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LABORATORY EVALUATION OF THE PERFORMANCE OF CALCIUM CARBIDE WASTE (HYDRATE LIME) IN CONCRETE

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ABSTRACT

The disposal of Calcium carbide waste can lead to groundwater contamination via leaching. Also, the production of Portland is increasingly having an effect on global warming and the continuous depletion of limestone deposits. With the aim of minimizing the negative effects associated with the production of cement and disposal of calcium carbide waste, physical and mechanical properties of Calcium carbide waste (CCW) – Ordinary Portland Cement (OPC) in concrete was investigated. Consistency test, initial and final setting time test, compressive, tensile and flexural strength test was carried out on CCW-OPC concrete. OPC was replaced with CCW at 5, 10, 15 and 20 %. A mixed ratio and water-cement ratio of 0.61 and 1: 1.5: 3.2 was adopted for a conventional grade of 20MPa. Eighty five cubes of size of 150 × 150 × 150mm were cast and tested for compressive strength after 7, 14, 28 ,and 56 days curing. Thirty cylindrical specimens of size 100 × 200 were cast and tested for tensile strength after 28 days curing. For flexural strength test, thirty rectangular beam specimens of size 100 × 100 × 500 mm were cast and tested after 28 days curing. Results of initial and final setting time decreased with CCW addition. Results obtained for compressive strength showed a decrement with CCW addition. The optimum compressive strength of 34.3 MPa was obtained at 5 % replacement, which was greater than the strength of plain concrete by 19.9 %. Partial replacement of cement with CCW in concrete led to a decrease in tensile strength. Maximum flexural strength was attained at 15 % cement replacement. A maximum strength of 7.856 MPa obtained was greater the strength of plain concrete (7.304 MPa).

Keywords: Calcium carbide waste, hydrated lime, compressive strength, flexural strength, split tensile strength

1. INTRODUCTION

Calcium carbide waste (CCW) also called lime hydrate or carbide lime sludge is a by-product obtained from the production of acetylene gas, as shown in equation 2. Pure calcium carbide reacts with water to form calcium carbide waste and acetylene gas. The pure calcium carbide which is colorless and odorless is produced by heating lime with coke as shown in equation 1.

$$2CaO+5C_{(s)}=2CaC_{2(s)}+CO_{2(g)} \quad (1)$$

$$CaC_2+2H_2O=C_2H_2+Ca(OH)_2 \quad (2)$$

Calcium carbide waste is whitish in nature and is made up of water and calcium hydroxide. The acetylene gas obtained from the reaction process is widely used in lightning, metal cutting, the ripening of fruits in agriculture, and in welding industries. In Nigeria, it is popularly used by welders and panel biters. Aside from the mentioned importance, countries like China and Thailand use the acetylene gas as industrial fuel, simply because it is cheaper compared to petroleum. They also use the calcium carbide in the production of polyvinyl chloride (PVC). For such countries, calcium carbide waste is disposed of in large amounts as waste in landfills (Tanalapsakul, 1998; Jaturapitakkul and Roongreung, 2003). Calcium carbide waste is also alkaline with a PH value greater than 7. Hence, the disposal of the waste can lead to environmental pollution such contamination of groundwater.

Interestingly, Findings from Ogork and Ibram, (2017) showed that calcium carbide waste could be used as a supplement for cement in concrete production due to the high percentage of CaO (75.96 %) it possesses. Furthermore, the use of the waste as a partial replacement for cement in concrete will also aid in reducing pressure on cement demands, minimize the degree of depletion of limestone deposits and reduce the amount of CO_2 emitted into the atmosphere during cement production process.

The research is aim at evaluating the physical and mechanical properties of calcium carbide waste when blended with cement in concrete production.

