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Experimental Study on Fowl Egg Shell Ash As Partial Replacement of Ordinary Portland Cement In Concrete Production.

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ABSTRACT
The unabated increase in the cost Ordinary Portland Cement, OPC, has been one of the major factors militating against the provision of adequate and affordable housing in Nigeria and most African countries. Hence, this study investigated the possibility of using fowl egg ash (FESA) as partial replacement for Ordinary Portland Cement (O.P.C) in the production of concrete. Fresh concrete of mix ratio 1:2:4, blended with graded levels of fowl egg ash: (0%; 5%; 10%; 15% ,20%,25% and 30%) , using water-cement ratio of 0.5, were prepared to cast a total of eighty-four (84) concrete cubes of size 150mm×150mm×150mm and cured in water bath for 7ays; 14days; 21days and 28days respectively. The resulting FESA blended concrete was subsequently tested for compressive strength, water absorption and consistency and workability in compliance with the American Society for Testing Materials (ASTM,).The results generally showed that both compressive strength and the water absorption of the test cubes increase with the level of FESA utilization. At 28 days curing particularly, the maximum values of compressive strength and water absorption of the FESAC were 27.92N/mm2 and 0.93% respectively. These were attained between 15% and 20%cement -ash substitution. Although, the workability of the fresh fowl egg shell ash-blended concrete varies inversely as the percentage of blending, a medium workability (true slump=4mm) is achievable at 15% cement-egg shell ash substitution. The study concluded that the germane properties of fowl egg ash – blended structural concrete under investigation are not compromised at 15% FESA cement – substitution.

KEYWORDS: *O.P.C, Fresh Fowl Egg Shell Ash, Compressive Strength, Workability, Water Absorption and Consistency*

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I. INTRODUCTION

Concrete, a mixture of sand, Ordinary Portland Cement (O.P.C) and water is arguably the most universal material used in construction works. It is used extensively in nearly all African countries including Nigeria. This is apparently due to the low level of technology and economic development prevalent in a continent, grapping with issues such as low capacity utilization, huge infrastructural deficit and poverty in the midst of untapped resources. The over -reliance on cement for concrete works has inevitably resulted in an unprecedented high and excruciating cost of the material in the last two decades, thus rendering the effort of past and successful Governments in making housing cheap and affordable for all, a mirage. Furthermore, the manufacture of several tons of cement by local companies has been a potential source of threat to environmental and health safety as considerable amount of various forms of carbon (IV) oxide, a silent killer is continually released to the atmosphere as bye product. [17] Towards arresting this ugly trend and thus convert wastes to wealth, curious attempts have been on for over a decade to utilize either mineral admixture or ash derivatives of solid agricultural wastes, as partial substitutes for cement in concrete production. Documented evidence abounds indicating that these efforts have been substantially fruitful both economically and otherwise, without compromising properties of structural concrete such as strength, workability and durability [15, 16, 14 & 12]. The egg shell is an important component of solid agricultural wastes, indiscriminately deposited in both urban and rural communities in Nigeria. They are mostly generated in large quantities by chick hatcheries, bakeries and fast food vendors and eateries e.t.c, as 'throw-away' waste material, constituting high nuisance value to the environment because of their indiscriminate deposition. Foul egg shell is composed entirely of calcium carbonate and protein which is responsible for its role in growth and strength development of bones in human beings and mammals generally. Although, the urge to tap this significant potentials of fowl eggs for beneficial uses in medicine, nutrition and dietetics agriculture and other allied professions is high, literatures on its calcium potential particularly, as substitutes for conventional engineering construction materials is still very scarce.

Hence, the present study seeks to determine the suitability of fowl egg shell ash (FESA) as substitutes for cement in concrete production.

