Scholars Journal of Engineering and Technology (SJET) **ISSN 2321-435X (Online)**
Sch. J. Eng. Tech., 2017; 5(11):655-660 **ISSN 2347-9523 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublisher.com

Effect of Calcium Carbide Wastes as Admixture in Mortar

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Article History
Received: 18.11.2017
Accepted: 25.11.2017
Published: 30.11.2017

DOI:
10.21276/sjet.2017.5.11.8

Abstract: This paper presents the results of an experimental study on the use of Calcium Carbide Wastes (CCW) as an admixture in a mortar. A mortar of ratio l:3 (cement to fine aggregate) at a constant water-cement ratio of 0.5 was prepared in the laboratory and CCW was added to the mix at a percentage of 0, 1, 2, 3, 4, and 5 by weight of cement respectively. The test parameters investigated include; the consistency and setting times of Cement-CCW paste, workability of cement-CCW mortar and, compressive and flexural strength of mortar prisms. A total of 72 mortar prisms were cast and tested for compressive and flexural strength at the curing age of 3, 7, 28 and 56 days. The results of the study demonstrated that addition of CCW increased the consistency, but decreased both initial and final setting times of cement at 5% CCW content. It was also found that addition of CCW to up to 5% by cement weight increased the workability of the mortar. The compressive and flexural strength of mortar prisms tested at 3, 7, 28 and 56 days indicate a positive increase in strength with increase in CCW content up to 2% by weight of cement and decreases with any further increase in the percentage of CCW content. The average compressive and flexural strength increase achieved by the mortar prisms containing 2% CCW is found to be 8% and 10% over that of a control specimen at 56days curing age. The results have also demonstrated a general increase in both compressive and flexural strength of mortar prisms with ages.
Keywords: Cement Mortar, Calcium Carbide Waste, and Compressive and Flexural Strength

INTRODUCTION

Over the last decades, increasing industrialization in developed countries has led to an increase in industrial output and subsequent growth of uncontrollable waste. Consequently, the increasing generation of agricultural and industrial waste is the major concern in developed countries as it could result in an unmanageable environmental pollution. It is clearly known that cement is one of the conventional materials used in the construction of civil engineering infrastructures. However, the price of cement has rapidly increased due to the sharp increase in the cost of energy since the 1970s. The over-dependence on the utilization of industrially manufactured Ordinary Portland Cement (OPC) have kept the cost of construction of concrete structures high. This up to now has continued to prevent the underdeveloped countries from meeting the infrastructure needs of their citizens.

It is a well-established fact that the best alternative to conventional materials is the utilization of agricultural and industrial wastes in the construction industries as pozzolanas to replace cement or as mineral admixtures or additives in concrete. A substantial amount of experimental studies has been conducted on the use of agricultural and industrial wastes (such as blast furnace slag, cocoa pod husk ash, condensed silica fume, groundnut shell ash, rice husk ash etc.) as admixtures in concrete [1–9]. The utilization of these wastes is limited due to insufficient data available and lack of confidence [10]. Consequently, most of these waste materials are disposed of as landfill. However, the reuse of these wastes in the construction industries does not only alleviates the disposal problems but also has economic, ecological and energy saving merits [11].

Among the recent experimental investigations on the use of local waste materials as admixtures in concrete and mortar includes Darweesh and El-Suoud [12] studied the influence of sawdust ash (SDA) as a partial replacement in cement pastes. They found that SDA could act as an accelerator in concrete when a dose of up to 25% is used as cement replacement. The influence of SDA on the mechanical and durability properties of concrete and cement pastes has been investigated by Ogork and Ayuba [13]. The results of their findings have shown that addition of up 2% SDA can significantly improve the compressive strength of the concrete in the normal and acidic environment. They also classified SDA as a retarding admixture as it increases the consistency, initial and final setting times of the cement paste. In their investigation, Cordeiro *et al.* [8] have reported that the pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars depends significantly on its fineness and particle size. Vincent and Yakubu [14] have investigated the influence of cocoa pod husk ash (CPHA) as admixture in concrete. The results have demonstrated a significant increase in durability, compressive strength and workability with increasing percentage addition of CPHA up to 0.6%. Similar results have been reported by Ogork and Audu [15].