2. MATERIALS AND METHODS

2.1 Materials

Calcium carbide waste (CCW), Ordinary Portland cement (OPC), Granite (coarse aggregate) and sand (fine aggregate) were used in the research. Calcium carbide waste was obtained from panel biters along Tanke road, Ilorin, Kwara state, Nigeria. Ordinary Portland cement was gotten from traders at Oke-odo, tanke, Ilorin, Kwara state. Sand and granite were procured from a construction site (Arafims Engineering Nigeria Limited) at University of Ilorin, Ilorin, Kwara State.

2.2 Preparation of test specimen

The calcium carbide waste was dried in an open space. Afterward, the waste was ground using grinding machine. The ground waste was passed through 75 μmm, and the samples that passed through were used in the research work. The granite and sand were also air-dried for about 1 hour until it's attained it saturated surface dried state.

2.3 Concrete mix design

The British department of environment (DOE) method of mix design was adopted for a standard grade of 20 MPa, and a water/cement ratio and mix ratio of 0.61 and 1:1.5:3.2 obtained from the calculation was used in the investigation. For the initial and final setting time test, compressive strength test, tensile strength, and flexural strength test; cement were partially replaced with sorghum waste ash (SWA) at 5 %, 10 %, 15 % and 20 %.

2.4 Determination of chemical properties of test specimen

Calcium carbide waste was tested for the presence of oxides in accordance with ASTM C618 (130. The oxides tested included; SiO_2, Al_2O_3, CaO, Fe_2O_3, MgO, Na_2O, SO_3, and K_2O. The test was conducted at the Industrial Chemical Department, University of Ilorin. The oxides were determined using Energy Dispersive X-ray Spectrometer (EDX) method. The element detected at high sensitivity and the detection lines gave results of the various oxides.

2.5 Determination of the physical properties of test specimens

Physical property test was conducted for fine aggregate, coarse aggregate, and calcium carbide waste. The test carried out for aggregate includes; specific gravity and particle size distribution. The various test procedures were carried out in accordance with BS 812-2 (1995), BS 812-103, (1985) and BS 812-103.1(1985). Sorghum waste ash was tested for specific gravity and bulk density.

2.6 Consistency, initial and final setting time test of blended cement mortar

The test was carried out on plain cement and the blend of the cement with calcium carbide waste. The test procedure was done in accordance with BS EN 196-3:1994. The cement mortar was replaced with the sorghum waste ash sample at 5 %, 10 %, 15 % and 20 %.

2.7 Slump test

The test was carried out in accordance with BS 1881 – 102: 1983, which describes the procedure for the determination of slump in concrete using the cone method.

2.8 Compressive strength test

Figure 1 and 2 shows the curing and crushing process of concrete cubes. Specimens of cube size, 150 ×150 ×150mmwas tested for compressive strength. This was carried out in accordance with BS EN 12390 – 1 (2000) specification. Sorghum waste ash sample was incorporated into the concrete mix at 5%, 10%, 15% and 20%. The concrete was demoulded after 24 hours and allowed to cure in water for 7, 14, 28 and 56 days. After curing, the cubes were tested using Universal Testing Machine with a load capacity of 2000 KN. The force at failure was recorded. Compressive strength was calculated using Equation (3).

$$S = \frac{L}{A} \qquad (1)$$

Where S = compressive strength (MPa), L = force at failure (kN), and A = Cross-sectional area of the cube (mm)

Figure 1: Curing process of cube specimen

Figure 2: Process of testing cube specimen

2.9 Density test

Specimens of cube size, 150 ×150 × 150 mm were used in determining the density in accordance with BS 812 – 2 (1995). The density was calculated using Equation (3).

$$\sigma = \frac{M}{V} \qquad (3)$$

Where $\sigma = densityofcubespecimen$ (kg/mm^3), M = mass of the cube specimen (kg) and V = volume of cube specimen (mm^3).

