COMPARATIVE ANALYSIS OF CONCRETE PRODUCED WITH DIFFERENT POZZOLANS

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Abstract

The study compared the strength of three different pozzolanic concrete- Rice Husk Ash (RHA), Powdered Burnt Brick (PBB) and Saw Dust Ash (SDA)) in ordinary water at 84 days. This was achieved by partially replacing Ordinary Portland Cement (OPC) with 10 percent (%) of each pozzolan to produce three different pozzolanic concrete cubes. Control Samples of 100% OPC were equally produced. Absolute volume method of mix proportioning was adopted using a mix ratio of 1: 2: 4. Water-cement (w/c) ratio of 0.65 was also adopted for all the specimens. Nine (9) concrete cubes were produced for each specimen. The specimens were completely immersed in ordinary water for 28, 56 and 84 days respectively, during which three (3) cubes from each specimen were removed and tested to determine their compressive strengths at every curing period. The strengths of RHA, PBB, SDA and the control specimens in ordinary water at 84 days were observed to be 28.25N/mm^2, 28.20N/mm^2, 22.80N/mm^2 and 31.60N/mm^2 respectively. The study concluded that OPC/ RHA and OPC/PBB concretes perform better than OPC/SDA at 84 days in ordinary water. The research recommended that RHA and PBB could be used for load bearing concrete structures.

Keywords: *Comparative Analysis, Pozzolanic Concrete, Rice Husk Ash, Powdered Burnt Bricks, Saw Dust Ash.*

Introduction

Concrete is a construction material composed of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite (Neville and Brooks, 2002). The major constituent of concrete is aggregate which may be natural (gravel or crushed rock with sand) or artificial (blast furnace slag, broken brick and steel shot). Another constituent is binder which serves to hold together the particles of aggregate to form concrete. Commonly used binder is the product of hydration of cementwhich is the chemical reaction between cement and water (Shetty, 2004). Admixture in form of pozzolans may also be added to concrete mixes to change some of its properties (Shetty, 2005). Rice Husk Ash (RHA), Powdered Burnt Bricks (PBB) and Saw Dust Ash (SDA) in this study are the pozzolans.

Pozzolana is defined as siliceous materials 22 which in itself possess little or no cementitious properties but in finely divided form and in the presence of moisture, chemically react with $Ca(OH)_2$ at ordinary temperature to form compound possessing cementitious properties (Neville, 2000). According to Shetty (2005), pozzolanas are classified into artificial and natural. These classes depend on the nature and sources of the pozzolana. Artificial pozzolanas include Rice Husk Ash, Powdered Burnt Bricks, Silica Fume, Fly Ash, Blast Furnace Slag and Surki. The naturally occurring pozzolanas include Clays and Shells, Calcined, Diatomaceous Earth, Opaline Chart, Volcanic Ash Tuffs and Pumicites. According to Malhotra (1992), RHA is the byproduct of Agricultural product gotten by burning rice husk. Rice husk produces a high quality of ash, about 20% by weight of the husk. The ash has a high silica content of up to 95% by weight. The active part of the silica is the amorphous not the crystalline part. During burning, the temperature is always below 700^oC as temperature above that could lead to crystallization of the silica content, which makes it less active. The colour of the ash is dark grey to white. Work carried out by Nensok et. at (2012) reviled that about 30% of Ordinary Portland Cement (OPC) concrete can be replaced by RHA. Its disadvantage is the increase in shrinkage, which could lead to crack in concrete.

Dahiru and Zubairu (2008) assessed the properties of concrete made with RHA as partial replacement of OPC and observed appreciable increase in concrete compressive strength at 10% replacement level.

According to Elinwa and Mahmood (2002), Sawdust is a waste product from the timber industry. Work carried out on the ash derived from the material has confirmed its pozzolanic properties with a pozzolanic index value of 75.9%. This material compares favorably with fly ash and wastes from the oil palm industry. The only difference noticed is the low content of Al_2O_3 (4.09%) and Fe_2O_3 (2.26%). Concrete mixes have been proportioned by Elinwa and Mahmood (2002) to various percentages of cement replacement with saw dust ash ranging from 0% to 30% by weight. The results of their investigation show that the compressive strength of concrete increased in SDA content of amount up to 10% replacement level of OPC and decreased with further percentage increase.

