Nanotechnology Application in the Development of Fonio Husk Ash and Calcium Carbide Waste Based-Binder Mortar

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Abstract

One of the measures taking during COVID-19 Pandemic was to avoid crowded places like markets, places of worships and others. The living environment of many of the low-income group of the Society is generally noted for been crowdy, un-hygienic and hence are avenue for ease spread of diseases during epidemic/pandemic. This therefore necessitate further research works towards sustainable low-cost houses using eco-friendly binders. This is coupled with the challenge of high carbon – dioxide (CO_2) emission, energy consumption and environmental degradation associated with Portland cement (PC) production. Recent efforts at the utilization of Agricultural wastes (rice husk ash (RHA); millet husk ash (MHA); sorghum husk ash (SHA), etc.) in combination with calcium carbide waste (CCW) for green concrete development gave reports of slow hydration and strength development. Hence the need for developing methods of improving the performance of the eco-friendly binders for which this study is one. This research examines the combination of FHA and CCW (agro - industrial wastes) with the incorporation of nanotechnology for improved hydration and strength enhancement. The study adopted a qualitative approach where Fonio husk obtained from Jaba Local Government Area of Kaduna State was incinerated using the locally fabricated incinerator in the Concrete Laboratory of the Department of Building, Federal University of Technology, Minna. Calcium Carbide waste obtained from Auto-mechanic village in Keteren Gwari area of Minna was oven-dried and calcined too and then pulverised. The FHA and CCW samples were analysed using an X-ray florescent machine to ascertain their chemical composition and further subjected to cement - based tests (i.e., setting time, consistency, soundness and strength tests). Trial combinations of FHA/CCW at 55/45, 50/50 and 45/55 was used as alternative binder in mortar mixes with the cast mortar cubes cured and crushed for compressive strength at 3, 7, 14 and 28 days. Data presented using tables were analysed for an informed conclusion on the performance of FHA/CCW binder – based mortar.

Key words: *Nano – silica particles (NSP), Fonio Husk Ash (FHA), Calcium Carbide Waste (CCW), eco – friendly binders, green concrete.*

1 Introduction

The COVID-19 experience world-over necessitates the need to discourage living in crowdy and un-healthy environments with the poor and low-income groups of the society noted to live generally in very crowdy and clustered areas with little or no provision at all for toilets and proper hygiene due to the ever-increasing high cost of construction. In a report by the Nigeria Centre for Disease Control (NCDC on the recent outbreak of Diphtheria, people who live in a crowded environment, in areas with poor sanitation and healthcare workers are the most susceptible to be infected (Premium Times, 25th Jan. 2023). This implies research sustainable low-cost building to house the rural mass using eco-friendly binders has to be a continuous thing.

Portland Cement (PC) known to be the major binding material used in the construction industry is poised with lots of challenges such as: the production of involves a lot of energy consumption; has been advocated to contribute above 5% of the total global anthropogenic carbon dioxide (CO_2) emission (Natapong *et al*., 2010); the challenge of climate change due to global warming (greenhouse gas, GHG)) which results from (CO_2) emission into the atmosphere is also a major problem. The impact of these emissions on the environment has caused many to focus on CO_2 emissions as the most critical environmental impact indicator (Natapong *et al*., 2010). Cement manufacture contributes GHG both directly through the production of CO_2 when calcium carbonate ($CaCO_3$) is thermally decomposed, producing lime (CaO) and CO_2; and also, through the use of energy, particularly from the combustion of fossil fuels (Environmental Impact Assessment EIA, 2011).

Gupta (2014) posits that there has been a lot of efforts made towards the reduction of the CO_2 emission from concrete primarily through the use of lower amounts of cement and higher amount of supplementary cementitious material (SCM). This will translate into a reduction in the GHG emission thereby giving rise to a safer environment. Gupta (2014) thereby concludes that green materials are mostly recycled, reusable or by-products and wastes which are environmentally friendly. In agreement with the above position, Saurabh (2016) asserts that green concrete is eco-friendly and saves the environment by using waste products generated by industries. Saurabh (2016) added that the use of green concrete helps in saving energy, emissions, waste water and it also leads to a cheaper concrete material. Jagadish *et al*., (2015) also asserts that a large number of industries produce waste materials which need to be either disposed-off or utilized for some other purposes. In most cases, disposal of these wastes usually poses major problems where in some cases large chunks of land are usually rendered useless or unusable due to disposal of such wastes. Nigeria being an agrarian society has plenty of post-harvest agro-wastes, while some industrial by-products abound, constituting a nuisance to the environment. These materials if well processed could serve as the requisite alternative green binder.

