Experimental Investigation of the Effect of Partial Replacement of Cement with Eggshell Ash on the Rheological Properties of Concrete

Afolayan J. O.

Abstract— **This research presents the experimental results of the effect of eggshell ash as a partial replacement of cement in concrete. The properties of concrete investigated include the compressive strength, workability and the setting time. The cement in the concrete mix were partially replaced with egg ash at varying percentages which includes 0%, 5%, 10%, 15%, 20%, 25% and 30% using a mix ratio of 1:2:4 and a constant water cement ratio of 0.55.**

The specimen produced for the various percentages of eggshell ash were cured for 7, 14, 21 and 28 days before carrying out the compressive strength test. The average compressive strength at 28days of curing for 5%, 10%, 15%, 20%, 25% and 30% are 31N/mm2 , 30N/mm2, 27N/mm2, 24N/mm2, 19N/mm2 and 15N/mm2 respectively. The results shows that increase in the percentage of Egg shell ash leads to decrease in the compressive strength. However at 15% replacement the compressive strength is 27N/mm2, which satisfied the require strength for grade 25 concrete in BS 8110.

Index Terms— **Eggshell, Eggshell ash, workability, setting time, compressive strength**

I. INTRODUCTION

The entire construction industry is in search of a suitable and effective waste product that would considerably minimize the use of cements and ultimately reduces the construction cost. It is a common knowledge that agricultural waste constitutes a sizeable proportion of the accumulated solid waste in many cities of the world (Afolayan, 2017). Eggshells are part of agricultural wastes that litter the environment. There is an increasing attempt to covert waste to wealth, the efficacy of converting eggshells to beneficial use becomes an idea worth investigating (Afolayan, 2017). The composition of the eggshells lends the effects of its ash on the cement to be articulated. It is scientifically known that the eggshell is mainly composed of compounds of calcium. Winton(2003) presented eggshell as being composed of 93.70% calcium carbonate, 4.20% organic matter, 1.30% magnesium carbonate, and 0.8% calcium phosphate. Calcium trioxocarbonate (IV), [that is calcium carbonate, ($CaCO_3$)], is the major composition of the eggshell, accounting for 93.70% of the total composition of the eggshell. Odesina(2008), also presented calcium trioxocarbonate (IV), as an important constituent of eggshells and seashells. Similarly, calcium trioxocarbonate (IV), [calcium carbonate, ($CaC0_3$)], is the primary raw material in the production of cement. Ordinary Portland Cement (OPC) composed of four main calcium compounds in the forms of dicalcium silicates, (C_2S), tricalcium silicate, (C_3S), tricalcium aluminate, (C_3A), and tetra-calcium aluminoferite, (C_4AF). It is, therefore, indicated that cement and eggshells have the same primary composition in calcium compounds. Eggshell ash can be considered to be a pozzolan. These materials can be blended with Ordinary Portland or as partially replace pure Portland cement commonly used in building materials such as concrete, masonry block, masonry mortar, bricks and other construction units. In terms of low cost there are substantial advantages to be gained in performance if well chosen pozzolans are used in cement-based construction materials. They are found to improve workability of concrete, lower heat of hydration, lower thermal shrinkage, increase water tightness, improve sulphate resistance, seawater resistance, and reduce alkali-aggregate reaction. The disadvantages that can occur with their use is mainly the result of using an inferior pozzolan; these are: slower rate of strength gain, slower rate of setting, increased drying shrinkage, increased water requirement, lower freeze-thaw resistance (Price, 1975).

