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Use of Cocoa Pod Husk Ash as Admixture in Concrete

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ABSTRACT

The paper presents the findings of an investigation into the admixture properties of cocoa pod husk ash, CPHA ,in concrete. The investigation was conducted on concrete cubes of 150 cubic millimeter cast from concrete mix of 1 : 2 : 4 on the basis of mix design results for grades of concrete; and also on concrete paste with varying percentage addition of CPHA of 0.0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively. The results of the study show increase in compressive strength with increase in percentage addition of CPHA up to 0.6% CPHA, after which the strength start decreasing with increase in percentage addition of CPHA. The highest strength were obtained with 0.6% addition of CPHA of 21.78N/mm^2, 22.82N/mm^2, 31.26N/mm^2 and 33.92N/mm^2 at 3 days, 7 days, 28 days and 56 days respectively. This represented 5.78%, 4.11%, 8.20% and 11.69% increase in strength from strength of control sample (0% addition of CPHA) respectively. The study also shows that the use of CPHA in cement paste increases the initial and final setting times with increase in percentage addition of CPHA. The initial and final setting times obtained for cement paste with 0% addition of CPHA, were 82 minutes and 169 minutes respectively. The percentage increases of initial and final setting times from the control samples of cement paste (0% addition of CPHA) were 39.02%, 62.20%, 64.63%, 73.17%, 74.39% and 6.51%, 20.71%, 27.81%, 29.59%, 31.36% for cement paste with 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively. CPHA improves the workability of fresh concrete, decreases water absorption of concrete and drying shrinkage of cement; hence it is considered suitable for use as a repellant admixture in concrete and plastering works. CPHA could be considered as a retarding admixture for up to 0.6% addition by weight of cement for maximum workability and strength.

SIGNIFICANCE: *The research exploits the use of CPHA as a cheap locally available substitute to the expensive imported admixtures in concrete in building and civil engineering works and* *utilizing the waste of CPHA to create wealth.*

KEYWORDS: *Concrete, cocoa pod husk ash, compressive strength, water absorption, setting time shrinkage.*

1.0 INTRODUCTION

1.1 PREAMBLE

Concrete is one of the major materials employed in the construction of buildings and civil engineering structures. It is basically obtained from the mixture of cement, fine aggregates, coarse aggregates and water in a specified proportion. Cement provides the binding medium which in the presence of water hydrates to form hard cementitious substances that exhibit high rigidity. Aggregates which are of two categories, fine (sand) and coarse (gravel or crushed stone), further enhance the rigidity and dimensional stability of the concrete. Sometimes, admixture may be added to the concrete during or immediately before its mixing in order to modify or improve the property of the fresh or hardened concrete or both. (Jackson and Dhir, 1996).

1.2 BACKGROUND

Admixture is defined as a material other than cement, water and aggregate, that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality performance or durability. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it more suitable and economical for any situation, (Shetty, 2005). These admixtures are of various kinds and are usually imported and expensive. And despite this, the importance of admixtures has always necessitated the need to develop cheaper admixtures from local materials, locally, to overcome such situations. These include (Aliyu 2004) on the use of 'Katsi' as admixture in concrete, (Rimi 2005) on the use of kargo fruits powder as admixture in concrete and (Ominijei 2003) as cited in (Rimi 2005) on the use of Gum Arabic as admixture in concrete. However, there is still need to research further on their use and also explore the use of other locally available materials.

Cocoa tree (theobroma cacao) is a small evergreen tropical tree. It needs a warm and humid climate, regular rainfall and grows in the shade where temperature is not much lower than 20^0C or higher than 28^0C. It is grown in the southern states (Ogun, Oyo, Osun, Ondo, Ekiti, Edo, Delta, Cross River, Akwa Ibon and Abia), of Nigeria. Considerable cultivation also takes place in central zone states. (Kogi and Kwara), as well as Taraba and Adamawa states, up north and North Easthern fringes of the central zone of Nigeria (Raw Materials Research and Development Council (RMRDC 2004).

Cocoa pods or fruits form from small flowers, which borne directly on branches (cauliflorous flowers). The ripe pods are cut from the trees and split open to remove the beans from the pods. The pod husks, which is 56% of the pods components, are usually discarded by stock piling as wastes products of cocoa industry and present a serious disposal problem, at present. According to this research findings, cocoa pod husk is very rich in potassium oxide (88.26%), and also contains magnesium oxide (3.59%), calcium oxide (2.02%), iron oxide (1.75%), silicon oxide (1.45) and other oxides in minute quantities. The procurement of this raw material is totally cost free, as it is usually discarded as a waste product. This therefore motivated this investigation to determine the admixture properties of CPHA in concrete and cement paste.Plate 1 shows a heap of cocoa pod husk.