2.10 Tensile strength test

Split tensile test strength was carried out on concretes based on ASTM C 496-11 using 100 by 200 mm cylindrical specimens. The split tensile strengths of cylindrical samples were determined after curing age of 28 days. Force obtained at failure was then used to calculate the tensile strength using Equation (4).

$$F = \frac{2p}{\pi LD} \qquad (4)$$

Where: F = tensile strength (N/mm^2), P = compressive load at fracture (N), L = length of cylindrical specimen, D = diameter of the cylindrical specimen

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2.11 Flexural strength test

The flexural strength under one point loading was done in accordance with BS EN 12390-5 (2000). 25 beams of size 100 × 100 × 500 mm were cast and cured in water for 28 days. The flexural strength test was carried out using the universal testing machine as shown in Figure 3.

Figure 3: Flexural Strength Test of Concrete Beam Samples

3. RESULTS AND DISCUSSION

3.1 Physical properties

The result of average specific gravity of the granite (coarse aggregate) and fine sand were 2.67 and 2.65 respectively. The specific gravity result falls within the range of 2.6 – 2.8, specified in BS 812-2:1995. Hence, the aggregate was suitable for usage in the research work. Calcium carbide waste had a specific gravity and density value of 2.43 and 473.4 respectively. As shown in Figure 4, for the coarse aggregate, the value of 1.58 obtained for the coefficient of uniformity (Cu) was less than four specified in the BS 882:1992. Results of 1.05 obtained for the coefficient of curvature lied between 1 and three specified in BS 882:1992. Hence, the coarse aggregate is well graded. As shown in Figure 5, for fine aggregate, the value obtained for the coefficient of uniformity was 2.18, less than four specified in BS 883:1992. Coefficient of curvature value obtained was 1.14, which lies between 1 and three specified in BS 882:1992. From the result obtained, the fine aggregate is well graded.

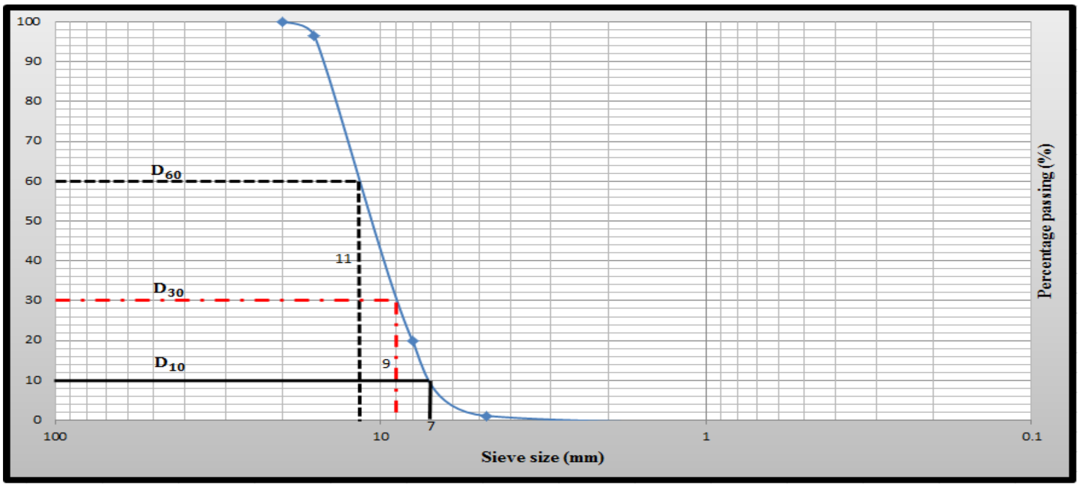

Figure 4: Particle size distribution curve of coarse aggregate.

