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ORIGINAL RESEARCH ARTICLE

PROPERTIES OF SELF-COMPACTING MORTAR MADE WITH SORGHUM HUSK ASH AND CALCIUM CARBIDE WASTE AS BINDER

I. O. Hassan[1], O. W. Bolaji[2*] and J. O. Adedapo[3]

[1]Department of Building. Federal University of Technology, Minna, Niger State, Nigeria
[2]Department of Agricultural and Bio-Environmental Engineering Technology,
Federal College of Forestry Mechanization Afaka, Kaduna State, Nigeria
[3]Department of Horticulture and Landscape Technology,
Federal College of Forestry Mechanization Afaka, Kaduna State, Nigeria
**Corresponding author's e-mail address: owbolaji@yahoo.com*

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ABSTRACT

The quest for the development of alternative and more sustainable construction material stemmed out from the current global concern on issues relating to global warming and green house effect. In recent time, research direction has shifted towards the use of agro-industrial waste as complete replacement of ordinary Portland cement. In this study the effects of the blends of sorghum husk ash (SHA) and calcium carbide waste (CCW) on the fresh properties of self compacting mortar was investigated where various tests were carried out which included physical and chemical properties of the constituents materials, Flow cone test for paste, Mini v-funnel flow time and Mortar flow spread test for determination of saturation dosage of HRWR for self compacting mortar made with sorghum husk ash and calcium carbide waste as binder, were carried out. Then developments in the compressive strength of the hardened mortar were determined at 3, 7, 14, 28, 56 and 90 days. The study revealed that SHA sample have high Silicon dioxide (SiO_2 (84%) while CCW is majorly Calcium oxide (CaO(66%).The optimum saturation dosage of High Range Water Reducer (HRWR) determined from Flow cone test and Mini-v-funnel was 3.5%. The 70/30 (SHA/CCW) shows the highest mortar flow spread of 290 mm compared to the control (295mm).The agro-industrial binder exhibited good binding properties at a slow hydration rate. Analysis of the compressive strength results show that 70/30 (SHA/CCW) proportion has the highest value of 14.08 N/mm2 at 90 days. Self compacting mortar made with SHA/CCW combinations as binder can be adopted for use in masonry work as it conforms to type N of ASTM C270 mortar

1.0 Introduction

Building components are fabricated by concrete been placed into formwork and then compacted, According to (Le et al., 2012), Sprayed concrete and Self compacting concrete (SCC) are two other construction strategies methods which could be used to eradicate the compaction process. In 1986 research programme on SCC and sprayed concrete commended at one of the institution in Asia (Topcu and Bilr, 2009). Due to its enhanced quality, productivity and working

condition, SCC gives more leverage in the construction process. Generally, SCC has great powder form and a reduced granite volume ratio than conventional concrete which in turn ensures SCC filling rate, passing rate and segregation impedance (Liu, 2011).

Largest manufactured product (concrete) depends majorly on Portland cement for strength and other desired properties (Mehta and Monteiro, 2014). The manufacturing process of this Portland cement is observed to have contributed up to 5% of global CO_2 emission resulting from clinkers production which involves heating calcium carbonate ($CaCO_3$) at temperature of above 900 °C which result into lime (CaO) and Carbon dioxide (CO_2) (Rubenstein, 2012).

The quick lime according to (Neville, 2011), is further made to react with materials that have silica (SiO_2), alumina (Al_2O_3) and iron (Fe_2O_3) at temperature of about 1450 °C.The combination is allowed to cool, grinded to powdered form and mixed with 5% gypsum content. The major strength determinant in Portland Cement (PC) which is a combination of CaO, SiO_2, Al_2O_3 and Fe_2O_3 is SiO_2 in combination of CaO, which form $Ca(OH)_2$ (hydrated lime) including water, which is the final stage for strength development (Neville, 2011).

Climate change which has been attributed to global warming caused due to the emission of greenhouse gases resulting from human and industrial activities has prompted research and development on alternative binder to replace Portland cement (NCA, 2014).

Past findings on the quest for alternative binders concentrated on making used of natural pozzolan such as volcanic ash (Hassan, 2006) or ashes from agricultural waste such as Corn Cob Ash (CCA) (Raheem, 2006) amongst others as partial PC replacement in Concrete and Mortar.