Plate 1: *Photograph of a heap of cocoa pod husk*

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for the research work are cement, aggregates, cocoa pod husk and water. The nature and quality of these materials are as follows.

1. *Cement:* The cement used for the research is ordinary Portland cement manufactured by Ashaka cement company plc. It was of recent supply and free from adulteration.

2. *Aggregates:* The fine aggregates are clean naturally occurring sharp sand and was obtained from dealers at corner Panshekara in Kano. The particle size distribution analysis indicates that the sharp sand was of zone 2. The coarse aggregates used are crushed granite stones obtained from dealers at corner Panshekara in Kano with maximum size of 20mm.

3. *Cocoa pod husk:* The cocoa pod husks (CPH) were obtained from Owu cocoa plantation in Owan East Local Government Area of Edo State .They were cleaned of dirt, air dried and incinerated with the use of an incinerator at the Federal Medical centre Yola. The ash was further ground with a grinding machine to powder and sieved through a 425µm B. S Standard test sieve to obtain the cocoa pod husk ash (CPHA) for the research.

4. *Water:* The water used for the research is clean and portable water obtained from the underground water tank in the civil engineering (structure) laboratory at Beyero University, Kano.

2.2 Method (Experimental Procedure)

Standard test, according to European National standard and British standard specifications, were carried out on test samples. These tests are (i) setting time tests (ii) drying shrinkage test (iii) slump test (iv) water absorption test and (v) compressive strength test. Setting times test were conducted using vicat apparatus in accordance with EN 196-3.1978 and while drying shrinkage tests were conducted on cement paste in accordance to BS 4550 part 3:1978 with percentage additions of CPHA of 0.0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0%, respectively. The absolute volume method of batching was used to produce a concrete of nominal mix of 1 : 2 : 4. Six water/(cement + ash) ratios of 0.53, 0.55, 0.55, 0.55, 0.58 and 0.60 were employed for 0.0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% addition of CPHA by weight of cement for the actual concrete mix, respectively. A total of 126 concrete cubes of 150mm^3 were cast in all. They were thoroughly mixed and compacted in accordance to BS 1881 : Part 108 : 1983 practice. Slump test was use to measure the workability of concrete mixes and was carried out in accordance with BS 1881 : Part 102 : 1983 practice.

Out of these, 36 cubes were cast for 18 trial concrete mixes, each mix comprising two cubes, which were cured in accordance to BS 1881 : Part 111 : 1981 practice in the laboratory for 7 days by complete immersion in a curing tank. A total of 72 cubes, 12 cubes per percentage addition of CPHA, were tested to determine the comprehensive strength and was carried out in accordance with BS 1881 : Part 116 : 1983 practice, using the universal testing machine, for 3 days, 7 days, 28 days and 56 days at various percentage addition of CPHA.

Also a total of 18 cubes, 3 cubes per percentage addition of CPHA were cast and cured for 28 days and used to determine the moisture absorption of the concrete in accordance with BS : 1881 : Part 122 : 1983 practice at various percentage addition of CPHA.

3.0 RESULTS AND DISCUSSION.

Fig 1 shows the variation of compressive strength of concrete with age (3, 7, 28 and 56 days) for the various percentage additions of CPHA. And the results of the test are presented in table 1a while the increase (difference) in compressive strength with respect to control specimen is presented in Table 1b.

