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Research Article

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Production of Pozzolan and its Comparison with Ordinary Portland Cement for Building Applications

A. E. Duke[1], A. D. Asiegbu[2], O. E. Ekpe[3]

[1]Department of Physics, Michael Okpara University of Agriculture,Umudike, Abia State, Nigeria
[2]Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
[3]Department of Physics, Michael Okpara University of Agriculture, Umudike. Abia State, Nigeria
Corresponding Author's E-mail; archibongduke18@gmail.com

Abstract Proper firing of rice husks at 600 ºC produced rice husk ash (RHA) which is manufactured to pozzolan that is amorphous silica (SiO_2), that can be added to cement for building applications. Cement was mixed with laterite soil in the ratio of 10%, 20%, 30%, 40% and 50%. The concrete was mould and cured for 7 to 28 days and also heat resistance was determined. It was observed that 50% of cement provides the heights strength with heat resistance of 1000 ºC and above. Pozzolan was mixed with laterite soil in the ratio of 10%, 20%, 30%, 40% and 50%. The concrete was mould and cured for 7 to 28 days and also heat resistance was conducted, it was observed that 50% of Pozzolan provides the heights strength with heat resistance of 1000 ºC and above. Pozzolan combined with cement and laterite soil in the ratio of 10%, 20%, 30%, 40% and 50%. The concrete was mould and cured for 7 to 28 days and also heat resistance was conducted, it was observed that 20% of Pozzolan combined cement provides the heights strength with heat resistance of 1000 ºC and above. The effects of different particle sizes of 75, 150, 212, 300, 425 and 600 microns were examine using a universal test machine, it indicated that 75 micron provides the heights strength also a graph of average strength against particle size indicate 3.4 Nm^{-2} as the heights strength at 75µm and 1.3 Nm^{-2} as the minimum at 150µm, which signify the contribution of particle size to ideal strength. From the ash size distribution, the presence of grains of different sizes were observed. The grains were weighed using electronic balance and a graph of particle size against percentage plotted to determine the particle size distribution. This showed that rice husk ash is coarse grain material. X–ray fluorescence (XRF) analysis was performed to determine the content of chemical oxides in rice husk ash which indicates Si, Mn, K, Mg, P, Ca, Ru, Fe, Zn, Mg, Cr, Ti, Ni, Cu, Rb, Sr, Y, Zr, Eu and Ba. X–ray diffraction (XRD) analysis indicates the presence of SiO_2 in the sample.

Keywords Pozzolan, Ash, Cement, Heat resistance, Coarse grain, Amorphous silica (SiO_2)

1. Introduction

Pozzolans are materials with reactive silica and alumina which have little binding property but when combined with lime will be active like cement. Pozzolans are useful addictive ingredients in the production of alternative cementing materials. Alternative cements provide good technical option to Ordinary Portland Cement at a very lower cost and have the quality to make a significant contribution towards the provision of low-cost building materials and affordable shelter. Pozzolans can be used in combination with lime and OPC. When mixed with lime, pozzolans will highly improve the properties of lime-based concrete for use in industries and domestic applications. Alternatively, they can be combined with OPC [1] to improve the durability of concrete, and reduce its cost. A wide variety of siliceous or aluminous materials may be pozzolanic [1] with the ash from agricultural wastes. Among agricultural wastes, rice husk has been identified as having the heights potentials, since it is available and on firing it produces a large proportion of ash, which contains about 90% silica [1].

Pozzolans have the quality to reduce substantially the cost of building. These materials can be combined with lime to produce blended cements which can replace pure Portland cement commonly used in construction materials such as concrete, block, mortar, bricks and other construction design. The energy needed to produced a lime-pozzolan cement (LPC) is substantially lower than that of Portland cement; in some cases the pozzolan requires no preparation. The cost associated with the manufacturing of LPC is due to the coal or oil used to produce the lime [2].

There are good uses of pozzolan if it well chosen in concrete manufacturing, they are found to produced quality concrete [2]. The effect that can happen with their use is the result of using a bad Pozzolan, these are slower rate of strength gain. Use of poor-quality pozzolans in practice, will result to failures in concrete.

Pozzolan as a siliceous materials reacts with calcium hydroxide in the presence of H_2O. This forms compounds possessing concrete properties at room temperature which have the ability to set with combination of water.

