose. The majority of the time, the generated CAW is disposed of by landfilling, which can lead to additional issues with dangerous compounds leaching into groundwater rainfall water runoff. The best substitute materials for cement in the construction industry are agricultural and industrial wastes used as pozzolanas, which are used to replace cement in mineral admixtures or concrete additives [10]. Similar to how ethylene is used, acetylene can also be used to accelerate fruit ripening [11]; [12]. A cement medium was created by reacting hydrated cement and water to make a block of concrete. A study was conducted by Ndububa and Omeiza [11] to examine the impact of using cement substitutes (CAW) in concrete. Ndububa and Omeiza [11] investigated the specific gravity, consistency, setting times, and compressive and flexural strengths of CAW at replacement with different mixtures at 5%, 10%, 15%, 20%, and 25% by weight. They compared the results to plain concrete (0% CAW) as the control. It was found that the CaO, as calculated by Wang and Handy [13], was 72%. Sun et al. [14] found out that 92% of the sample contained calcium hydroxide, 2.9% calcium carbonate, 1.32% silica, 0.94% ferric oxide, and 0.06% alumina [15]. The high calcium hydroxide content of CAW suggested that it can react with pozzolanic material to form a cementitious material [16]. The use of techniques like compaction, mechanical stabilization, and the addition of stabilizers or calcium hydroxide admixtures, and soil stabilization was to enhance the soil's mechanical and physical properties [17]; [18] and [1]. China uses massive amounts of acetylene gas as industrial fuel since it is less expensive to produce and use locally than to import petroleum products for the same purpose. A number of parameters, including specific gravity, loss on ignition, silica, alumina, iron, calcium, magnesium, chloride, carbon, and sulphate, were reported in earlier studies about the characteristics of CAW [11]; [13]. Waste carbide ash was examined to assess the level of suitability as an additive or replacement to Ordinary Portland Cement (OPC) for mortar production [13]. The parameters that were investigated in order to determine the properties of CAW based on the process of making concrete are specific gravity, consistency and setting times, compressive strength, flexural strength, density test, workability, and moisture content [11]. It was concluded, that CAW is an industrial waste when disposed in an indiscriminate way to pollute the environment. They can be recycled or transformed into a valuable and significant building material, lowering the cost of producing concrete, without sacrificing strength. The main material used in the construction industry is concrete is produced by reacting hydrated cement with water [19]; [20]. Ihejirika et al. [21] examined how waste dumpsites for calcium carbide affected the quality of the soil. The CAW is an environmental pollutant, but it can be recycled or converted into a valuable building material without sacrificing strength, according to Ndububa and Omeiza [11]. This lowers the cost of producing concrete. Brick production for construction is one of the industrial uses of CAW. Agbede & Joel et al., [22], stabilization of soil microbes to prevent groundwater pollution according to research by Ihejirika et al. [21], the full and partial substitute for OPC in the production of concrete materials as demonstrated in the work of Sun et al. 2015[14]. This study aims to characterize CAW samples that may be used to make cement for a variety of applications. The research gap in this study is that previously, most of the local automobile industries in Lagos State usually disposed of their wastes indiscriminately without any consideration for environmental pollution. Presently, the industries are being checkmated by enforcing environmental compliance using law enforcement agents to arrest offenders and prosecute offenders who are sentenced to jail or pay fines for non-compliance.

2. Materials and Methods

2.1. Study Area

Ajegunle is a town located in Lagos State, Nigeria, in the Ajeromi-Ifelodun Local Government Area. Ajeromi Local Government Area and Amuwo Odofin Local Government Areas were the two Local Government areas carved out from Ojo Local Government Area in 1996. Known as "AJ City" to the general public, Ajegunle is a slum or ghetto area located in Southwest Nigeria, home which accommodated an estimated 2,000,346 people. It has a population of 57,276.3 people per square kilometer, and it is one of the most densely populated towns in the world. Approximately 550,000 people from various ethnic groups in Nigeria live in Ajegunle. This coordinate—6.4540° N, 3.3553° E, indicating where it is situated. Ikorodu has borders with Ogun State, and it is situated northeast of Lagos State along the Lagos Lagoon. Ikorodu Town is situated at coordinates 6.6194° N, 3.5105° E, close to the Lagos Lagoon. Ikorodu's population was estimated at 1,724,040 by the 2023 census.

