International Journal of Civil Engineering, Construction and Estate Management
Vol.5, No.3, pp.43-54, August 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

INVESTIGATING THE EFFECT OF EGGSHELL ASH ON THE PROPERTIES OF SANDCRETE BLOCK

Afolayan J. O*, Oriola F.O.P, Moses G and Sani J.E

Department of Civil Engineering, Nigerian Defence Academy, Kaduna, Nigeria

ABSTRACT: *The use of agricultural waste as pozzolan is widely accepted, because of several improvements possible in sandcrete composites and the overall economy. However, eggshell ash is a pozzolan that appears to have significant potential for the production of high strength and high performance sandcrete block. Although available information on eggshell ash sandcrete is limited, this research attempt to investigate and presents an experimental study on the effect of replacing cement with eggshell ash (ESA) in sandcrete block production. Results of the compressive strength test of sandcrete block containing ESA at varying replacement levels were discussed and compared with those obtained with the control (100% Portland cement sandcrete block). The total partial replacement was considered in the range of 0% (control specimen) to 40% by weight in steps of 5%. The combination for each replacement level apart from 0% are as follows: 95% cement and 5% ESA, 90% cement and 10% ESA, 85% cement and 15% ESA, 80% cement and 20% ESA, 75% cement and 25% ESA, 70% cement and 30% ESA, 65% cement and 35% ESA, 60% cement and 40% ESA. Sandcrete blocks specimen were produced and tested at 7, 14, 21 and 28 days of curing respectively to appreciate the strength development of each replacement value. It was observed that the strength decrease with increase in percentage replacement. But the best results were obtained at 30% replacement with a value of compressive strength of 4.7N/mm^2 of the 28day strength of that of the control at 28days, which met the standard requirement in Nigerian building code.*

KEYWORDS: Eggshell ash, Cement, Sandcrete block and Compressive strength

INTRODUCTION

Sandcrete blocks are made from a mixture of sand, cement and water. Sandcrete is a yellowish-white building material made from a binder (typically Portland cement), sandcrete block is produced in a mix ratio of 1:6. Sometimes other ingredients may be added to reduce the amount of expensive Portland cement such as pozzolanas. They are used extensively in virtually all African countries including Nigeria. The high and increasing cost of cement brought about by high exchange rate of local currency which discourage importation coupled with low production level by local industries have made it important to search for other alternatives. This high cost of cement has also contributed to the non-realization of adequate housing for both urban and rural dwellers in Nigeria. An alternative to cement as a material for construction is desirable in both short and long term as a stimulant for socio-economic development. The major cost component of these blocks is cement, since sand is readily available at relatively cheaper price. As such any reduction in cement component will subsequently reduce the cost of this material. As part of solution to the high material cost is to replace either partially or totally the cement content, but yet achieve the desired properties. In the short run, any material that can complement cement and is much cheaper will be of great interest. However, over the past decades, the presence of mineral admixtures in construction materials has been observed to impart significant improvement on their strength, durability and workability (Mental, 1994;

