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EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH EGGSHELL ASH ADMIXED WITH PLASTIMENT BV-40 IN CONCRETE

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ABSTRACT

The use of eggshells ash for partial cement replacement in concrete has been well established in earlier studies.The effect of such partial replacement of cement with an eggshell ash admixed with Plastiment BV-40 was investigated in this paper.Tests including slump test, compressive strength test, splitting tensile strength test and concrete density test were carried out on concrete in which cement was partially replaced with 0%, 5%, 10%, 15%, 20% and 25% eggshell ash admixed with Plastiment BV-40 and presented. The test results indicate that eggshell ash decreases the workability of concrete. Also, for the compressive strength there was an improved maximum compressive strength at 5% ash content, after which there is a decrease in the compressive strength with increase in the ash content. Furthermore, eggshell ash is found to increase the concrete splitting tensile strength. It was concluded that eggshell ash has the potential of being utilized in concrete as partial replacement of cement.

Keywords: Eggshell ash, concrete, partial replacement, slump, density, compressive and splitting tensile strengths

INTRODUCTION

Search for alternative less expensive materials to improve concrete properties and to reduce cost and increase economic viability of projects is presently under more focus. The high cost of cement, which is the prime material in concrete is making the construction industry not very sustainable. Sustainable development is an emerging political and social issue of global significance. The increasing need for the concrete industry to comply with the fundamental goals of sustainable development and to reduce its impact on the environment, has led scientists and researchers to improve upon the properties of concrete products and at the same time to develop materials and technologies that can recycle the various wastes for their effective and economical use in cement based products and thus ultimately making these materials as commodity products. Over the years, many waste materials like fly ash, ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, wheat straw ash, have been tried as pozzolona or alternate cementitious materials in cement based products (Aliyu, 2019; Ogork, *et al.*, 2015; Ajayi, *et al.*, 2007).

Environmental scientists are generally of the view that Portland cement is not particularly environmentally friendly (Pierre and Sidney, 2011; Peter and John 2010; and Safiuddein Md *et al.*, 2010). Thus the challenges of producing and using concrete, is aggravated by the dire need and consumption of cement which is causing the environmental threats as outlined by the environmentalists (Pierre and Sidney, 2011). This means because of environmental problems associated with producing and using Ordinary Portland Cement for construction work and the fact that construction work require concrete being a major construction material which mainly depends on cement, then a situation requiring some balancing is created. That is the construction industry is faced with the task of having to use as much concrete, but with as little Portland cement as possible , and this means to replace as much Portland cement as possible by supplementary cementitious materials, especially those that are by-products or wastes of industrial processes, and to use recycled materials in place of natural resources. Also other researchers have opined that the best way for the construction industry to become sustainable is by using wastes from other industries as building materials (Tavokolin *et-al*, 2013: Meyer, 2009 and Mehta, 1992). One such waste material considered is the eggshell ash. It is evident today that the costs/environmental hazards of producing cement for instance is attracting good attention amongst construction experts. According to Heidari and Hasonpour (2013), Portland cement clinker production consumes large amounts of energy (850 kcal per kg of clinker) and has a considerable negative environmental impact. This involves massive quarrying for raw materials (limestone, clay, etc) as it takes 1-7 tones to produce 1 ton of clinker, as well as the emission of green house and other gases (NO_x, SO_2, CO_2) into the atmosphere. Gartner (2004) further states that around 850kg of CO_2 is emitted per ton of clinker produced. Therefore, the replacement of cement in concrete in concrete by other waste products (or materials) represent a tremendous saving of energy and has important environmental benefits. Besides, this can also have a major effect of decreasing concrete cost, since the cost of cement represents more than 45 percent of the concrete cost (Heidari and Hasonpour, 2013). It is thus evident today that the costs and environmental hazards of producing cement for instance, is attracting concern amongst construction experts.

Waste products such as rice husk ash, bagasse ash, fly ash, bottom ash etc. have been utilized as partial replacement of cement in construction products (mainly concrete and mortar) to maximize the profit while reducing the amount of wastes generated from other industrial processes (Tsado *et al*., 2014; Seco *et al*., 2012).