Afolayan J. O., Department of Civil Engineering, Nigerian Defence Academy, Kaduna, Nigeria

II. POULTRY EGG PRODUCTION IN NIGERIA

Over 60 million tonnes of eggs were produced throughout the world per year, but according to Nigerian Poultry Association about 10.3billion eggs were produced per annul in Nigeria. It also put the per capital consumption of egg at 65 per year.It is evident that egg shell waste is available in abundant quantity. Egg shell ash has lime content which is similar to the property of cement it can be used as a pozzollana in concrete, by replacing cement by egg shell ash to a certain degree. Utilization of egg shell ash in concrete production will preserve the clean environment and natural resources. In 2004 ASTM International C150 allowed incorporation of up to a 5 % mass fraction of limestone in ordinary portland cement. Hawkins et al (2003) reported that use of up to 5 % limestone does not affect performance of Portland cement. Furthermore, Bentz et al (2009) reported that higher limestone percentage can also be used in concrete at lower w/c ratio. Furthermore, lime production involves energy intensive process and consumes water. Therefore, identifying analogous material from waste and using the same in concrete production could be a wise idea. Calcium rich egg shell is a poultry waste with chemical composition nearly same as that of limestone. Use of eggshell waste instead of natural lime to replace cement in concrete can have benefits like minimizing use of cement, conserving natural lime and utilizing waste material. However, majority of the eggshell waste is deposited as landfills. Eggshell waste in landfills attracts vermin due to attached membrane and causes problems associated with human health and environment. Few investigations were conducted to use eggshell waste in civil engineering applications. Amu et al., 2005 studied eggshell powder as a stabilizing material for improving soil properties. A. J. Olarewaju et al, (2011) studied suitability of eggshell stabilized soil as subgrade material for road construction. Although eggshell is calcium rich and analogous to limestone in chemical composition, it is a waste material. Therefore, to initiate use of eggshell waste for partial replacement of cement in concrete, there is a need to understand concrete properties made with eggshell powder. Thus, the primary objective of this study was to understand the possibilities of use of eggshell ash in concrete. Investigations were systematically conducted on performance of eggshell powder concretes in terms of strength properties like compressive strength.

2.1 PROPERTIES OF EGGSHELLL ASH

The typical chemical composition and physical properties of eggshell ash are given in Table 1

Table 1. Chemical Composition of Eggshell ash

Constituent	% Composition
Fe_2O_3	2.6
SiO_2	0.11
CaO	50.7
Al_2O_3	0.05
Na_2O	0.14
K_2O	1.88
L.O.I	6.00

Eggshell ash (Solid ash)

Eggshell ash a cementitious material

The results of the chemical analysis of Eggshell ash confirms that it has pozzolanic properties and can be classified under class ''F'' group of Pozzolans on The American Society for Testing and Materials (ASTM) classification system. As such, it can be recommended for use as partial replacement in concrete production in construction

The advantages of using eggshell ash and other pozzolans in concrete are:

Increased compressive and flexural strengths (Zhang et al., 1996; Ismaila 1996; Rodriguez 2005), Reduced permeability (Zhang et al., 1996; Ganeggshell ashn et al., 2007), increased resistance to chemical attack (Chindaprasirt et al., 2007), increased durability (Coutinho 2002), reduced effects of alkali-silica reactivity (ASR) (Nicole et al., 2000) reduced shrinkage due to particle packing, making concrete denser (Habeeb et al., 2009) enhanced workability of concrete (Coutinho 2002; Habeeb et al., 2009; Mahmud et al., 2004), reduced heat gain through the walls of buildings (Lertsatitthanakorn et al., 2009), reduced amount of super plasticizer (Sata et al., 2007) and reduced potential for efflorescence due to reduced calcium hydracids (Chindaprasirt et al, 2007)

2.2 WATER:

Water is very important in the production of concrete, these are very important factors to be considered when water is being used in the production of concrete;

Odour, turbidity, pH, hardness, iron, chloride, colour, dissolved solids, calcium, magnesium, copper, manganese, sulphate, nitrate, fluoride, zinc, alkalinity and cconductivity.