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Falade, 1997; Oyekan, 2001). Agricultural waste constitutes a sizeable proportion of the accumulated solid waste in many cities of the world. Attempts have been made by various researchers to convert solid waste to beneficial applications with a high level of success as a way of reducing solid waste accumulation (Osinubi and Ijimdiya, 2005; Jimoh, 2006; Gbemisola, 2007). Eggshells are part of agricultural wastes that litters the environment. In the ever increasing endeavors to covert waste to wealth, the efficacy of converting eggshells to beneficial use becomes an idea worth investigating. 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. As previously mentioned, calcium trioxocarbonate (IV), [i.e., 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, (CaC03)], is the primary raw material in the production of cement (Neville, 2003; Osei, 2007; Odesina, 2008). The produced OPC is composed of four main calcium compounds in the forms of dicalcium silicates, (C2S), tricalciumsilicate, (C3S), tricalcium aluminate, (C3A),and tetra-calcium aluminoferite, (C4AF), (Shirley, 1980). It is, therefore, indicated that cement and eggshells have the same primary composition in calcium compounds. The calcium trioxocarbonate (IV) which has been established to be common to eggshell and cement is a naturally abundantly available mineral. On the basis of the common compositional characteristics of cement and eggshells, it was reasoned in this study that the incineration of the eggshells could produce elements and/or compounds in the resulting eggshell ash (ESA) that could induce changes in the properties of cement. This investigation, therefore is unveiling another area of interest in the continuous quest for safe and economically viable ways of getting rid of solid waste in the environment; and finding local substitutes for construction materials. Okpala (1993) partially substituted cement with rice husk ash in the percentage range 30–60% at intervals of 10% while considering the effect on some properties of the block. His results revealed that a sandcrete mix of 1:6 (cement/sand ratio) required up to 40% cement replacement and a mix of 1:8 ratio required up to 30% to be sufficient for sandcrete block production in Nigeria. However, it is worthy of note that replacing cement with such high volume of RHA could be economically counterproductive for local sandcrete block manufacturers thereby defeating the main purpose of the substitution which is to reduce the unit cost of the block.

MATERIALS AND METHODS

Materials

Cement

Ordinary Portland Cement (OPC) was used, gotten from Dangote cement company, kogi State, Nigeria with properties conforming to BS 12 (British Standards Institution, 1971).

Eggshell

Fowls' eggshells are agricultural waste materials generated from chick hatcheries, bakeries; fast food restaurants among others which can litter the environment and consequently

ISSN 2055-6578(Print), ISSN 2055-6586(online)

constituting environmental problems/pollution which would require proper handling. Egg Shell Ash (ESA) was obtained by incinerating fowls' eggshells to ash.

Sand

The fine aggregate used was river-bed sand passing 4.75*mm* sieve and falls within zone 2.It was free from deleterious substances such as clay, loam, dirt and any organic or chemical matter.

Water

Water is needed for the hydration of cement and to provide workability during mixing and for placing there is not much restriction for water except that the water must not be severely contaminated with impurities. The water used for this research was tap water obtained from the faculty of engineering tank Nigerian defence academy which is suitable for drinking.

METHODS

Method of burning eggshell

Eggshell ash was obtained from poultry farm and cadet mess of Nigerian Defence Academy and was burned into ash. The eggshell is been dry under sun for a period of three (see Figure 1) days and burn locally using charcoal burner though the eggshell was not allowed to make contact with the charcoal. The eggshell was burn into ashes using method of dry frying.

FIGURE 1.0: Dried eggshell

Grinding of eggshell ash (ESA)

The burned ash is been taking to a grinding machine where the ashes were grinded to powder similar to the case of the cement where the clinker are also been grand to powder (see Figure 2).

ISSN 2055-6578(Print), ISSN 2055-6586(online)

FIGURE 2: Eggshell ash (ESA)

Sieving of eggshell ash (ESA)

The eggshell ashes were sieved with 75um sievein accordance with BS 12 (1991), and all materials that passed through was stored in an air tight container before usage.

Mixing procedure

The mixing procedures were divided into three stages. In the first stage, all binders (cement, eggshell ash) were weighted accordingly and mixed by mini mixer machine until all the constituents mixed uniformly. This was to make sure all binders were mixed thoroughly to produce a homogenous mix. The second stage involves mixing the binder with the aggregate for about 5 minutes. At the final stage measured water was added in to the sandcrete mix. This step was crucially important to make sure that the water was distributed evenly so that the sandcrete will have similar water-cement ratios for every cube. After that the mix was then poured into the mould.

Preparing sandcrete block

The size of the mould used to produce the cubes was 50×50×50mm. The sandcrete was poured into the mould in three layers where each layer was compacted twenty five times (25 times) using a steel bar (see Figure 3). The cubes were removed from the moulds after 24 hours and cured by method of sprinkling adopted in accordance with NIS (2000).