Eggshells are available as waste materials in hatcheries, bakeries and restaurants among others and can be environmental nuisance if not handled properly. The composition of eggshell promotes its consideration for incorporation into cement based materials as it contains lime content which is similar to that of cement (Afolayan, 2017; Hut, 2014). Studies by (Jhatial *et al*., 2019; Ujin *et al*., 2017; Gajera & Shah, 2015) have shown that eggshells ash can be used for partial cement replacement in concrete. Also, eggshell ash has been established to be good accelerator for cement based material because of extra calcium oxide produced by the addition of eggshell ash (Dhanalakshmi *et al*., 2015; Mtallib & Rabiu, 2011).

Eggshells are incinerated into ash by dry frying at a temperature of 500^{0}C (Afolayan, *et al.,* 2017; Asman, *et-al.*, 2017). Eggshell is reported to comprise of 93.70% calcium carbonate, 4.20% organic matter, 1.30% magnesium carbonate and 0.8% calcium phosphate (Afolayan, *et al* 2017).

Eggshells have a pure and more stable form of $CaCO_3$ called calcite, whereas limestone may contain impurities such as sand, clay, and other minerals (Shiferaw *et-al*., 2019). It has also been established by Okonkwo, *et al* (2012) that during incineration of eggshell to ash the calcium carbonate will decompose into calcium oxide and carbon dioxide as shown in Equation (1).

$$CaCO_3 \rightarrow CaO + CaO_2 \quad (1)$$

Calcium oxide is an important and major compound in cement hydration (Aliyu, 2019).

Strength is a primary criterion in concrete application. The effect of any supplementary cementitious material on the strength of concrete depends on the pozzolana content and pozzolanic activity of the material during hydration. Supplementary cementitious materials (SCM) as mineral admixtures have been identified in literature as being essential towards achieving low cost construction materials with the main benefits of saving natural resources and energy as well as protecting the environment (Imbabi *et-al*, 2012; Meyer, 2009; Elinwa and Mahmoud, 2002). Strength is a primary criterion in concrete application. The effect of any supplementary cementitious material on the strength of concrete depends on the pozzolana content and pozzolanic activity of the material during hydration. This paper investigates the effect of partial replacement of cement with an eggshell ash admixed with Plastiment BV-40. The admixture Plastiment BV-40 is designed for use in concrete to allow increased workability and for water reduction to be achieved.

MATERIALS AND METHODS

Cement

The cement used in conducting this research was ordinary Portland-limestone cement produced in Nigeria by Dangote Cement Company Plc known as Dangote 3X, Grade 42.5N with specific gravity of 3.15. This complied with CEM II of NIS-444 Part 1(NIS-444, 2003).

Fine Aggregates

River sand obtained from river Challawa, Kano-Nigeria, was used as fine aggregate. It was clean, sharp and free from clay, loam, dirt and any other deleterious materials. Sieve analysis carried out on the fine aggregate showed that the particle size distributions fall within the grading zone 2 of BS EN 888: 1992 (w/d;2004) as presented in Figure 1.