III. MATERIALS AND METHODS.

The materials used for this research includes eggshell ash, granite, sharp sand and ordinary Portland cement (OPC)

3.1 MATERIALS PREPARATION

The eggshell ash used for this research was obtained from different locations at around Kaduna North. The material was gathered and spread out dry for 24 hours before burning in an open air environment, the ash of the burnt shell was taken to the laboratory where it was sieved using BS Sieve No. 200 (75µm). The sharp sand, coarse aggregates (16mm) and bags of Dangote cement (50kg each) were obtained within the state of Kaduna of Kaduna State.

3.2 EQUIPMENTS.

Equipments used for this research work include moulds, shovel, tamping rod, tamping bar, measuring pan, sieves of various sizes, mixing tray, scoops, trowels, concrete mixer and weighing balance. The mould size used was the 100mm x 100mm cubicle mould.

3.3 MATERIALS USED.

3.3.1 FINE AGGREGATE

The fine aggregates used in this report was sun dried for 24 hours and passed through seize size 2.25mm to meet the size requirement specifies for this report.

3.3.2 COARSE AGGREGATE

The coarse aggregate used in this report was retained on sieze size 4.75mm

3.4 METHODS.

3.4.1 Experimental Study

Experimental Variables

Experimental variables were Ordinary Portland Cement to eggshell ash ratio. Details of these ratios are tabulated in Sand to binder ratio 1:2.

3.5 MIXING.

The mixing was done manually with the use of a pan, hand trowel and shovel. The mix ratio 1:2:4 was adopted and water ratio of 0.55. The required sand, ESA and cement was first measured and perfectly mixed and poured on the mixing pan. The coarse aggregate was introduced and further mixed, measured water based on the water/ESA ratio was finally added and thoroughly mixed until a uniform mixture was achieved, ensuring good quality control.

3.6 WORKABILITY.

To ensure that the concrete used for the casting of the cubicles were of good workability, two tests were carried out namely; the slump and the compaction factor test for every batching (Neville, 2006 compaction test).

3.6.1 COMPACTION TEST

The compaction factors test measured the degree of compaction of standard amount of work and after reliability assessment of workability concrete. The compaction factor test was done for the respective replacement of cement with ESA at 0%, 5%, 10%, 15%, 20%, 25% and 30%. Partial compaction was carried out using compacting equipment having 2 cones with openings at each bottom and a mental cylinder at the bottom. The mixture is loaded into the first cone using a trowel ensuring that the cone is properly filled before the latch to the bottom is released and the mixture flows into the second cone the latch will also be released and the mixture pours into the cylinder. The mixture will be weighed on the weighing balance. After the partial compaction, the mixture is poured back in the mixing pan and mixed again. The mixture is put into the cylinder in 6 batches and each batch is tamped 25 with a tampering rod. After it is fully compacted, the mixture will be weighed.

3.6.2 SLUMP TEST.

The slump test is carried out using a cone which is placed on flat metal surface and supported on both sides to ensure that there is no space between cone and the flat surface. The mixture is poured into the cone in 4 bactches each time it is tampered 25 times with the tampering rod. After the procedure is completed, the cone is gently removed and placed at the side of the mass, the tampering rod on the cone to the highest peak of the mixture to check is shearing occurred or not. If shearing occurred, a measuring ruler is used to determine the height of the shear.

3.7 CASTING OF CUBES AND CURING.

The concrete was cast in 100mm x 100mm x 100mm cubicle moulds. They were filled and compressed in 2 layers. This was achieved using a tampering bar and tampered 25 times in accordance to BS812:1975. After casting, the cubicles were left to stand for 24 hours before demoulding. The concrete cubes were cured by total immersion in water. Concrete Cubes were cast with ordinary Portland cement (OPC) which include dangote ordinary Portland cement and eggshell ash in varying percentages. Compressive strength test was carried out on the concrete cube subjected to water treatment at intervals of 7 days, 14 days, 21 days and 28 days.

IV. RESULTS ANALYSIS

4.1. PROPERTIES OF EGGSHELL ASH

The egg shell used for this research was Kurmin mashi area of Kaduna, it was burnt over open fire with any accelerants added. It was sieved to meet with the required cement texture after which test were carried out to determine the chemical properties so as to ascertain the suitability to be used as replacement for cement.