Fonio also called "*digitarial exilis*" or "*digitarial eburua*" is known as "*Acha*" in Hausa language. The husk obtained from de-husking the grain is one of the agro-wastes that are generated annually. This study aims at using the ash obtained from incinerating the Fonio husk in combination with Calcium Carbide Waste (CCW) - a by-product of acetylene gas welding (an industrial waste) for utilization as a substitute for PC in mortar. These two waste materials constitute environmental nuisance and hazards, because when they are not disposed-off properly, the FHA emits foul odour after rainfalls or the Fonio husks if undisposed can also be blown off by wind as dust, while the CCW can leach harmful chemicals into the ground when washed by rain thereby making underground water to become unwholesome. The need for an investigation into the utilization of FHA and CCW as an alternative binder in mortar/concrete will go a long way towards establishing green and eco – friendly construction.

Vichan & Rachan (2013); Horpibulsuk *et al*., (2011) defined CCW or carbide lime as a by-product of acetylene manufacturing, which dissolves in water to produce $Ca(OH)_2$. CCW and hydrated lime are similar in their chemical and mineralogical compositions with the exception of the presence of carbon in CCW. Makaratat *et al*., (2010) studied calcium carbide waste – fly ash (CCW-FA) concrete, for a weight ratio of 30-70 (CCW-FA) used as a binder to cast concrete. CCW was reported to have specific gravity value of 2.32 (Horpibulsuk *et al*., 2011). Yunusa (2015) asserted that concrete cubes cast using 0 to 50% replacements at 10% step increments replacement of cement with CCW possess the properties (such as setting time, soundness and workability) of PC cubes with reduction in compressive strength when exceeding 10% replacement owing to increase in water absorption of the mix. Gupta & Wayal (2015) used CCW ground in a mill to increase its fineness and was mixed with fly ash (FA) at a ratio of 30:70 (CCW: FA) as a binder without PC. The setting times (initial and final) of CCW: FA concretes were much longer than the normal concrete with compressive strength values between 19.0 and 24.7 N/mm^2 at 28 and 90 days respectively. The lower the W/B ratio, the higher the compressive strength of CCW: FA concrete. The hardened concrete was reported to be of same properties as that of the PC-based concrete (Makaratat *et al*., 2010). Jaturakkul & Roongreeung (2003) worked on cementing material from CCW and RHA and reported that a pozzolanic reaction occurred when CCW is mixed with RHA for mortar and achieved a highest compressive strength of $15.6N/mm^2$ at 28 days of age.

In the past research effort was centred on partial replacement of PC with SCM. The work of Ndububa *et al.*, (2016) on FHA showed that it could be used to replace PC up to 10% without adverse effect on compressive strength. The study further showed that the tricalcium silicate (C_3S) content in the ash was not too significant. It was established in literature Neville (2013); Mehta and Monteiro (2014) that C_3S content in PC is responsible for its fast reaction. Studies also revealed that the di-calcium silicate (C_2S) content of the FHA was high which accounts for the slow setting and hydration of concrete produced as evidenced both in the work of Ndububa *et al.*, (2016) and Matawal (2012). Recently, study on total replacement of PC with agro-industrial based waste materials (RHA/CCW and MHA/CCW) has been reported by Olawuyi *et al*., (2017) with promising results obtained, but revealed slow hydration and low strength characteristics.