Cement is a substance used for industrial and domestic application that sets and adheres to other materials. Cement is produced through a closely controlled chemical combination of calcium, silicon, aluminium etc. Common used for the manufacturing of cement include limestone, shells, clay etc. These ingredients, when properly heated at high temperatures from a rock like substance that is ground into a fine powder is called cement [3].

Portland cement is the most widely cement use in the world as a basic ingredient of concrete, mortar and stucco. It was produced from other types of hydraulic lime and usually originates from limestone. It is a fine powder, manufacture by heating limestone and clay minerals in akiln to form clinker. Portland cement is grey in colour, but white Portland cement is also available [4].

Emmanuel, *et al*., [5] examined rice husk ash (RHA) as Substitute in concrete for building applications. They examined that proper firing of (RHA) produced amorphous silica ($Si0_2$), which was introduced in to cement in the ratio of 0%, 5%, 10%, 20% and 30% of concrete. The concrete was cured for 7 to 28 days. Particle sizes mixture of 600 micron, 425 micron, 300 micron, 212 micron, 150 micron and 75 micron was investigated. X-ray fluorescence (XRF) analysis was conducted to identify the elements present in RHA and X-ray diffraction (XRD) analysis was also done to determine the atomic and molecular structure of the compounds in RHA They came to a conclusion that 20% replacement of RHA gives the heights strength and 75 % micron gives the heights strength.

Sudisht Mishra and Deodhar, S.V [6] focused on the effect of rice husk ash on cement concrete in terms of application, strength and quality. The amount of useful internal work necessary to overcome the internal friction to produce full compaction is termed as workability. Size, shape and water-cement ratio, use of admixtures and mix proportion are important factors affecting workability. Strength is to bear the ideal stresses within the permissible factor of safety in expected exposure condition. Quality is sustenance of shape, size and strength; resistance to exposure conditions and wearing under adverse conditions. End 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 heights needed to be added in concrete production when the husk was burnt under field condition.

Kartini, K., [7] examined Rice Husk Ash Pozzolanic Material for Sustainability. He investigated an intensive study of RHA to determine its suitability from different grade of concrete (Grade 30, 40, 50) studied. Conclusion shows that up to 30% substitution of cement with rice husk ash has the quality to be used as partial cement replacement having a quality strength performance. Hence the potential of using rice husk ash as partial replacement material can contribute to industrial and domestic application.

Duke, A.E. and Eno E.E. [8] investigated rice husk ash pozzolan as valuable supplement in concrete for industrial and domestic applications. We investigated that proper firing of rice husk < 700°C produced rice husk ash (RHA) which is predominantly amorphous silica. RHA was substituted for laterite and cement in proportions of 5%, 10%, 15%, 20%, 25% and 30% of concrete, cast and cured for 7 days, 14 days, 21 days and 28 days. The effect of different particle sizes of 75, 150, 212, 300, 425 and 600 microns were tested, x-ray fluoresce (XRF) analysis was performed to determine the content of various chemical oxides in RHA. Instrumental Neutron Activation Analysis (INAA) was performed to determine the various elements in RHA and x – ray diffraction (XRD) analysis was performed to determine the atomic molecular structure present in the sample. We concluded that 20% of RHA provides the optimum strength, $2.9Nm^{-2}$ as the optimum strength at 75µm and $1.2Nm^{-2}$ as the minimum at 150µm. Particle size distribution was determine indicating that RHA is coarse grain material.

Omatola [8] carried out an instrumental analysis of RHA. He examined that rice husk ash is the most silica raw materials containing about 90 - 98% silica after combustion of other agro – wastes. Ash samples from rice husks of five origins were produced at two different temperatures, 500 °C and 1000 °C 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 embrace for the characterization of each sample heated to 1000 °C in terms of silica content. While XRD analysis indicated the compounds present in each sample, XRF and INAA analysis indicate only impurity elements present in each sample. XRF and INAA showed that RHA had a low impurity concentration, indicating that rice husk which is an agricultural waste is a potential source of silica. The result was affirmed 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 [10] focused on the use of rice husk ash as cement substitute material. The effect of grinding on the particle size and the surface area was first carried out then XRD analysis was performed to identify the presence of amorphous silica in the sample. Furthermore, the effect of particle size and percentage on concrete workability, fresh density, super plasticizer (SP) content and the compressive strength were also examined. They concluded that RHA concrete gave good strength for 10% replacement and up to 20% of cement could be substituted with RHA without influencing the strength.