ISSN 2055-6578(Print), ISSN 2055-6586(online)

FIGURE 3: Production of sandcrete block.

Sieve analysis of aggregates

The purpose of sieve analysis is to determine the relative proportions of different grain sizes as they are distributed among certain size ranges. The aggregates samples were collected and dry under sun for three days, 300g mass of sample was weighed and used for the sieve analysis.

Mix Design

A good mix design should aim at achieving a good degree of workability and a minimum compressive strength at 28 days based on the value assumed by the design of the structure.

The water cement ratio of 0.5/1:6 are often used to influences the compressive strength of sandcrete . Care must be taken, therefore, in the selection of suitable water/cement ratio. The mix should also be cohesive in order to avoid possibility of honeycombing, grout separation and other problems associated with segregation, as this may be detrimental to the final product the proportioning of the cement replacement by eggshell ash is presented in Table 1.

Table 1: Proportioning of cement replacement material.

SPECIMEN IDENTIFICATION	CEMENT %	EGGSHELL ASH %
A1-A12	100	0
B1-B12	95	5
C1-C12	90	10
D1-D12	85	15
E1-E12	80	20
F1-F12	75	25
G1-G12	70	30
H1-H12	65	35
J1-J12	60	40

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Laboratory test Procedure

810g of cement and 5040g of sand was measured to ratio 1:6 and mixed for a period of 4minutes. 360g of tap water was added and continue to mix for further 4mins, producing a cement mortar of homogenous consistency. Precautions were ensured so that none of the materials are allowed to escape during mixing. A thin film petroleum jelly was added to the joints of the two halves of the clean mould and also to the contact surfaces of the bottom of the mould and its base. The assembled mould was compacted using a tamping rod for 25 blows in 3 different layers. The cube been in the mould was covered with impervious sheet and allow to cure at room temperature for 24 hours, the cube was removed from the mould, marked for identification A1-A12 as control and was allowed to cure at room temperature. Sprinkling method of curing was adopted in accordance with NIS 2000. The above process was repeated for 95% cement and 5% replacement of eggshell ash (B1-B12), 90% cement and 10% replacement of eggshell ash (C1-C12), 85% cement and 15% replacement of eggshell ash (D1-D12), 80% cement and 20% replacement of eggshell ash (E1-E12), 75% cement and 25 % replacement of eggshell ash (F1-F12), 70% cement and 30% replacement of eggshell ash (G1-G12), 65% cement and 35% replacement of eggshell ash (H1-H12), 60% cement and 40% replacement of eggshell ash (J1-J12). The strength of the prepared cubes was tested at 7 days, 14 days, 21days and 28days.

DISCUSSION OF RESULTS

Properties of Materials Used

The oxide composition of egg shell ash (ESA) and cement carried out at National Geo-science research laboratories centre, Kaduna are presented in Table 2 and the properties of the materials are shown in Table 3.

Table 2: Oxide Composition of Eggshell Ash (ESA) and Cement.

Oxide composition	ESA (%)	Dangote Cement (OPC) (%)
CaO	46.69	64.45
SiO_2	0.12	21.55
AL_2O_3	0.49	5.28
Fe_2O_3	0.32	3.95
MgO	0.18	1.85
SO_3	0.57	1.50
K_2O	0.21	-
Na_2O	0.19	-

The results obtained from the chemical analysis of eggshell ash indicate high percentage of lime (CaO = 46.69%), but not exceeding the required amount. The presence of lime in sufficient amount is required to form silicates and aluminates of calcium. The deficiency of lime will causes the eggshell ash to set quickly. Since the lime is not presence in an excess amount therefore the eggshell ash is sound and will not expand and disintegrate.

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Table 3: Properties of materials

Materials	Specific Gravity (SG)	Density kg/m^3
Water	1.0	1000
Cement	3.15	1440
Sand	2.65	1550
Eggshell ash	2.14	1500

Sieve analysis of aggregates

The grain size distribution curve for the fine aggregage use is shown in Figure 4. The particle size as shown from the graph are well graded sand with its particle size less than 5mm which is in accordance with BS 882 requirement for fine aggregates.

