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# Comparative Analysis of Properties of Some Artificial Pozzolana in Concrete Production

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## ABSTRACT

Due to increasingly search for alternative in terms of full or partial substitute for cement, there is need to justify pozzolanic properties of the various pozzolana use in structural work as applied to structural strength of the end product quality. This paper compares and presents analysis of some properties of artificial pozzolana that are common in Niger State, Nigeria: - Rice Husk Ash (RHA), Corn Cob Ash (CCA) and Sheanut Shell Ash (SSA). Laboratory analysis was adopted for the research. The three samples were burnt in open air to produce Ash, chemical composition of all the ashes, setting time as well as the density, workability and compressive strength of the concrete were determined. Each of the Ash was used separately to produce concrete cubes using various replacement levels of 0, 10, 20 and 30 percent of Ordinary Portland Cement (OPC). A total number of 48 cubes were cast from each ash replacement and cured in water for 7, 14, 21 and 28 days respectively. The chemical composition of all the ashes ascertained their pozzolanic properties. The result shows that the density of the concrete cube samples decreased as the percentage replacement of OPC increased. The initial and final setting time increased with increased in the percentage replacement. The compressive strength of all the ashes increases with increase in curing period and decreases with increase in all the ash substitution. There was a sharp decrease in compressive strength beyond 20% in all the ash substitution. The substitution of cement with any of the three ashes in concrete is relatively possible not exceeding 20%.

**Keywords:** *Sheanut, Corn cob, Rice husk, Ash, Cement, Concrete, Compressive strength.*

## 1. INTRODUCTION

Cement or some form of binding agent is a vital element in almost all types of construction and in recent years the cement market has been dominated by one product, Ordinary Portland Cement (OPC). In many countries, particularly Nigeria, OPC is an expensive and sometimes scarce commodity and this has severely limited the construction of affordable housing. Consequently, alternative cements provide an excellent technical option to OPC at a much lower cost and have the potential to make a significant contribution towards the provision of low-cost building materials and, consequently, affordable shelter. [2].

The addition of a pozzolana in either a lime or OPC-based product has two major advantages. Firstly, the properties of the cement will be improved, and secondly, as the costs of a pozzolana are usually low and certainly well below that of lime or OPC, overall cost will be significantly reduced assuming the pozzolana does not have to be transported too far.Industrialization in developing countries has resulted in an increase in agricultural output and consequently accumulation of unmanageable agro waste pollution arising from such waste is a cause of concern for many natures like Nigeria. Recycling such waste material in to a new construction material might be a viable solution to the problems of high cost of construction materials in the developing nation [1]. This, coupled with the pollution associated with cement production has necessitated a search for an alternative binder which can be used solely or in partial replacement of cement in concrete production. More so, disposal of agricultural waste materials such as rice husk, ground nut husk, corn cob and coconut shell an environmental challenge hence the need to convert them into useful materials to minimize their negative effect on the environment [2, 16]. Pozzolanas are materials containing reactive silica and/ or alumina which on their own have little or no binding property but, when mixed with lime in the presence of water, will set and harden like cement. They are an important ingredient in the production of alternative cementing material to Portland cement (OPC). Consequently, pozzolana is defined as a siliceous and aluminous materials, which in itself possesses little or no cementitious properly, but will in finely divided form and in the present of moisture chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [7]. Pozzolanas can be divided into two groups: natural pozzolana such as volcanic ash and diatomite, and artificial pozzolana such as calcined clay, pulverized fuel ash, and ash from burnt agricultural waste [12]. Many plant ashes have high silica content and are therefore suitable as a pozzolana [12].

In recent years considerable research has gone into identifying plant waste whose ashes produce goods pozzolana and which are available in exploitable up to 70% of Portland cement can be replaced by using materials such as primarily fly ahs silica fume, natural pozzolana, rice husk ash; wood ash and agricultural product ash [3, 10]. Despite the lower early strength the addition of natural pozzolana (up to 20-30%) could also improve the compressive, splitting and flexural strengths of the concrete [8, 11, 13].

Fly ash is defined as a material collected from a product combustion device after the fuel is consumed [17]. This type of material imports technical expertise to the resulting concrete, and also enables large qualities of cement replacement to be achieved [3]. The ash under study is similar to fly ash; fly ash with potential for use in concrete is classified in two categories as class C and class F. The classification is based on sum of ($Si0_2$ + $Al_20_3$ + $F0_2$ $0_3$) where the sum is greater than or equal to 70% the ash is classified as class F, while if it is greater than or equal to 50% it is class C [6,14, 15]. In the search for alternate of fully or partially replacement of OPC for concrete work, there in need to justify pozzolanic properties of the various pozzolana use in structural work as applied to structural strength of the end product quality. This research addresses the forgoing issues by comparing properties of three types of pozzolana used in concrete work.