Attempt to completely replace cement in concrete brought about studies into geo-polymer concretes which simply involves alkali activation of pozzolanic materials with the use of chemical based hydroxide (NaOH) at an elevated temperature (Turner and Collins, 2013) Other studies on total replacement of cement with pozzolans includes combination with alternative CaO which is the source Calcium Carbide Waste (CCW) in the works of Makaratatet et al. (2010) combining fly ash (FA) and CCW sourced within Nigeria and reportedly observed hydration reaction with a 28 days strength of 11N/mm^2 without any treatment on the CCW.

Pozzolans are silicate based materials that react with calcium hydroxide generated by hydrating cement to form additional cementitious materials. Incinerated ashes from agro wastes at a regulated temperature have being found to be pozzolanic with major components been amorphous silica which combines with lime in a moisture form to give cementitious properties (Neville, 2011).

Portland cement according to (Mehta and Monteiro, (2014) react using Tri calcium Silicate (C_3S) with water (H_20) to give calcium silicate-Hydrate and calcium Hydroxide which is a pozzzolans cement reaction. The pozzolanic reaction is basically lime consuming and does not necessarily require presence of cement but an active source of lime; hence the thought for alternative source of lime to enhance pozzolanic reaction with an agricultural waste ash as silica source sorghum husk ash (SHA) is of great importance in the present day study. SHA is ash gotten from open air burning of the husk and Sorghum or Guinea Corn being popular which serve as major staple food in the country Nigeria. Calcium carbide waste (CCW) is reported to be 70-80%

Corresponding author's e-mail address: owbolaji@yahoo.com

calcium hydroxide ($Ca(OH)_2$) with the impurities in it, listed as lead, copper, iron, manganese, nickel and zinc (Chukwudebelu et al., 2013).

The quest by Nigerian Government towards food security and sustainability, with maize and other cereals grains like millet and sorghum being the central focus and Northern Nigeria known as a major contributor to sorghum and cereals production is a pointer that the husk of these crops will always be available. The usage of this agricultural and industrial waste material in mortar and concrete production should be seen as action taken in the right direction. The sustainability of these materials to guarantee total Portland Cement (PC) replacement promises to offer great contribution towards improving knowledge in concrete technology and development of Nigeria as a Nation.

The aim of this research is to determine the performance of self compacting mortar made with sorghum husk ash and calcium carbide waste as binder. The specific objectives are as follows;

To examine the chemical properties of sorghum husk ash and calcium carbide waste.

Determination of degree of hydration of sorghum husk ash and calcium carbide waste as binder.

To assess the features of fresh self compacting mortar made with sorghum husk ash and calcium carbide waste as binder.

To assess the strength property of the self compacting mortar made with sorghum husk ash and calcium carbide waste as alternative binder.

2.0 Materials and Methods

2.1 Materials

The materials used for the research are Sorghum Husk Ash (SHA), Calcium Carbide Waste (CCW), Portland Cement (PC-CEM1 42.5N). The Fine Aggregate (FA), MasterGlenium Ace 456 High Range Water Reducer (HRWR) and Portable water available at the building laboratory of the Federal University of Technology, Minna (FUTMINNA) was used for the mixing and curing.

2.1.1 Portland Cement

The PC used was CEM1 42.5N from Obajana factory of Dangote cement company which served as the binder for the control of Self Compacting Mortar (SCM) mix.

2.1.2 Sorghum Husk Ash (SHA)

The sorghum husk ash was collected from a local guinea corn mill at Tundun Fulani near Bosso Area in Minna, Niger State, Nigeria. The husk were collected and burnt in an open air with a locally fabricated incinerator available in the Building Department of Federal University of Technology Minna, Niger State, Nigeria. The ash was collected and ground to finer particles then sieved with a 75µm sieve (BS EN 196-6:2016). The particles passing were used as the SHA for the experiments.

2.1.3 Calcium Carbide Waste (CCW)

The calcium carbide waste was gotten in slurry form as a by-product of acetylene gas production and was packed from the dumping area of a local automobile welder's (Panel Beater's) workshop around Minna environs. CCW was sun-dried for approximately 4 days and later oven-dried at 105°C for 24 hrs before it was ground in a local mill at Gidan- Kwano Village of Minna and

Corresponding author's e-mail address: owbolaji@yahoo.com

sieved with 75µm sieve (BS EN 196-6:2016). Then the particle passing was used as the CCW samples for the experiments.