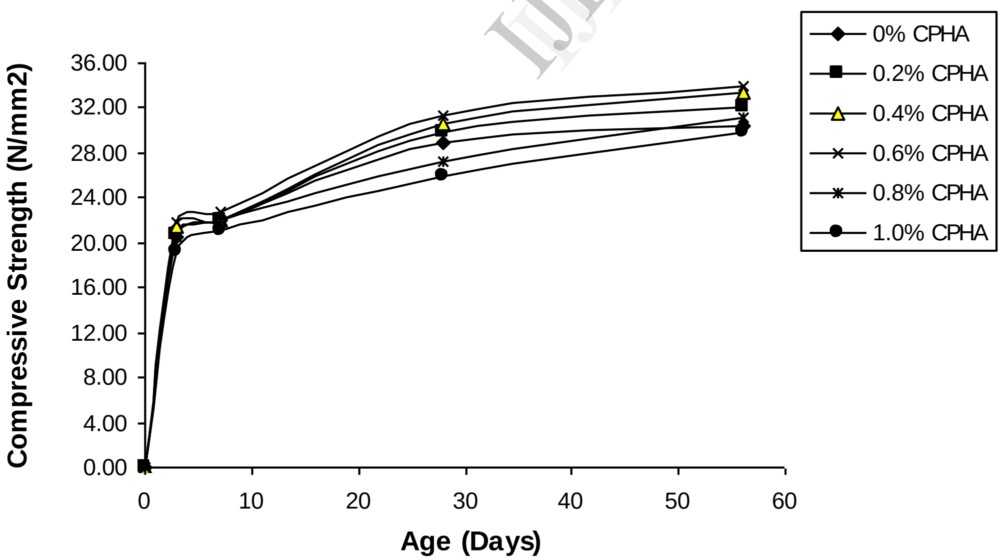

Fig. 1*: Variation of compressive strength of concrete with age for a particular CPHA content*

Table 1a Summary of result of compressive strength and density of concrete

Percentage	Mean compressive strength (N/mm^2)

addition of CPHA				
(%)	3 days	7 days	28 days	56 days
0	20.59	21.92	28.89	30.37
0.2	20.74	21.95	29.92	32.15
0.4	21.48	22.08	30.52	33.48
0.6	21.78	22.82	31.26	33.92
0.8	20.44	21.93	27.26	31.11
1.0	19.12	21.11	25.95	29.78

Table 1b : *Difference in mean compressive strength with respect to control specimen.*

% addition of CPHA	3 days		7days		28days		56days	
	Different in strength (N/mm^2)	% difference	Different in strength (N/mm^2)	% difference	Different in strength (N/mm^2)	% difference	Different in strength (N/mm^2)	% difference
0								
0.2	+0.15	+0.73	+0.03	+0.14	+1.03	+3.57	+1.78	+5.86
0.4	+0.89	+4.32	+0.16	+0.73	+1.63	+5.64	+3.11	+10.24
0.6	+1.19	+5.78	+0.90	+4.11	+2.37	+8.20	+3.55	+11.69
0.8	-0.15	-0.73	+0.01	+1.00	-1.63	-5.64	+0.74	+2.44

1.0	-1.47	-7.14	-0.81	-3.70	-2.94	-10.18	-0.59	-1.94

The results show an increase in compressive strength with increase in percentage addition of CPHA up to 0.6% CPHA, and then decreases with increase in percentage addition of CPHA. The highest strength of 21.75N/mm^2, 22.82N/mm^2, 31.26N/mm^2 and 33.92N/mm^2 at 3days, 7days, 28days and 56days respectively was obtained with 0.6% addition of CPHA. This represents 5.78%, 4.11%, 8.20% and 11.69% increase in strength from strength of control samples, (0% CPHA) respectively. The trend of strength variation may be associated with high concentrations of potassium from CPHA. The potassium combined with the cementitious compounds, tricalcium silicates,C_3S and dicalcium silicates, C_2S, in the cement in the presence of water resulting in higher strength. According to Bajah and Godman's (1976) explanation on metal reactions, as reported in Ogork and Rimi (2007), the potassium in CPHA reacts with the hydrates of C_3S and C_2S to give potassium silicate, which is responsible for high early strength in concrete. The reaction is complex and may be simplified as given below.

$2C_3S + 6H \rightarrow C_3S_3H_3 + 3Ca(OH)_2$…………………..1

$2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2$...............................2

$C_3S_2H_3 + 6K \rightarrow 3K_2O + S_2H_3 + 3Ca$…………………………3

$3K_2O + S_2H_3 \rightarrow 6KOH + S_2$……………………………………4

$2KOH + S \rightarrow K_2SiO_3 + H$………………………………………..5

Where C = CaO, S = SiO_2 and H = H_2O

However, further increase in the percentage addition of CPHA above 0.6%, increase the concentration of potassium which displaces more of the calcium in cement to form potassium silicate resulting in less calcium silicates. This is what is contributory to the reduction in strength of concrete. Therefore 0.6% addition of CPHA is the optimum value above which the CPHA will be saturated and will be giving retrogressing results.