Powdered Burnt Bricks (PBB) are clays which result from the weathering (mechanical and chemical disintegration) of igneous rocks, shale's and clayey lime stone. (Neville and Brooks, 2002); Sa'ad et. al (2007) carried out an extensive work on the compressive strength of Pozzolana-Portland cement mortar in which OPC was replaced with certain percentages of PBB to produce mortar cubes, 10% replacement level of all the OPC/PBB mortar cubes tested had appreciable compressive strength at 28 days.

This research was carried out to compare the effects of three pozzolanas (RHA, PBB and SDA) on the properties of concrete produced under the same condition with the aim of finding out the one that has the highest strength increase on concrete at 28, 56 and 84 days hydration periods.

Methodology Materials

The materials used for the research work were: Powdered Burnt Bricks (PBB), Rice Husk Ash (RHA), Saw Dust Ash (SDA), Fine Aggregate

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(Sand), Coarse Aggregate (Gravel), Ordinary Portland Cement (OPC) (Dangote Brand) and Tap Water. PBB was obtained from broken burnt bricks which were sourced from Funtua Bricks Producing Industry Funtua, Katsina State. Pieces of the broken bricks were subjected to manual crushing using pestle and mortar in the laboratory to form powdering particles. The powder was then sieved using electric vibrating table shaker. Only powder particles that passed through the 75 micron standard BS sieve (No. 200) were collected and used for the research. The Rice Husk used was obtained from Samaru Rice Milling Factory, Zaria and burnt into ashes by using the Electric Furnace in Industrial Design Centre, Zaria. Rice Husk was converted into ashes at control temperature of 650^0C for six hours. The ash obtained was then ground in grinding machine and sieved with the use of the same micrometer sieve used in PBB. The saw dust used for the research work was obtained from Local Furniture Making beside Samaru Market in Zaria. It was sun-dried and then converted into ashes at control temperature of 650^0C for six hours. The ash obtained (SDA) was then ground in grinding machine and sieved using the same sieve as above.

The coarse aggregate used was crushed granite stones obtained from a Single Quarry Site along Sokoto-Zaria road opposite School of Aviation Technology Zaria. The aggregate was sieved using standard sieves and the one obtained in 10 and 20mm sieves were used to produce the test samples. The fine aggregate (sand) used was naturally, occurring clean sharp river sand. It was sieved using standard BS 4.75mm sieve size to remove impurities and only those that passed through the sieve was used for samples production. Ordinary tap water, which was free for drinking, was used for the research work.

Physical Properties of Materials

The specific gravity of the various samples of PBB, RHA and SDA were determined in the Laboratory in accordance with the requirement of ASTM C 127 – 93. The un-compacted bulk density of each pozzolan and fine aggregate were determined by the method recommended by BS EN 1097: Part 3 (1999). The moisture content test of samples of RHA, PBB and SDA were determined in accordance to BS EN 1097: Part 5 (1999).

Chemical Properties of Materials (RHA, PBB and SDA)

Physical property test was carried out on each pozzolan (RHA, PBB and SDA) to determine their percentage composition of iron oxide (Fe_2O_2), silicon oxide (SiO_2), magnesium oxide (MgO), aluminum oxide (Al_2O_3) and Loss on Ignition (L.O.I) if they really comply with the one stipulates by ASTM C 618-94. ASTM C 618 – 94 stipulates that the percentage total content of SiO_2, Al_2O_3 and fe_2O_3 in any pozzolan should not be less than 70%. ASTM C 618-94 further stated that the L.O.I in any pozzolan should not be more than 12% maximum. The chemical analysis test was carried out on each pozzolan through the use of Absorption Analysis Spectrometer (AAS) and Volumetric Gravimetric Analysis (VGA) methods. The VGA method was used to determine the % silicate content and loss on

Results and Discussions

Results of Physical Properties of Materials

ignition while AAS method was used to determine other elements (Al_2O_3, MgO and Fe_2O_3).