II. MATERIALS AND METHODS

Fowl eggs used in this study were collected from food sheds scattered around a settlement, ‘ Rounder’ on coordinate 05° 53’ 00”N, 08° 01’ 16”, in Abeokuta, Ogun State, Nigeria. The shells were washed, cleaned with warm water to remove micro-organism and impurities of organic origin. They were later dried and crushed before being calcined in Muffle furnace in the Materials Laboratory of The Federal Polytechnic, Ilaro, Ogun State. The ashing temperature ranged between 500°C and 650°C, each ashing circle lasted 45 minutes. X-Ray Florescent (XRF) chemical analysis was conducted on the resulting ash in accordance to [1] with a view to establishing the optimum ashing temperature and the class of pozzolana to which the foul egg shell ash belong. Ordinary Portland Cement, having properties conforming to British Standard Institution [3] was obtained directly from a Dangote Cement Depot to guarantee the integrity of the material. Coarse aggregate and fine aggregate applied in this study were obtained from a construction site within the Federal Polytechnic campus, Ilaro, Ogun State. All the aggregates were properly graded using sieve analysis in compliance with the British Institution Standards [5] The control specimens (concrete) and those of the FESA-blended species were prepared in sets of three each for 7 days 14days , 21 days and 28 days respectively, using plain cement , FESA modified cement(5%;10%;15% ;20%;25% and 30%); sand and crushed granite in proportion 1 :2 : 4. This design mix was prepared and batched by weight in accordance with the British Standards (BS8110-1:1997), using water: cement ratio of 0.5 throughout. Workability for the various fresh concrete mixes were determined using Slump test, as stipulated by the British Standards [6 &13]The resulting concrete specimens were cast into 150mm× 150mm × 150mm steel moulds, allowed to set under the ambient temperature , demoulded and then transferred into water bath to cure for 7days; 14days; 21days and 28days, respectively . Compressive Strength, density and water absorption property were determined in accordance with the British Standards [8, 7& 10]. The data obtained were analysed with the aid of Microsoft- excel 2010.

Figure 1: Dried Eggshell after washing

Figure 2: Pulverized fowl egg shell

III. RESULT AND DISCUSSION

Chemical Composition of Fowl Egg Ash (FESA)

The result of the XRF analysis conducted on the FESA is presented in Table1. The result revealed that while the Alumina (Al2O3) and the Iron oxide contents of the ash are comparable with that of O.P.C, its Silica content of approximately 65% exceedingly surpassed that of conventional cement. On the contrary, the Calcium Oxide content of FESA of 17.3% is comparatively lower than that of O.P.C. The implications of these results is that fowl egg shell ash like most sea food shell ash, contains all the major constituents of a typical O.P.C and in nearly similar proportion with the exception of Calcium Oxide. Furthermore, the 73.7% total composition of the major oxides: affirms the pozzolanic nature of FESA according to the American Society for Testing Materials [1].

Table 1(Chemical Composition of oxides of Fowl Egg Shell Ash (FESA) and Ordinary Portland cement)

Chemical constituents (Samples)	Fowl egg shell Composition (%)	Ordinary Portland Cement (%)
SiO_2	64.9	19.99
Al_2O_3	5.25	4.78
Fe_2O_3	3.55	3.57
MnO	0.04	-
CaO	17.30	63.73
P_2O_5	0.08	0.10
K_2O	1.55	0.70
TiO_2	0.02	
MgO	0.35	1.90
Na_2O	0.38	0.21
SO	-	2.70
Loss on Ignition (LOI)	5.76	2.41
Total	100	100

Particle Size Distribution

The result of sieve analysis showing the particle size distribution of fine and coarse aggregates utilized in this study are as depicted in figures 3 & 4. All the fine aggregates passed through sieve of size 5mm, whereas, all coarse aggregates passed through sieve size 19mm as recommended for normal concrete [13]. The coefficients of gradation curvature, Cc for the two aggregates further revealed that both are well graded [5].

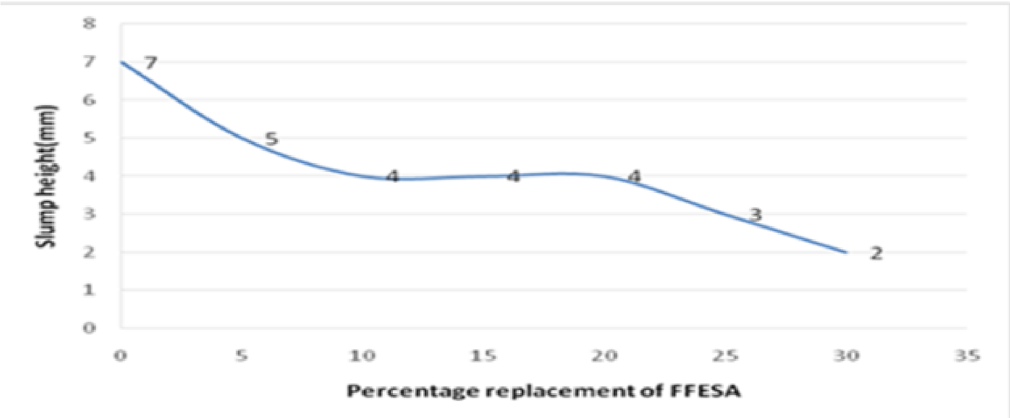

Figure 3: Particle size distribution curve for coarse aggregates (granite)

