An Assessment of the Durability Properties of Binary Concrete Containing Rice Husk Ash

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Abstract
Waste is one of the major problems facing the present generation, that is why two of the basic actions towards sustainability specified in rio agenda 21 are minimization of total waste production and maximization of environmentally sound waste and recycling. The study evaluates the durability properties of binary concrete containing rice husk ash. The durability properties of the binary concrete was assessed using abrasion resistance and water absorption tests, then exposure to magnesium sulfate. Results show that the binary concrete has higher compressive strength, tensile strength, abrasion resistance, resistance to magnesium sulfate and low water absorption. It was concluded that the binary concrete can find application in a magnesium sulfate rich soil because of its higher resistance to magnesium sulfate. It is recommended that the Nigerian institute of building (NIOB) should incorporate the use of rice husk ash as a pozolan in to the national building code because of its ability to improve some properties of concrete.
Keywords: Waste**,** Rice Husk Ash**, S**ustainability, compressive strength and durability**.**

1. INTRODUCTION

One of the major problems of human activities in the environment is the generation of waste. For instance according to Dahiru (2007), over 70% tons of waste are produced in the construction industry each year and this amounts to 24kg per week for every person in the United Kingdom. Besides that, Dahiru (2007) further noted that construction activities account for approximately 40% natural resources use and 40% waste generated as a result of such activities. He confirmed that, virtually all construction materials have an impact on the environment in same way from the extraction of mineral such as iron ore and bauxite to the disposal of demolition material at the end of a building life. Moreover Dahiru *et al* (2009) stated that, waste is one of the two most serious problems facing the present generation, that is why two of the basic actions toward sustainability specified in general Rio agenda 21 are; minimization of total waste production and maximization of environmentally sound waste and recycling. Measures were devised to solve the problem of waste, prominent among them is what is popularly called the three Rs- Reduce, Re-use and Recycle-waste.

Sustainable cement production in the concrete industry requires the utilization of industrial and agricultural waste components at present for a variety of reasons. Firstly, it consumes huge quantities of virgin materials which can remain for the next generations. Secondly, the principal binder in concrete is Portland cement, its production is a major contributor to green house gas emissions which contribute to global warming and climate change. Thirdly, many concrete structures suffer from lack of durability which may waste the natural resources. Therefore, finding solution to substitute a practical recycled part of cement seems to be desirable for sustainable development. (Ramezanianpour *et al,* 2009). The recycling of waste components contributes to energy savings in cement production, conservation of natural resources and protection of the environment. Furthermore the use of certain components with potentially pozzalanic reactivity can significantly improve the properties of concrete. (Razavi 2005, Bui 2001, Bui *et al,* 2005).

Since the mid 90s, a significant increase in the production of blended cements incorporating Portland cement and supplementary cementing materials (SCMs) were recorded. Besides that, the use of waste for the production of concrete/cement used compressive strength as the quality index. As a matter of fact, advancement in concrete technology has been on the strength of concrete. However, it is now recognized that strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which the concrete is exposed over its entire life is equally important. According to Sinha *et al* (2011), it was experienced and hence realized over a period of time, that it was not only the strength that is important, other attributes of concrete such as durability, workability etc. were also vital performance parameters. Shetty (2009) stated that, in the past only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all pervading factor for all other desirable properties of concrete including durability. For the first time this pious opinion was proved wrong when it was found that series of failures of concrete pavements have taken place due to frost attack. Moreover, shetty (2009) stated that, although compressive strength is a measure of durability to a great extent, it is not entirely true that, the strong concrete is always a durable concrete. Shetty (2009) also noted that, it is structurally possible to build jetty pier in marine conditions with 20Mpa concrete, but environmental conditions can lead this structure to failure. Engineers are, by nature, fascinated and indeed obsessed by high strength concrete. Part of fascination arises from the widely held misconception that, high strength concrete are, per se, durable. Narayan (2007).

Designers of concrete were mostly interested in the strength characteristics of materials for a variety of reasons. Firstly, it's used for measuring most of the concrete parameters and secondly quality control engineers use it as a benchmark, but the environmental conditions to which the concrete is exposed is also important.