2. Materials and Methods

The materials used were rice husk, furnace, kiln, thermocouple, forceps, crucibles, container, hammer mill, sieve machine, mould 100 x 100, test machine and electronic balance. The husk was obtained from Obubra Local Government Area in Cross River State Nigeria. The husk was fiery for the carbon to escape, and poured into a crucible which was placed in a furnace for a temperature of 600 ºC. The ash at this temperature was allowed to cool, then was poured in to a container.

The ash was ground into fine powder. Hammer mill was used for the grounding. The sample was sieved with sieve machine, and this becomes they pozzolan.

10%, 20%, 30%, 40% and 50% ratio of cement were mixed with laterite soil, mould and cured for 7 to 28 days tested with the help of a universal test machine to know the strength. And also tested with the help of kiln and thermocouple to know the heat resistance.

10%, 20%, 30%, 40% and 50% ratio of pozzolan were mixed with laterite soil, mould and cured for 7 to 28 days tested with the help of a testing machine to know the strength. And also tested with the help of kiln and thermocouple to know the heat resistance.

10%, 20%, 30%, 40% and 50% ratio of Pozzolan were mixed with cement and laterite soil, mould and cured for 7 to 28 days tested with the help of a testing machine according to American Society for Testing Materials (ASTM) to know the strength. And also tested with the help of kiln and thermocouple to know the heat resistance.

3. Results

Table 1 shows the results of various mixed ratios of cement concrete at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a testing machine and they are represented graphically in fig 1 indicating the heights strength at 50%. Also tested with the help of kiln and thermocouple to know the heat resistance, the result indicates that cement concrete is a heat resistance material above 1000 ºC.

Table 2 shows the results of various mixed ratios of Pozzolan concrete at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a testing machine and they are represented graphically in fig 2 indicating the heights strength at 50%. Also tested with the help of kiln and thermocouple to know the heat resistance, the result indicates that Pozzolan concrete is a heat resistance material above 1000 ºC.

Table 3 shows the results of various mixed ratios of Pozzolan combine with cement at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a universal test machine and they are represented graphically in figure 3 indicating the heights strength at 20%. Also tested with the help of kiln and thermocouple to know the heat resistance, the result indicates that Pozzolan combine with cement is a heat resistance material above 1000 ºC.

Table 4 shows the results of various mixed ratios of 75 micron, 150 micron, 212 micron, 300 micron, 425 micron and 600 micron mould and cured for 7 to 28 days tested with the help of a testing machine and they are represented graphically in figure 4 indicating the heights strength at 75 micron.

Table 5 shows the results of average strength of various particle size also represented graphically in figure 5 showing 3.4Nm^{-2} as the heights strength at 75 micron and 1.3 as the minimum strength at 150 micron.

Table 6 shows the results of particle size distribution also represented graphically in fig 6 showing that rice husk ash (RHA) is coarse grain material.

Table 1: Strength of Mixed Ratio of Cement Concrete

No. of Days	**Strength at Cement 10%**	**Strength at Cement 20%**	**Strength at Cement 30%**	**Strength at Cement 40%**	**Strength at Cement 50%**
7	47.34	53.83	68.98	120.04	132.24
14	51.48	56.52	82.41	136.26	158.61
21	54.21	58.43	91.32	152.42	176.23
28	56.35	63.98	121.64	174.52	198.34

