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Rice Husk Ash Pozzolan as Valuable Supplement in Concrete for Industrial and Domestic Applications

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Authors' contributions

This work was carried out in collaboration between both authors. Author AED designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author EEE managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Controlled burning of rice husks at<700°C produced rice husk ash (RHA) which is predominantly amorphous silica (SiO2). RHA was used as a substitute for laterite and cement in proportions of 5%, 10%, 15%, 20%, 25% and 30% of concrete. The concrete was cured for 7 days, 14 days, 21 days, and 28 days respectively. It was observed that 20% of RHA provides the optimum strength. The effects of different particle sizes of 75, 150, 212, 300, 425 and 600 microns (µm) were tested using a compression test machine. A graph of average strength against particle size indicates 2.9 Nm-2 as the optimum strength at 75 µm and 1.2 Nm-2 as the minimum at 150 µm. From the ash size distribution, the presence of grains of several different sizes was observed. The grains were weighed using a weighing machine and a graph of particle size against percentage plotted to determine the particle size distribution. This showed that rice husk ash (RHA) is coarse grain material.

Keywords: Coarse grain; pozzolan; ash; laterite; amorphous silica (SiO2).

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1. INTRODUCTION

Rice husks are the natural sheaths that form on rice grains during their growth. These are removed during the milling of rice. Although these seem to have no commercial value, they can however be made useful through a variety of thermo chemical conversion processes [1]. In a majority of rice producing countries, much of the husks produced from the processing of rice is either burnt or dumped as waste. Rice husk is unusually high in ash compared to other biomass fuels, it has close to 20% of ash as by – product [2]. The ash is 92 – 95% silica, highly porous and light weight, with external surface area. So with large ash content and silica content in the ash it becomes economical to extract silica from ash which takes care of ash disposal [2].

Rice husk ash (RHA) is a term describing all types of ash produced from burning rice husks which vary considerably according to burning techniques. According to Kalapathy et al. [3], the silica in the ash undergoes structural transformations depending on conditions such as duration and temperature of combustion. At 500°C to 700°C amorphous ash is formed and at temperature greater than this, crystalline ash is formed [4]. These types of silica have different properties and it is important to produce ash of the correct specification for the particular end use.

Pozzolans are materials containing reactive silica and 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 [5]. Pozzolans are important additive ingredients in the production of alternative cementing materials to Portland Cement. Alternative cements provide an excellent technical option to Ordinary Portland Cement (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. Pozzolans can be used in combination with lime and OPC. When mixed with lime, pozzolans will greatly improve the properties of lime-based mortars and concretes for use in a wide range of building applications. Alternatively, they can be blended with OPC [6] to improve the durability of concrete, and considerably reduce its cost. A wide variety of siliceous or aluminous materials may be pozzolanic [6], including the ash from a number of agricultural and industrial wastes. Among agricultural wastes, rice husk has been identified as having the greatest potentials, since it is widely available and, on burning, produces a relatively large proportion of ash, which contains about 90% silica [6].

Pozzolans have the potential to reduce substantially the cost of building. These materials can be blended with lime to produce blended cements which can replace pure Portland cement commonly used in building materials such as concrete, masonry block, masonry mortar, bricks and other construction units. The energy required to manufacture a lime-pozzolan cement (LPC) is substantially less than for Portland cement; in some cases the pozzolan requires no preparation. The cost associated with the production of LPC is mainly due to the coal or oil used to produce the lime [4].

There are substantial advantages if well-chosen pozzolans are used in cement-based construction materials. They are found to improve quality of concrete; lower heat of hydration, lower thermal shrinkage, increase in water tightness, improve sulphate resistance, improved seawater resistance, and reduction in alkali-aggregate reaction [4]. 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 [4]. Use of poor-quality pozzolans in practice, with resultant failures, is a principal reason why the confidence in the use of the materials is not high.

Pozzolan as a siliceous and aluminous material reacts with calcium hydroxide in the presence of water. This forms compounds possessing cementitious properties at room temperature which have the ability to set with addition of water.