Yu Chen, *et al*., (2016) worked on the influence of Nano-silica particles (NSP) on the consistency, setting time, early-age strength and shrinkage of composite cement pastes and concluded that there was significant reduction of setting times and that the effect of the NSP was remarkable as there was also improved early–age strength development when NSP was added to the mix. The influence of NSP was also seen on early age shrinkage which was due to smaller sizes of the NSP because of higher surface area leading to a higher reactivity (Yu Chen *et al*., 2016). Narender & Meena (2017) in their work reported that Nanotechnology is an interesting but emerging field of study which is under constant evolution offering a very wide scope of research activity. It was stated that if the particle size ranges between 1nm to 100nm, they are generally called Nano-particles or materials. As fineness increases, the surface area increases, which also increases the 'reactivity' of the material. Narender & Meena (2017) hold the view that the application of Nano-cement in concrete can lead to significant improvements in the strength and life of the concrete. The use of finer particles which translates to higher surface area has advantages in terms of filling the cement matrix and increasing the density of the concrete thereby resulting in higher strength and faster chemical reaction which is also called hydration. Nano-cement particles can accelerate cement hydration due to their high re-activity. They can fill pores more effectively to enhance the overall strength and durability of concrete (Narender & Meena, 2017).

Narender and Meena (2017) concluded that:

i. The improvement in mechanical properties due to the incorporation of NSP was made possible because of the pore filling effect of the NSP and also due to pozzolanic reactions.

ii. The Nano-size materials reduced the pore size making the concrete denser and accounts for increase in durability.

iii. The dense parking also helps in restricting the entry of unwanted substances such as air, water and other chemicals into the concrete thereby increasing the durability of the concrete.

iv. The reason for the increase in concrete strength with increase in NSP content is that it acts as activator to promote the hydration and also to improve the microstructure of cement paste if NSP were uniformly dispersed. The strength is enhanced with NSP addition, especially at early stages, and the pozzolanic activity of NSP was greater than other materials.

v. It was observed that NSP blended concretes have higher strength as compared to non-blended-concretes, as the strength was found to be higher at all ages for NSP-blended concretes.

Most of the research works discussed above are limited to cement pastes with only a few researchers having worked extensively on mechanical properties and permeability of the concrete incorporating NSP. It is in view of the foregoing that this study aims at researching into the utilization of FHA/CCW binder incorporating NSP to cater for the already established slow hydration and low strength characteristics of the agro – industrial wastes as reported by Ndububa *et al.*, (2016); Matawal (2012) and Olawuyi *et al.*, (2017).

2. Materials and Method

This study adopted the inductive method of research design where materials were sourced and taken to the Concrete Laboratory of the Building Department of the Federal University of Technology, Minna for processing. The materials used in the study are discussed in the following subsections.

2.1 Portland Cement (PC)

The PC (CEM I 42.5 N) used for this study is the Dangote (3X) brand of cement. The reason for the use of this brand is that it is readily available in the research location and its strength has been attested to by many users. Precaution was taken to ensure that the cement was of recent supply and free of adulteration. The cement as stated in the package conforms to NIS 444-1: 2003.

2.2 Fonio Husk Ash (FHA)

The Fonio husk was obtained from Fonio milling shops in Kwoi, Jaba Local Government of Kaduna State and taken to the Concrete Laboratory of the Building Department of Federal University of Technology, Minna and calcined using the locally fabricated incinerator available in the Laboratory. The resulting ash was then taken to the Civil Engineering Department of the Federal Polytechnic Bida for pulverising using the Los Angele's Abrasion Testing Machine.

The ash was sieved using the 75 and 45µm sieves before three (3) kilograms of the ash passing through the 45µm taken to the Centre for Genetic Engineering of the Federal University of Technology, Minna for Nano-silica particles (NSP) production. Chemical analysis of the FHA and NSP was conducted at the Chemical Engineering Department of Kaduna Polytechnic.

2.3 Calcium Carbide Waste (CCW)

The CCW was obtained from auto – mechanic workshops at Keteren Gwari area of Minna and taken to the Building Department where it was sun-dried, subjected to further drying in the incinerator and also pulverized with the Los Angeles Abrasion machine before sieving with the 75µm sieve. A sample of the resulting CCW powder was also sent to the Chemical Engineering Department of Kaduna Polytechnic for chemical analysis.

2.4 Nano-Silica Particles (NSP)

Nano-silica particles were produced using the pulverized FHA at the Centre for Genetic Engineering, Federal University of Technology, Minna using the particles that passed through the 45µm sieve. The NSP were produced and incorporated into the mortar mix at percentages ranging from 0 to 5.0% at staggering steps.