Fig 2. presents the water absorption test of concrete with various percentage addition of CPHA, while the results are presented in Table 2

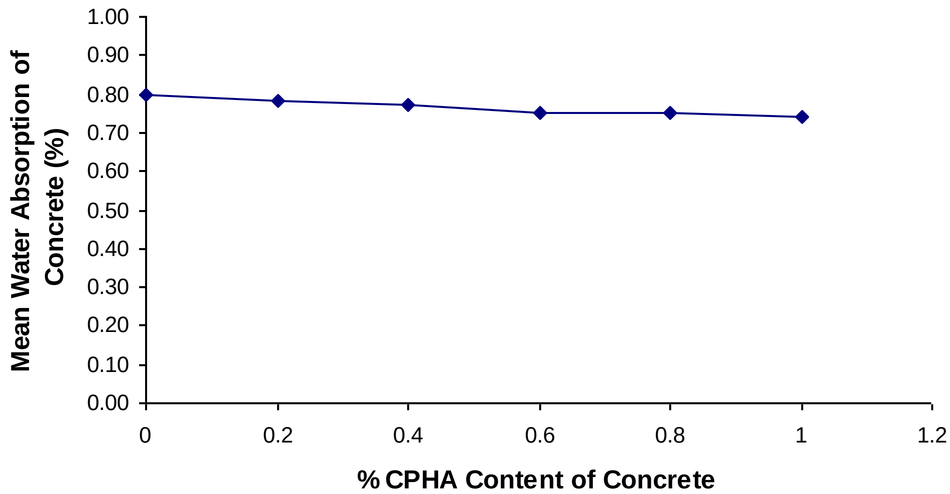

Fig. 2 : *Effect of CPHA on the water absorption of concrete*

Table 2; *Summary of water absorption test*

Percentage Addition of Cocoa Pod Husk Ash (CPHA) (%)	Mean Water Absorption (%)
0	0.80
0.2	0.78
0.4	0.77
0.6	0.75
0.8	0.75
1.0	0.74

The results show a decrease in water absorption with increase in percentage addition of CPHA. This is an indication that CPHA is a water reducing admixture

Fig3 illustrates the setting times of cement paste at various percentage addition of CPHA, while the results are presented in Table 3.

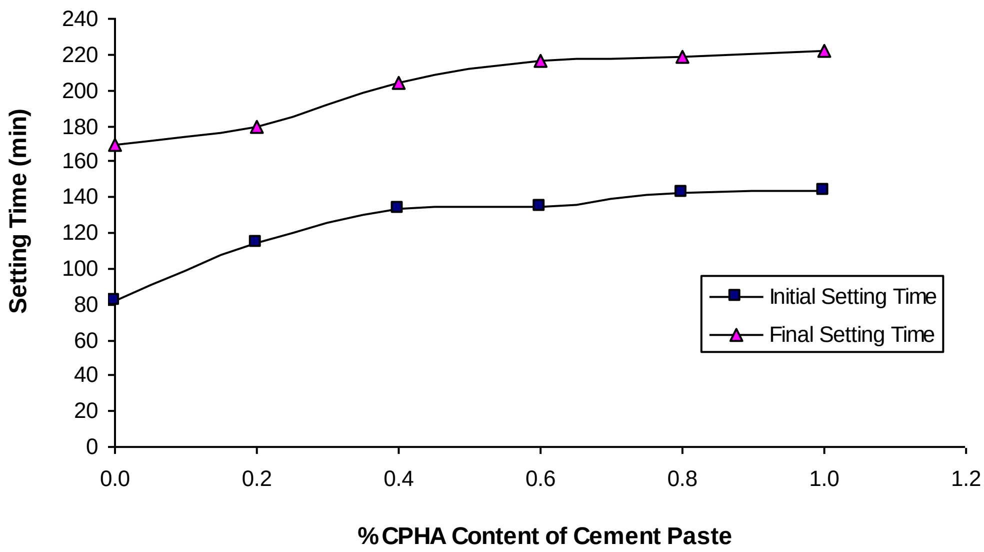

Fig. 3 Variation of setting times of cement and CPHA –cement

Table 3: *Summary of the effects of CPHA on setting times of cement*

CPHA content (%)	Initial setting time (min)	Final setting time (min)
0	82	169
0.2	114	180
0.4	133	204
0.6	135	216
0.8	142	219
1.0	143	222
Standard value	≥ 45	≤ 600

The results show a continuous increase in the initial and final setting times, with the increase in percentage addition of CPHA. It was observed that the results meet the standard requirement of ENV 197-1 : 1992 of setting times (initial and final) of ordinary Portland cement, OPC, 0f 45 minutes and 600 minutes, (10 hours) respectively, (Neville 2003).