2.1.4 Fine Aggregate

The fine aggregate retained within 1.18 mm and 75µm (simulated reference sand) sieved out from the available natural sand obtained from Bosso Local Government Area, Minna, Niger State, Nigeria in accordance with BS EN 196-1 (2016) reference sand prescription for strength test on cement was used for the experiments.

2.1.5 Tap water

Portable tap water available at the building laboratory of Federal University of Technology Minna, Niger State, Nigeria was used for mixing and curing. Water was ensured clean and free from contaminations harmful to the setting of mortar. The water is also free from impurities that would affect the hydration mechanism of the cementitious components within the mix (Neville, 2011).

2.1.6 Superplasticiser (Master Glenium ACE 456)

The choice of superplasticiser (MasterGlenium ACE456) is because of its ability to hasten the concrete or mortar hydration by uncovering an expanded surface of the bond grain to respond with water. Thus it is conceivable to acquire prior advancement of the warmth of hydration a quick improvement of the hydration item and as a result, higher quality at the early age. MasterGlenium ACE456 meet the requirement Type A, E&F of BS.EN 934-2 (2009) and ASTM C494 (2013).

2.2 Physical Analysis of the Constituents Materials

Particle Size Distribution (PSD) of the available natural sand was analyzed using the dry-sieve approach in -line with the BS EN 196-1 (2016) for proper classification of the available natural sand. The reference sand required for mortar production in strength determination test specified in the standard BS EN 196-1 (2016) was then extracted using an arrangement of sieve size 1.18 mm to 75 µm. The particles passing the 1.18 mm sieve but retained on the 75 µm sieve was used for the mortar mixture for the strength test. The 1.18 mm sieve was adopted as the upper limit value for the simulated reference sand instead of the 1.6 mm sieve specified by BS EN 196-1 (2016). Table 3.1 shows the Particle Size distribution of Fine Aggregate used. Additional physical properties determined for all the materials used for this experiment are the Bulk density in line with ASTM C128 (2015) and Fineness test conducted on PC and varied combination of SHA/CCW via-wet-sieving method as prescribed by BS EN 196-6 (2016) using a 45 µm sieve available in the laboratory.

2.3 Chemical Analysis of Cementitious Materials (PC, SHA and CCW)

20g of each samples of PC,SHA and CCW which was sieved by 75 µm was package and then taken to Ewekoro work department of Lafarge cement using XRF Analyser fitted with digital display system for data acquisition to analysed the respective chemical compositions and X-Ray Fluorescence analysis for determination of oxides composition of PC, SHA and CCW sample.

Corresponding author's e-mail address: owbolaji@yahoo.com

2.4 Fresh properties of self compacting mortar made with SHA and CCW.

Hassan,(2015) procedure was adopted in an attempt to establish an optimum paste and mortar volume that will satisfy certain flow time in which the method considered a fixed water binding ratio of 0.4 and superplasticiser dosages ranging from 1.5%, 1.75%, 2.00%, 2.25%, 2.50%, 2.75%, 3.00%, 3.25%, 3.50% and 3.75%.

2.4.1 Filling ability of the paste.

The filling ability in respect to the flow time was evaluated by a flow cone which is in line with (ASTM C939, 2010). The flow cone was levelled with the prepared sample according to the method considered a fixed water binding ratio of 0.4 and superplasticiser dosages ranging from 1.5%, 1.75%, 2.00%, 2.25%, 2.50%, 2.75%, 3.00%, 3.25%, 3.50% and 3.75%. Then the discharge tube was closed using a rubber stopper. The paste measured up to the calibration mark in the flow cone, the rubber stopper was then removed to allow the paste to flow out of the cone simultaneously, a stop watch was used to record the flow time of the paste. The discharge paste was collected using a container and subsequently released into the mixer pan for further mixing with additional MasterGlenium ACE456. Numerous additional dosages of MasterGlenium

ACE456 were added to the paste and the flow time was determined for each increment.

Figure 2.1: Set up for Filling ability (Flow Cone Test).

2.4.2: Flow Ability of Mortar (Mini V-funnel Test).