Repair and replacement cost of structures arising from material failure have become substantial portion of the construction budget. The escalation in replacement cost of structures and growing emphasis on the life cycle cost rather than the first cost are forcing engineers to pay attention to durability issues (Mehta and Montero, 2006). Durability is the sine qua non for sustainable growth of the construction industry, and then enhancement of the durability properties of the material is the first and key step to enhance the quality of concrete construction.

Recent studies on the effect of RHA on the properties of concrete have indicated good results. For instance, Dahiru and Zubairu (2008) assessed the properties of pozzalanic concrete and observed appreciable increase in compressive strength of concrete at 10% replacement level of OPC for RHA. Also Rashid et al (2010) carried out a study on mortar incorporating rice husk ash. He concludes that, the strength and porosity of mortar incorporating rice husk ash was better at 20% replacement level of OPC by RHA.

However, concrete structures could be exposed to thermal and chemically aggressive environments or any other process of deterioration which are detrimental to its long service life. The incorporation of RHA in OPC concrete is known to improve the pore structure of the concrete there by reducing its porosity. The refinement of pore structure of concrete enhances resistance to external deteriorating agents such as acid, sulfate, abrasion, water absorption and heat due to elevated temperature. Nonetheless there is no information on the durability properties of Nigerian rice husk ash concrete. This work therefore is designed to study the durability properties of binary concrete containing RHA

2 MATERIALS AND METHODS

2.1 Materials

The materials used in this study includes: ordinary Portland cement, fine aggregates, coarse aggregates, rice husk ash and water. The OPC used was manufactured by Dangote cement company Plc. The coarse aggregate used was crushed gravel while the fine aggregate was fine river sand. They were mixed with tap water fit for drinking.

2.2 Methodology

Preliminary test of the individual constituents of the concrete i.e RHA and cement was carried out and a trial test so as to determine the most suitable water-cement ratio and method of compaction. The preliminary test that was carried out includes chemical composition analysis, specific gravity, moisture content and sieve analysis of aggregates. These tests were performed in accordance to the relevant standards such as BS 4550 (1978), BS 812 (1984), BS 812 (1985) and BS 882 (1965).

This was followed by the preparation of concrete cubes. The preparation and subsequent test follows the relevant British standard specifications e.g. BS 1881 (1983). British research establishment method was used to design the concrete using a water-cement ratio of 0.62. Two set of concrete cubes were produced. The first group of concrete specimens was made of cement and RHA while the second group was cubes made of cement only-they are the control cubes.

A total of one hundred and fifty cubes were produced, with each set consisting of seventy five specimens. At fresh stage the concrete cubes were tested for workability using slump and compacting factor test while at hardened stage the concrete specimens were tested for compressive strength, tensile strength, abrasion resistance, water absorption and exposure to aggressive environment by simulating the condition in the laboratory through the exposure of the concrete samples to 1% $MgSO_4$.

3. Tests Results

The results of the different tests on the aggregates and concrete samples described above are as follows.

Table 1: Chemical composition analysis of cement and RHA

	Content (%)	
Oxides	Cement	RHA
Silica (SiO_2)	20.55	87.16
Aluminum (Al_2O_3)	5.08	0.38
Iron oxide (Fe_2O_3)	3.10	0.35
Sodium oxide (Na_2O)	-	0.78
Calcium oxide (CaO)	64.51	0.83
Magnesium oxide (MgO)	1.53	0.42
Potassium oxide (K_2O)	0.73	3.27
Sulfur oxide (SO_3)	2.53	0.24
Loss on ignition (LOI)	1.58	7.41

Table 2: Sieve analysis for fine aggregate

BS sieve size	Weight retained (g)	Weight passing (g)	Percentage passing (%)
4.75 mm	320	4680	93.6
2.36 mm	550	4130	82.6
1.18 mm	1345.5	2784.5	55.69
600 ɥm	1350.4	1434.1	28.68
300 ɥm	965	469.1	9.38
150 ɥm	320	149.1	2.98
Pan	80	69.1	1.38

Table 3: Sieve analysis of coarse aggregates

BS sieve size	Weight retained(g)	Weight passing(g)	Percentage passing
20 mm	280	5720	95.3
10 mm	2780	2940	46.3
4.75 mm	1660	1480	34.3
2.36 mm	1240	20	32.1