Specimens Production and Compressive Strength Test

The materials used for the production of the concrete specimens for the research work comprised of cement, RHA, PBB, SDA, fine aggregate (sand) and coarse aggregate. They were mixed thoroughly in the mix ratio 1:2:4 (cement: fine aggregate: coarse aggregate) with w/c ratio of 0.65 for 100% OPC cubes and 0.65 for the cubes with pozzolan (RHA, PBB and SDA). Absolute volume method of calculation was used to determine the quantities of materials used for the research. Physical properties such as workability, setting time and soundness of each mix were determined in accordance with ASTM C 14378, ASTM C 192-92 and BS EN 196: Part 3 (2000) respectively, after which nine (9) concrete cubes were produced for each specimen.

Table 1 shows the quantities of materials required for a batch of nine 9 concrete cubes in kg. Specimens were cured in ordinary water by complete immersion method and then tested at 28, 56 and 84 days as stipulated by Dashan and Kamag (1999) to determine their compressive strengths at each hydration period.

PBB complied with BS EN 1097: Part 3 (1999) which specified its range to be minimum of 2.20 and maximum of 2.80. The result is also in agreement with the findings of Sa'ad (2005) on different PBB samples. The specific gravity of RHA and SDA are within the range of 1.9 to 2.4 recommended for pulverized fuel ash (Neville and Brooks 2002) and also similar to the values reported by Dashan and Kamang (1999); Oyetola and Abdullahi (2006) on Acha Husk Ash (AHA) and RHA which was 2.12 for AHA and 2.13 for RHA. The difference in the specific gravity of the materials (RHA, PBB, and SDA) may be due to the differences in fine particles of the materials which consequently, may lead to differences in weight. Conclusively, SDA is the lightest in weight followed by RHA. The specific gravity of the sand was found to be 2.65. The value obtained falls within the limit for natural aggregates which ranges from 2.6 to 2.7 (Neville and Brooks 2002). The compacted bulk density of RHA, PBB and SDA were found to be 670 kg/m^3, 1117kg/m^3 and 660 kg/m^3 respectively. The values obtained in RHA and SDA are closed to the one reported by Dahiru and Zubairu (2008) on the compacted bulk density of RHA which was found to be 740 kg/m^3 while Oyetola and Abdullahi (2006) reported a value of 530 kg/m^3. The value obtained on PBB is close to 1115 k/m^3 reported by Taylor (1991). In comparison, the bulk density of RHA, PBB and SDA is less than the bulk density of OPC (1440kg/m^3), this means that the three materials are light weight materials. The compacted bulk density of sand was found to be 1600kg/m^3. This value is very close to the range given for bulk density before excavation of sandy soils which ranges from 1650 Kg/m^3 to 1850kg/m^3(BS EN 1097: Part 3 (1999)).

Table 1: Physical Properties of RHA, PBB, SDA and Sand

S/NO	Properties	Sample Type and Description			
		RHA	PBB	SDA	Sand
1	Specific Gravity	2.15	2.54	2.13	2.65
2	Compacted Bulk Density (kg/m^3)	670	1117	660	1600
3	Un compacted Bulk Density (kg/m^3)	540	980	530	1490
4	Absorption Capacity (%)	27.55	22.45	27.55	-
5	Moisture Content (%)	2.04	2.04	2.04	-

Table 1 shows the results of physical highest specific gravity of 2.54. The specific properties of the materials used for the gravity of RHA is 2.15 while SDA gives the research. From the results, PBB gives the lowest value of 2.13. The value obtained on

Results of Workability Test

Table 2: Workability of the Pastes

Paste Sample	W/C Ratio	Degree of Workability	
		Slump(mm)	Compacting Factor
100% OPC	0.6	10	0.74
RHA/OPC	0.65	6	0.72
PBB/OPC	0.65	8	0.73
SDA/OPC	0.65	6	0.72

The results of the workability test on each specimen sample show that the slumps for 100% OPC and that of 10% replacement of each pozzolana was within the range of 6 - 10 mm which indicates low workability (ASTM C 143 -78).The result of the compacting factor test on all the pastes ranges from 0.72 to 0.74 which also indicates low workability (BS EN 12350: Part 2 (2001)).The compacting factor test on all the pastes is close to the range of 0.85 – 0.92

The results of the workability test on each recommended by Orchard (1973) for roads and slabs concrete. It was observed from the tests results that mixes containing 10% replacement of RHA and SDA have lower slump than that of PBB and 100% OPC. This was due to the high un-burnt carbon content in RHA and SDA pastes which made them to absorb more water than PBB and 100% OPC pastes. This agreed with the findings of Dashan and Kamang (1999) on Acha Husk Ash (AHA).