The reason behind the increase in setting times of CPHA-cement may be explained as follows. The high predominance of potassium oxide K_2O in CPHA, (88.26%) and its high solubility in water may have resulted in the formation of potassium silicate, K_2SiO_3, due to the interaction of K_2O and SiO_2, with the incorporation of CPHA in cement in the presence of water. However, this may have eventually resulted in increasing the setting times of cements, because the presence of high percentage content of potassium oxide, K_2O hinders complete combination of lime and causes setting anomalies or negative effect on setting, (Stocchi 1990). There is also the possibility of the formation of magnesium silicate, $MgSiO_3$, which is known to be a retarder thereby causing delay in the setting time of cement. And thus, in the reaction of CPHA with cement and water, the following reactions may take place.

$$K_2O + H_2O \longrightarrow 2KOH \qquad (6)$$

$$2KOH + SiO_2 \longrightarrow K_2SiO_3 + H_20 \qquad (7)$$

$$MgO + H_2O \longrightarrow Mg(OH)_2 \qquad (8)$$

$$Mg(OH)_2 + SiO_2 \longrightarrow MgSiO_3 + H_2O \qquad (9)$$

The slow setting of CPHA concrete makes it suitable for concrete works in very hot and dry weather condition and in area of mass concrete application.

The results of drying shrinkage of cement paste are presented in Table 4 while Figure 4 illustrates the effect of CPHA on drying shrinkage.

Table 4 Summary of result of drying shrinkage of cement with various percentage addition of CPHA

Percentage addition of CPHA (%)	Mean drying shrinkage (%)
0	2.80
0.2	1.43
0.4	1.25
0.6	1.07
0.8	0.89
1.0	0.71

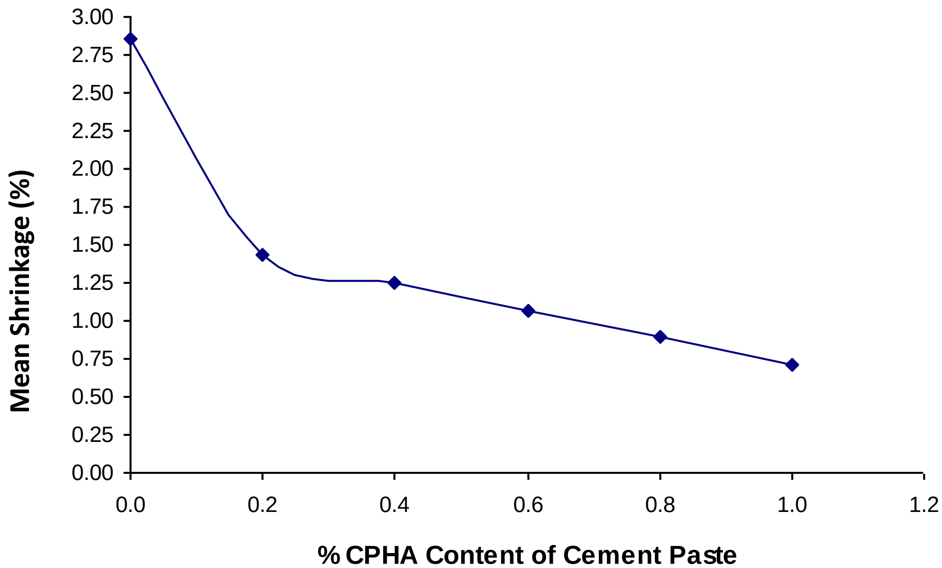

Fig 4: *Effect of CPHA on drying shrinkage*

The results show a decrease in (linear) drying shrinkage with percentage addition of CPHA. This indicates that the concrete/cement mortar in which CPHA is incorporated is not likely to contract, there is likelyhood of no cracking with increase percentage of CPHA.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusions

Based on the research conducted the following conclusions are drawn.

i. CPHA increases the setting times of Portland cement and decreases the drying shrinkage with increase in CPHA addition.

ii. The incorporation of CPHA as admixture in concrete increases the slump of concrete up to 1.0% addition.

Iii. The use of CPHA as admixture in concrete effectively enhances the compressive strength with the optimum strength at 0.6% addition.

iv. CPHA possesses the quality material for use as water reducing or repellant admixture in concrete.

4.2. Recommendations.

Based on the research findings, the following recommendations are hereby given:

i. The use of CPHA as retarding admixture (at 0.6% addition by weight of cement) should be tried for use in concrete works in very hot and dry weather conditions and in area of mass concrete application, like dams, with proper care and under controlled conditions.

ii. The application of CPHA should be explored in plastering and rendering works.

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