Mishra and Deodhar [7] investigated the effect of rice husk ash on cement mortar and concrete in terms of application, strength and durability. They found that the amount of useful internal work necessary to overcome the internal friction to produce full compaction is termed as workability. Size, shape, surface texture and grading of aggregates, water-cement ratio, use of admixtures and mix proportion are important factors affecting workability. Strength is to bear the desired stresses within the permissible factor of safety in expected exposure condition. Durability is sustenance of shape, size and strength; resistance to exposure conditions, disintegration and wearing under adverse conditions. Conclusion was reduction in water absorption, based on results obtained from 6 tests on concrete and 3 tests on mortar samples. Up to 10% RHA with concrete and mortar enhance all the listed properties and 12.5% of Rice Husk Ash by mass of cement as the optimum needed to be added in concrete production when the husk was burnt under field condition.

Kartini [8] investigated Rice Husk Ash Pozzolanic Material for Sustainability. He conducted an intensive study of RHA to determine its suitability from the various grade of concrete (Grade 30, 40, 50) studied. His conclusion shows that up to 30% replacement of OPC with RHA has the potential to be used as partial cement replacement (PCR), having good compressive strength performance and durability. Hence the potential of using rice husk ash (RHA) as PCR material which can contribute to sustainable construction.

Duke [9] investigated Rice Husk Ash (RHA) as A Supplement in Cement for Building Applications (MSc Thesis). He found that controlled burning of RHA produced amorphous silica SiO_2, which was substituted for cement in proportions of 0%, 5%, 10%, 20% and 30% of concrete. The concrete was cured for 7 days, 14 days, 21 days and 28 days respectively. Comparison was made between particle sizes of 600, 425, 300, 212, 150 and 75 microns. X-ray fluorescence (XRF) analysis was conducted to determine the elements present in the sample and X-ray diffraction (XRD) analysis was also conducted to determine the atomic and molecular structure of the compounds in the sample. He concluded that 20% replacement of rice husk ash provides the optimum strength which is also achievable with 75 microns.

Omatola [10] carried out an instrumental analysis of rice husk ash. He posited that rice husk ash (RHA) is one of the most silica raw materials containing about 90 - 98% silica after complete combustion among the family of other agro – wastes. Ash samples from rice husks of five origins were prepared at two different temperatures, namely 500°C and 1000°C respectively and the ash content evaluated at each temperature. X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), Instrumental Neutron Activation Analysis (INAA) alongside with a simple chemical process were the techniques adopted for the characterization of each ash sample heated to 1000°C for silica content. While XRD analysis indicated the compounds present in each sample, XRF and INAA analysis indicate only trace (impurity) elements present in each ash sample. XRF and INAA showed that RHA had a very low impurity concentration, indicating that rice husk which is an agricultural waste is a potential source of silica. The result was confirmed by the XRD analysis where almost all the compounds present were silicates and the simple chemical process employed confirmed the very high silica presence of between 93 – 96%. The XRF result shows a high purity level of 94 – 98.9% while the INAA showed a purity level of 88.4% - 96.5%.

Ghassan and Hilmi, [11] focused on the use of rice husk ash as cement replacement material. The effect of grinding on the particle size and the surface area was first investigated, then XRD analysis was conducted to verify the presence of amorphous silica in the ash. Furthermore, the effect of average particle size and percentage on concrete workability, fresh density, superplasticizer (SP) content and the compressive strength were also investigated. Conclusion was that RHA concrete gave excellent improvement in strength for 10% replacement (30.8% increment compared to the control mix), and up to 20% of cement could be valuably replaced with RHA without adversely affecting the strength.

Emmanuel B, et al. [12] investigation of Rice Husk Ash (RHA) as supplement in Cemeent for Building applications. They investigated that controlled burning of rice husk ash produced amorphous silica SiO_2, which was substituted for cement in proportions of 0%, 5%, 10%, 20% and 30% of concrete. The concrete was cured for 7 days, 14 days, 21 days and 28 days respectively. Comparison of mixtures with particle sizes of 600 micron, 425 micron, 300 micron, 212 micron, 150 micron and 75 micron. X-ray fluorescence (XRF) analysis was conducted to determine the elements presents in the sample and X-ray diffraction (XRD) analysis was also conducted to determine the atomic and molecular structure of the compounds in the sample. They concluded that 20% replacement of rice husk ash provides the optimum strength and 75 micron provide the optimum strength.