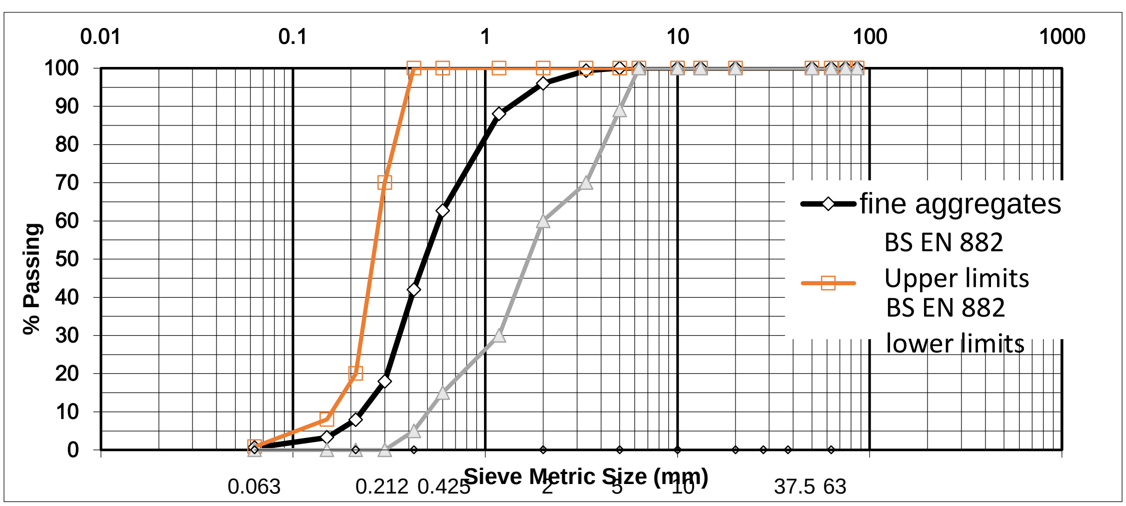

Figure 1: Particle Size Distribution of fine aggregates

Coarse Aggregates

Locally available crushed granite of 20mm nominal diameter and 2.85 specific gravity was used as coarse aggregate. The coarse aggregate was free from impurities with bulk density of 1500 kg/m^3 and average impact value of 20.85%.

Water

Water used for both mixing and curing was ordinary tap water, which is fit for human consumption in accordance with (BS-EN1008, 2002).

Eggshell ash

This was obtained by burning eggshells in to ash, and sieved through 75 µmm test sieve according to BS EN 933-1: 1997.

Plastiment – BV40

The admixture used in this research is Plastiment –BV40 concrete admixture, which is a versatile and economical multipurpose admixture, with a wide dosage range suitable for various application. It is a locally available admixture material that is readily sold in the construction materials (Admixtures) markets across the country. In this research the dosage of Plastiment –BV40 used was 0.5% by weight of the cement used.

METHODS

Mix Proportion

Concrete mix grade 30 was designed using the Absolute Volume Method and used for the experimental works. The cement was partially replaced with various percentages of eggshell ash. The percentages are 0%, 5%, 10%, 15% and 20% by weight of cement. Appropriate quantity of Plastiment – BV40 admixture was added as shown in Table 1.

Table 1: Concrete design mix proportion

Mix	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	Eggshell Ash (kg)	Plastiment – BV40 admixture (ml)
0%	4.77	9.93	10.74	2.15	0	0
5%	4.53	9.93	10.74	2.15	0.24	20
10%	4.29	9.93	10.74	2.15	0.48	20
15%	4.06	9.93	10.74	2.15	0.72	20
20%	3.82	9.93	10.74	2.15	0.95	20
25%	3.58	9.93	10.74	2.15	1.19	20

Slump Test on Fresh Concrete

Slump test was carried out on fresh concrete with 0%, 5%, 10%, 15% and 20% eggshell replacement. The test was done in accordance (BS1881-102, 1993).

Compressive Strength

Compressive strength test on concrete cubes containing eggshell ash of size 150 x 150 x 150 millimeter were carried out. Thirty six (36) cubes specimens were prepared, they were weighed to determine the density before being tested for compressive strength at 7 and 28 days in accordance with BS EN 12390 – 3:2009.

Splitting Tensile Strength

Splitting tensile strength test was carried out on concrete using cylinder specimens of 150mm diameter and 300mm long in accordance with BS EN 12390-2 (2009). The cylinders were tested after 28 days of curing in water. The rate of loading is as prescribed in BS EN 12390 – 6: 2000.

DISCUSSION OF RESULTS

Effect of Eggshell Ash on Concrete Workability (Slump test)

The variation of slump value when cement in the concrete is partially replaced with 5, 10, 15, 20 and 25% eggshell ash and Plastiment BV-40 can be seen in Figure 2. The slump decreases with an increase in the percentage replacements of eggshell ash. This indicates that eggshell ash causes higher demand of water and lowers workability in concrete mix despite use of admixture Plastiment BV-40. This may be attributed to the high specific surface area of the ash which is a view supported by Aliyu *et al,* (2020), and Ogork, *et al* (2015) in their works on the various ashes they worked on.