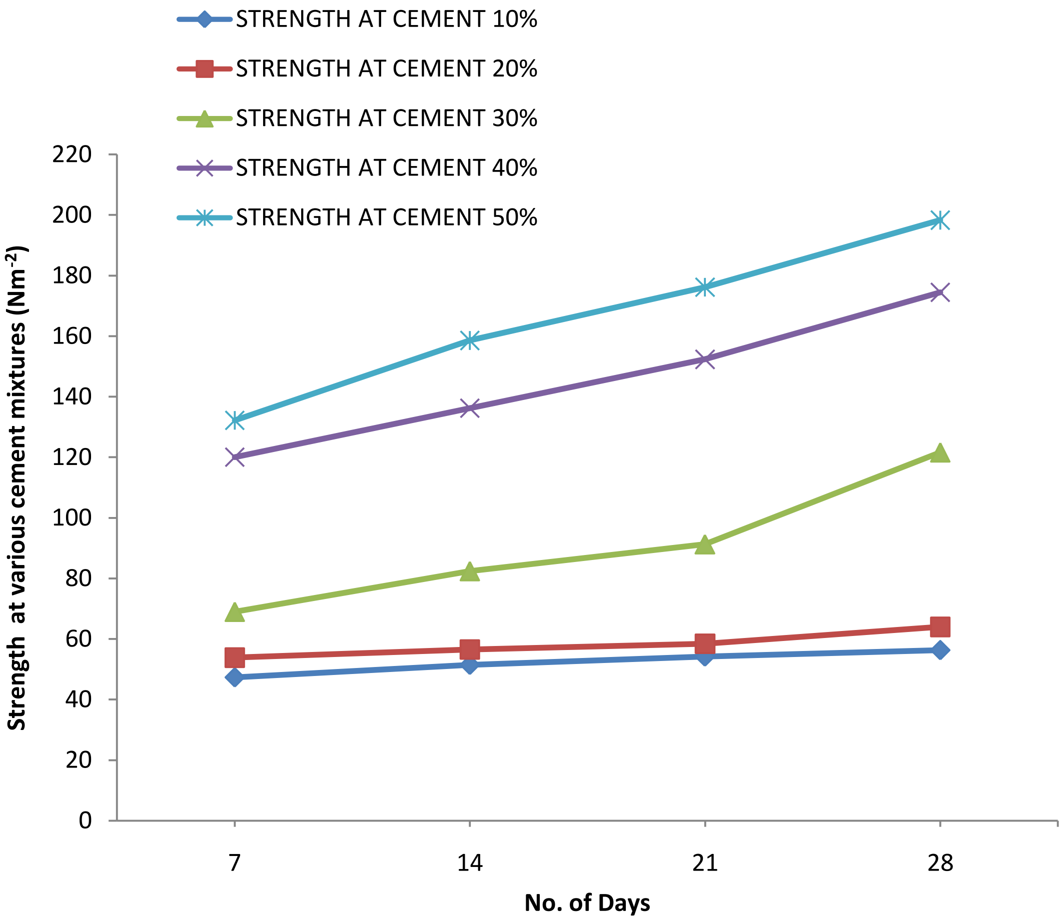

Figure 1: Strength of various cement concrete mixtures against number of days

Table 2: Strength of Mixed Ratio of Pozzolan Concrete

No. of Days	Strength at Pozzolan 10%	Strength at Pozzolan 20%	Strength at Pozzolan 30%	Strength at Pozzolan 40%	Strength at Pozzolan 50%
7	43.26	50.28	63.81	112.53	128.27
14	48.32	54.16	78.94	124.13	146.18
21	51.43	56.27	89.24	148.06	163.46
28	53.19	60.12	98.12	167.93	186.12