4.1.1. CHEMICAL PROPERTIES OF EGGSHELL ASH

OXIDE COMPOSITION	PERCENTAGE
SiO_2	0.07
TiO_2	0.087
Al_2O_3	0.30
Fe_2O_3	0.543
CaO	49.02
MgO	0.015
Na_2O	0.23
K_2O	0.328
ClO	0.538
SrO	0.493
SO_3	0.40
BaO	0.20
L.O.I	47.78

SOURCE: **National Geosciences Research laboratories Kaduna**

The chemical composition analysis was done at the National Geosciences Research Laboratories Kaduna, Kaduna State using X ray Atomic Spectrophotometer to determine the possibility of eggshell ash as pozzolana, with the high presence of CaO which is a major component of cement. It can be concluded that eggshell ash can be used in the production of mortar. According to Kamang et. al., (2004), each element and compound present in pozzolana or cements plays an important part in the properties of the resultant concrete. For instance, calcium which is the principal compound in Portland cement reacts rapidly on hydration, while silica reacts marginally in combination and hardly on its own. Neville 1988 as reported by Isa (2008) stated that trace elements such as magnesium oxide are known to cause unsoundness in concrete products, sulphur dioxide corrodes reinforcement and carbon which when present is not reactive and acts essentially as filler.

4.2 PHYSICAL PROPERTIES OF THE AGGREGATES USED

The aggregates both fine and coarse used for this research work are the sharp sand and granite/gravel. They were passed through various sieve sizes accordingly.

4.2.1. SETTING TIME

The addition eggshell ash to the cement decreases the setting time of cement. From the percentage decreases in the initial and final setting times from using 0 - 2.5% partial replacement of OPC, it can be seen that the higher the contents of eggshell ash in the cement paste, the faster the setting of the cement. For all the percentage contents of eggshell ash used, both the initial and final setting times satisfy the requirements of BS 12: 199. It should be recalled that BS 12:1991 requires that the initial and final setting times of OPC should not be less than 45 minutes, and not greater than 10 hours, respectively. It can also be observed that eggshell ash has similar decreasing effect on the initial and final setting times of cement. This similar effect being that the decrease in the setting time of OPC between successive percentage additions of eggshell ash is generally gradual for the initial setting time as well as for the final setting time. The decrease in the setting time of the OPC due to addition of eggshell ash portrays eggshell ash as an accelerator. Therefore, eggshell ash can be used to advantage as an admixture in concrete.

4.3 COMPRESSIVE STRENGTH RESULTS:

The variations of compressive strength with age at curing are presented below. The compressive strength generally increases with age at curing. The reaction between the cement particle with water or cement/ESA with water is known as hydration. Hydration proceeds with the presence of evaporable water. Water was continuously provided in the course of curing and the hydration process continued. This ensured an increase in the value of compressive strength. In the absence of the evaporable water there can be no gain in strength according to Neville in his work properties of concrete. This result is in line with the submission made by Al-Khalif et al.