2.5 Fine Aggregate

The sharp sand used for this research work is the natural river sharp sand obtained from the local sand suppliers in Minna, Niger State. The particles retained within 1:18 mm (Sieve No. 16) to 75µm (Sieve No. 200) in accordance with BS 812-103.1: 2000 served as the simulated reference sand, an alternative to the standard CEN reference sand.

2.6 Water

The water used for the production and curing of mortar samples of this research work was the clean potable water available at the Building Laboratory of the Federal University of Technology Minna, Niger State.

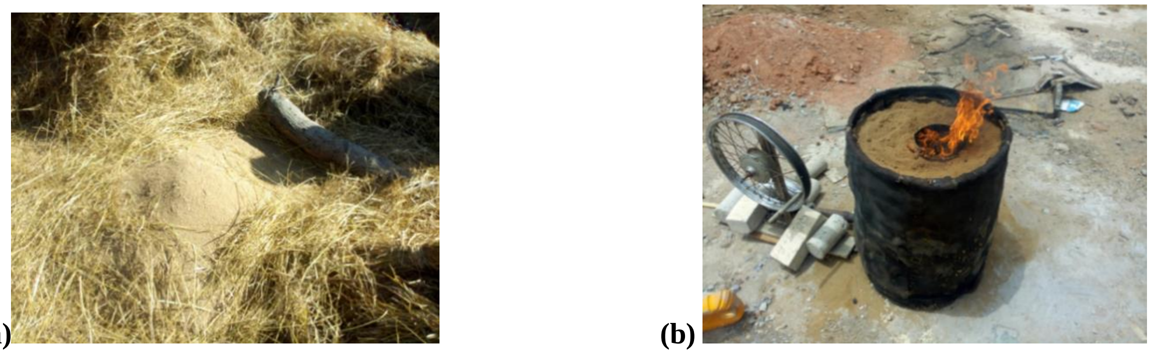
2.7 Mortar Mix Details

Mortar was prepared using 50 mm cube size in accordance with BS EN 196-1: 2016. Three combination proportions (55/45, 50/50 and 45/55) of FHA/CCW were produced as the alternative binders, while the PC based-mortar mix denoted as CEM I served as the control for the study in determining the most suitable appropriate combination proportion. The NSP content was made to vary as earlier explained at 1% steps from 0.5% to 5.0% (Table 1). Thirty (30) cubes were cast (Figure 2a) from each mix and cured for varied curing ages (3, 7, 14, 21 and 28 days). Batching and mixing of mortar samples was carried out using 1:3 cement/sand (c/s) and 0.5 water/cement (w/c) ratio as specified by BS EN 196 -1:2016 for CEM II as control. The alternative binders comprised of varied proportion combinations of FHA/CCW, while the w/c ratio (0.65) used was noted to be slightly higher than that of the CEM II. The cast samples were kept in the mould and covered with jute bags and cured by water sprinkling for 24 hours before de-moulding (Figure 2b) and further cured in water by immersion for crushing at the various ages.