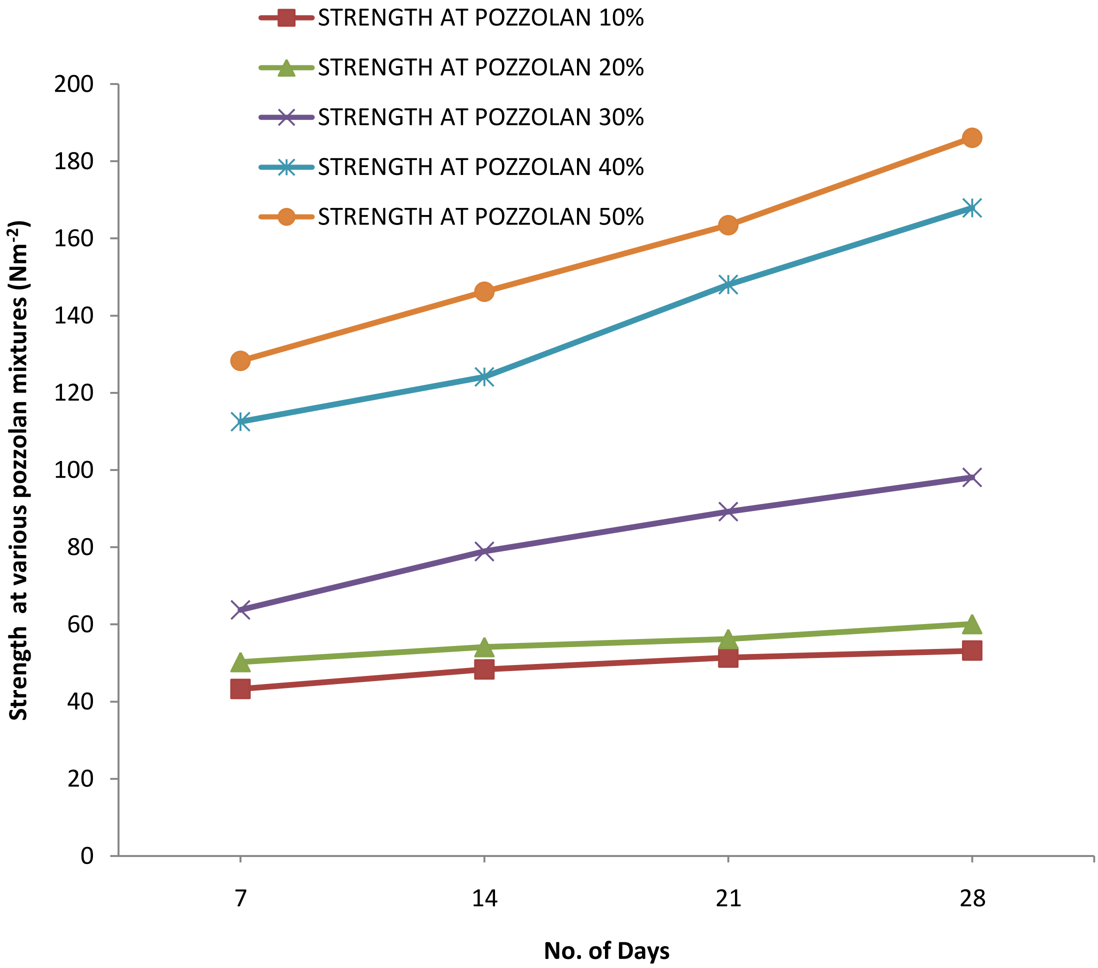

Figure 2: Strength of various Pozzolan concrete mixtures against number of days

Table 3: Strength of Mixed Ratio of Pozzolan with Cement

No. of Days	Strength at Pozzolan with Cement 10%	Strength at Pozzolan with Cement 20%	Strength at Pozzolan with Cement 30%	Strength at Pozzolan with Cement 40%	Strength at Pozzolan with Cement 50%
7	83.12	142.47	108.46	127.04	134.21
14	92.52	163.14	116.04	138.15	152.06
21	98.21	186.29	123.25	146.34	167.14
28	102.26	204.16	138.56	169.32	183.24