Table 6: Table showing the specimen, age of curing, and load at failure

Mix Ratio	Specimen ID	Curing Days	Mass of specimen (g)	Average mass of specimen (g)	Density of Specimen (g/cm^3)	Average Density of specimen (g/cm^3)	Load at failure (KN)	Average Load at failure (KN)	Compressive strength (N/mm^2)
100% OPC, 0% ESA	A1		2400		2.4		220		
	A2	7	2545	2498.33	2.545	2.498	340	266.7	26.7
	A3		2550		2.5		240		
	A4		2580		2.58		420		
	A5	14	2345	2473.3	2.345	2.473	230	293.3	29.3
	A6		2495		2.495		230		
	A7		2510		2.51		380		
	A8	21	2475	2450	2.475	2.45	320	326.7	32.7
	A9		2365		2.365		280		
	A10		2455		2.455		320		
	A11	28	2535	2470	2.535	2.47	380	360	36
	A12		2420		2.42		380		
95% OPC, 5% ESA	B1		2525		2.525		320		
	B2	7	2445	2550	2.445	2.55	315	318.3	31.8
	B3		2680		2.68		320		
	B4		2570		2.57		240		
	B5	14	2665	2573.3	2.665	2.573	370	323.3	32.2
	B6		2485		2.485		360		
	B7		2670		2.67		320		
	B8	21	2670	2696.7	2.67	2.697	260	300	30
	B9		2750		2.75		320		
	B10		2565		2.565		345		
	B11	28	2500	2620	2.5	2.62	295	308.3	30.8
	B12		2795		2.795		285		
90% OPC, 10% ESA	C1		2510		2.51		220		
	C2	7	2555	2561.7	2.555	2.562	240	273.3	27.3
	C3		2620		2.62		360		
	C4		2690		2.69		100		
	C5	14	2490	2570	2.49	2.57	140	113.3	11.33
	C6		2530		2.53		100		
	C7		2455		2.455		320		
	C8	21	2645	2566.7	2.645	2.567	270	313.3	31.3
	C9		2600		2.6		350		
	C10		2595		2.595		320		
	C11	28	2590	2541.7	2.59	2.542	340	313.3	31.3
	C12		2440		2.44		320		
85% OPC, 15% ESA	D1		2425		2.425		280		
	D2	7	2425	2411.7	2.425	2.412	320	306.7	30.7
	D3		2385		2.385		320		
	D4		2485		2.485		200		
	D5	14	2610	2601.7	2.61	2.602	320	273.3	27.3
	D6		2710		2.71		300		
	D7		2715		2.715		260		
	D8	21	2555	2566.7	2.555	2.567	200	251.7	25.2
	D9		2430		2.43		295		
	D10		2595		2.595		200		
	D11	28	2580	2581.7	2.58	2,582	260	243.3	24.3
	D12		2570		2.57		270		

80% OPC, 20% ESA	E1		2570		2.57		280		
	E2	7	2420	2516.7	2.42	2.517	300	286.7	28.7
	E3		2560		2.56		280		
	E4		2580		2.58		280		
	E5	14	2445	2501.7	2.445	2.502	275	258.3	25.8
	E6		2480		2.48		220		
	E7		2535		2.535		285		
	E8	21	2485	2495	2.485	2.495	300	295	29.5
	E9		2465		2.465		300		
	E10		2585		2.585		280		
	E11	28	2585	2515	2.585	2.515	280	273.3	27.3
	E12		2375		2.375		260		
75% OPC, 25% ESA	F1		2580		2.58		220		
	F2	7	2590	2570	2.59	2.57	200	220	22
	F3		2570		2.57		240		
	F4		2585		2.585		225		
	F5	14	2440	2470	2.44	2.47	260	248.3	24.8
	F6		2385		2.385		260		
	F7		2435		2.435		160		
	F8	21	2605	2540	2.605	2.54	180	176.7	17.7
	F9		2580		2.58		190		
	F10		2390		2.39		195		
	F11	28	2585	2478.3	2.585	2.478	160	188.3	18.8
	F12		2460		2.46		210		
70% OPC, 30% ESA	G1		2430		2.43		180		
	G2	7	2490	2481.7	2.49	2.482	185	181.7	18.2
	G3		2525		2.525		180		
	G4		2410		2.41		200		
	G5	14	2585	2511.7	2.585	2.512	200	186.7	18.7
	G6		2540		2.54		160		
	G7		2440		2.44		120		
	G8	21	2380	2453.3	2.38	2.453	100	113.3	11.3
	G9		2585		2.585		120		
	G10		2435		2.435		140		
	G11	28	2420	2433.3	2.42	2.433	140	153.3	15.3
	G12		2445		2.42		180		

Table showing compressive strength of concrete

Table 7: Table showing Concise result of compressive strength of OPC and OPC/ESA concrete