2. MATERIALS AND METHODS

The materials used were rice husk, forceps and spatula, crucibles, pan, burning furnace, hammer mill, sieve machine, mould 150 x 150, weight balance and compression test machine. The rice husk was obtained from Bekwara Local Government Area, known to be the major rice producers in Cross River State. The husk were properly burnt for the voltaic hydrocarbon to escape, and poured into a crucible which was placed in a muffle furnace for combustion to a temperature of 700°C. The ash obtained at this temperature was allowed to cool in the muffle furnace and with the use of forceps and spatula, the content of the crucibles was transferred into a pan.

The rice husk ash was groundinto fine powder. Hammer mill was used for this purpose. The RHA was then sieved with different sieve sizes with the help of a sieve machine of aperture of 600, 425, 300, 212, 150 and 75 microns and this becomes our pozzolan. 5%, 10%, 15%, 20%, 25%, and 30% ratio of pozzolan were mixed with laterite, and cement cast and cured for 7 days, 14 days, 21 days and 28 days tested with the help of a compression testing machine according to American Society for Testing Materials (ASTM) to know the optimum strength.

3. RESULTS

Table 1 shows the results of different mixed ration of Pozzolan at 5%, 10%, 15%, 20%, 25% and 30%, cast and cured for 7 days, 14 days, 21 days and 28 days tested with the help of a compression test machine and they are represented graphically in Fig. 1 indicating the optimum strength at 20%.

Table 2 shows the result of average strength of different particle size also represented graphically in Fig. 2. Indicating 2.9 Nm^{-2} as the optimum strength at 75 micron and 1.2 as the average minimum strength at 150 micron.

Table 3 shows the result of particle size distribution also represented graphically in Fig. 3 indicating that rice husk ash (RHA) is coarse grains material.

Table 1. Strength of mixed ratio of pozzolan

No of days	Strength at pozzolan 5%	Strength at pozzolan 10%	Strength at pozzolan 15%	Strength at pozzolan 20%	Strength at pozzolan 25%	Strength at pozzolan 30%
7	1.20	2.35	3.55	4.45	3.15	4.00
14	1.35	2.50	3.85	6.25	3.90	4.55
21	2.45	3.00	4.00	8.00	4.85	5.00
28	2.00	3.25	4.15	9.15	5.00	7.15