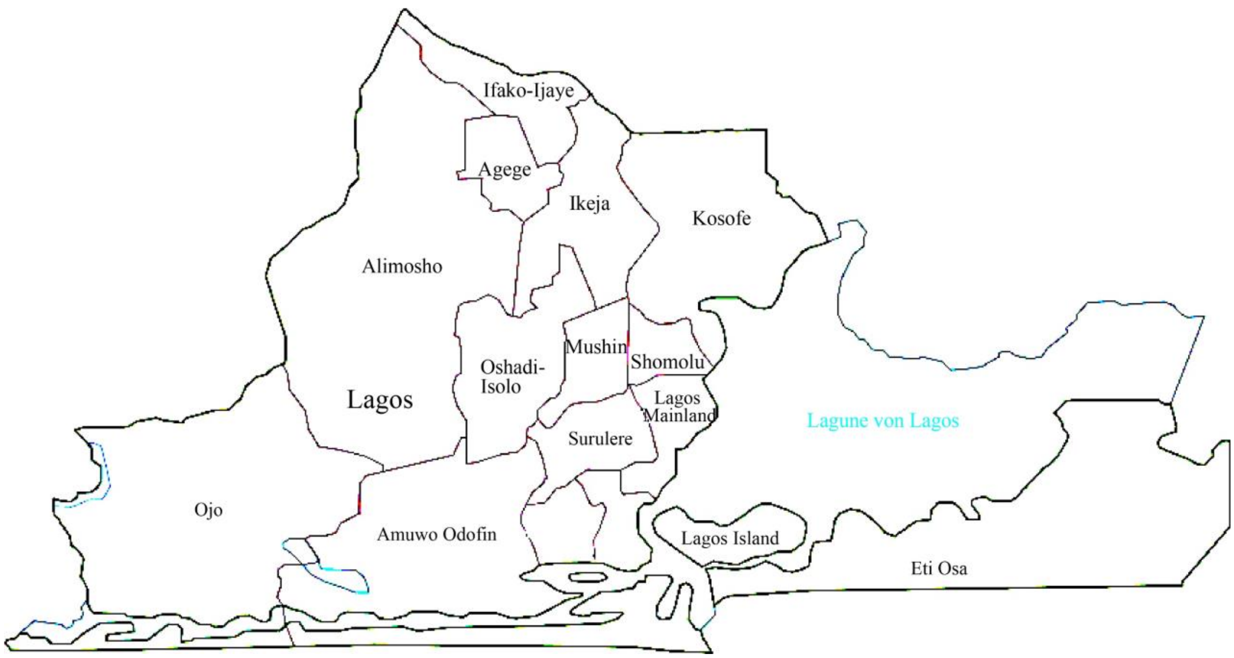


Fig. 1 Location of Ikorodu and Ajegunle areas in Lagos State

2.2. Sample Collection

Samples of carbide ash wastes were gathered from two distinct sites, specifically local government districts, in the Lagos State of Nigeria. Sample 2 was collected from Ajegunle town, while Sample 1 was gathered from an auto mechanic workshop in Ikorodu town. The availability of Carbide Ash Waste (CAW) and the ease of access to the dumpsites determined the sample collection strategy. Figure 1 shows the locations of the sample collection sites.

2.3. Sample Preparation

Samples of Carbide Ash Waste (CAW) were taken from neighborhood auto repair shops in Ikorodu and Ajegunle, in the local government areas of Ikorodu and Ifelodun-Ajeromi, respectively, and sun-dried for a week. The carbide ash samples were grinded to a fine powder with a mortar and pestle, and the resulting fine-sized aggregate particles were then sieved.