Curing Time (Days)	OPC/ESA 0% (N/mm^2)	OPC/ESA 5% (N/mm^2)	OPC/ESA 10% (N/mm^2)	OPC/ESA 15% (N/mm^2)	OPC/ESA 20% (N/mm^2)	OPC/ESA 25% (N/mm^2)	OPC/ESA 30% (N/mm^2)
7	26.7	31.8	27.3	30.7	28.7	22	18.2
14	29.3	32.2	11.3	27.3	25.8	17.7	18.7
21	32.7	30	31.3	25.2	29	18.8	11.3
28	36	30.8	31.3	24.3	27.3	18.2	15.3

For the seek of this report, the required grade of concrete to be produced was grade 25, i.e having minimum compressive strength of $25N/mm^2$. The results shown below are of those that met that requirement. At the 7 days hydration period only concrete made with 100% OPC ($26.7N/mm^2$), 95% OPC (31.8 N/mm^2), 90% OPC (27.3 N/mm^2), 85% (30.7 N/mm^2) and 80% OPC (28.7 N/mm^2), met the minimum required standard for concrete ($25N/mm^2$). At the 14 days hydration period only concrete made with 100% OPC ($29.3N/mm^2$), 95% OPC (32.2 N/mm^2), 85% OPC (27.3 N/mm^2) and 80% OPC ($25.8N/mm^2$) met the minimum required standard for concrete (25 N/mm^2). At 21 days hydration period 100% OPC(32.7 N/mm^2), 95% OPC(32.7 N/mm^2), 95% OPC (30 N/mm^2), 90% OPC (31.3 N/mm^2), 85% OPC (25.2 N/mm^2) and 80% OPC (29 N/mm^2) met the minimum required standard for concrete (25 N/mm^2). At the 28 days hydration period only concrete made with 100% OPC (36 N/mm^2), 95% OPC (30.8 N/mm^2), 90 % OPC (31.3 N/mm^2) and 80% OPC (27.3 N/mm^2) met the minimum required standard for concrete (25 N/mm^2). The 95% replacement is then the optimum replacement level of OPC with ESA. This is so because it is the cheapest concrete that met the minimum compressive strength required for concrete in 28 days and much more, the quickest higher strength. At this 28 day, all concrete really meets up with the characteristic strength of the concrete. Due to the fineness particle of ESA, it has been able to show a competitive strength compared to normal concrete. This fineness helps in combating against the effect of chemical attacks and it also serves much as a plasticizer which allows for a better or complete reaction in the concrete. Since a pozzolanic concrete increase in strength a breadth with long duration of curing age.

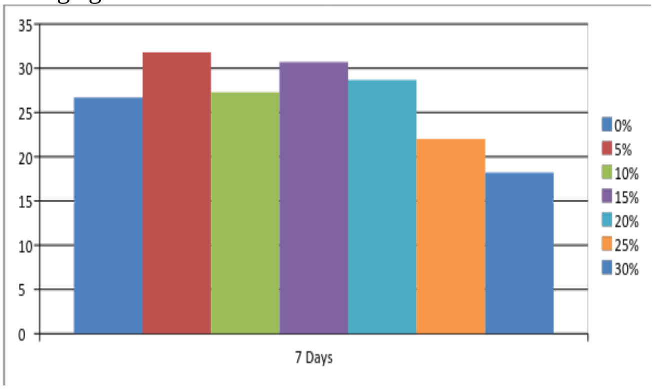


Chart 1: Compressive strength of OPC and OPC/ESA at 7 days.