The flow ability of the mortar was tested using the mini v-funnel test, this measure the time it takes for the mortar to flow through the funnel, which enabled the determination of the mortar viscosity. The test apparatus was assembled firmly in the ground, the wall of the funnel was lubricated to allow for easy flow of mortar. The trap stopper closed and the funnel filled to the brim, after a delay of 5s, the stopper opened and the time taken for mortar to flow from the funnel to the time it takes to sight the light was recorded. This time interval is referred to as v-funnel flow time (Akram et al., 2009).The V-funnel apparatus is shown in Figure 2.2.

Figure 2.2: Set up for Flow ability of Mortar (Mini-V-Funnel).

Corresponding author's e-mail address: owbolaji@yahoo.com

Figure 2.3: Mortar Flow Mould

2.4.3: Filling ability of Mortar (flow Mould Test).

The flow mould test was conducted to investigate the filling ability of the mortar at various dosage of MasterGlenium ACE456. A standard flow mould which attunes to ASTM C 231/C 231M (2010) was locally fabricated and used to evaluate the filling ability with respect to the mortar flow spread. The flow mould used was shown in the Figure 2.3. The mould was placed over a leveled Plexiglas plate. Then the mould was raised vertically without any disturbance after it has been filled with mortar sample and the mortar was allowed to flow over the Plexiglas Plate. The average diameter of the mortar spread was the flow spread.

2.5: Determination of Degree of Hydration of the Binders.

Determinations of degree of hydration of the binders were carried out using 50mm mortar cubes. Production of the mortar samples involved weighing out the appropriate constituents materials and making sure that the SHA and CCW were properly mixed before measured quantity of simulated sand was injected. Then the sand and the binders were mixed properly before the weighed mixing water already added with HRWR mixed continuing until a uniform mix was attained before casting into 50 mm cubes mould. The control mortar a sample, on the other hand was mixed as described above. Then the samples were left covered with jute bags and cured by water sprinkling until 3 days before de-moulding and water curing by immersion until testing age. The step taken in achieving the determination of degree of hydration highlighted below adopted similar procedures reported in (Olawuyi, 2016).

The mortar cubes were cast and crushed at different curing ages (3, 7, 14 and 28 days) immediately after de-moulding.

The crushed sample of the mortar cubes was then milled properly by iron mortar and pestle and kept in an air tight polythene bag to stop further hydration.

A known weight of the vacuum dried sample about 20g from the particle passing 75μm standard sieve.

20g of the vacuum dried sample was oven dried for 24hours at 105°C and then weighed to determine the mass of the evaporated water.

This sample was then placed in the furnace set to 900°C at one hour time after the furnace temperature reads 900°C, the furnace was switched off and allowed to cool and the sample weighed.

Corresponding author's e-mail address: owbolaji@yahoo.com

All calculations were then based on ignited weight basis to give the following equation. Hence, the percentage of non – evaporable water ($w_n\%$) is calculated by using the following formula:

$$w_n\% = \frac{100 \text{ x (dried weight of paste} - \text{ignited weight of paste)}}{\text{(Ignited weigth of paste} - \text{loss on ignition of cement)}} \quad (1)$$

The degree of hydration (α) is then:

$$\alpha = 100 \text{ x} \frac{Wn}{0.23} \quad (2)$$

2.6: Compressive strength

The test was done with the Digital Universal Testing Machine (DUTM). The strength is the most important factor which determines the overall quality of masonry unit. The strength test was carried out on three specimens for each of the mortar mix corresponding to 3, 7, 14, 28, 56 and 90days for compressive strength test which is in line with the procedure of ASTM C39/39M, (2012).

3.0: Results and Discussion

3.1: Particle Size Distribution of Fine Aggregate.

Table 3.1: Particle Size Distribution of Fine Aggregate

Sieve opening (mm)	CEN Reference Sand (%)	Simulated Reference Sand (%)
2.00	0	0
1.60	7 ± 5	0
1.00	33 ± 5	3
0.50	67 ± 5	16
0.16	87 ± 5	92
0.08	99 ± 1	99

Table 3.1 however presents PSD of the CEN reference sand for determination of strength of cement as compared to the simulated reference sand used. It was observed that the simulated reference sand was in-line with three (3) of the six (6) range requirements of the CEN reference sand as prescribed in BS EN 196-1 (2016). The strength of the mortar samples from PC used in this study serves purely as a reference to which the strength of the alternative agro-industrial waste binder was compared.