2.4. Characterization

A Bruker D8 Advance x-ray diffractometer with Cu Kα radiation (45kV, 40mA, λ = 1.542Å) was used, and the mineral phases found in the CAW particles were independently identified through X-ray powder Diffraction (XRD). A scan was carried out between 10° and 80° (2θ). Scherer's equation was used to calculate the particle size of CAW. The elemental composition of major oxides in CAW samples was determined using the X-ray fluorescence (XRF) technique, with the aid of a Phillips PW 1480 X-ray spectrometer instrument set at 40 kV and 50 mA tube operating conditions necessary for sample analysis. Using the HITACHI S-4700 electron microscope, High-Resolution Scanning Electron Microscopy (HRSEM) was utilized to assess the morphology of the CAW samples. The Nicolet Magna-IR Spectrometer model 550 was used to measure the FTIR spectra of the CAW samples. The sample's FTIR was measured using a Thermo-Nicolet Avatar 370 model FTIR, within the range of 4000–400 cm^{-1}.

3. Results and Discussion

3.1. Moisture

Ajegunle had 5.83% moisture content, and Ikorodu had 1.05%, according to Figure 2 presentation of the CAW samples' moisture content. It suggests that the Ajegunle ash sample had a higher moisture content than the Ikorodu ash sample. The environment's weather at the time the samples were taken may be to blame for this.

3.2. Characterization

3.2.1. XRD

Calcite (C), Portlandite (PD), and Portlandite Calcite (PDC) are the three main mineral phases identified in the carbide ash waste samples from Ikorodu and Ajegunle, and the results of XRD spectra are presented in Figure 3. The principal constituents of carbide ash wastes are calcite ($Ca_6C_6O_{18}$) and Portlandite ($Ca(OH)_2$). The results of the CAW mineral phase show spectra that are comparable to those published by Cardoso et al. [2] (Cardoso et al., 2009)[2]. Using Scherer's equation, the particle sizes of the CAW samples were determined to be 0.3 nm for CAW 1 and 0.2 nm for CAW 2, respectively.

3.2.2. SEM

Figure 4 displays the results of the SEM images of CAW 1 and CAW 2 at magnifications of approximately x1500. The carbide ash samples' morphology showed big, rough particles in a range of sizes. The images showed some agglomeration brought on by the trapped carbon dioxide and moisture. Figure 4's SEM images demonstrate that the dry CAW 1 and CAW 2 particles are composed of irregularly stacked small particles, with the aggregates' surface revealing irregularly shaped and textured particles. The samples are a coarse agglomerate of CAW, and the SEM-EDS morphology showed the presence of Ca, C, and O elements. In these regions, the EDS spectrograms show calcium carbonate. Clusters formed by aggregates of the predominant calcium hydroxide crystals during observations were visible in the SEM images.