Table 1: Mix Proportions for Mortar Samples

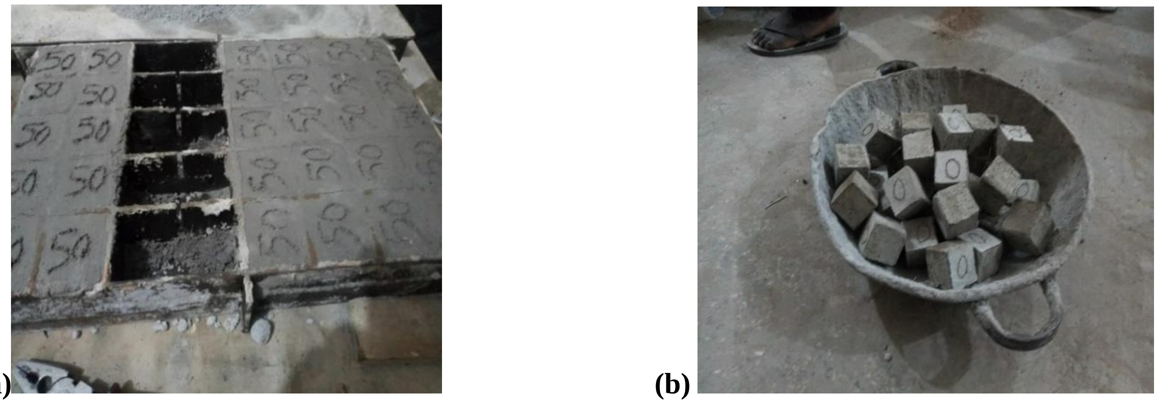
S/No	Specimen	CEM	FHA	CCW	SAND	NSP($\%_{bwob}$)	Water
1	CEM II	1775	0	0	5325	0 (=0g)	888
2	55/45a	0	975	800	5325	0 (=0g)	888
3	55/45b	0	975	800	5325	1.5 (=26.6g)	888
4	55/45c	0	975	800	5325	2.5 (=44.4g)	888
5	55/45d	0	975	800	5325	4.5 (=79.9g)	888
6	55/45e	0	975	800	5325	5.0 (=88.8 g)	888
7	50/50a	0	888	888	5325	0 (=0g)	888
8	50/50b	0	888	888	5325	1.5 (=26.6g)	888
9	50/50c	0	888	888	5325	3.0 (=53.3g)	888
10	50/50d	0	888	888	5325	4.5 (=79.9g)	888
11	50/50e	0	888	888	5325	5.0 (=88.8)	888
12	45/55a	0	800	975	5325	0 (=0g)	888
13	45/55b	0	800	975	5325	0.5 (=8.9g)	888
14	45/55c	0	800	975	5325	1.5 (=26.6g)	888
15	45/55d	0	800	975	5325	2.5 (=44.4g)	888
16	45/55e	0	800	975	5325	3.5 (=62.1g)	888
17	45/55f	0	800	975	5325	4.5 (=79.9g)	888
18	45/55g	0	800	975	5325	5.0 (=88.8g)	888

Photo Gallery



(a) **(b)**

Figure 9: (a) Harvesting of Fonio and (b) Incineration of Ash Started



(a) **(b)**

Figure 10: FHA/CCW Mortar cubes: (a) cast cubes (b) De-moulded mortar cubes

3. Results and Discussion

Table 2 presents the result of the X-ray florescent (XRF) for FHA, CCW as Compared with PC composition. From the result, it can be seen that the FHA has SiO_2 (86%) as its major oxide and total useful oxide (SiO_2 + Al_2O_3+ CaO+ Fe_2O_3) of 89% which is above the minimum content specified in ASTM C618-19 (35% for SiO_2 and 70% for total useful oxides). The CCW on the other hand has CaO

(83%) as its major oxide and this was found to be greater than the expected CaO content (67%) in typical PC. The proportion of the composition matters a lot for an assessment of the pozzolanic tendencies of the materials. This result shows that the silica is very high in the FHA. The major composition of FHA (86% SiO_2) and CCW (83% CaO), if found reactive should result in Calcium Silicate Hydrate (C-S-H).

Table 2: Oxide Composition of FHA and CCW as Compared with PC

Oxide	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	ZnO	CuO	MnO	Cr_2O_3	TiO_2	PO	P	C	Na	SO
FHA	85.64	8.13	0	3.58	2.01	0.12	0.02	0.23	0.01	0.26	0	0	0	0	0
CCW	2.3	82.6	2.19	0.71	0.47	0	0	0	0	0	0.3	0.1	8.3	0	0
PC	17-25	60-67	3.0-8.0	0.5-0.6	0.1- 4	0	0	0	0	0	0	0	0	0.3	2.-3.5

*PC's oxide composition as provided in literature (Neville, 2012; Mehta & Monteiro, 2014).

Table 3 presents setting times result (Initial and Final). The mortar samples without the NSP had higher initial and final setting times, but after the NSP was added to the mix, the rate hydration improved tremendously where the 55/45 FHA/CCW binder without NSP gave an initial setting time of 138 minutes and a final setting time of 225 minutes (i.e. 135 minutes longer setting). This implies 150% delay when compared to CEM II based mortar samples. The 50/50 FHA/CCW binder produced an initial setting time of 140 minutes and a final setting time of 240 minutes which is 150 minutes delayed setting (167%) to CEM II, while the 45/55 FHA/CCW binder without NSP produced an initial set time of 125 minutes and a finally set at 205 minutes which is 115 minutes (128%) beyond that of the CEM II.