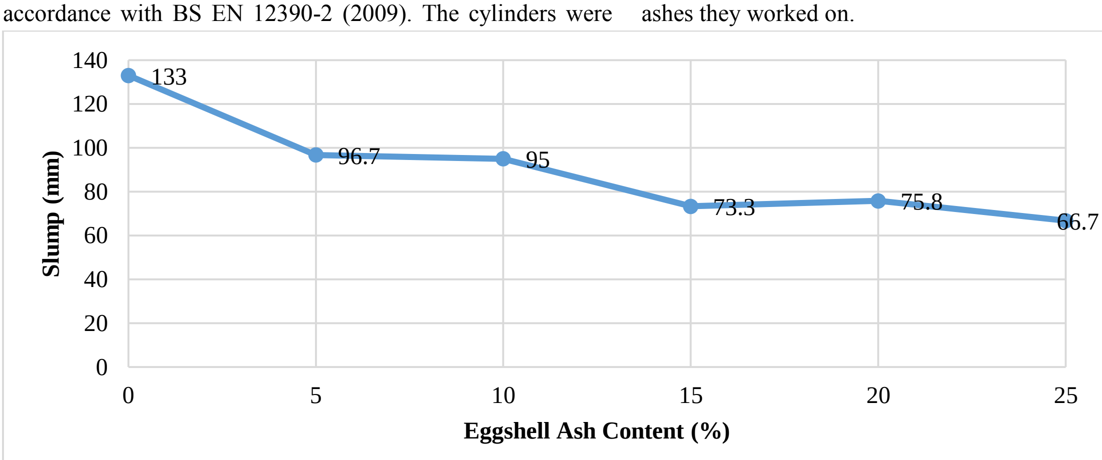

Figure 2: Concrete slump against various percentage replacement of eggshell ash content

Effect of Eggshell Ash on Concrete Compressive Strength

The most valuable property in concrete is compressive strength because it gives the overall definition of the quality of concrete strength that relates to the hydrated cement paste. Figure 3 shows the result for the compressive strength of concrete in which cement is partially replaced with eggshell ash at 7 and 28 days.

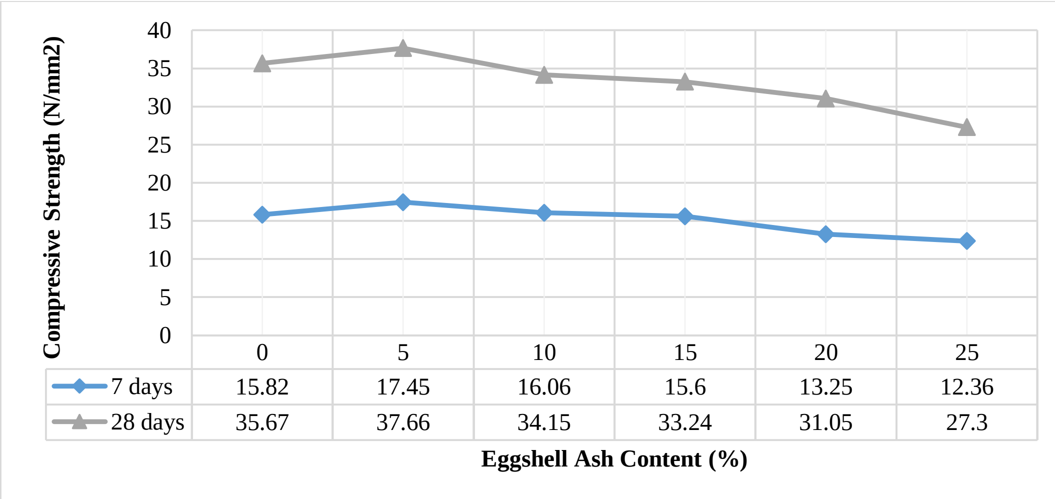

Figure 3: Compressive Strength against Various Percentage replacement of Eggshell Ash Content

From Figure 3, it is observed that the compressive strength initially increased for up to a replacement percentage of 5%, and there after decreased as the ash content was increased. 5% eggshell ash content has the maximum compressive strength, which gives an increase of 6% over the control (0% Ash content). All the samples were able to reach the mix design target grade of 30N/mm^2, except the 25% eggshell ash content.

Effect of Eggshell Ash on Concrete Density

Figure 4 shows the effect of partial replacement of cement with eggshell ash content on concrete density at 28 days.