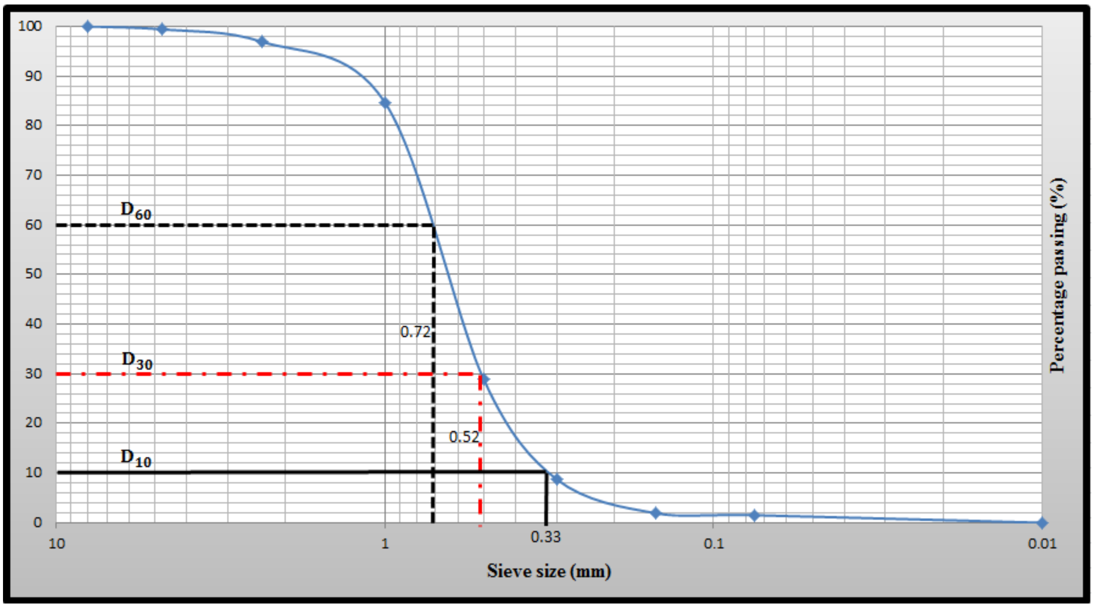

Figure 5: Particle size distribution curve of fine aggregate.

3.2 Chemical properties

The result of chemical composition of calcium carbide waste is shown in Table 1. The waste had a silica and calcium oxide content of 1.54 and 67.02 %.

Table 1: Chemical composition of calcium carbide waste sample

Elemental Oxides	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	SO_3	K_2O	LOI	% Ash
Calcium carbide waste	1.54	0.50	67.02	0.03	1.26	0.02	-	0.05	1.02	-

3.3 Consistency, initial and final setting time

The result of the standard consistency and setting time of the paste are shown in Table 2 and Figure 6. It was observed that the initial and final setting time decreased with increase in CCW content. A similar finding was reported by Masimawati et al., (2015). The reason for the reduction in setting time was due to the presence of CaO in the CCW. Calcium oxide enhances an improvement in strength properties on reaction with water. The results of initial and final setting time of CCW- cement paste was not less than 45 minutes and final setting time not more than 375 minutes, as specified in ASTM C150-81(23).