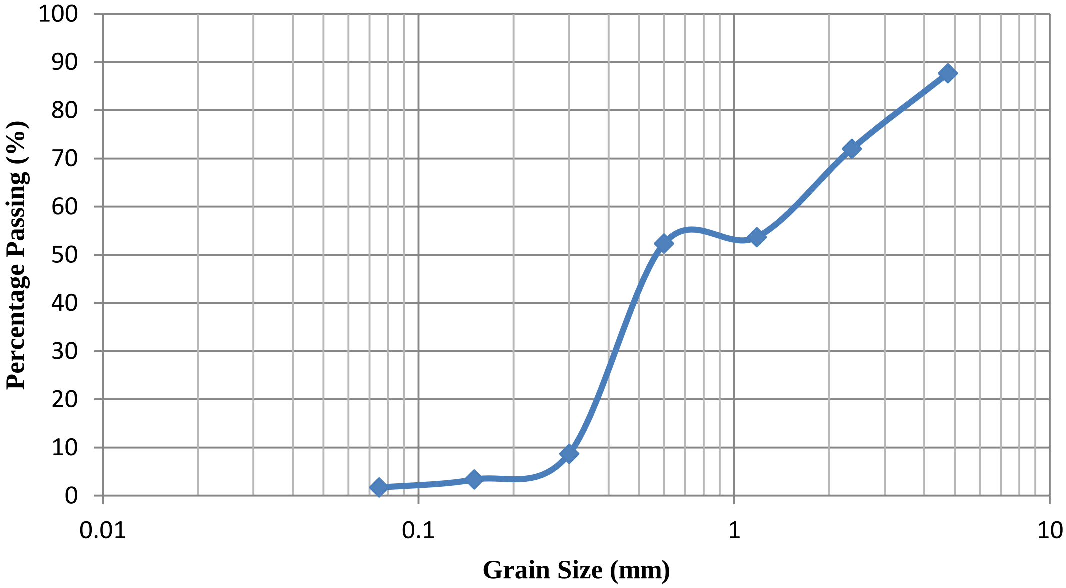

FIGURE 4: Grain size distribution curve

Compressive strength of sandcrete block

Compressive strength of sandcrete block at 7 days curing

The variation of compressive strength of sandcrete block at varying eggshell ash for 7 days curing period is shown in Figure 5. The result shows an initial decrease in compressive strength value with increase in the percentage ash of 5 and 10%, and thereafter increases to a peak value of 3.1 N/mm^2 at 30% eggshell ash content which is higher than the natural value of 2.1 N/mm^2. Beyond 30% there is a sharp decrease in the compressive strength value of the sandcrate block. there was decrease in the compressive strength. Similar trend were recorded by Al-Khalaf and Yousif (1984), Oyetola and Abdullahi (2006) and Mahmoud, *et al.*, (2012). The eggshell content is responsible for the early strength gain which is above the natural value due to the present of high CaO of 46.69%.

ISSN 2055-6578(Print), ISSN 2055-6586(online)