Table 3.2: Bulk Density of Constituent Materials (kg/m^3)

Material	Bulk density(kg/m^3)
PC	3150
SHA	3320
CCW	2290
SAND	2580

Corresponding author's e-mail address: owbolaji@yahoo.com

Table 3.2 presents the bulk density for materials and the valves obtained corresponded to what was reported by (Neville, 2011) on bulk density of PC for mortar production.

Table 3.3: Fineness of the Binders

Binder	PC	SHA	CCW
Wt. of binder before sieving (g)	250	250	250
Wt .of binder residue after sieving (g)	10	12	14
Fineness (%)	4	4.8	5.6

Table 3.3 present the average result on fineness of the binder. The Table reveals that the fineness of the binder used in this study are 4, 4.8 and 5.6% for PC, SHA and CCW respectively of the percentage retained. The fineness value of the binders conforms to ASTM C786 (2016) of 10% maximum of the retained.

Table 3.4: Result of XRF Analysis for Oxides Composition of Cementitious Material

Samples	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	TiO_2	P_2O_5	MnO_3	Cr_2O_3	AR	SR	SiO_2 +Al_2O_3 + Fe_2O_3
SHA	5.6	83.0	2.9	2.7	1.3	0.8	0.0	0.2	2.8	0.2	0.5	0.0	0.0	1.1	14.7	88.6
CCW	26.4	3.6	1.6	1.3	65.8	0.2	0.0	0.1	1.0	1.0	0.1	0.0	0.0	1.2	1.2	6.5
PC	0.0	21.5	5.2	1.2	64.0	2.9	4.5	0.6	0.0	0.1	0.2	0.0	0.0	4.5	3.4	27.8

Table 3.4 shows the oxides composition of the various cementitious materials obtained through XRF conducted at Larfarge cement in Ewekoro. The SHA sample is major in silica and SiO_2 of 83%. The table indicated the agro waste as class N pozzolan with total SiO_2 +Al_2O_3+ Fe_2O_3 above 70%, SO_3 below 4% and loss on ignition (LOI) of less than 10%. The CCW was detected to contain 66% CaO, a similar value to the CaO content (64%) of the PC sample. The CCW was however noted to be of lower in SiO_2 and Al_2O_3 when compared to the PC sample.

3.3 The Fresh Properties of Self Compacting Mortar.

Hassan,(2015) procedure was adopted in an attempt to establish an optimum paste and mortar volume that will satisfy certain flow time in which the method considered a fixed water binding ratio of 0.4 and superplasticiser dosages ranging from 1.5%, 1.75%, 2.00%, 2.25%, 2.50%, 2.75%, 3.00%, 3.25%,3.50% and 3.75%. The result of Filling ability of paste, Flow ability of mortar and Filling ability of mortar made from varied combinations of SHA/CCW (70:30) was gotten from the Tables below.

Corresponding author's e-mail address: owbolaji@yahoo.com

Table 3.5: Flow cone test for paste (70:30)

PN	SHA %	CCW %	W/B RATIO	SHA (Kg)	CCW (Kg)	H_2O	HRWR	FT (Sec)
70/30 A	70	30	0.40	282.14	121.18	161.56	1.50	15:30
70/30 B	70	30	0.40	282.14	121.18	161.56	1.75	13:34
70/30 C	70	30	0.40	282.14	121.18	161.56	2.00	11:26
70/30 D	70	30	0.40	282.14	121.18	161.56	2.25	8:40
70/30 E	70	30	0.40	282.14	121.18	161.56	2.50	7:13
70/30 F	70	30	0.40	282.14	121.18	161.56	2.75	6:01
70/30 G	70	30	0.40	282.14	121.18	161.56	3.00	4:03
70/30 H	70	30	0.40	282.14	121.18	161.56	3.25	2:22
70/30 I	70	30	0.40	282.14	121.18	161.56	3.50	1:08
70/30 J	70	30	0.40	282.14	121.18	161.56	3.75	1:06

Result of the flowing ability of binder paste which involves determining the time of flow of the proportion of binder (70:30%) SHA : CCW paste at an incremental dosage of HRWR from 1.5 to 3.75% by weight of binder. Ten (10) batches of pastes were tested for flowing ability. Table 3.5 show the filling ability of series of binder pastes with respect to the flow time at various dosage of HRWR. As can be seen, the filling ability increases as the flow time of the paste decrease. Also the decrease in the flow time is as a result of increase in the dosage of HRWR. It is particularly due to the reduction in the plastic viscosity of the binder paste. This occurs because of the liquefying ability of the HRWR. Lastly it was observed that at greater than 3.25% the flow time of the binder paste becomes relatively close, this shows that if the HRWR dosage increase beyond 3.5% saturation dosage or point is attained, any addition of HRWR dosage will not have noticeable effect on the flow time of the respective binder paste.