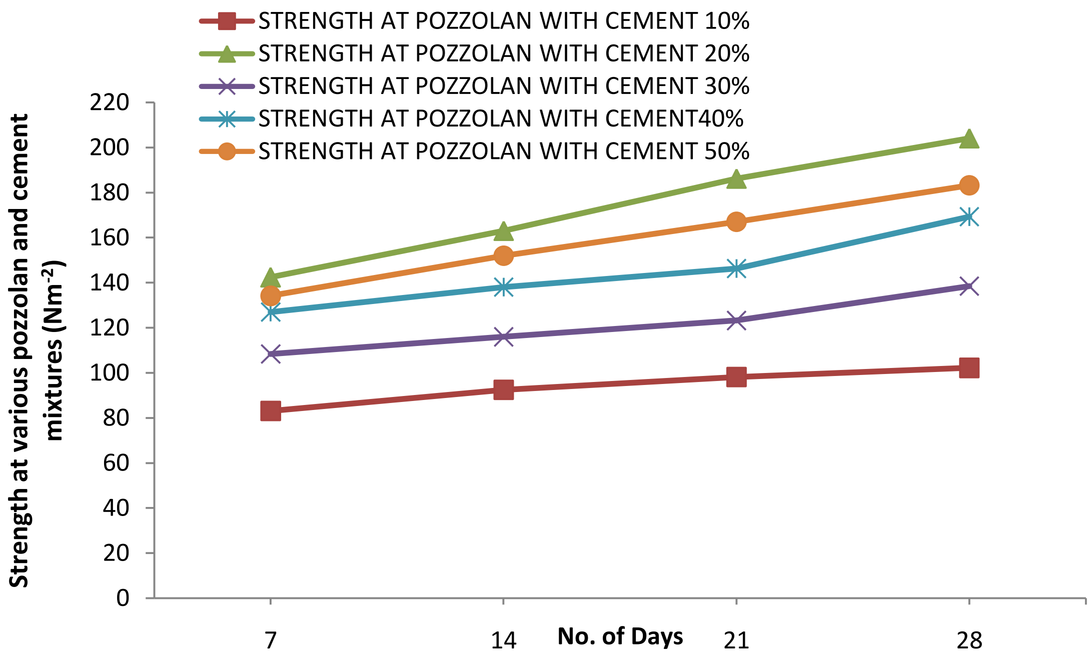

Figure 3: Strength at various Pozzolan and cement mixtures against number of days

Table 4: Strength of Mixed Ratio of Different Micron Concrete

Particle size / No. of Days	75 micron	150 micron	212 Micron	300 micron	425 Micron	600 Micron
7	2.81	1.12	1.04	1.17	1.00	1.53
14	3.10	1.23	1.38	1.31	1.46	1.64
21	3.48	1.47	1.51	1.60	1.92	1.87
28	3.94	1.52	1.56	1.68	2.63	2.03

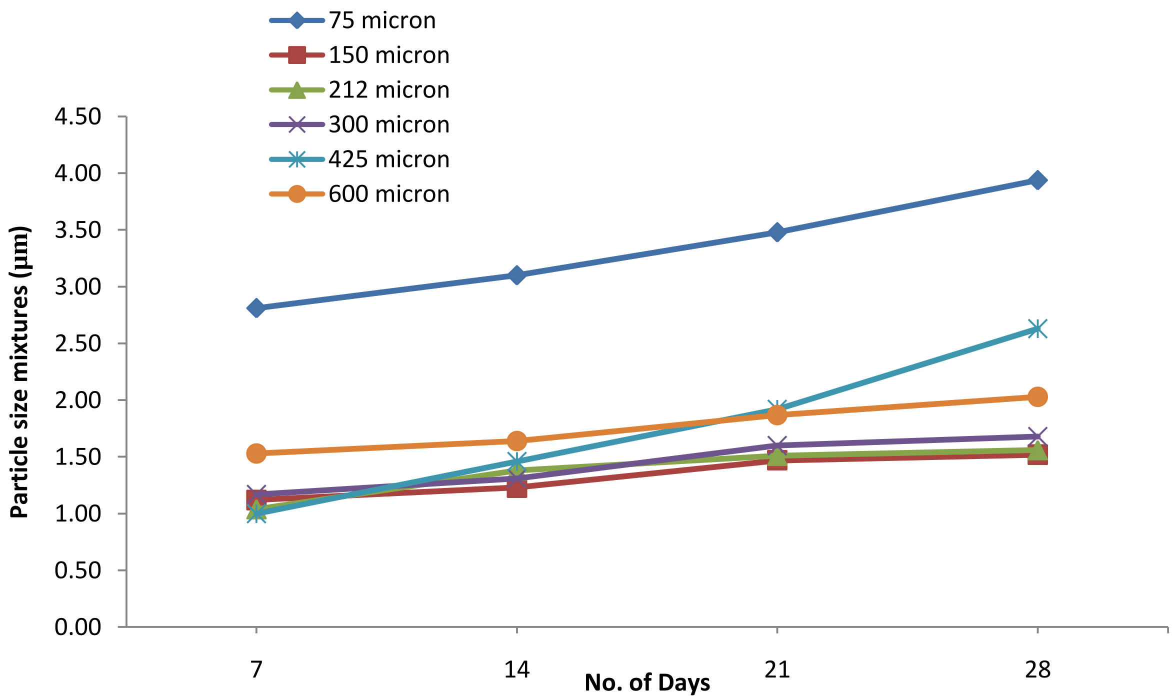

Figure 4: Strength at various Pozzolan sizes (in micron) against number of days

Table 5: Strength of Different Particle Size

Average Strength (Nm^{-2})	Particle Size (µm)
3.33	75
1.34	150
1.37	212
1.44	300
1.75	425
1.77	600