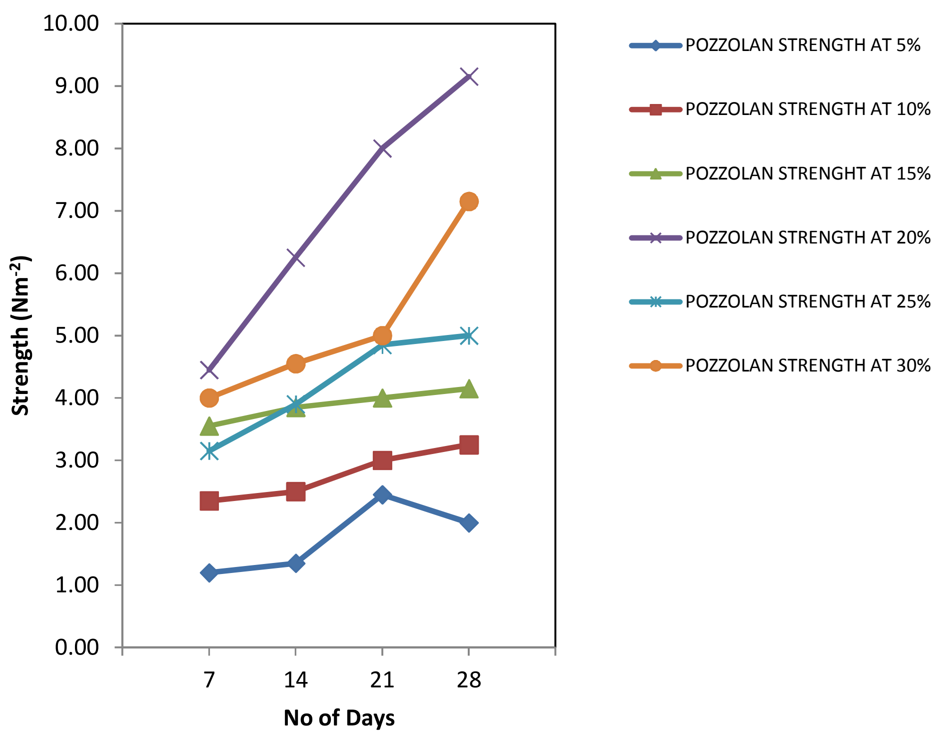

Fig. 1. A graph of pozzolan mixtures against number of days

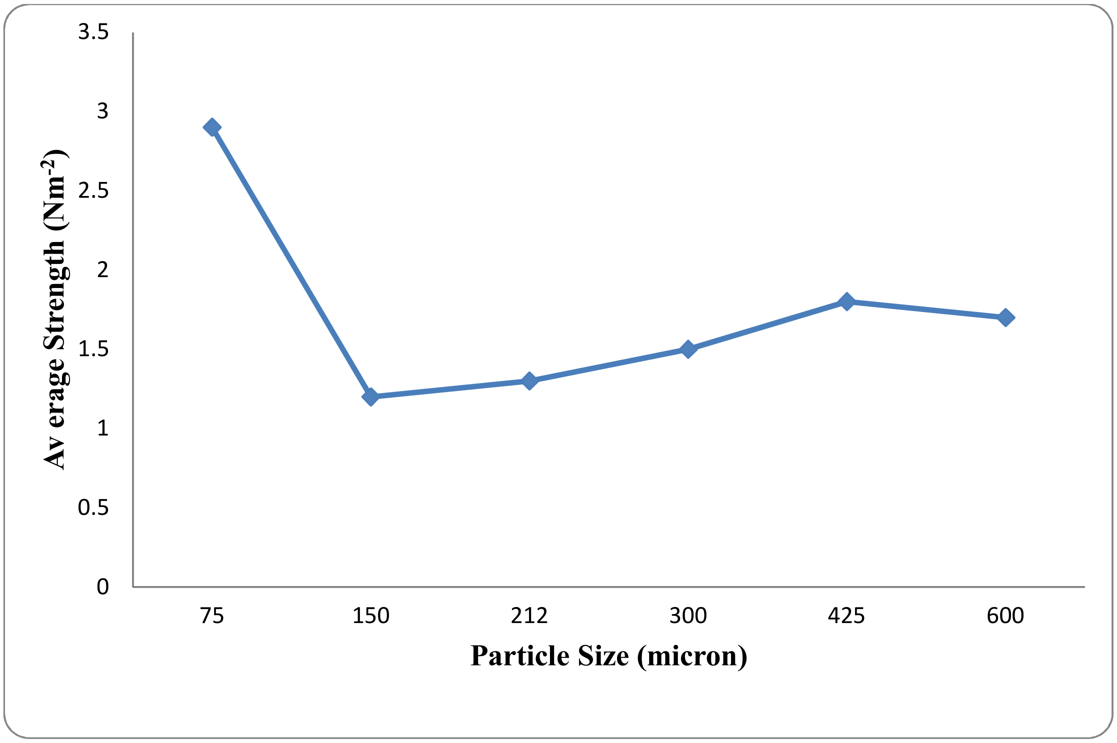

Fig 2. Strength against particle size

A GRAPH OF PARTICLE SIZE DISTRIBUTION

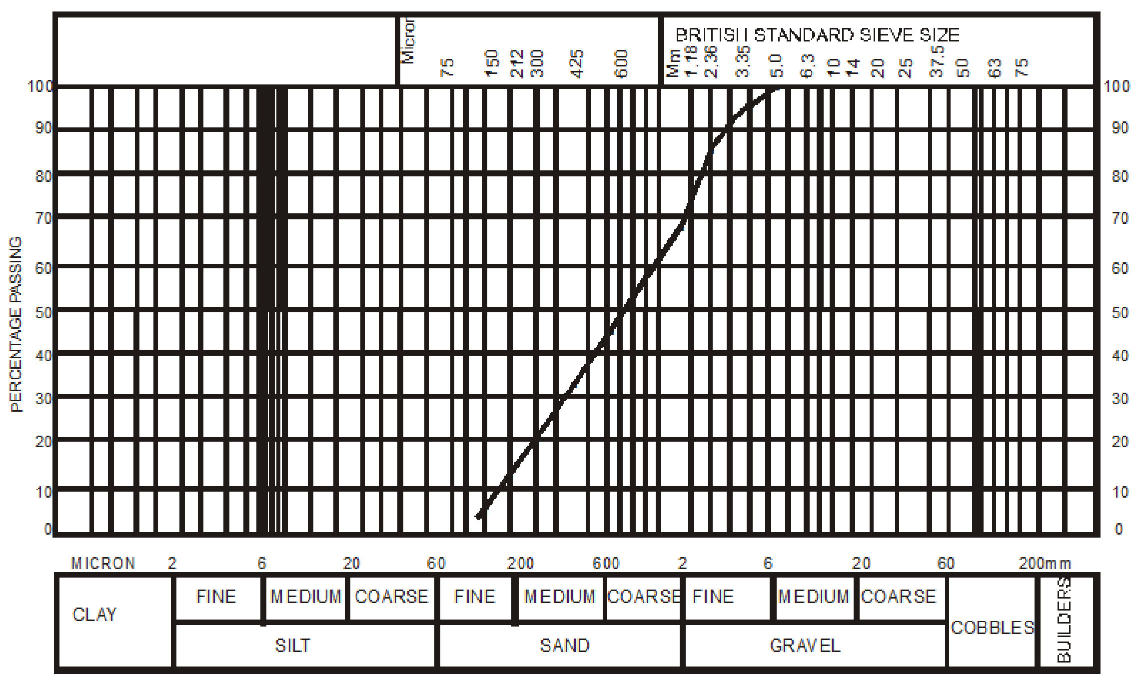

Fig.3. Graph of particle size distribution

Table 2. Average strength of different particle size

Average strength (Nm^{-2})	Particle size (μm)
2.9	75
1.2	150
1.3	212
1.5	300
1.8	425
1.7	600

Table 3. Particle size distribution

Bs sieve	Mass retained	Cumulative retained	% Retained	% Passing
5.0mm				100
3.35mm	10	10	5.65	94.35
2.36mm	16	26	9.04	85.31
1.18mm	30	56	16.95	68.36
600micron	43	99	24.29	44.07
425micron	20	119	11.30	32.77
300micron	21	140	11.86	20.91
212micron	16	156	9.04	11.87
150micron	12	168	6.78	5.09
75micron	9	177	5.09	
Pan				

4. DISCUSSION AND CONCLUSION

The ash heated at<700°C was milky in colour indicating that there is no un-burnt carbon present. Table 1 shows the results of different mixture ratios of pozzolan at 5%, 10%, 15%, 20%, 25% and 30%, cast and cured for 7 days, 14 days, 21 days and 28 days and tested with the help of a compression test machine. These are represented graphically in Fig. 1. We found that the optimum strength is at 20%. This is fairly in agreement with earlier findings by [11], who suggested the optimum strength at 10% - 20%. It is to be expected that the optimum ratio has to depend on the particle sizes of