Results of Chemical Analysis Table 3: Chemical Analysis of RHA

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	69.5	2.16	4.50	1.50	4.52

Table 4: Chemical Analysis of PBB

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	60.50	5.30	10.00	1.70	0.78

Table 5: Chemical Analysis of SDA

Constituent	SiO_2	Fe_2O_3	Al_2O_3	MgO	L.O.I
% composition	46.5	2.14	12.5	9.25	12.5

The chemical analyses of RHA, PBB and SDA are presented in Tables 3, 4 and 5 respectively. The percentage total content of silicon dioxide (SiO_2), iron oxide (Fe_2O_3) and aluminum oxide (Al_2O_3) on RHA, PBB and SDA were found to be 76.16%, 75.8% and 61.14% respectively. Both values on RHA and PBB are greater than the minimum of 70% specified in ASTM C 618-94 while that of SDA is less. ASTM C 618 – 94 stipulates that the percentage total content of SiO_2, Al_2O_3 and Fe_2O_3 in any pozzolan should not be less than 70%. The Loss on Ignition (L.O.I) obtained was 4.52 for RHA, 0.78 for PBB and 12.5 for SDA. The value obtained on RHA and PBB are less than the 12% maximum required for pozzolans (ASTM C 618 -94) while that of SDA is slightly higher. This means that SDA contain more un-burnt carbon that might have reduced its pozzolanic activities (Oyetola and Abdullahi, 2006).

Results of Setting Time Test Table 6: Setting Time (Minutes)

S/No	Sample paste	Initial setting time (minutes)	Final setting time(minutes)
1	100% OPC	90	190
2	RHA/ OPC	150	240
3	SDA/ OPC	180	290
4	PBB/ OPC	130	270

The result of the setting time test for each pozzolan and 100% OPC pastes are presented in Table 6. From the results, it can be observed that SDA paste has the highest initial and final setting time while 100% OPC has the least. This could be due to the higher heat of hydration evolved by 100% OPC paste over SDA, RHA and PBB pastes as the reaction between cement and water is exothermic leading to liberation of heat to the surrounding and evaporation of moisture and consequent stiffening of the pastes. As OPC is replaced with pozzolan, the rate of reaction reduces and the quantity of heat liberated also reduces leading to late stiffening of the pastes. It is expected that with the introduction of pozzolan to cement paste, the lower the heat librated hence, the longer the hydration period as well as the setting time period (Neville, 2000).The difference in initial and final setting times of each pozzolan paste might be due to difference in carbon content (L.O.I) found in each pozzolan. The initial and final setting time of all the pastes tested were within the range recommended for OPC paste of 45 minutes as minimum for initial setting and a maximum of 10 hours for final setting ASTM C 192-92.

Results of Soundness Test

Table 7: Soundness (mm)

S/No sample	Specimen	Initial pointers reading before boiling (mm)	Final pointers reading after boiling (mm)	Expansion (mm)
1	100% OPC	3	3.5	0.5
2	RHA	3	3.2	0.2
3	PBB	3	3.2	0.2
4	SDA	3	3.5	0.5

The results obtained on soundness tests carried out on each sample of pozzolans and 100% OPC paste are presented in Table 7. It was observed that RHA and PBB have lower expansion as compared to SDA and 100% OPC cubes. The results of all the samples tested complied with BS EN 196: Part 3 (2000) recommendation which stipulates that expansion should not exceed 10mm.

Results of Density and Compressive Strength

Table 8: Average 28 Days Compressive Strengths of Specimen Cubes in Water

S/No	Specimen Sample	W/C Ratio	Average Density (kg/m^3)	Average Compressive Strength(N/mm^2)
1	100% OPC	0.60	2439.50	24.70
2	RHA/OPC	0.65	2380.45	21.10
3	PBB/OPC	0.65	2400. 00	22.70
4	SDA/OPC	0.65	2390.00	18.05