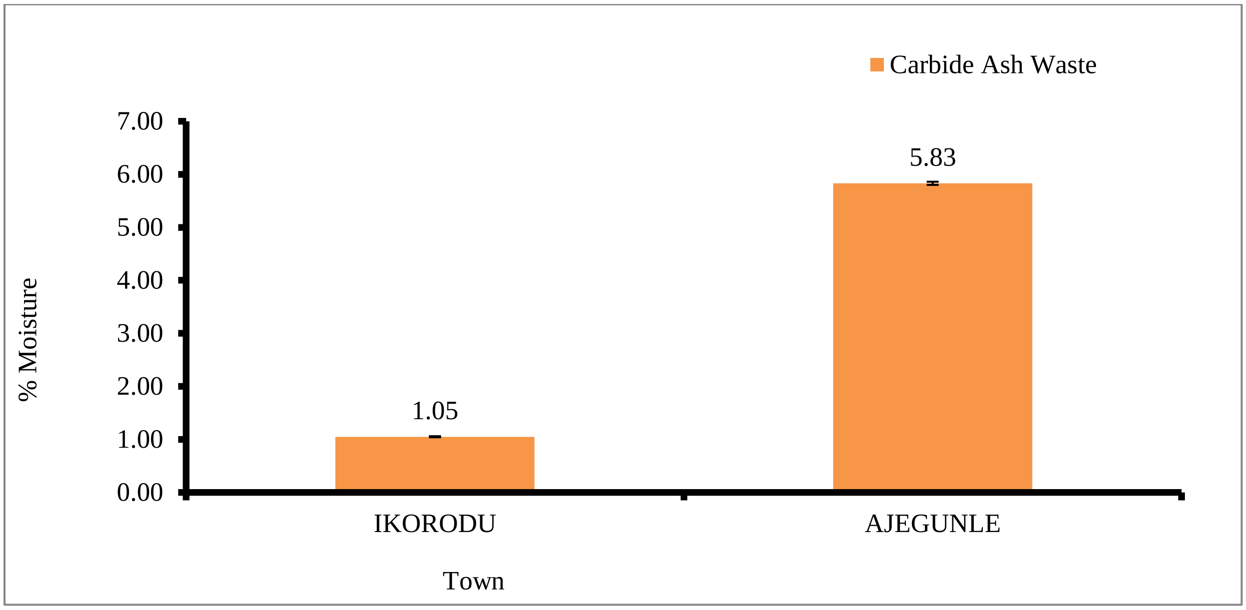
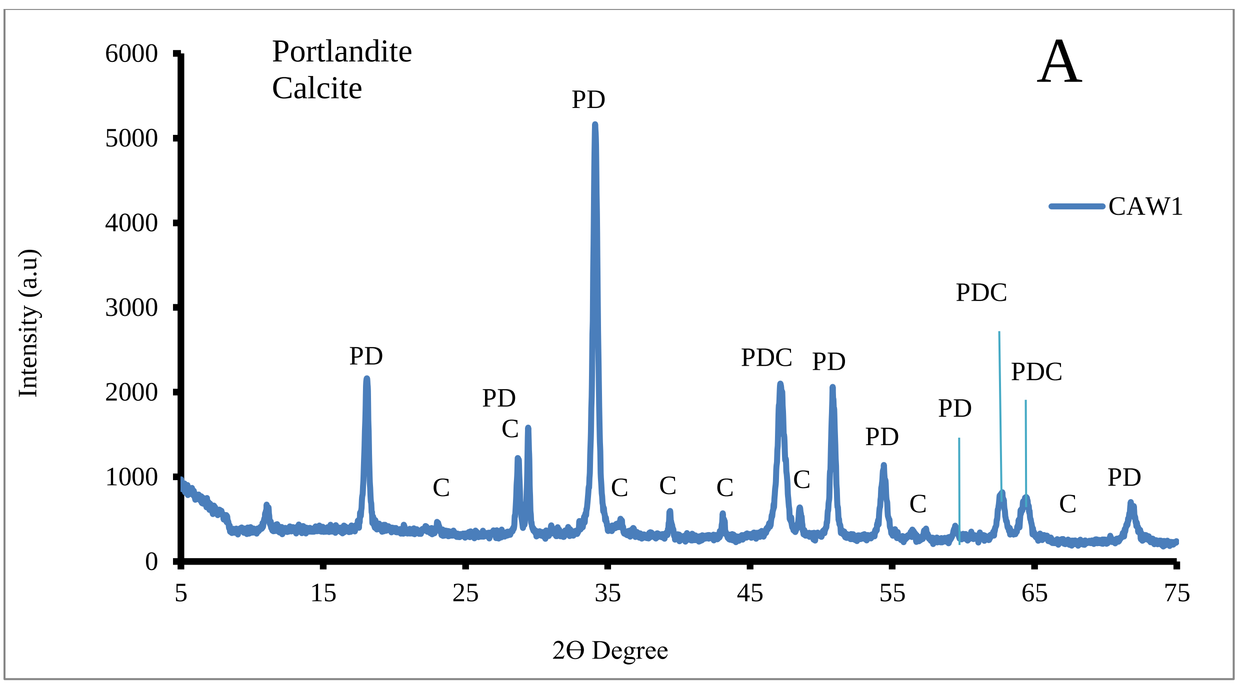