Calcium Carbide Waste (CCW), a by-product from acetylene gas (C_2H_2) production [16]. It is obtained from the reaction between water and calcium carbide (CaC_2) as shown in the equation below:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \qquad (1.0)$$

Beyond its obvious values acetylene as a fuel gas is employed in agriculture for repining of fruits and as an excellent choice for many critical heating processes including; flame heating, flame gouging, welding, flame hardening, flame cleaning, flame straightening, thermal spraying and many other heating applications [16,17]. However, in most of the developing countries including Nigeria acetylene gas is used in oxy-acetylene gas welding. The residue (CCW) is mostly disposed of carelessly as a waste in the environment which sooner or later gets incorporated into the soil [18]. An investigation carried out by Abiya *et al*. [18] have shown that a concentration of CCW above 100g could drastically reduce the growth rate of Okra plant. Regardless of its adverse effect on the environment, CCW also has its essential advantages. A research study conducted by Wang *et al*. [19] has confirmed that the main chemical compositions of the calcium carbide slag were basically the same as that of natural limestone. Jaturapitakkul and Roongreung [20] also reported that a pozzolanic reaction could occur when calcium carbide residue is mix with rice husk ash in a mortar and achieved a highest compressive strength of 15.6 MPa at 28 days.

This study is aimed at investigating the influence of calcium carbide waste on the mechanical and strength properties of cement mortar with a view to utilize the waste as a mineral admixture in cement and to reduce its accumulation as a waste in the environment.

EXPERIMENTAL PROGRAM

Materials

The materials, used in this study included Dangote brand of ordinary Portland cement with an average specific gravity of 3.15. Natural, clean and air-dried river sand with a specific gravity of 2.63 and conforming to BS 882-2 [21] was used as fine aggregate. The sand was sieved to remove larger particles of stone, and other harmful substances like leaves, broken glass and wooden particles. The particle size distribution curve of the River Sand is illustrated in Figure-1. The Calcium Carbide Wastes (CCW) was obtained from a local Panel beating specialist along Kabuga road, Kano Nigeria. The CCW was air-dried and sieved through 75mm sieve in the laboratory. The average specific gravity of CCW was found to be 2.18 compared to 3.15 of cement indicating that CCW is lighter than cement. The chemical composition of CCW is also portrayed in Table 1 [7].

Table-1: **Chemical composition of CCW [7]**

S/No	Parameter	Weight (%)
1	SiO_2	2.1
2	Al_2O_3	0.5
3	Fe_2O_3	0.54
4	CaO	95.69
5	MgO	-
6	K_2O	0.47
7	Na_2O	-
8	SO_3	0.31
9	TiO_2	-
10	BaO	0.09
11	L.a.I	-

Table-2: **Mix quantities of mortar in Kg/m^3**

Percentage of CCW addition (%)	CCW quantity (Kg/m^3)	Cement quantity (Kg/m^3)	Sand quantity (Kg/m^3)	Water quantity (Kg/m^3)
0%	_	507.28	1521.84	253.64
1%	5.07	507.28	1521.84	253.64
2%	10.15	507.28	1521.84	253.64
3%	15.22	507.28	1521.84	253.64
4%	20.29	507.28	1521.84	253.64
5%	25.36	507.28	1521.84	253.64

Mortar Mix Proportions

The absolute volume method of calculation was used in determining the quantities of materials required for one cubic meter of Mortar. A prescribed mix proportion of one part of cement to three part of fine aggregate (1:3) was used. The CCW additions were varied at 0%, 1%, 2%, 3%, 4% and 5% by weight of cement. The batches were thoroughly mixed in the laboratory on mixing tray by hand trowel. The workability of the fresh mix mortar was determined according to the recommendation of BS EN 12350-2 [22]. Table 2 Summarized the proportion of the constituent materials used in the mortar production. The batches were thoroughly mixed in the laboratory on mixing tray by hand trowel. The slump result of the fresh mix mortar is illustrated in Figure-4. The mixed mortar was cast in prisms mould of size 40x40x160mm, in 2 layers each tamped with 25 numbers of blows of the tamping rod and compacted manually by careful vibration of the mould. The prisms were removed from the moulds on the following day and cured in water for a period of maximum 56 days in the laboratory.

Test Procedure

Test on Cement-CCW Pastes

In this study, six mix samples were prepared for the determination of consistency and setting times of cement-CCW paste. The consistency and setting time tests were conducted according to BS EN 196-3 [23] design guideline. The mix samples include; CM-0%CCW, CM-1%CCW, CM-2%CCW, CM-3%CCW, CM-4%CCW and CM-5%CCW. The letters CM and CCW denote the cement and calcium carbide waste contents while the percentages 0%, 1%, 2%, 3%, 4% and 5% denote the varying percentage addition of CCW in the mix. For each mixed sample, three tests were conducted and the average result was recorded. Figures-2 and 3 illustrate the results of consistency and setting times for the cement-CCW paste.