## 2. MATERIALS AND METHODS

### MATERIALS

The materials used for the study include: Shea nut shell, Rice husk and Corn-cob. These were all obtained in Doko Area of Bida, Niger State, Nigeria. The cement used was Dangote brand of cement of new stock and it was obtained from local distributor in Bida, Niger State, Nigeria.

### 2.1 Aggregate

The fine aggregate used was the sharp sand obtained from river Gbako near Bida, Niger State, Nigeria and the coarse aggregate is the river side aggregate obtained along Kateregi via Bida in Niger State, and it is of 20mm nominal size.

### 2.2 Water

The water used was portable water from a bore hole in Federal Polytechnic Bida, Niger State, Nigeria.

### METHODS

The research was through laboratory analysis. The entire three samples (Shea nut Shell Ash, Rice Husk and Corn Cob) were sun dried for one week to remove moisture from it and each of them was subjected to uncontrolled combustion separately, using open air burning. The burnt ash was collected separately and each was sieved through 200 microns sieve. Atomic Absorption spectrometer (AAS) was used to determine the pozzolanic properties of each ash. The chemical analysis was conducted at Hegada Scientific Laboratory Service Limited, Moniya, Ibadan, Nigeria. The chemical composition of the Shea nut shell Ash (SSA) Rice Husk Ash (RHA) and Corn Cob Ash (CCA) used are presented in Table 1.

**Table 1. Chemical Composition of RHA, SSA and CCA**

| Component | RHA (%) | SSA (%) | CCA (%) |
|---|---|---|---|
| Si 02 | 48.44 | 41.50 | 38.75 |
| Al2 03 | 23.31 | 22.50 | 15.28 |
| Cao | 8.12 | 5.18 | 10.60 |
| Fe2 03 | 4.89 | 9.05 | 5.35 |
| Mg 0 | 1.25 | 1.04 | 2.31 |
| Na2 03 | 0.35 | 0.81 | 0.59 |
| K2 0 | 0.83 | 0.95 | 0.72 |
| S03 | 1.92 | 2.10 | 13.76 |
| Others | 2.35 | 7.44 | 5.29 |
| LOI | 7.53 | 9.55 | 7.35 |

The mix was designed using absolute weight method, a mix ratio of 1:2:4, a water binder ratio of 0.60 was adopted in this work, the control mix was produced using ordinary Portland cement only as a binder while in others mixes the three samples Shea nut shell Ash (SSA) Rice Husk Ash (RHA) and corn cob Ash (CCA) was used to replaced 10%, 20% and 30% of the mass of ordinary Portland cement. The mixing was done manually; slump test was used in assessing the workability of the fresh concrete, setting times test was also conducted on the binder paste. A total of sixty (60) cubes of 150mm were cast for each sample, the cubes were demoulded after 24 hours and were cured in curing tank containing clean water. The compressive strength was determined by crushing concrete cubes at 7, 14, 21 and 28 days of curing using compressive testing machine.

## 3. RESULTS AND DISCUSSION

### 3.1 Chemical Composition

The results of the chemical analysis of the three pozzolanic materials are shown in table 1. The Rice Husk Ash (RHA) has the highest total combined ($S_i$ $0_2$ +$Al_2$ $0_3$) of 77.65% follow by Shea nut shell Ash of the 73.03% and corn cob Ash with the lowest of 59.38%. Fly ash with potential for use in concrete is classified into two categories as class C and class F (ASTMC 618-9 1991). The classification is based on sum of ($S_i\ 0_2$ +$Al_2\ 0_3$) while the sum is greater than equal to 70% the ash is classified as class F, while if it is greater than or equal to 50% it is class C. From this result Rice Husk Ash and Shea nut Ash (SSA) are Pozzolanic material and falls under class F fly ash while corn cub Ash (CCA) is a class C fly Ash.

### 3.2 Workability

The result of the slump test indicating the workability of the three pozzolanic concrete are shown in Table 3, as the percentage replacement of cement increases, the workability of all the concrete decreases.

**Table 3. Workability of RHA,SSA and CCA**

| % Replacement | Workability (Slump( mm)) | | |
|---|---|---|---|
| | RHA | SSA | CCA |
| 0 | 30 | 30 | 30 |
| 10 | 28 | 25 | 28 |
| 20 | 27 | 22 | 26 |
| 30 | 25 | 20 | 23 |

Replacing cement by an equal mass of pozzolana causes an increase in volume since the density of cement is higher than that of pozzolana [10].