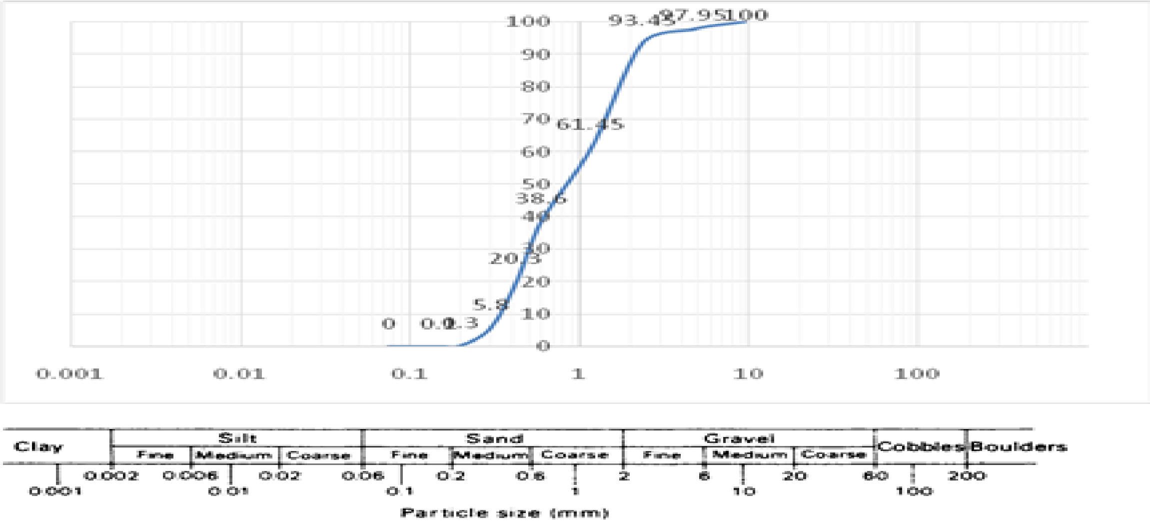

Figure 4: Particle size distribution curve of fine aggregates (sand)

Table 2(Consistency of Cement and fresh fowl egg shell ash)

SAMPLES	INITIAL SETTING TIME	FINAL SETTING TIME
Dangote (OPC)	2hours 40minutes	4hours 40minutes
Fowl egg shell ash	4hours 40minutes	6hours 40minutes

The initial and final setting time of cement and fresh fowl egg shell ash fall within the limit of initial and final setting of ordinary Portland cement (OPC) which is its initial setting time should be at least 45 minutes and final setting time should not be greater than 10 hours in accordance to [2].

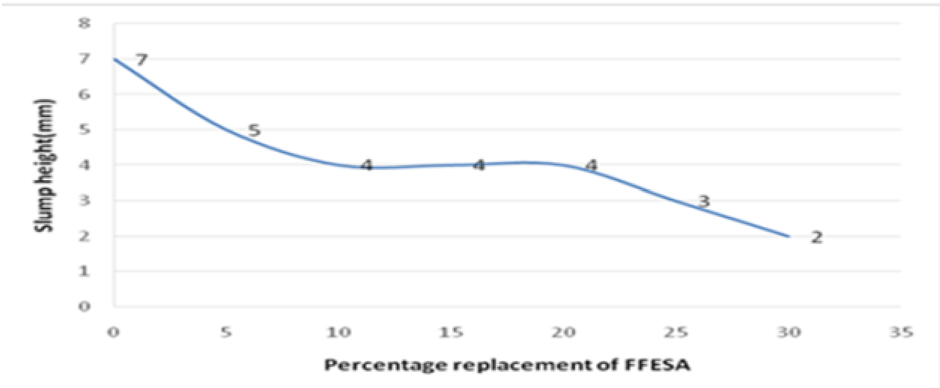

Figure 5: Graph of slump height against the percentage replacement of modified concrete.

It was observed that at control the slump was 7mm then declined at 5% replacement to 5mm and 10% replacement of 4mm maintained till 20% and later fall to 3mm and 2mm at 25% and 30% respectively. The higher the egg shell ash in concrete the less workable the concrete.

Density of FFESA Concrete

The result presented in Table 3 revealed that density of FESAC generally, though sparingly, increases with the level of ash application and ranged between 2192kg/m3 (0%) and 2265Kg/m3 (10%) . However, all the results tended to suggest that maximum concrete density at 0.5 water: cement can be achieved between 10% and 20% levels of ash utilization. Relying on the suggested range of level of ash utilization, the result will further reveal that FESA concrete can be

Classified as normal weight concrete.