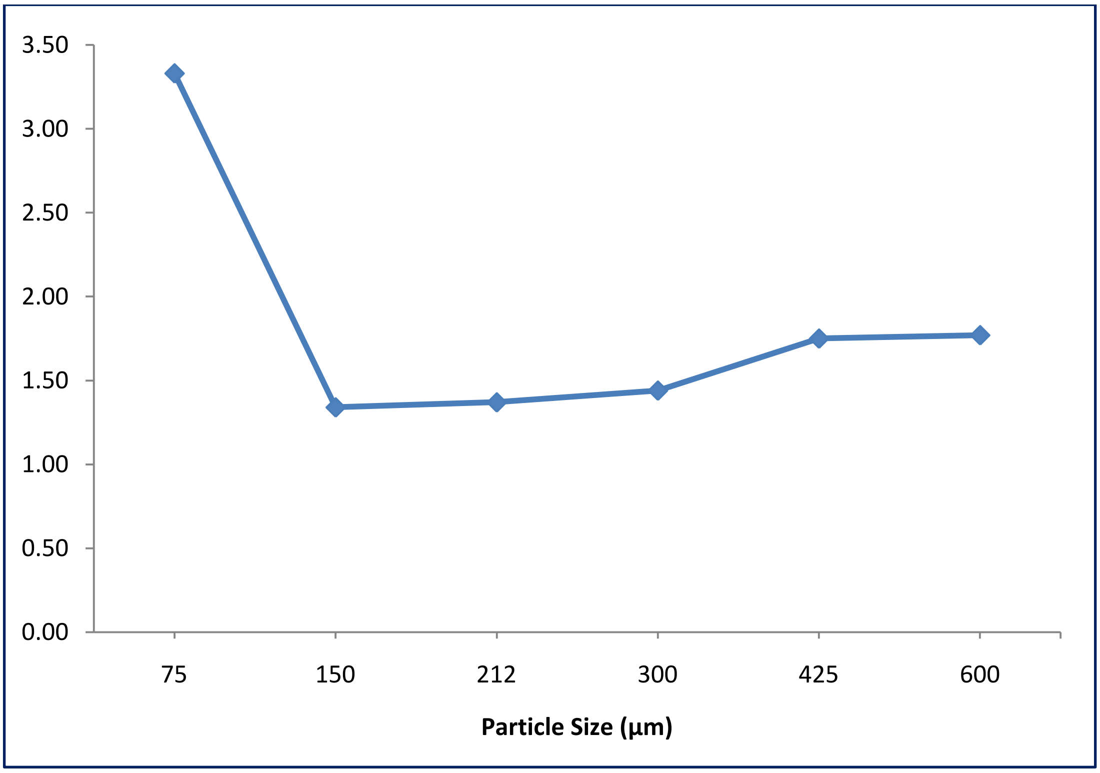

Figure 5: Strength against particle size

Table 6: 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	

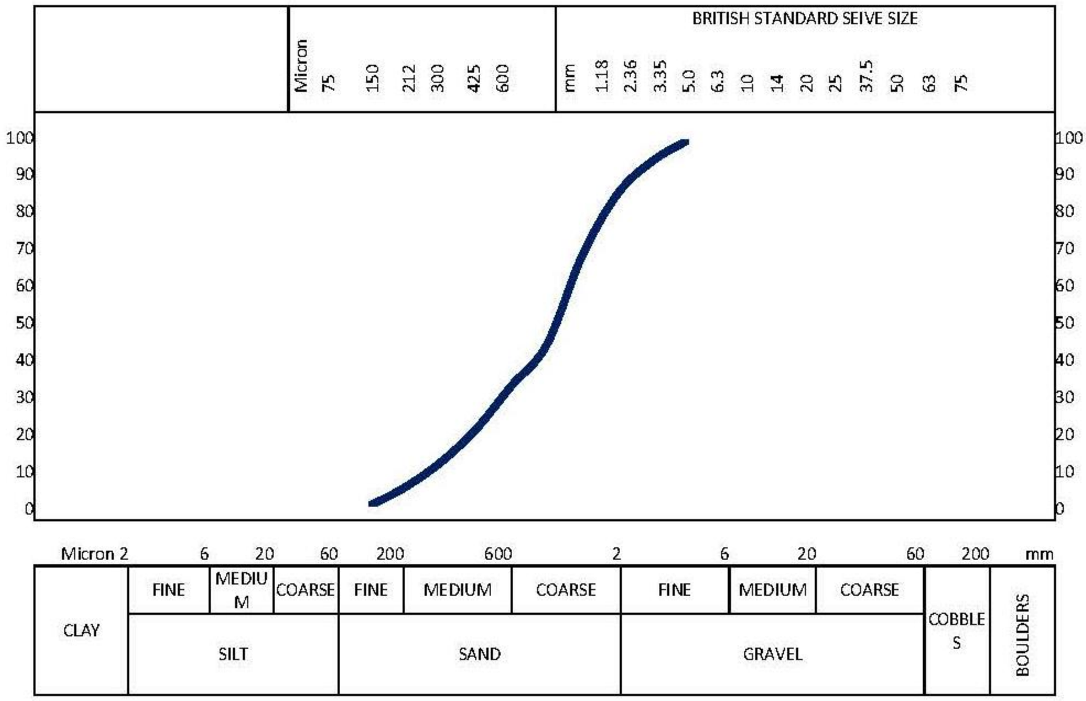

Figure 6: Graph of Particle Size Distribution

Discussion and Conclusion

The ash fiery at 600 ºC was white in colour indicating that there is no carbon present. Table 1 shows the results of various mixed ratios of cement concrete at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a universal test machine. These are represented graphically in figure 1 indicating the heights strength at 50%, which was acquired after 28 days. And also indicates cement concrete as heat resistance material which was acquired after firing it with kiln to above 1000^0C. Table 2 shows the results of various mixed ratios of Pozzolan concrete at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a testing machine. These are represented graphically in figure 2 indicating the heights strength at 50%, which was acquired after 28 days. And also indicates Pozzolan concrete as heat resistance material which was acquired after firing it with kiln to above 1000 ºC. Table 3 shows the results of various mixture ratios of Pozzolan with cement at 10%, 20%, 30%, 40% and 50%, mould and cured for 7 to 28 days tested with the help of a testing machine. These are represented graphically in figure 3 indicating the heights strength at 20%. This is in agreement with earlier findings by Ghassan *et al.