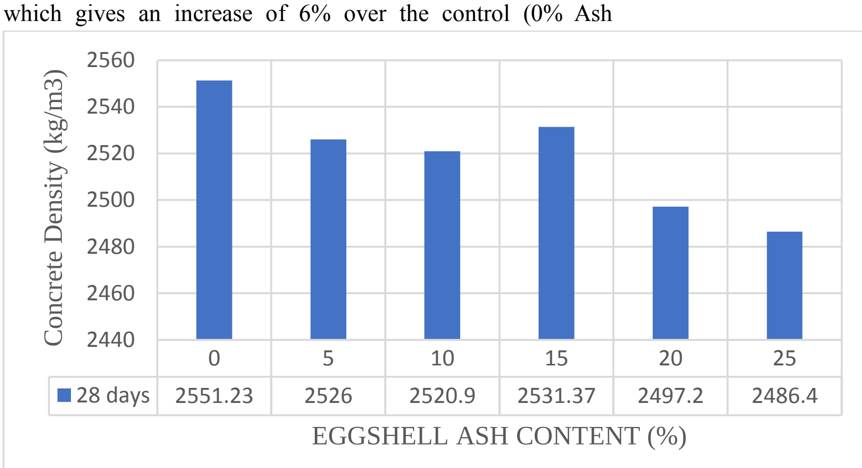

Figure 4: Variation of Concrete Density against Eggshell Ash Content

It can be observed from the figure that 0% eggshell ash content has the highest density, which then reduces with increase in the eggshell ash content. This may be attributed due to lower density of eggshell ash when compared with that of cement. From the results, it is seen that the concrete densities when compared with the recommendations of BS EN 206 -1:2001 which stipulates (minimum density of 2000 kg/m^3 and maximum of density of 2600 kg/m^3 for normal- weight concrete) are normal- weight concrete.

Effect of Eggshell Ash on Concrete Splitting Tensile Strength

The influence of partial replacement of cement with eggshell ash on concrete splitting tensile strength at 28 days is presented in Figure 5.

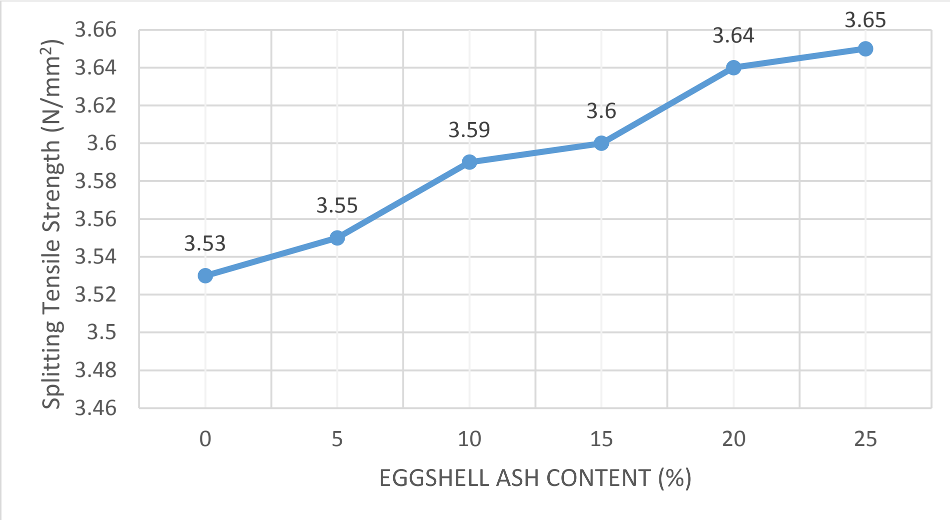

Figure 5: Splitting Tensile Strength against eggshell ash content

It can be observed that using eggshell as a partial replacement to cement increases the concrete splitting tensile strength. The strength increases with increase in eggshell ash content. The maximum splitting tensile strength of 3.65 N/m^2 was observed at 25% ash replacement.

CONCLUSIONS

Based on the test results and discussions, the following conclusions can be drawn:

Eggshell ash replacement has an effect on concrete workability. It decreases the slump thereby making the concrete less workable. The ash replacement in concrete has the maximum compressive strength at 5% content, after which there is a decrease in the compressive strength with increase in the ash content. At 28 days, all the samples have satisfied the target designed compressive strength of 30 N/mm2 except for the 25% ash content. Therefore Eggshell ash has the potential of being utilized in concrete.

The density of concrete reduces with increase in Eggshell ash content. This may be attributed to lower density of Eggshell ash when compared with that of cement. Also Eggshell ash is found to increase the concrete splitting tensile strength.

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