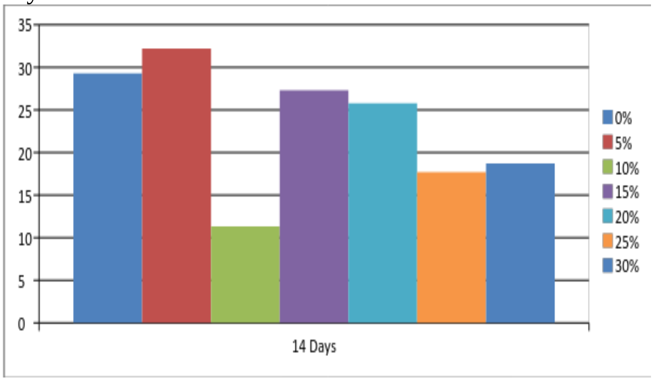


Chart 2: Compressive strength of OPC and OPC/ESA at 14 days.

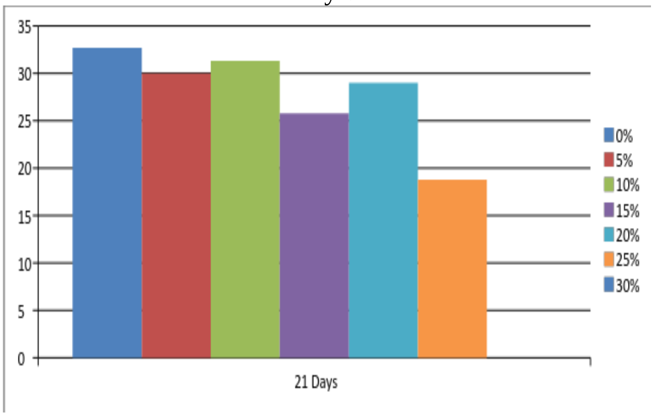


Chart 3: Compressive strength of OPC and OPC/ESA at 21 days.

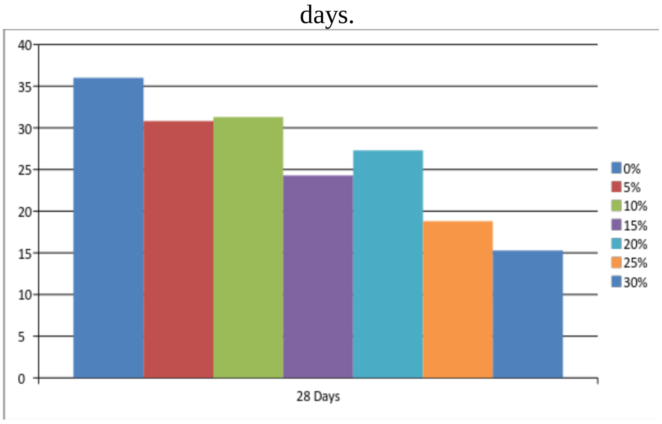
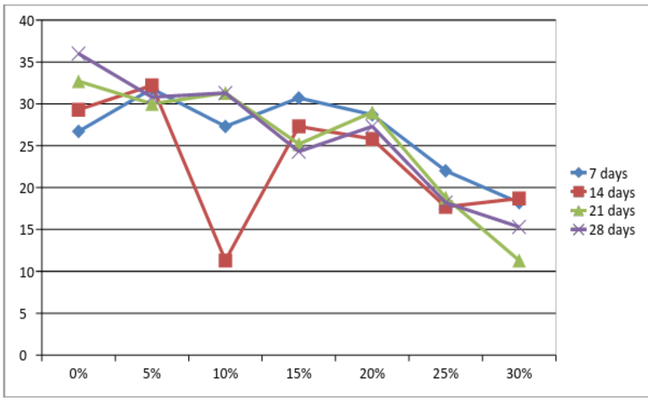


Chart 4: Compressive strength of OPC and OPC/ESA at 28 days.



Graph 1: Graph plotted showing the varying percentages against the curing days.

V. CONCLUSION AND RECOMMENDATION.

5.1 SUMMARY OF FINDINGS

Based on this research work, the following properties of eggshell ash were determined.