Table 3.6: Mini V – Funnel Reading for Mortar (70/30)

PN	SHA %	CCW %	WB RATIO	FA (Kg)	SHA (Kg)	CCW (Kg)	H2O %	HRWR %	FT (Sec)
70/30 A	70	30	0.40	826.2	282.14	121.18	161.56	1.50	10:42
70/30 B	70	30	0.40	826.2	282.14	121.18	161.56	1.75	9:22
70/30 C	70	30	0.40	826.2	282.14	121.18	161.56	2.00	8:36
70/30 D	70	30	0.40	826.2	282.14	121.18	161.56	2.25	5:32
70/30 E	70	30	0.40	826.2	282.14	121.18	161.56	2.50	4:52
70/30 F	70	30	0.40	826.2	282.14	121.18	161.56	2.75	3:01
70/30 G	70	30	0.40	826.2	282.14	121.18	161.56	3.00	2:19
70/30 H	70	30	0.40	826.2	282.14	121.18	161.56	3.25	0:47
70/30 I	70	30	0.40	826.2	282.14	121.18	161.56	3.50	0:37
70/30 J	70	30	0.40	826.2	282.14	121.18	161.56	3.75	0:35

Result of the flowing ability of mortar which involves determining the time of flow of the proportion of binder (70:30%) SHA : CCW mortar at an incremental dosage of HRWR from 1.5 to

Corresponding author's e-mail address: owbolaji@yahoo.com

3.75% by weight of binder. Ten (10) batches of mortar were tested for flowing ability. Table 3.6 shows the flowing ability of series of mortar with respect to the flow time at various dosage of HRWR. As can be seen, flowing ability increases as the flow time of the mortar decreases. Also the decrease in the flow time is as a result of increase in the dosage of HRWR. It is particularly due to the reduction in the plastic viscosity of the binder paste. This occurs because of the liquefying ability of the HRWR. Lastly it was observed that at greater than 3.25% the flow time of the binder paste becomes relatively close, this shows that if the HRWR dosage increase beyond 3.5% saturation dosage or point is attained, any addition of HRWR dosage will not have noticeable effect on the flow time of the respective mortar.

Table 3.7: Flowing ability of Mortar-flow Mould test

Mortar Nomenclature	Fine Aggregate (kg).	Water(kg)	Saturation Dosage (%)	W/B Ratio	Flow (mm)	Spread
PC (CONTROL)	826.2	161.06	3.5	0.40	295	
SHA/CCW(70/30)	826.2	161.06	3.5	0.40	290	
SHA/CCW(60/40)	826.2	161.06	3.5	0.40	285	
SHA/CCW(50/50)	826.2	161.06	3.5	0.40	280	
SHA/CCW(40/60)	826.2	161.06	3.5	0.40	275	
SHA/CCW(30/70)	826.2	161.06	3.5	0.40	265.	

The result of Flow Mould Test presented in Table 3.7 shows the flow spread characteristic exhibited by different group of mortar formulated as shown in Table 3.7. The flowing ability was discussed in terms of how mortar spread, and from the results obtained the spread varied between 265-295 mm for the different mortar which was in accord with 260 mm specified by EFNARC (2002). Thus the saturation dosage of the corresponding mixtures was found to be sufficient. Therefore the importance of the flow spread results of mortar has shown that the flow pattern of mortar is greatly affected by HRWR dosage and powder content of the binder. The end means of this research helps in sufficient proportioning of high range water reducer (HRWR) for production of SCM.