Results also show that after the NSP addition the hydration of the materials improved tremendously. The 55/45 FHA/CCW binder + NSP gave an average initial setting time of 118 minutes a final setting time of 210 minutes which is 120 minutes delay (133%) compared to CEM II. The 50/50 FHA/CCW binder + NSP gave an average of 105 initial setting time and a final setting time of 185 minutes which is 95 minutes delay (106%) compared to CEM II. Finally, the 45/55 FHA/CCW binder + NSP produced an initial set time of 94 minutes and a final setting time of 144 minutes which is 54 minutes delay (60%) beyond CEM II.

Table 3: Result of Setting Times of Cement and Alternative Binders

S/N	Specimen	NSP ($\%b_{wob}$)	Initial Setting Time (Mins)	Final Setting Time (Mins)	Difference with PC (Mins)	Percentage Difference (%)
1	CEM II	0	35	90	0	0
2	55/45a	0	138	225	135	150
3	55/45b	1.5	110	215	125	139
4	55/45c	2.5	115	210	120	133
5	55/45d	4.5	125	205	115	128
6	55/45e	5.0	120	210	120	133
7	50/50a	0	140	240	150	167
8	50/50b	1.5	115	190	100	111
9	50/50c	3.0	100	170	80	89
10	50/50d	4.5	95	185	95	106
11	50/50e	5.0	110	195	105	117
12	45/55a	0	125	205	115	128
13	45/55b	0.5	100	160	70	78
14	45/55c	1.5	95	145	55	61
15	45/55d	2.5	90	135	45	50
16	45/55e	3.5	100	140	50	56
17	45/55f	4.5	85	130	40	44
18	45/55g	5.0	95	155	65	72

Table 4: Compressive strength results of PC and the FHA/CCW Combinations without + NSP (N/mm^2)

S/N	Specimen	NSP (%)	3 Days	7 Days	14 Days	21 Days	28 Days

1	**CEM II -Control**	**0**	**14.11**	**18.24**	**23.31**	**27.03**	**27.58**
2	**55/45a –Control**	**0**	**1.22**	**1.37**	**1.43**	**1.51**	**1.71**
3	55/45b	1.5	1.59	1.75	1.65	2.07	2.05
4	55/45c	2.5	1.66	1.70	1.54	2.03	1.62
5	55/45d	4.5	1.65	1.77	1.67	2.48	2.48
6	55/45e	5.0	1.87	1.81	2.50	2.68	2.63
7	**50/50a -Control**	**0**	**0.87**	**0.89**	**1.04**	**1.10**	**1.16**
8	50/50b	1.5	1.83	1.91	1.78	1.95	1.77
9	50/50c	3.0	1.83	2.20	1.95	4.65	1.64
10	50/50d	4.5	1.77	3.97	4.58	5.26	6.26
11	50/50e	5.0	1.83	3.24	4.38	2.26	5.50
12	**45/55a –Control**	**0**	**1.32**	**1.43**	**1.60**	**1.79**	**2.07**
13	45/55b	0.5	5.07	**6.75**	4.86	5.95	8.97
14	45/55c	1.5	**5.24**	5.23	7.14	5.55	7.63
15	45/55d	2.5	3.61	2.89	**9.75**	**9.11**	**9.28**
16	45/55e	3.5	2.37	3.44	4.25	4.13	5.66
17	45/55f	4.5	3.01	2.93	4.18	4.18	4.02
18	45/55g	5.0	2.62	3.34	4.42	4.33	4.79

Table 4 presents the compressive strength results of the PC, 55/45, 50/50 and 45/55 FHA/CCW binders first as controls then added with NSP. The controls are highlighted in the Table (S/N. 1, 2, 7 & 12).

From the results, the 55/45a FHA/CCW binder had 3 days compressive strength of 1.22 N/mm^2 but 28 days of age with a strength value of 1.71 N/mm^2. This represents a total development of 28.65% from 3 days of age to 28 days of age. These values are extremely low if consideration for their usage as mortar is to be made.