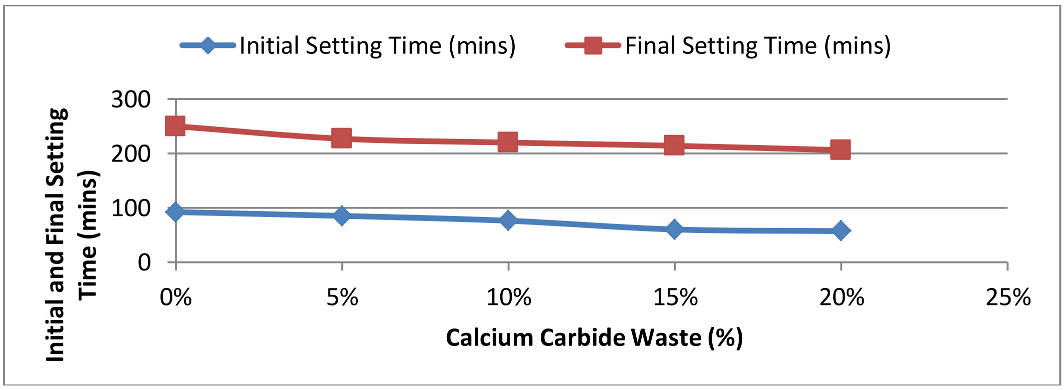

Figure 6: Initial and Final Setting Time of Calcium carbide waste (CCW) Mortar

Table 2: Consistency, Initial, and Final Setting Time Result

Calcium Carbide Waste in Cement Mortar (CCW)						
Ash (%)	Weight (g)	Water Content (mm)	Penetration Depth (mm)	Consistency (%)	Initial Setting Time (min)	Final Setting Time (min)
0 %	400	132	33	33.00	92	250
5 %	380	135	33	33.75	85	227
10 %	360	137	34	34.25	76	220
15 %	340	140	34	35.00	60	214
20 %	320	145	35	36.25	57	206

The consistency of CCW cement paste increased with the addition of CCW content, as shown in Figure 7. More water is required to achieve a consistent paste as cement is partially replaced with sorghum waste ash.

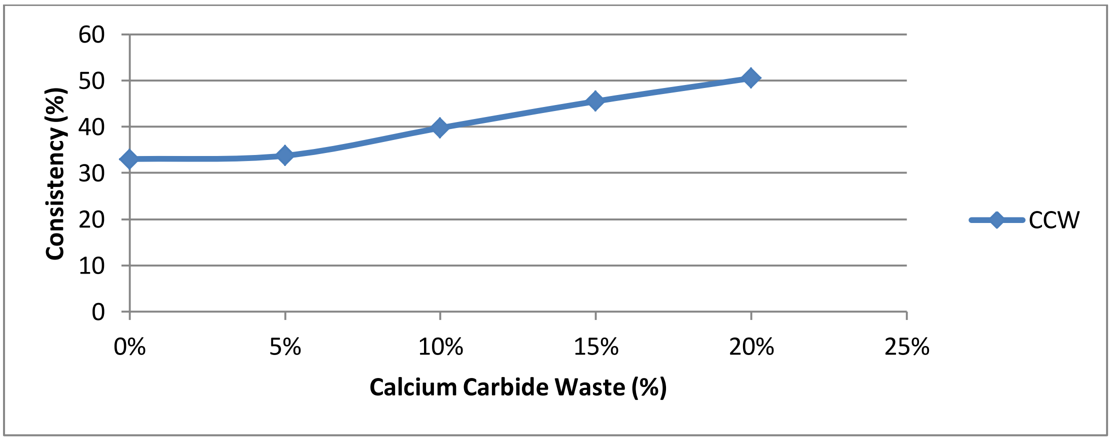

Figure 7: Consistency of the Mix with Cement Replacement

3.4 Slump

The result of slump test is shown Table 3. The water content demand in the mix increased with increase in the CCW content. This means that more water is required to coat the surface of the sample and allow for workability in the fresh concrete mix.

Table 3: Result of Slump Test

Calcium Carbide Waste (CCW)								
Ash Content (%)	Weight of ash (A) Kg/m^3	Weight of cement (C) Kg/m^3	Weight of sand (FA) Kg/m^3	Weight of Granite (CA) Kg/m^3	Moisture content Kg/m^3	Mix ratio (C:A:FA:CA)	W/C	Slump values (mm)
0 %	-	369	544	1212	230.00	1:1.5:3.28	0.61	45
5 %	18.45	350.55	544	1212	239.60	1:0.05:1.55:3.4 4 3.46	0.65	51
10 %	36.90	332.10	544	1212	228.40	1:0.11:1.64:3.6 5	0.62	42
15 %	55.35	313.65	544	1212	260.30	1:0.18:1.73:3.8 6	0.70	49
20 %	73.80	295.20	544	1212	273.10	1:0.25:1.84:4.1 1	0.74	59

3.5 Density and compressive strength

Table 4 shows the result of density and compressive strength of CCW concrete. The results obtained falls within the range of 2300 – 2700 Kg/m^3 specified in ASTM C 230 (2009) classification for a normal weight concrete.