*, [10] and Duke & Eno [8] who suggested the optimum strength at 20%. And also indicates Pozzolan combine with cement as heat resistance material which was acquired after firing it with kiln to above 1000 ºC. Table 4 shows the results of various mixed ratio of 600 micron, 425 micron, 300 micron, 212 micron, 150 micron and 75 micron, mould and cured for 7 to 28 days tested with the help of a testing machine. These are represented graphically in fig 4 indicating the heights strength at 75 micron. Figure 5 shows a graph of average strength against particle size indicating $3.4Nm^{-2}$ as the heights strength at 75µm and $1.3Nm^{-2}$ as the lowest strength at 150µm. This signifies the contribution of particle size to strength. Figure 6 shows the graph of particle size distribution against percentage passing, showing that rice husk (RH) is coarse grains material. Signifying, high silica which increases a good concrete. (XRF) analysis performed to determine the chemical oxides in RHA, which are: Mg, Si, P, Ti, Cr, V, Ca, Zn, K, Sr, Zr, Mn, Fe, Ni, Y, Eu, Rb, Ba, Ru and Cu. In all showed that Si contains the highest percentage of silica. Instrumental Neutron Activation Analysis (INAA) was performed to determine the elements, which indicates Eu, Co, V, Lu, Zn, Rb, Ba, Ta, Sb, Th, Mn, Hf, Yb, Ti, Br, Cr, Sc, Ca and Fe. XRD analysis indicates the presence of SiO_2. Chemical composition of literate used are S_iO_2, CaO, MgO, Al_2O_3, Fe_2O_3 and chemical composition of cement used are SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Na_2O, K_2O, and ZnO.

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