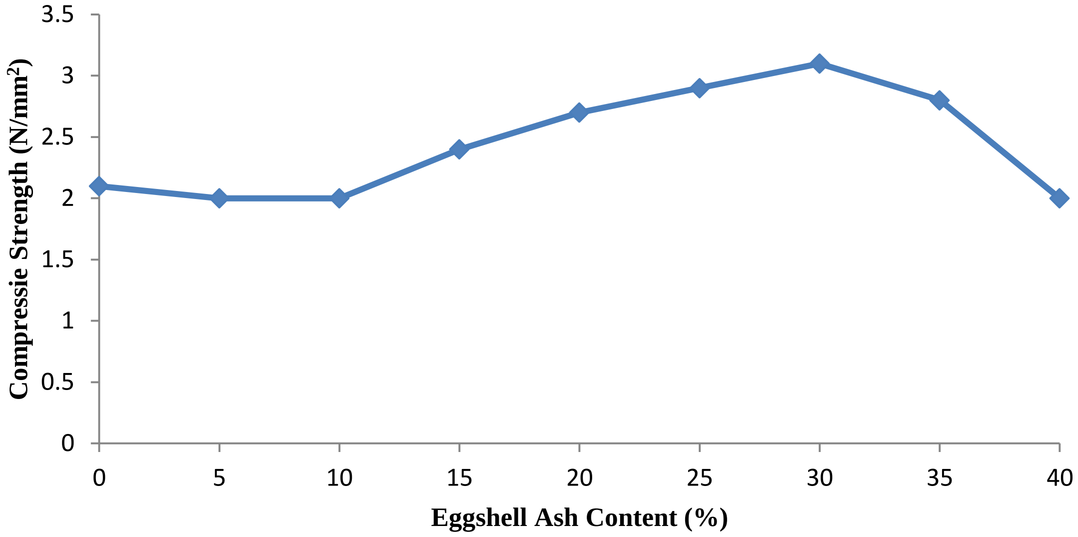

Figure 5: Variation of compressive strength of sandcrete block at varying eggshell ash content for 7 days curing period

Compressive strength of sandcrete block at 14 days curing

The variation of compressive strength of sandcrete block at varying eggshell ash for 14 days curing period is shown in Figure 6. Unlike the 7 days curing, the effect on the eggshell ash on the compressive strength of sadcrate block shows a decrease in its compressive strength as the percentage of the eggshell ash increases. The value decrease form a value of 4.5 N/mm^2 to a value of 2.5 N/mm^2 at 40% eggshell ash content.

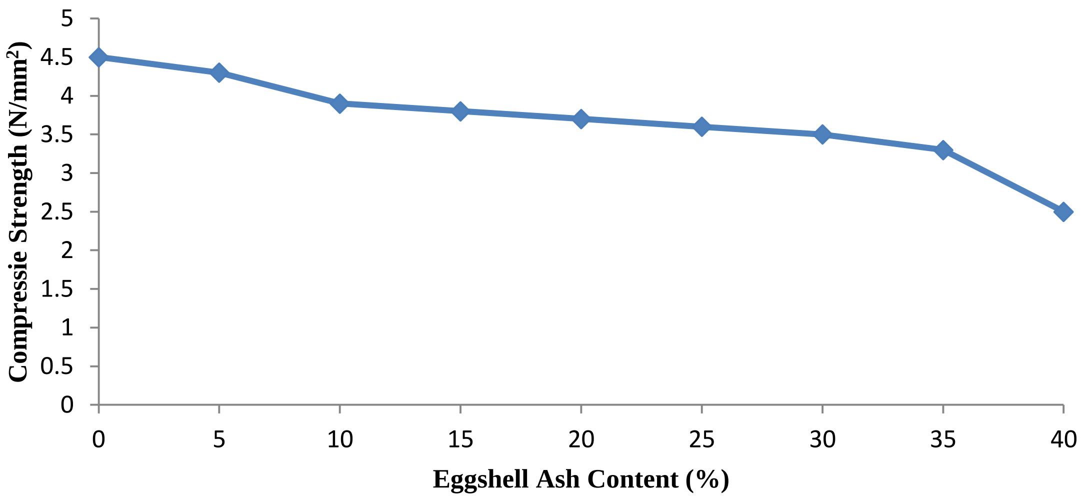

Figure 6: Variation of compressive strength of sandcrete block at varying eggshell ash content for 14 days curing period

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Compressive strength of sandcrete block at 21 days curing

The variation of compressive strength of sandcrete block at varying eggshell ash for 21 days curing period is shown in Figure 7. The result of 21 days curing period also shows a decrease in the compressive strength value of sadcrate block with increase in the percentage of the eggshell ash up to 15% then therafter increaes to a peak value of 4.4 N/mm^2 at 30 % eggshell ash. As the percentge of eggshell ash increases to 40% there was a decrease to a value of 3.3 N/mm^2.