As shown in Figure 8, a maximum compressive strength of 34.3 MPa was obtained at 5 % replacement. The result (34.3 MPa) was higher than the strength of plain concrete by 19.9 %. Beyond 5%, a decrease in strength was observed with the addition of CCW content. An increase in strength gain was observed with age of curing. In a similar report by Ndububa and Omeiza (2016), optimum strength was also attained at 5 % cement replacement. They also reported a decrease in strength with increase in CCW content.

Table 4: Average density and compressive strength of CCW concrete

Calcium Carbide(Average Density Kg/m^3/ Compressive Strength Mpa) (CCW)										
Testing age	0 %		5 %		10 %		15 %		20 %	
7	2506	20.8	2668	28.1	2523	25.5	2475	19.0	2491	14.6
14	2523	26.1	2703	32.1	2576	28.5	2487	23.4	2562	19.5
28	2618	28.6	2739	34.3	2583	33.1	2529	26.7	2757	23.6
56	2634	33.3	2747	39.2	2661	37.1	2533	28.0	2777	27.5

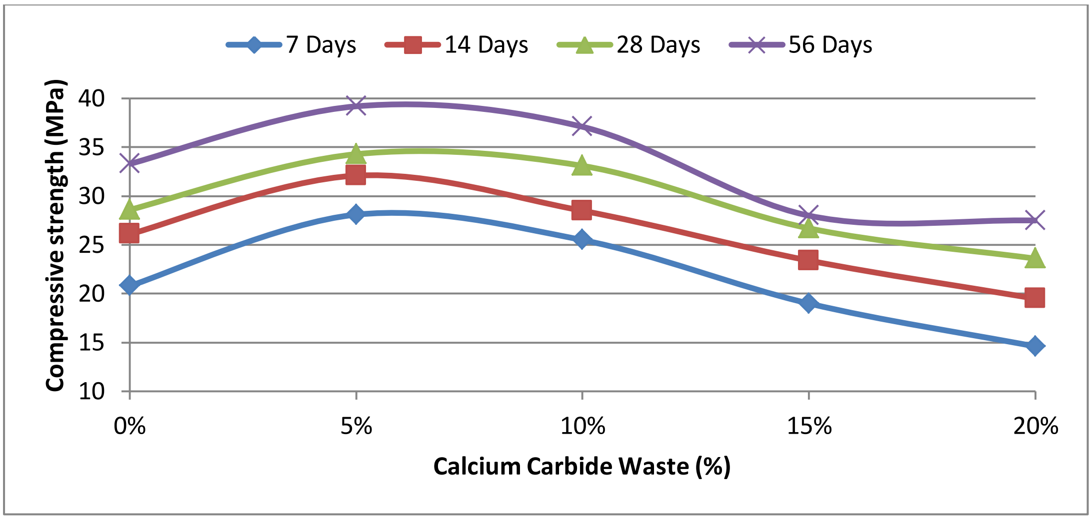

Figure 8: Rate of Strength Development with Cement Replacement

3.6 Tensile strength

Table 5 and Figure 9 shows the result of the tensile strength of CCW concrete. For CCW concrete, a decrease in strength was noticed with CCW addition. The optimum tensile strength was achieved at 5 % cement replacement with carbide. A result of 3.19 MPa obtained was higher than the strength of plain concrete by 4.6 %. A linear relation exists between tensile and compressive strength, regarding the pattern of strength development with carbide addition.