the components, which is cement and laterite in this work. The composition of laterite used is SiO_2, Al_2O_2, Fe_2O_2 and CO_2. Fig. 2 indicate 2.9 Nm^{-2}as the optimum strength at 75 micron and 1.2 as the average minimum strength at 150 micron. This underlines the significance of the contribution of particle size to the desired strength. Table 3 shows data for particle size distribution for one sample. Fig. 3 shows particle size distribution, which indicates that rice husk ash (RHA) is coarse grains material. Significantly, highly silica in nature which increases the quality of concrete. X-ray fluorescence (XRF) analysis was performed to determine the content of various chemical oxides in RHA, which indicated Fe, Ru, K, Mn, P, Mg, Ca, Si and Zn. Instrumental Neutron Activation Analysis (INAA) was performed to determine the various elements, which indicates Sc, Th, Hf, Ca, Sb, Eu, Rb, Co, Mn, V, Lu, Yb, Cr, Ti, Zn, Br, Rb, Ta, Fe and Ba. X-ray diffraction (XRD) analysis indicate the presence of SiO_2 in the sample, which is amorphous silica.

The results from this work show that substituting cement with RHA improves the strength, workability, durability and quantity of concrete. Hence rice husks as an agricultural waste can be converted into valuable product with so many industrial and domestic applications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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