Compressive and Flexural Strength Tests

A series of 72 mortar prisms were cast and tested for compressive and flexural strength at the age of 3, 7, 28 and 56 days. The test was carried out in accordance with BS EN 1015-11 [24] recommendations. The flexural strength is determined by three-point loading of a prism specimen, subsequent to the failure and breakage of this specimen the compressive strength is determined on each half of the mortar prism. The test results were based on the average of three specimens for both compressive and flexural strength tests respectively.

TEST RESULTS AND DISCUSSION

Physical properties of constituent materials

The result of the average specific gravity of CCW, cement and fine sand is presented in Table 3. It can be seen clearly that the CCW is extremely fine in size having a low specific gravity of 2.18 compared to 3.15 of cement implying that CCW is lighter than cement. The average specific gravity of fine sand was also found to be 2.63 which is said to be within the acceptable range [21]. The results of the particle size distribution of river Sand is shown Figure-1. It is obvious from the figure that the grading of the sand falls in zone 2 which is good for structural mortar production [21].

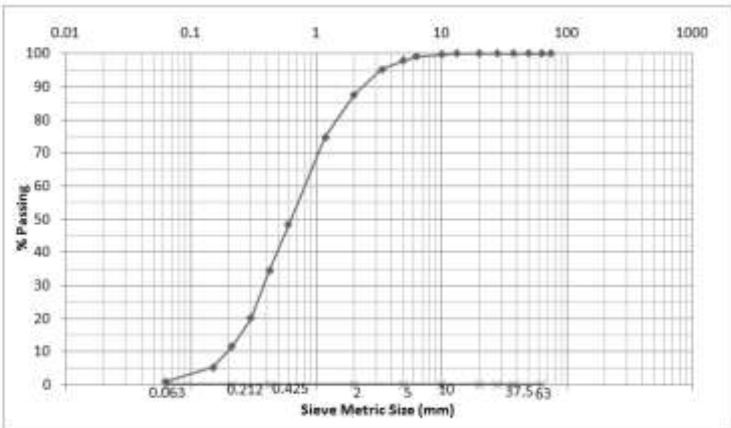

Fig-1: Particle size distribution of river sand

Table-3: **Specific gravity of constituent materials**

S/No	Material	Average Specific gravity
1	CCW	2.18
2	Cement	3.15
3	Fine Sand	2.63

Influence of CCW on consistency and setting times of cement paste

From Figure-2, it is obvious that the normal consistency of cement paste increases with increase in percentage CCW addition. The increase in the water required for wetting the particles is mainly influenced by the increased percentage of CCW content which is extremely fine with low specific gravity [7,25,26]. The setting times of cement paste containing varying percentages of CCW addition is illustrated in Figure-3. It is clear that the initial and final setting times of cement paste with varying percentages of CCW addition decreases with increasing CCW content. This is attributed to the increased hydration of silica and alumina resulting from CCW addition in the paste to form additional calcium silicate and calcium aluminate and may lead to the early setting of the paste. Furthermore, the initial setting time of cement-CCW paste with up to 3% was found to be 31mins less than 45mins as recommended by BS EN 197-1 [27].

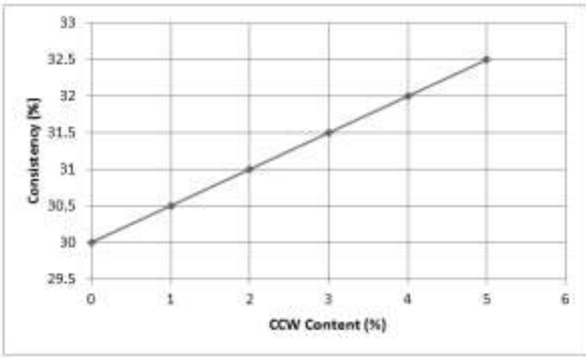

Fig-2: **Normal consistency of Cement-CCW paste**

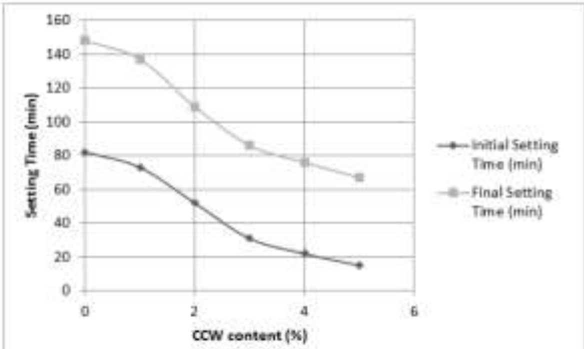

Fig-3: Initial and final setting times of Cement-CCW paste

Slump of Cement-CCW mortar

Figure-4 illustrate the slump of cement mortar admixes with varying percentages of CCW. It can be clearly seen from the figure that the workability of the mortar increases with the addition of CCW compared with that of a normal cement mortar. This is mainly influenced by the CCW particle parking effect of voids in the product of hydration.