**3.3 Compressive Strength**The compressive strength of the concrete cubes for the three pozzolanic materials tested at 7, 14, 21 and 28days are presented in Table 2, and shown graphically in Figure 1.

**Table 4. Compressive Strength of RHA, SSA and CCA**

| Replacement (%) | Curing Age | Average Strength (N/mm$^2$) | | |
|---|---|---|---|---|
| | | RHA | SSA | CCA |
| | 7 | 14.35 | 14.35 | 14.35 |
| | 14 | 20.07 | 20.07 | 20.07 |
| 0 | 21 | 26.25 | 26.25 | 26.25 |
| | 28 | 33.62 | 33.62 | 33.62 |
| | 7 | 13.66 | 12.10 | 11.56 |
| | 14 | 15.04 | 14.30 | 13.43 |
| 10 | 21 | 20.53 | 21.72 | 18.85 |
| | 28 | 30.58 | 28.22 | 27.10 |
| | 14 | 13.05 | 13.86 | 12.36 |
| 20 | 21 | 18.30 | 19.46 | 17.02 |
| | 28 | 26.51 | 25.62 | 23.65 |
| | 7 | 10.59 | 10.03 | 9.25 |
| | 14 | 12.83 | 11.74 | 1041 |
| 30 | 21 | 14.36 | 13.21 | 12.95 |
| | 28 | 17.68 | 15.82 | 14.06 |

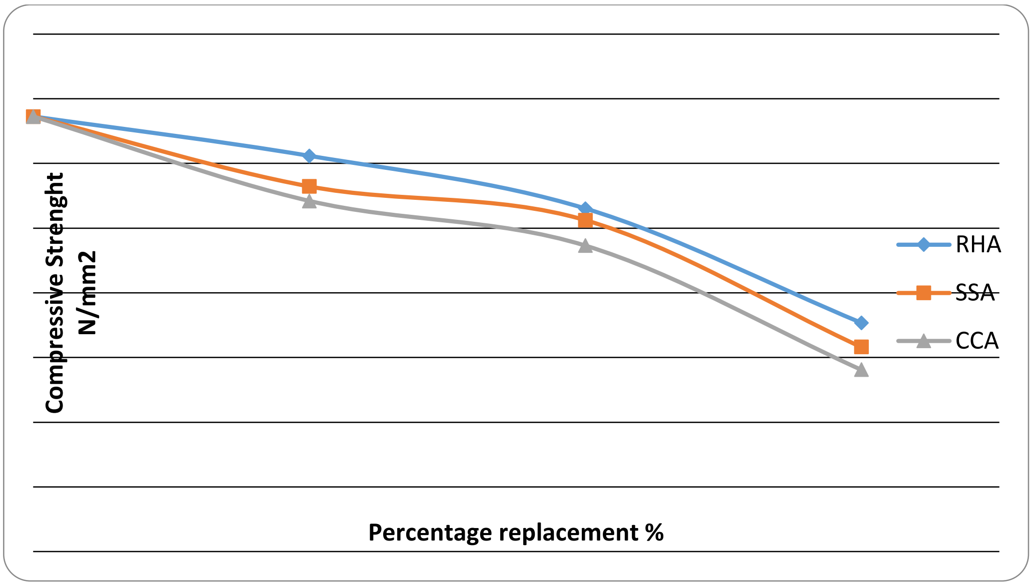


**Fig 1. Comparative Compressive Strength of RHA, SSA and CCA**

From the figure it indicates that the compressive strength generally increases with curing period and varies with increasing pozzolanic content. The highest compressive strength was obtained at 10% replacement as follow; 30.58N/mm$^2$ (RHA), 28.22N$^2$ (SSA) and 27.01N/mm$^2$ (CCA) for 28 days curing period. The 20% replacement gives compressive strength of 26.51N/mm$^2$ (RHA), 25. 32 N/mm$^2$ (SSA) and 23.65N/mm$^2$ (CCA) and the lowest compressive strength occurs at 30% replacement as follow 17.68N/mm$^2$ (RHA) 15.82N/mm$^2$ (SSA) and 14.06N/mm$^2$ (CCA) at 28 days. The variation is similar in all crushing ages. The strength development of concrete containing pozzolana is more adversely affected by short curing periods under water than plain Portland cement containing concretes, such behavior depends on the fact that at least during the first 7-day of curing the most common pozzolana do not take part in the hydration process and they solely act as a diluting agent.