Table 9: Average 56 Days Compressive Strengths of Specimen Cubes in Water

S/No	Specimen Sample	W/C Ratio	Average Density (kg/m^3)	Average Compressive Strength(N/mm^2)	Percentage Gained in strength (%)
1	100% OPC	0.60	2449.38	28.80	16.60
2	RHA/OPC	0.65	2380.45	24.30	15.17
3	PBB/OPC	0.65	2409.88	26.30	15.86
4	SDA/OPC	0.65	2370.78	20.10	11.36

Table 10: Average 84 days Compressive Strengths of Specimen Cubes in Water

S/No	Specimen Sample	W/C Ratio	Average 27 Density (kg/m^3)	Average Compressive Strength (N/mm^2)	Percentage Gained in strength (%)
1	100% OPC	0.60	2488.89	31.60	27.94
2	RHA/OPC	0.65	2390.00	28.25	33.89
3	PBB/OPC	0.65	2419.75	28.20	24.30
4	SDA/OPC	0.65	2400.00	22.80	26.32

The results of densities and compressive strengths of sample specimens (100% OPC, RHA, PBB and SDA) in ordinary water at 28, 56 and 84 days hydration periods are presented in table 8, 9 and 10. From the results, it can be observed that the densities of the various concrete cubes in ordinary water vary. The 28 days density of 100% OPC cube was observed to be 2439.50 kg/m^3 while that of RHA, PBB and SDA were observed to be 2380.45kg/m,^{3} 2400.00kg/m^2 and 2390.00kg/m^2 respectively. Little difference exists in densities of thespecimens in ordinary water at 84 days when compared to the densities at 28 days. This might mean that specimens were adequately compacted during mixing which did not allow for excessive water penetration into the capillary pores of the specimens that could lead to weight increase (Neville and Brooks 2002). The densities of all the specimens in ordinary water at 28, 56 and 84 days are within the range recommended for normal weight concrete which is between 2355 to 2560 kg/m^3 (Everett,1990).At 28 days curing period, all the concrete mixes attained the minimum compressive strength recommended by BS EN 12390: Part3 (1999) for structural concrete which is between 20-40 N/mm^2 apart from SDA/OPC cubes that had compressive strength of 18.05 N/mm^2. Specimen with 100% OPC gave the highest strength in water at 28, 56 and 84 days. At 28 days, the strength of 100% OPC specimen was observed to be 24.70 N/mm^2 while that of RHA, PBB and SDA were observed to be 21.10 N/mm,^{2} 22.70N/mm^2 and 18.05N/mm^2 respectively. At 84 days, the strength of 100% OPC specimen was observed to be 31.60 N/mm^2 while RHA, PBB and SDA were observed to be 28.25 N/mm,^{2} 28.20N/mm^2 and 22.80N/mm^2 respectively. The strength of PBB was observed to be higher than the strength of RHA in water at 28 and 56 days but at 84 days, the strength of PBB was observed to be lower than the strength of RHA. The low strength observed in RHA at 28 and 56 days complied with the behavior of Portland Pozzolan Cement which gain strength slowly with ages and should therefore, be cured for a long period (Neville and Brooks 2002).

Conclusion

Little difference was observed in the physical properties tests (Specific gravity, Bulk density and Moisture content) carried out on RHA and SDA. The physical properties of PBB were observed to be more in values than that of RHA and SDA. Out of the three materials tested, SDA is the lightest in weight followed by RHA.The strengths of RHA, PBB, SDA and the control specimens in ordinary water at 84 days were observed to be 28.25N/mm^2, 28.20N/mm^2, 22.80N/mm^2 and 31.60N/mm^2 respectively, both RHA and PBB have negligible strength difference at this day. This was due to their little differences in silica content. SDA has low silica content in comparison with RHA and PBB hence, the low strength. The study concluded that OPC/ RHA and OPC/PBB concretes perform better than OPC/SDA at 84 days in ordinary water and can be refer to as more reactive pozzolans than SDA.

Recommendations

i. RHA and PBB could be used for the construction of load bearing concrete structures because of the satisfactory strength they obtained at 28 days.

ii. SDA concrete could be used in the production of non-load bearing concrete structures e.g. partitioning walls.
iii. Tests different from compressive strength should be carried out on the three hardened concretes. Tests such as tensile strength, chemical

and shrinkage tests should thus, be carried out.
iv. Further study on Ternary Blended Cement Concrete using RHA and PBB should be undertaking to ascertain their performance.

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