- The combined essential wide ($CaO+S_iO_2+Fe_2O_3+Al_2O_3$) content of eggshell ash was 59.256%, while lime (CaO) content and loss on ignition (LOI) was found to be 1.36% and 17.78% respectively and a PH value of 8.2 which is neutral.
- The ESA/OPC concrete were found to attain its optimum compressive strength at 5% replacement of the 14 days curing period having values of 32.27N/mm^2, while the least strength gotten at 30% having values of 11.33N/mm^2 of 21 days curing period competing with the normal conventional concrete having optimum compressive strength of 36.N/mm^2, and least strength gotten at 7 days having values 26.7N/mm^2.

5.2 CONCLUSION;

From the preliminary studies and tests carried out on the properties of concrete made with eggshell ash, the following conclusion has been reached

- The eggshell ash produced using charcoal from firewood is pozzolanic and therefore is suitable for use in concrete;
- For a given mix, the water requirement decreases as the eggshell ash content increases (Due to presence of eggshell ash, workability of mortar increases compared to an ordinary mixture with only ordinary Portland cement).
- The eggshell ash contained high percentage combination of Silica (S_iO_2), Iron (Fe_2O_3) Aluminum (Al_2O_3) and Calcium (CaO) of 50.256%.
- There is a general increase in the compressive strength with increase in the curing ages of 7, 14, 21 and 28 days.
- The optimum replacement level of OPC with eggshell ash is 10%.
- The maximum compressive strength of 32.2N/mm^2 was reached at 5% replacement at 14 days curing.

The employment of eggshell ash in cement and concrete has gained considerable importance because of the requirements of environmental safety and more durable construction in the future. The use of eggshell ash as partial replacement of cement in mortar and concrete has been extensively investigated in recent years. This literature review clearly demonstrates that eggshell ash is an effective pozzolana which can contribute to mechanical properties of concrete. Eggshell ash blended concrete can decrease the temperature effect that occurs during the cement hydration. Eggshell ash blended concrete can improve the workability of concrete compared to OPC. It can also increase the initial and also final setting time of cement pastes. Additionally, eggshell ash blended concrete can decrease the total porosity of concrete and modifies the pore structure of the cement, mortar, and concrete, and significantly reduce the permeability which allows the influence of harmful ions leading to the deterioration of the concrete matrix. Eggshell ash blended concrete can improve the compressive strength as well as the tensile and flexural strength of concrete. Eggshell ash helps in enhancing the early age mechanical properties as well as long-term strength properties of cement concrete. Partial replacement of cement with eggshell ash reduces the water penetration into concrete by capillary action. Eggshell ash replacement of cement is effective for improving the resistance of concrete to chlorides and sulfate attack. Substitution of eggshell ash has shown to increase the chemical resistance of such mortars over those made with plain Portland cement. Incorporation of eggshell ash as a partial cement replacement between 5% and 20% may be sufficient to control deleterious expansion due to alkali-silica reaction in concrete, depending on the nature of the aggregate. It can be concluded that the use of eggshell ash leads to enhanced resistance to segregation of fresh concrete compared to a control mixture with Portland cement alone. Finally, this literature search showed that the Mechanical properties of concrete are enhanced when the substitution of Portland cement was done with eggshell ash.

5.3 RECOMMENDATION

- Research should also be done using a longer curing period of up to 56 and 90 days for a higher strength determination.
- Since it has proven a high compressive strength and less adverse effects (when used by workers) it should be used more in construction works.

5.4 CONTRIBUTION TO KNOWLEDGE

This research work has contributed to knowledge by providing vital information as regards the quality of eggshell ash used as pozzolan and fine aggregate in production of concrete respectively.The compressive strengths gotten from the respective curing periods, revealed that the 10% rice husk ash shows a higher strength all through the curing period. This combination can therefore be regarded as the bench mark which produces the best outcome in terms of the compressive strength of ESA/OPC concrete. The maximum tensile strength 32.2N/mm^2 at 14 days. Hence, eggshell can be used as an alternative replacement of Portland cement in achieving a faster high strength in concrete and helps in resisting attack of dangerous chemicals in concrete

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