Table 3 (Weights and densities of concrete cube at 28days)

FESA (%)	Weight (kg)	Density(kg/m^3)
0	7.40	2192.59
5	7.63	2259.75
10	7.65	2265.68
15	7.57	2243.95
20	7.60	2251.85
25	7.64	2263.70
30	7.43	2202.47

Compressive Strength

Theresult of compressive strength test for the hardened concrete presented in Table 4, showed that compressive strength increases gradually with increase in the level of application of the fowl egg shell ash. This indispensable quality parameter also varies directly with the age of concrete, reaching a maximum of 27.92N/ mm2 at 28 days when the level of FESA application lies between 15% and 20% as shown in fig.6. The implication of this is that FESA concrete at 28day not only compared favourably well with the control cube , but also meets the strength requirement of a good structural concrete, provided the level of ash-cement substitution does not exceed 20%. Polynomial regression analysis of the data also show that the application level of FESA has a fairly positive correlation with compressive strength (R^2 =0.617) as shown in fig.7.

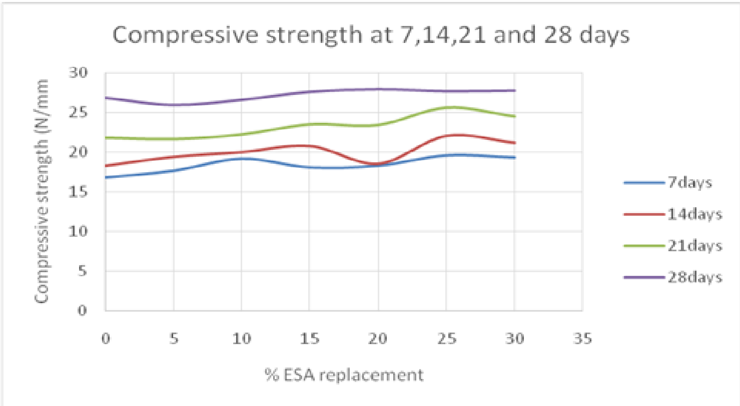

Figure 6: Compressive strength against percentage replacement of FESA

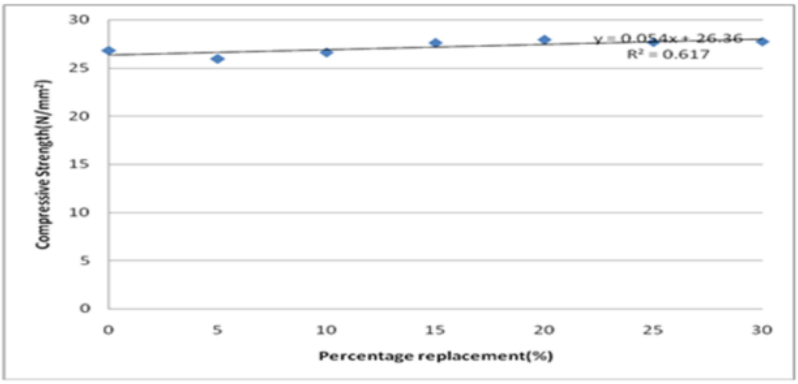

Figure 7: Regression analysis showing relationship between compressive strength of modified concrete and percentage replacement of FESA.

Water Absorption

The water absorption capacity of FESAC at 28days is depicted in Table 5. It increases sharply with increase in the level of application of egg shell ash, reaching a maximum value of 0.93% at 20% cement -ash substitution. This trend was punctured, following a sharp decline which brought the water absorption to 0.40% at 30% FESA application. The result again tends to suggest that optimal performance, particularly for durability of the FESAC is achievable between 15% and 20% FESA application.

	Weight of cubes (g)	Weight of cubes (g)	% Water Absorption
% Replacement	Before curing	After curing	
0%	7333	7400	0.67
5%	7550	7627	0.77
10%	7600	7647	0.47
15%	7500	7573	0.73
20%	7507	7600	0.93
25%	7593	7640	0.47
30%	7393	7433	0.40

Table 5 (Water absorption of concrete with Fowl egg ash at 28 days)

IV. CONCLUSION

An experimental study investigating the suitability of fowl egg shell ash (FESA) for structural concrete has been conducted, using graded levels of the ash between 0% and 30%. From the outcome of four major performance parameters determined in the FESA-blended concrete mix of 1:2:4 having water: cement ratio of 0.5, it may be concluded that:

(1) Fowl egg shell ash could replace cement in structural concrete without compromising the key performance parameters such as workability; Compressive Strength; density and water absorption

(2) A good pozzolanic activity of the fowl egg shell ash which guarantees optimal performance in FESA-blended concrete could be achieved with 15%-20% FESA-cement substitution

(3) While low to medium workability could be attained with water-cement ratio of 0.5, at 15%-20% FESA application, density, water absorption and compressive strength at 28days of curing , respectively hit maximum values which favourably compared with those of control

(4) In terms of durability, 15%-20% FESA concrete may have great implications on water retaining and buried structures because of its high water absorption capacity.

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