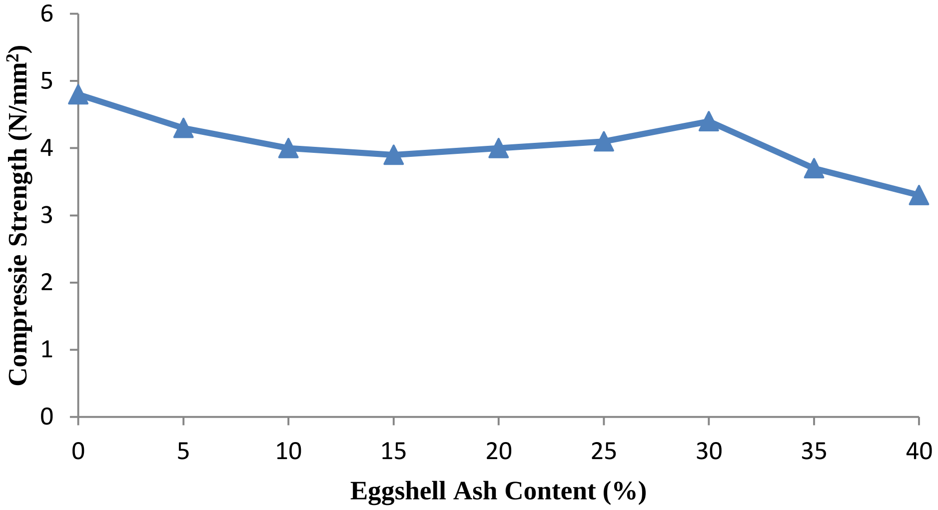

Figure 7: Variation of compressive strength of sandcrete block at varying eggshell ash content for 21 days curing period

Compressive strength of sandcrete block at 28 days curing

The variation of compressive strength of sandcrete block at varying eggshell ash for 28 days curing period is shown in Figure 8. The result of 28 days curing period also shows a decrease in the compressive strength value of sadcrate block with increase in the percentage of the eggshell ash. The value decrease form a value of 5.1 N/mm^2 to a value of 4.1 N/mm^2 at 40% eggshell ash content. After the initial decrease in the compressive strength value there was an increase to a peak value of 4.7 N/mm^2 at 30% eggshell ash replacement. Similar trend were recorded by Al-Khalaf and Yousif (1984), Oyetola and Abdullahi (2006) and Mahmoud, *et al.*, (2012).

ISSN 2055-6578(Print), ISSN 2055-6586(online)

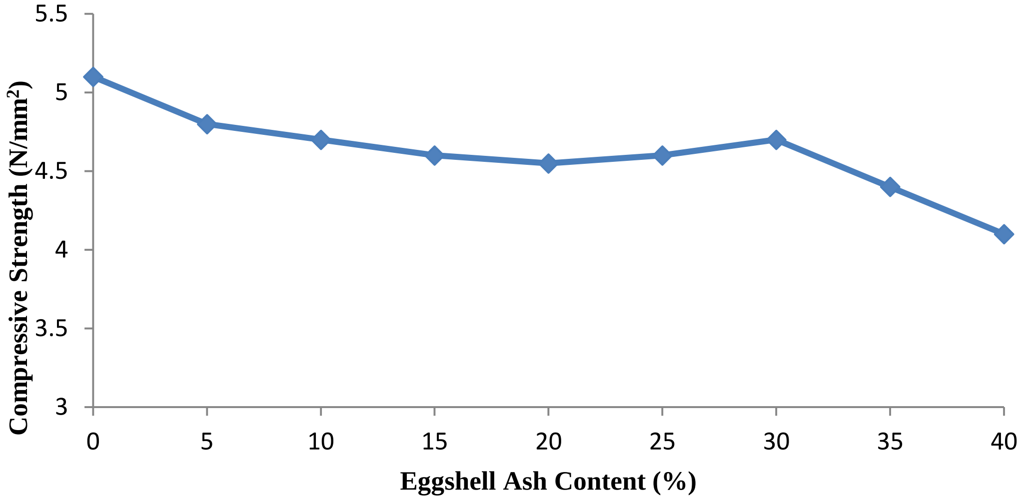

Figure 8: Variation of compressive strength of sandcrete block at varying eggshell ash content for 28 days curing period