## 4. CONCLUSION

Based on the analysis of the results obtained from the research the following conclusion can be drawn.

1. All the three material are suitable for use as a pozzolana, the RHA and SSA is classified as a class F fly ash since ($S_i$ $0_2$ +Al203+$Fe_2$03 ) is more than 70% CCA is classified as a class C fly ash since ($S_i$ $0_2$ +$Al_2$ $0_3$ + $Fe_2$ $0_3$) is more than 50%.
2. All the three materials have low early strength compared with the control value. This may be due to the slow development of pozzolanic reaction.
3. The setting times increases with increases in the percentage replacement for all the three material used.
4. The workability of the concrete decreases with an increase in the percentage replacement for all the three materials used.
5. The compressive strength generally increase with curing period and decreases with increasing percentages replacement for all the three samples.
6. Only substitution of up to 20% replacement is adequate for general concrete work.

## RECOMMENDATIONS

Since a compressive strength of 30.58N/mm$^2$, 28.22 N/mm$^2$ and 27.10 N/mm$^2$ for 10% and 26.51 N/mm$^2$, 25.62 N/mm$^2$ and 23.65N/mm$^2$ for 20% replacement were achieved, all the three materials are recommended for use as a partial replacement for ordinary Portland cement. RHA and SSA should not exceed 20% while CCA should not exceed 10% replacement for structural uses as stipulated in [5]

## REFERENCES

[1] Abdulfatai, A.M., Mustapha A.G. and Bashir, A.U. (2013). Performance of Corn Cob Ash Filler in Hot mix Asphalt Using Stone Dust as Control. Proceedings of 3rd Biennial Engineering Conference, School of Engineering and Engineering Technology, Federal University Technology Minna, Niger State, Nigeria, pp.268-275.

[2] Abdullahi, A., Abubakar, A. and Afolayan, A. (2013). Partial Replacement of Sand with Sawdust in Concrete Production. Proceedings of 3rd Biennial Engineering Conference, School of Engineering and Engineering Technology, Federal University Technology Minna, Niger State, Nigeria, pp.333-338.

[3] Akeem Ayinde Raheem and Olumide Adenuga (2013). Wood ash from bread bakery as partial replacement for cement, *International Journal of Sustainable Construction Engineering and Technology, vol. 4 (1), 2013.*

[4] ASTMC618-9, (1991). Standard Specification for fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete, ASTM International, West Conshohacken. USA.

[5] British Standard Institution BS8110: Part 2: (1985), Structural use of concrete, code of practices for design and construction, London, UK.

[6] Jerath, S. and Hanson, N. (2007) "Effect of fly ash content and aggregate gradation on the durability of concrete pavement". *Journals of Materials in Civil Engineering, 19 (5)*.

[7] Malhotra and mahta, pozzolanic and cementitious materials gariulion and breach publisher UK

[8] Mouh, M. and Khelafi, H. (2008). Performance characteristic of light weight aggregate containing natural pozzolana. *Building and Environmental Journal, 43(1).*

[9] Myer Kutz (2002). Handbook of Materials Selection, John Wiley & Sons, Inc., USA

[10] Osei, D.Y and Jackson, E.N. (2012). Compressive strength and workability of concrete using natural pozzolana as partial replacement of ordinary Portland cement. *Advances in Applied Science Research Journal, 3(6).*

[11] Papadakis, V.G. and Tsimas, S. (2002). Supplementary Material in Concrete: Efficiency and Design. Cement and Concrete Research, Vol.32

[12] Practical action, technical brief (2000). Schumacher Centre for Technology and Development, Rugby UK.

[13] Rodrogne, C.E. and Urube, A.R. (2002). Importance of using the natural pozzolana on concrete durability, Cement and Concrete Research, Vol. 32

[14] Shetty, M.S. (2002).Concrete Technology, Theory and practice. 5th Edit., Chard and Company, Ram Nagar, New Delhi.

[15] Taylor, G.D. (2002). Materials in Construction – Principles, Practiceise and Performance. *Pearson Publishers. www.pearsoned.co.uk ISBN-13:978-0-582-36934-4*

[16] Utsev, J.T and Taku, J.K. (2012). Coconut shell Ash as partial replacement of ordinary Portland cement in concrete production, *International Journal of Scientific and Technology Research*, 1 (8).

[17] Wang, S., miller, A., Liamazoa. E., Fonsera F. and Baxter, L. (2008) .Biomass fly ash in concrete; mixture proportioning and mechanical properties, *Fuel Processing Technology*, Vol. 87.