The 50/50a FHA/CCW binder compressive strength result at 3 days of age as low as 0.87 N/mm^2 and 1.16 N/mm^2 at 28 days. The 45/55a FHA/CCW binder on the other hand gave a compressive strength of 1.32 N/mm^2 at 3 days and peaked at 28 days with a strength value of 2.07 N/mm^2. The 50/50a combination though improved by about 25% during the entire duration of strength development from 3 days to 28 days, the 3 days and 28 days strength values were found to be very low compared to the 45/55a combination. The 45/55a binder gave results that were better than the first two binders, but the results were still very low.

After the NSP addition, there was an improvement in the compressive strength of all the mixes. There were total of seven (7) trial percentages of NSP addition in all, they are: 0.5%, 1.5%, 2.5%, 3.0%, 3.5%, 4.5% and 5.0%. The NSP content addition that gave the best result for the 45/55 FHA/CCW is the 2.5% which yielded a compressive strength value of 9.75 N/mm^2 at 14 days. The compressive strength value of the 45/55 FHA/CCW without NSP at the same age was found to be 1.60 N/mm^2. Values of the 45/55 combination's general performance are presented in Table 4.

The 45/55 FHA/CCW binder produced the best result generally, although its early strength of 3 and 7 days was found to be poor compared to the other percentages. This is because, the best compressive strength result of the 45/55 FHA/CCW plus NSP at 3 days was that of the 1.5% NSP content which gave a compressive strength value of 5.24 N/mm^2, this result is 62.86% lower than the corresponding CEM II control at the same age which was found to be 14.11 N/mm^2.

After 14 days of curing, the best performed of the 45/55 FHA/CCW + NSP was that with 2.5% NSP found to be 9.75 N/mm^2. This result is 58.17% lower compared to the corresponding CEM II control at the same age which was found to be 23.31 N/mm^2. The 45/55 binder also produced both the 21 days and at 28 days best compressive strength values of the entire experiment which were found to be 9.11 N/mm^2 and 9.28 N/mm^2, representing 66.30% and 66.58% lower compared to the corresponding CEM II control at both 21- and 28-days age which was found to be 27.03 N/mm^2 and 27.77 N/mm^2 respectively.

Summary of Findings

The following were the major findings of the study:

1. Chemical analysis of the FHA revealed that the ash contained 85.6% SiO_2, 3.58% Fe_2O_3, 8.1% CaO, and 2.01% MgO. Other elements were present in the ash at very insignificant quantities.
2. Oxide composition of the CCW revealed that 82.6% CaO, 2.3% SiO_2, 2.19% Al_2O_3 and 8.51% Carbon. Other minor compounds were found to be very insignificant.
3. The study revealed tremendous improvement in the hydration process as there was reduced final setting times for all three combinations of FHA/CCW when NSP addition. The 40/60 with NSP saved up to 65 minutes (i.e., 29%) savings in the duration of final setting of the combination. The 50/50 with NSP also saved up to 70 minutes (also, 29%) savings in the duration of final setting of the combination and finally the 45/55 with NSP saved up to 75 minutes (i.e., 37%) savings in the duration of final setting of the binder combinations. The experiment produced a general average savings of 31.7% in final setting time which indicates that NSP addition saved close to one third (1/3) of time during the hydration process of the materials.
4. Compressive strength results of the combinations without NSP were found to be very low, with the best performed having 2.07 N/mm^2 as 28 days strength of the 45/55 combination. However, after the addition of NSP, there was a boost in all the cubes crushed for all three combinations. The best performed for the 40/60 combination with 5% NSP with average increase of 57.6%. The 50/50 combination with 4.5% NSP gave average increase of 321.4%, while 45/55 combination with 2.5% NSP has average increase of 308.2%.

The general average increase (in percentage) after addition of NSP to the binder combinations was found to be 229.1%. This shows that the effect of NSP on both hydration and strength improvement cannot be over emphasized as can be seen from the results of this study.

References

American Society for Testing Materials, ASTM C618 - 19 (2018) Standard specification for Coal Fly-Ash and Raw or Calcined Natural Pozzolana for use in Concrete. ASTM International, Philadelphia, PA, 2018. Book of Standards, 04.01.

British Standards BS EN – 196 – 1 – 2016, Methods of Testing Cement. Determination of Strength of Mortar and Concrete. BSI.