Effects of curing days on the compressive strength of sandcrete

The variation of the compressive strength of sandcrete block at different eggshell replacement and varying curing period is shown in Figure 9. The result shows that as the curing periods in days increases there is a corresponding increase in compressive strength value for all treatment this is as a result of strength development with time due to the effort of complete hydration of the constituent of the cement and eggshell ash replaced. Similar trend were recorded by Al-Khalaf and Yousif (1984), Oyetola and Abdullahi (2006) and Mahmoud, *e al.*, (2012).

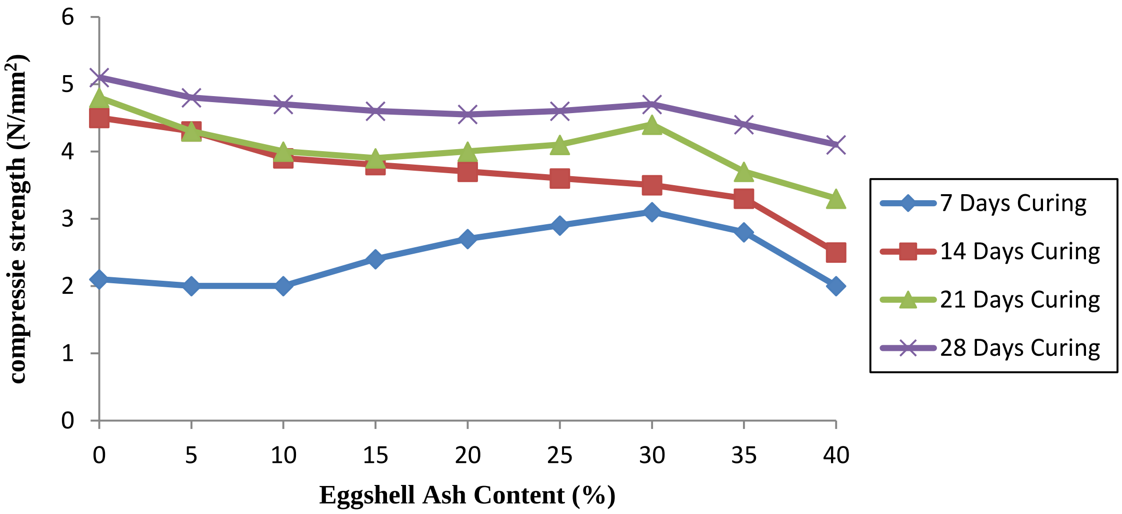

Figure 9: Variation of compressive strength of sandcrate block with eggshell ash content at varying curing period in days

ISSN 2055-6578(Print), ISSN 2055-6586(online)

CONCLUSION

From the results of the study, it is concluded that Eggshell ash can be used as an accelerator. The more the percentage of the ESA content, the higher the accelerating effect. The compressive strength obtained at different content of eggshell ash is satisfactory. The strength satisfies BS 4550 Part 3 section 3.4 requirement. Cement mortar partially replaced with eggshell ash can be used for plastering masonry or plastering concrete. Agriculture wastes such as eggshell ash shows good pozzolanic property in the production of sandcrete blocks. The sandcrete cubes samples mixed with eggshell ash show decrease in compressive strength compared to the control sample. The results obtained from the chemical analysis indicate high percentage of lime (CaO = 46.69%) and less percentage of Al_2O_3, Fe_2O_3 and SO_3.