Fig. 2 Moisture contents of CAW samples from Ikorodu and Ajegunle area



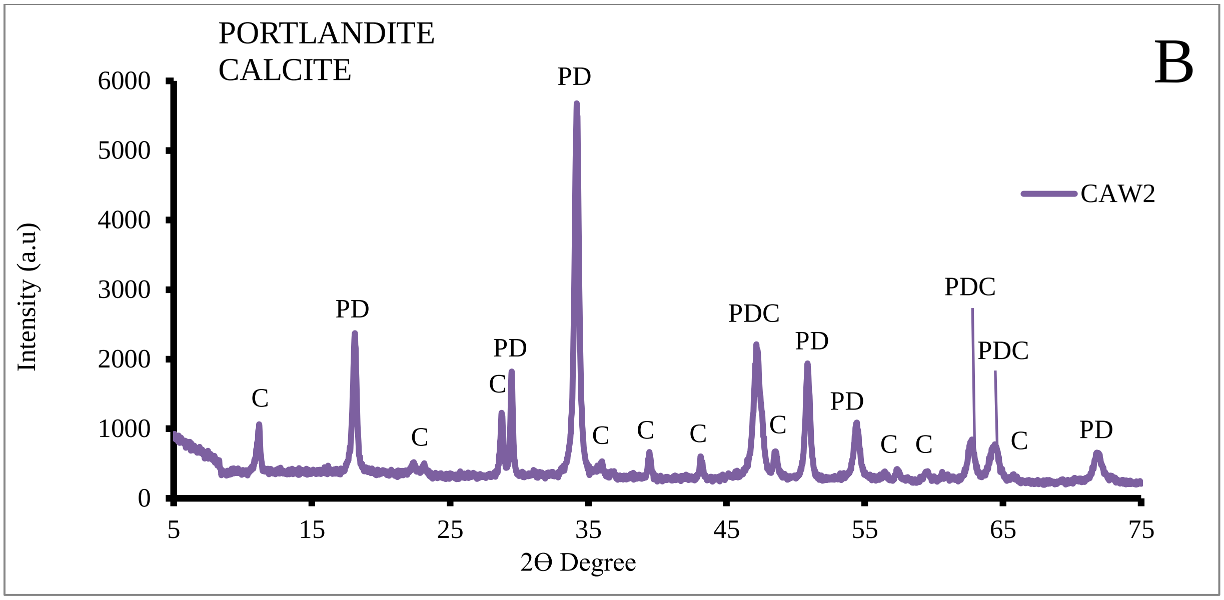


Fig. 3 XRD spectral analysis of CAW 1 (A) and CAW 2 (B) samples: PD = Portlandite, C = Calcite, PDC = Portlandite, Calcite, CAW 1 = Carbide ash waste from Ikorodu, CAW 2 = Carbide ash waste from Ajegunle

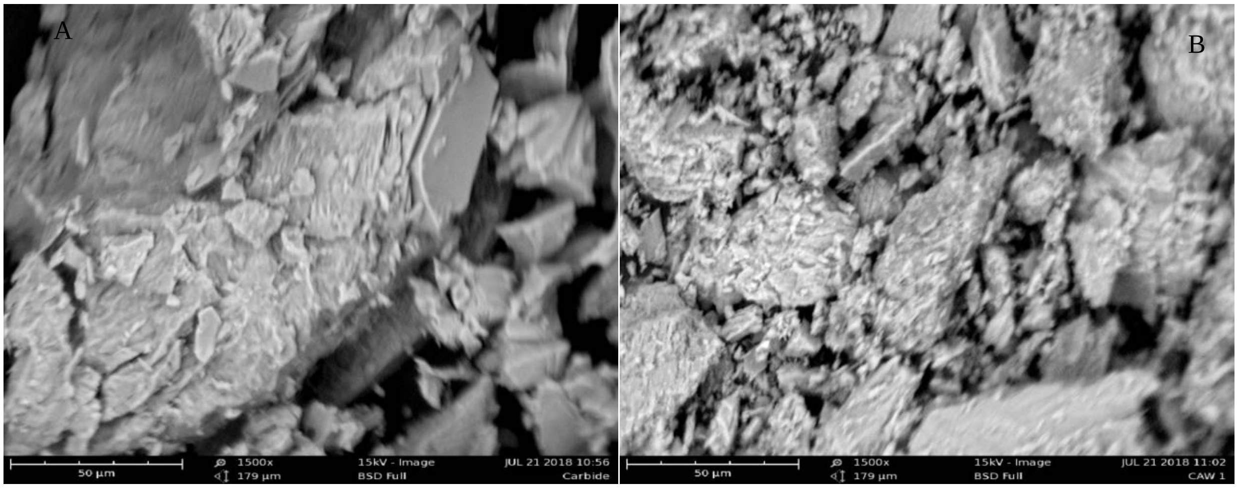


Fig. 4 SEM images of CAW 1 (A) and CAW 2 (B) at magnification x1500: CAW 1 = Carbide ash waste from Ikorodu, CAW 2 = Carbide ash waste from Ajegunle