Environmental Impact Assessment EIA (2011). Emissions of greenhouse gases in the U.S. 2006 – Carbon Dioxide Emissions; accessed, 2011. 05-23 at the wayback machine.

Gupta, A.I & Wayal, A. S. (2015). Use of Rice Husk Ash in Concrete: A Review. Journal Of Mechanical and Civil Engineering. 12(4), 29-31.

Gupta, Y. P. (2014). Concrete Technology and Good Construction Practices. New Age International Publishers Limited, New Delhi, 16-67.

Horpibulsuk, S., Phetchuay, C. & Chinkulkijniwat, A. (2011). Soil Stabilization by Calcium Carbide Residue and Fly Ash. Journal Of Materials in Civil Engineering, 24 (2), 184 – 193

Jagadish, K.S., Venkatarama, R. B.V. & Nanjunda, R. K.S. (2015). Alternative building materials and Technologies. New Age International Publishers; 2015. 88-107.

Jatturapitakkul, C. & Roongreung B. (2003). Cementing Material from Calcium Carbide Residue – Rice Husk Ash. Journal of Materials in Civil Engineering, 15(5), 470-475.

Makaratat, N., Jaturapitakkul, C. and Laosamathikul, T. (2010). Effect of calcium carbide residue fly ash binder on maechanical properties of concrete. Journal of Materials in Civil Engineering; 22(11), 1164-1170.

Matawal, S.D. (2012). Role of Ordinary Portland Cement in Curbing the Incidences of Building Collapse in Nigeria. National Workshop on Building Collapse in Nigeria, Abuja, Nigeria. 15th -16th May, 2012.

Mehta, P. K. and Monteiro, J. M. (2014). Concrete: Microstructure, Properties, and Materials Fifth Edition; McGraw – Hill Education, 338 Euston Road, London. 1- 89.

Narender, A. R & Meena T. (2017). A Comprehensive Overview on Performance of Nano Silica Concrete; International Journal of Pharmacy and Technology; 9 (1), 5518 – 5529

Nattapong, M., Chai, J. & Thanapol, L. (2010). Effects of Calcium Carbide Residue –Fly Ash Binder on Mechanical Properties of Concrete. Journal of Materials in Engineering, 14(44), 1164 – 1170.

Neville A.M. (2013). Properties of Concrete, (5thedition); Pearson Education Limited, Edinburgh Gate, Harlow England. 58-661.

Ndububa, E.E., Okonkwo, J.S. & Ndububa, O.I. (2016). The Potential Use of Fonio Husk Ash As a Pozzolana in Concrete. Nigerian Journal of Technology (NIJOTECH), Faculty of Engineering, University of Nigeria, Nsukka. 35(1), 31-36.

NIS: 444 – 1: 2003 Nigerian Standards for Construction Materials and Building Manufacturing Engineering: Cement Standards and Application in Nigeria.

Olawuyi, B.J., Joshua, O., Hassan, I.O., Enejiyon, M.O. & Egwuda, C. I. (2017). Exploratory Study on Agro-Waste Ashes Combination with Industrial Waste as Alternative Binders in Concrete, Proceeding of Nigerian Building and Road Research Institute; International Conference on Emerging Materials and Technologies for Sustainable Building & Road Infrastructure, NAF Conference Centre, Abuja, 20 – 22nd June, 2017; 21.

Premium times Newspaper of Nigeria of 25th January, 2023. Accessed online on https://www.premiumtimes.ng.com on 30th January, 2023.

Saurabh, K. S. (2016). Building Materials and Construction, S. K. Kataria and Sons, New Delhi - 110002, India. 93 – 145.

Vichan, S. & Rachan, R. (2013). Chemical stabilization of soft Bangkok clay using the blend of calcium carbide residue and biomass ash. Soils and Foundations, 53, (2), 272 – 281.

Yu chen, Yi-fan D. & Meng-qiang L. (2016). Influence of NanoSiO2 on The Consistency, Setting Time, Early-age Strength and Shrinkage of Composite Cement Pastes; Advances in Materials Science and Engineering. Special Issue; accessed online at https://www.hindawi.com on 22nd February, 2021.

Yunusa, S. A. (2015). Investigation into the use of Calcium carbide waste as a partial replacement of cement in concrete. International Journal of Engineering and Management Research, 5 (2), 675 – 680.