RECOMMENDATION

The following conclusions can be drawn;

i. The use of eggshell ash as accelerator is recommended in cement mortar.
ii. The use of cement mortar partially replaced with eggshell ash is recommended for plastering masonry or plastering concrete.
iii. The use of electric burning machine would give the accurate temperature required in case of further research.
iv. The eggshell ash content should be used at higher percentages above the one used so as to observed further effects.
v. 30% replacement of eggshell ash should be used in the production of sandcrete block as this will produce strength above the required standard.

REFERENCES

Al-Khalaf M. N. and Yousif H. A., *Use of Rice Husk Ash in Concrete*, The International Journal of Cement Composites and Lightweight Concrete, 6(4), p. 241-248, 1984.

BS (1971): Method of testing cement, British Standard Institution, Milton Keynes, London.

BS 12 (1991) Specification for Portland cement Requirements for composition, strength, physical and chemical properties of four strength classes.

BS 4550 Part 3 (1978): Method of testing cement, British Standard Institution, Milton Keynes, London.

BS 882 Part 2 (1992): Specification for aggregates from natural sources for concrete, British Standard Institution, London.

Falade F (1997). The use of ground broken bottles as partial replacement of cement in concrete. In: Proceedings of Fourth International Conference on Structural Engineering Analysis and Modelling, Ghana. p. 473–486.

Gbemisola M.B. (2007). Effects of lime-rice husk ash on the engineering properties of lateritic soils. M. Eng Thesis, Department of Civil Engineering, Bayero University, Kano, 2007 87Pp. A. U (2003).

Jimoh A.A. Investigation into the engineering properties of rice-husk ash stabilizer lateritic soils. M. Eng Thesis, Department of Civil Engineering, Bayero University, Kano, 2006, pp. 73.

ISSN 2055-6578(Print), ISSN 2055-6586(online)

Mahmoud, H., Belel, Z. A., & Nwakaire, C. (2012). Groundnut shell ash as a partial replacement of cement in sandcrete blocks production. *International Journal of Development and Sustainability Online ISSN: 2168-8662 – www.isdsnet.com/ijds Volume 1 Number 3* , 1-7.

Mental PQ (1994). Mineral admixtures for concrete – an overview of recent developments. In: Advances in Cement and Concrete. Proceedings of Engineering Foundation Conference, University of New Hampshire, Durham. p. 243-256.

Neville A. Am (1981).Properties of Concrete, Pitman International Text 3rd Edition

Nigeria Industrial Standard (2000), NIS87: 2000. "Standard for Sandcrete blocks". Standard Organization of Nigeria, Lagos.

Odesina, I.A. Essential chemistry for senior secondary schools, 2nd edition. Tonad Publishers Limited, Ikeja, Lagos, 2008.

Okpala DC (1993). Some engineering properties of sandcrete blocks containing rice husk ash. Build. Environ., 28(3): 235-241.

Osei, Y.A. New school chemistry for senior secondary schools. Revised edition Africana First Publishers Limited, Onitsha, Nigeria, 2007.

Osinubi, K.J and Ijimdiya, T.A. (2005). Economic utilization of an agro-industrial waste- Bagasse ash. Book of Proceedings, 4th Nigerian Materials Congress, NIMACON 2005, November, Zaria, 2005, pp. 36-40.

Oyekan GL (2001). Effect of granite fines on the compressive strength of sandcrete blocks, In: Proceedings of Conference on Construction Technology, Sabah, Malaysia. p. 14-17

Oyetola E.B. and Abdullahi M. (2006), "The Use of Rice Husk Ash in Low – Cost Sandcrete Block Production", Leonardo Electronic Journal of practices and Technologies. Available at: http://lejpt.academicdirect.org/ A08/58_70.htm (accessed: 5/10/2011).

Shirley, D.C. Introduction to concrete. Cement and Concrete Association, Wexham Springs, Slough SL3 6PL, 1980.

Winton, A.L. Poultry eggs. Agrobios Publishers. Behind Nasrani Cinema, India, 2003.

ISSN 2055-6578(Print), ISSN 2055-6586(online)