Table 5: Split Tensile Strength of CCW Concrete

Ash content (%)	0 %	5 %	10 %	15 %	20 %
Tensile strength (MPa)	3.05	3.19	2.71	2.46	1.98

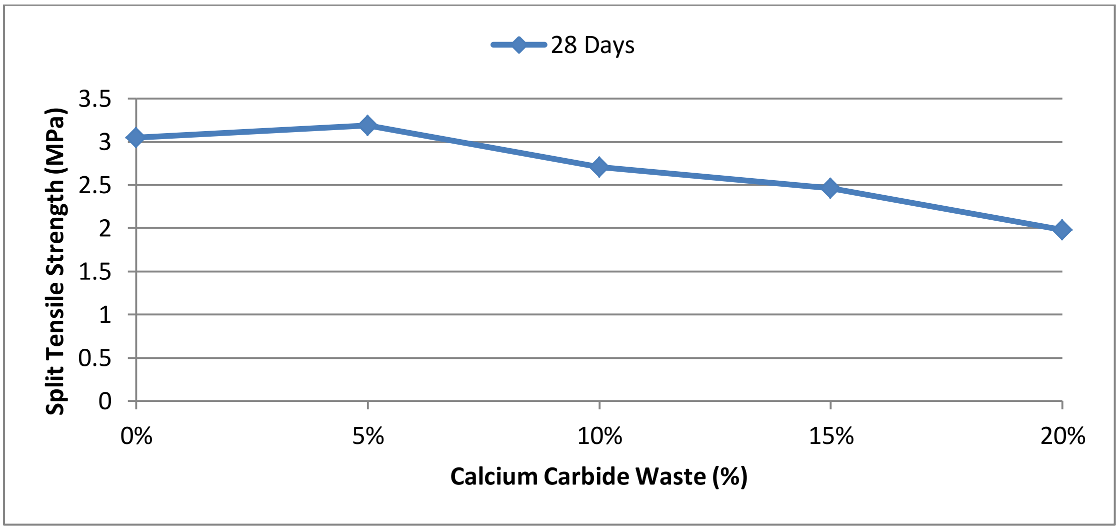

Figure 9: Rate of Change in Tensile Strength with Cement Replacement

3.7 Flexural strength

The result of flexural strength is shown in Table 6 and figure 10. An increase in flexural strength was observed with CCW addition. The optimum flexural strength value was obtained at 15 % replacement. Optimum strength value of 7.856 Mpa was higher than the strength of plain concrete by 7.6 %. Beyond 15 % replacement, a decrease in strength was observed. The presence of CaO in the CCW played a significant role in enhancing cementitious reaction in the concrete matrix. Calcium carbide is also finer and has a lower specific gravity than cement. More improved bonding between the cement paste and aggregate is achieved, resulting in a more improved strength.

Table 6: Flexural Strength of CCW Concrete

Calcium Carbide (CCW)				
Ash Content (%)	Density (kg/m^3)	Peak Force (kn)	Peak Deflection (mm)	Ex. Flexural Strength (MPa)
0 %	2341.7	9071.5	1.887	7.304
5 %	2267.8	7754.0	3.388	5.815
10 %	2364.6	8245.0	2.648	6.184
15 %	2332.7	8475.0	2.312	7.856
20 %	2262.0	8803.0	2.942	6.602