3.2.3. XRF

Table 1 presents the results of the XRF elemental composition of the CAW samples that were collected from Ajegunle and Ikorodu. Calcium oxide (CaO) makes up a significant portion of the major metal oxide component in both the CAW 1 and CAW 2 samples, with CaO elemental compositions of 91.78% and 91.62%, respectively. In comparison to the alumina contents of both samples, the silica content of the CAW samples is higher. Because of pozzolanic reactions, CAW, which is cementitious, can be combined with specific pozzolanas that have high levels of silicon dioxide and aluminum oxide in a hydrated mixture to create products that resemble those that come from the cement hydration process. Because CAW contains a high concentration of calcium hydroxide, it can react with pozzolanic material to create cementitious materials [23](Aderinola et al., 2018). Research has shown that when CAW is combined with certain pozzolans with high amounts of SiO2 and Al2O3 could be due to pozzolanic reactions from cement from the hydration process [9](Quadri et al., 2019). The results of the two ash samples' XRF elemental composition in this study are consistent with that of earlier research, which revealed that they are both calcium-rich hydrated lime with no MgO detected [2]; Cardoso et al., 2009]. Both samples had a minimum quantity of at least 90% calcium oxide (CaO) according to ASTM C977 [Saldanha et al., 2021] [24] Saldanha et al., 2021. Technical and environmental performance of eggshell lime for soil stabilization. Construction and Building Materials, 298, 123648. [25] (ASTM, 2018).

3.2.4. FTIR

The broad absorption band at 3291.2 cm^{-1} seen in Figure 5 FTIR results point to the presence of OH stretch brought on by moisture. Notably, the Ajegunle CAW 2 sample's band value was larger than that of the Ikorodu CAW 1 sample. Stretching peaks were visible in both samples at 3219–3473 cm^{-1}, 1600–1760 cm^{-1}, and 723.1–764.1 cm^{-1}, revealing O–H, C=O, and CaO, respectively.

Table 1. XRF elemental composition of carbide ash waste samples (CAW 1 and CAW 2)

ELEMENTAL COMPOSITION	Ikorodu (CAW 1) (%)	Ajegunle (CAW 2) (%)
Al_2O_3	2.043	2.2
SiO_2	5.198	5.24
CaO	91.78	91.62
Fe_2O_3	0.231	0.189
SO3	0.426	0.437
K_2O	0.08	0.076
TOTAL	99.758	99.762