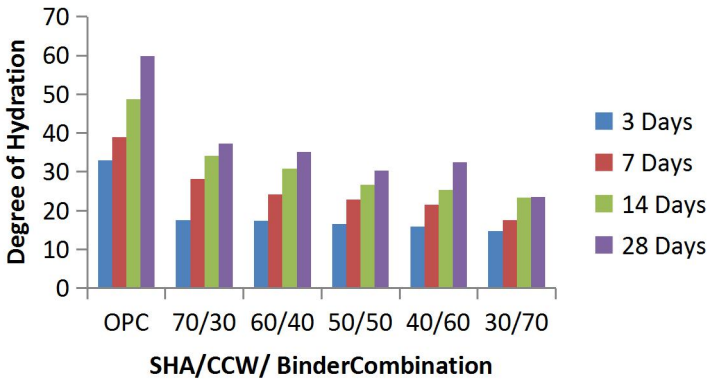

Figure 3.1: Degree of Hydration of Hardened SHA/CCW Mortar

Corresponding author's e-mail address: owbolaji@yahoo.com

3.4 Degree of Hydration

The degree of hydration presented in Figure 3.1 shows the trend of hydration rate of binder combination with their respective ages. The Graph shows that 70/30 of SHA/CCW has the highest degree of hydration value of 52.7% as compared to PC at 28 days curing ages. Also the hydration process proofed to improve as the curing ages advanced likewise the binders are expected to show good long term age strength development.

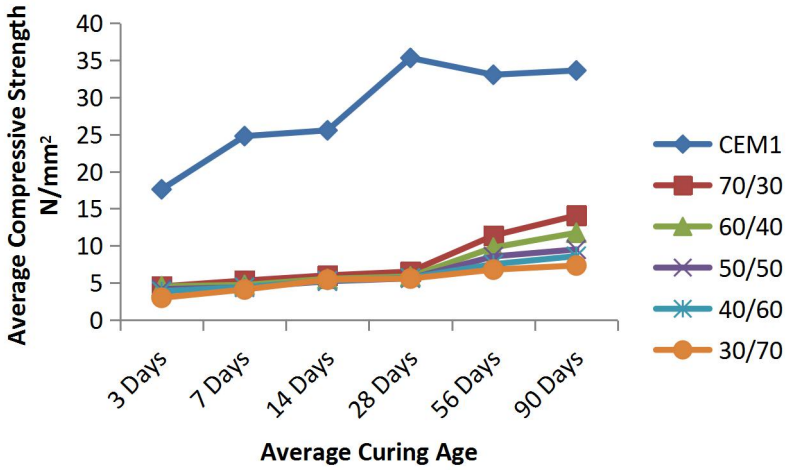

Figure 3.2: Average compressive strength of SCM

The compressive strength test presented in Figure 3.2 was determined over a period of 90 days. A rise in compressive strength was observed until the end of the 90 days for all SCM and this is as a result of enhancement in the hydration process. The compressive strength at the first 28 days was in the range of 5.29-6.52 N/mm^2 and at age of 90 days it ranges from 7.34-14.08 N/mm^2. SHA/CCW (70/30) by proportion shows a higher compressive strength (14.08 N/mm2) comparing with the work of Egwuda (2018). The compressive strength value was 7.56N/mm2 for 28 days which is about 36% of PC strength and for 90 days (8.03N/mm^2) about 37% of PC strength. More so, a direct proportional relationship between the curing ages and the strength because there is slow hydration process due to the presence of SHA and CCW which is triggered the pozzolanic reaction at later ages. Also it was observed that the samples bind effectively with the fine aggregates after de-moulding at the third day after casting and the mortar made from agro based binders did not dissolve all through the curing ages (by total immersion in water).

4.0 Conclusion

The chemical analysis shows SHA as class N pozzolans with Total SiO_2 +Al_2O_3+ Fe_2O_3 above 70% according to ASTM C618-05 (2017) while CCW was observed to contain 66% Calcium oxide a similar value to the Calcium oxide content (64%) of the PC sample. The fineness of the constituent's materials conforms to BS EN 1097-6 (2013). The highest compressive strength of SCM made with SHA/CCW was gotten at 90 days of SHA/CCW (70/30) proportion with the value of 14.08 N/mm^2 which is in line with type N of ASTM C270 mortar. The optimum saturation dosage of 3.5% was obtained from flow cone test for paste and mini-v-funnel test for mortar. The SHA/CCW (70/30) shows the highest mortar flow rate of 290mm compared to the control (PC) 295mm. The alternative binder from agro waste (SHA) in combination with industrial waste (CCW) has a good binding property.

Corresponding author's e-mail address: owbolaji@yahoo.com

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Corresponding author's e-mail address: owbolaji@yahoo.com

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Corresponding author's e-mail address: owbolaji@yahoo.com