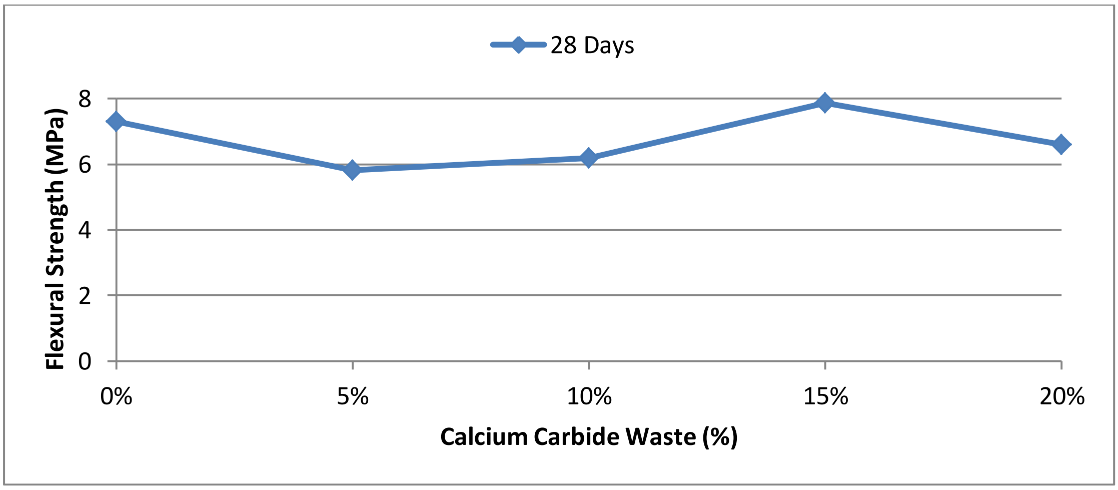

Figure 10: Rate of Change in Flexural Strength with Cement Replacement

The flexural load-deflection curve of CCW concrete beams is shown in Figure 11. The peak load of 10475 N was obtained at 10 % replacement, with a resultant deflection of 2.312 mm. This deflection obtained was greater than the deflection of plain concrete beam by 22 %. The rate deflection also increased linearly as the load was gradually applied on the concrete beam.

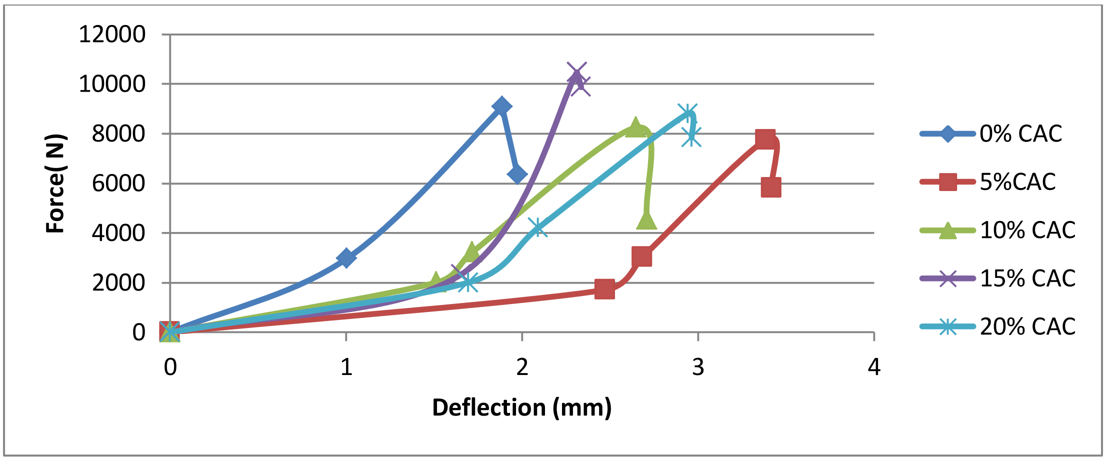

Figure 11: Flexural load deflection curve for calcium carbide waste (CCW) in concrete beams

4. CONCLUSION

Calcium carbide waste can be used as supplements for cement due to the presence of Calcium oxide (67.4 %) in CCW. It cannot be cannot be regarded as a pozzolan. The initial and final setting time decreased with CCW in cement paste. The results obtained were also within the ASTM C150-81(23) specification limits for a mortar to be considered a cementitious material. A peak compressive strength of 34.3 was gotten at 5 % replacement. The result was greater the strength of plain concrete by 17 %. Partial replacement of cement with CCW resulted to a decrease in compressive strength. Tensile strength decreased with addition of CCW in concrete. Blending of the ash with cement up to 15% replacement can produce a concrete of flexural strength, 7.6 % higher than plain concrete strength.

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