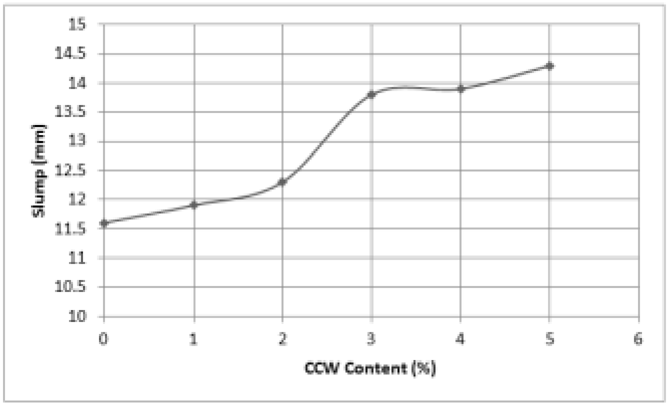

Fig-4: Slump of Cement-CCW fresh mortar

Compressive and flexural strength of CCW-mortar prisms

Figures-5 and 6 portray the variation of flexural strength and compressive strength of mortar prisms with age for a various percentage of CCW content. It is obvious from the figures that both flexural and compressive strength of the mortar prisms increases significantly with age. This may be attributed to the secondary hydration reaction of Portland cement and CCW content [28]. It is also clear from the figures that addition of up 2% CCW indicated a positive increase in both compressive and flexural strength of the mortar prisms compared to that of a pure cement mortar. However, any further increase in the CCW content demonstrated a general decrease in compressive and flexural strength of the mortar prisms. At 56days curing age, the average compressive and flexural strength increase achieved by the mortar prisms containing 2% CCW is found to be 8% and 10% over that of a control specimen.

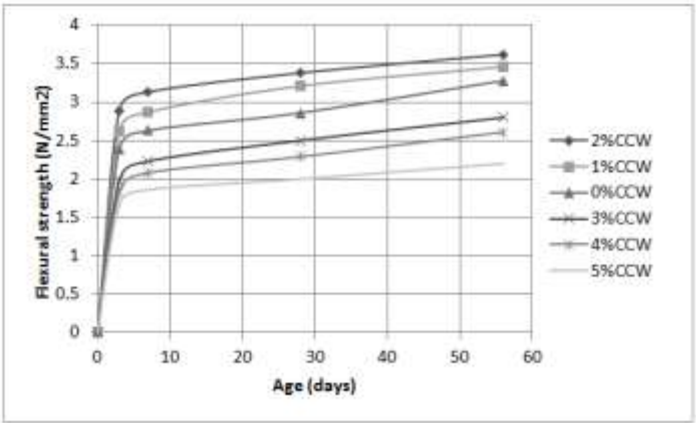

Fig-5: **Variation of flexural strength with age for various percentage of CCW content**

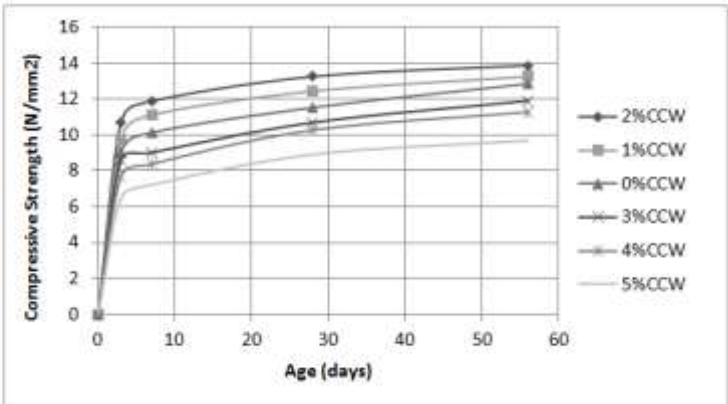

Fig-6: **Variation of compressive strength with age for various percentage of CCW content**

CONCLUSIONS

From the experimental results described above, it was found that CCW possess certain potential characteristics for use as admixture in mortar, the following conclusions can be drawn

- The use of CCW in cement have increased the consistency, but decreased both the initial and final setting times, hence CCW could be classified as an accelerating admixture in cement mortar.
- Addition of CCW in the mix has also increased the workability of the mortar.
- Addition of CCW to up to 2% of the cement content has significantly improved the compressive and flexural strength of the mortar prisms.

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