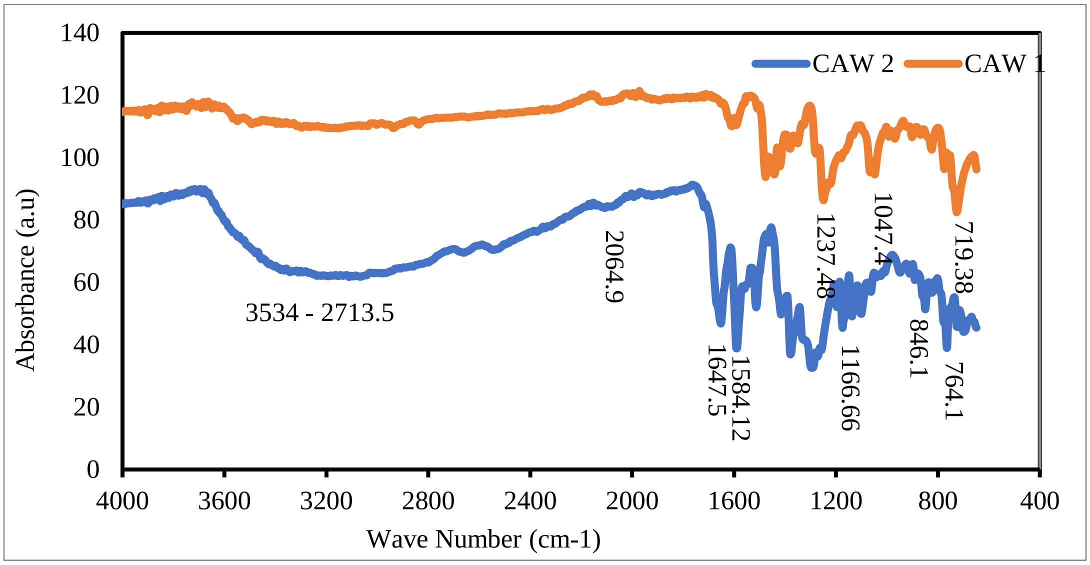


Fig. 5 FTIR absorption spectra of CAW 1 and CAW 2 samples

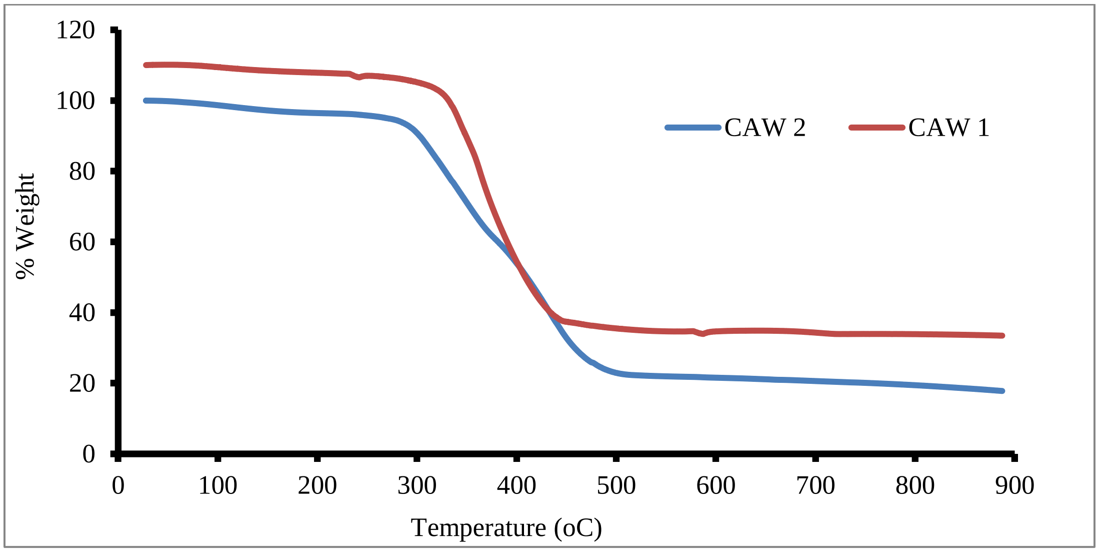


Fig. 6 TGA analysis of CAW 1 and CAW 2 samples

3.2.5. TGA

The TGA results, which are shown in Figure 6, showed that the sample weight gradually lost weight until it reached a temperature of 278.11 ºC for CAW 2 and 316.7 ºC for CAW 1. After that, it began to fall sharply until it stabilized at 38 g and 20.3 g for CAW 1 and CAW 2, respectively. Figure 6 TGA results showed that the weight of CAW samples' thermal stability was stable until mass loss with temperature increase until it reached 320 ºC for CAW 2 and 360 ºC for CAW 1.

After that, the sample weight started to fall sharply until it stabilized at 38 g and 20.3 g for CAW 1 and CAW 2, respectively. The TGA shows that both CAW samples were thermally stable. However, CAW 1 was more stable than CAW 2.

4. Conclusion

The conclusion of the results from this study on the carbide ash wastes are:

1. The XRD of the two samples identified three major mineral phases: Portlandite, Portlandite Calcite and Calcite, which could be used in the construction industry.
2. XRF elemental composition revealed calcium oxide to be the major component of both samples, which ranges from 91.78% to 91.62%; thus, carbide samples will be an appropriate substitute for cement and concrete making.
3. TGA analysis of CAW revealed that both samples are thermally stable
4. SEM analysis revealed rough, irregular particle sizes with some agglomeration
5. FTIR analysis identified some functional groups, which are O-H, C=O, C-O, and CaO.

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