Table 4: Slump test result for control and binary concrete

Concrete samples	Slump (mm)
Control concrete	20
Binary concrete	13

Table 5: compacting factor test result for control and binary concrete

Concrete sample	Compacting factor
Control concrete	0.92
Binary concrete	0.88

Table 6: Average compressive strength for control and binary concrete specimens

			Compressive strength(N/mm^2)		
Concrete Samples	3 days	7 days	14 days	28 days	90 days
Control concrete	8.68	12.5	20.8	29.5	31.2
Binary concrete	10.5	13.8	23.4	31.2	33.6

Table 7: Average compressive strength of concrete samples exposed to 1% $MgSO_4$

			Compressive strength(N/mm^2)		
Concrete samples	3days	7 days	14 days	28 days	90 days
Control concrete	9.2	12.6	19.4	27.3	29.6
Binary concrete	10.8	14.2	22.9	30.8	32.4

Table 8: Average tensile strength for control and binary concrete

			Tensile strength		
Concrete samples	3 days	7 days	14 days	28 days	90 days
Control concrete	1.26	1.52	1.98	2.86	3.64
Binary concrete	1.29	1.55	2.38	3.11	4.14

Table 9: Average abrasion resistance for control and binary concrete

			Loss of weight (%)		
Concrete sample	3 days	7 days	14 days	28 days	90 days
Control concrete	0.22	0.18	0.13	0.11	0.07
Binary concrete	0.16	0.14	0.09	0.06	0.03

Table 10: Average water absorption test result for control and binary concrete

		Water absorption (%)	
Concrete samples	28 days	56 days	90 days
Control concrete	5.96	5.26	4.56
Binary concrete	5.76	4.98	4.2

4. Discussion

4.1 Workability:

The workability of the binary and control concrete samples was evaluated using slump and compacting factor test

i. Slump test:

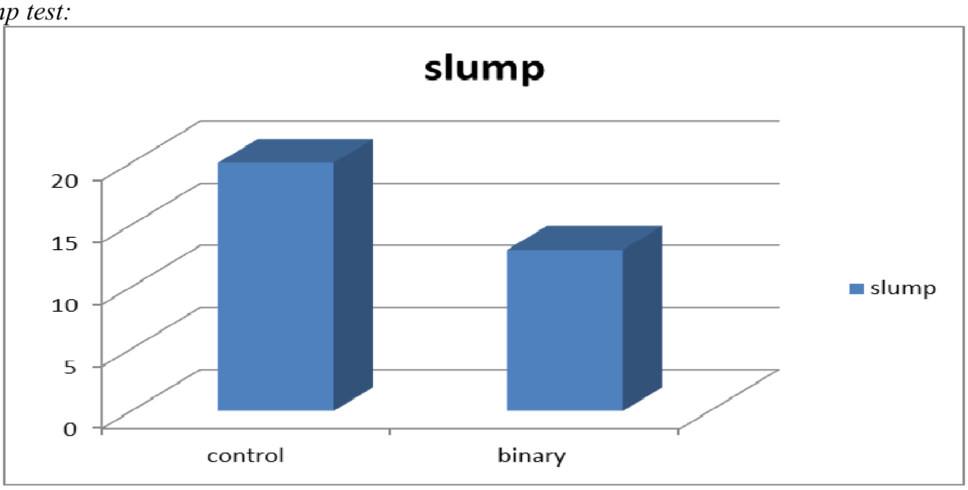

Figure 1: Slump of binary and control concrete

Figure 1 present the result of slump test for control and binary concrete. From the figure it can be clearly seen that, the control concrete has a slump of 20mm while the binary concrete has a slump of 13mm. this indicates that the control concrete was more workable than the binary concrete .

ii. Compacting factor test:

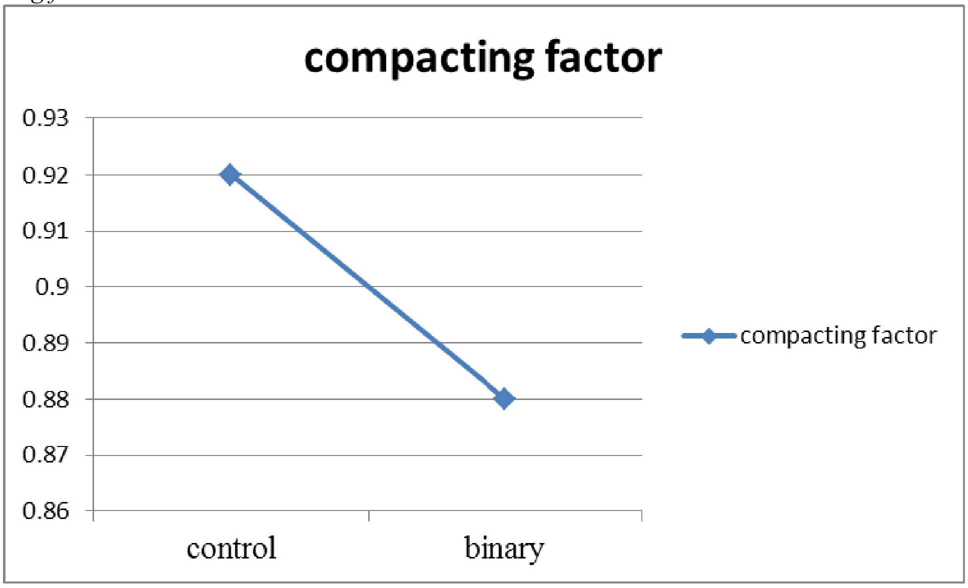

Figure 2: Compacting factor for binary and control concrete

Figure 2 shows the compacting factor test result for control and binary concrete. The control concrete has a compacting factor of 0.92 while the binary concrete has a compacting factor of 0.88. The control concrete was more workable than the binary concrete. From the result it can be observed that, the result of compacting factor test agrees with that of slump test, because both the tests results indicates that, the control concrete is more workable than the binary concrete.

4.2 Compressive strength

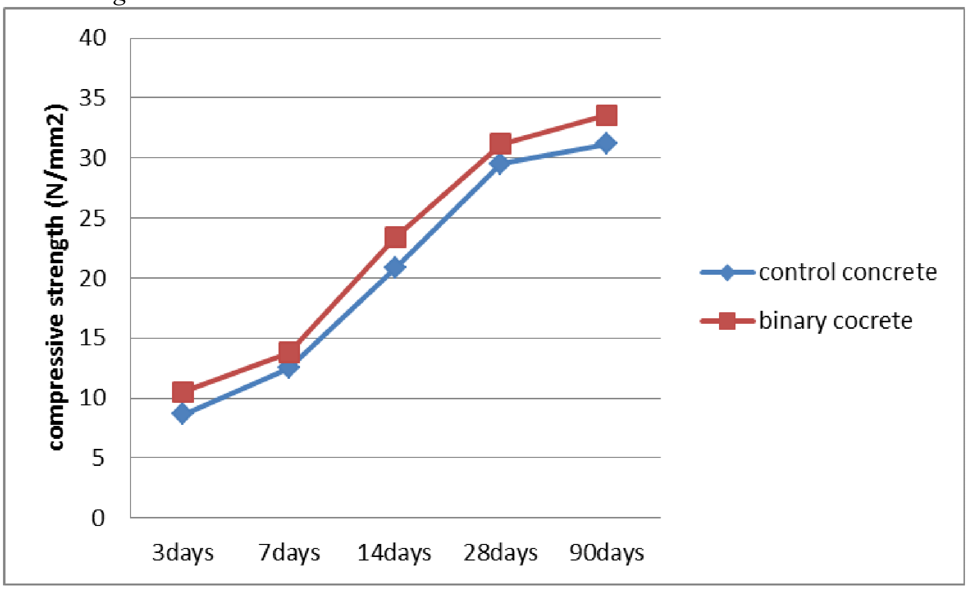

Figure 3: Compressive strength for binary and control concrete

Figure 3 shows the compressive strength test result of concrete samples cured in water at 3, 7, 14, 28 and 90 days curing period.

Compressive strength was one of the most important property used to evaluate durability of the concrete specimens. As it can be noted from the result, it can be clearly seen that the binary concrete attained a compressive strength result of 31.2 N/mm^2 at 28 days as against 29.5 N/mm^2 for the control concrete. This represent 5.4% increase in compressive strength which indicates that, the binary concrete was stronger than the control concrete.

4.3 Compressive strength of concrete samples exposed to 1% $MgSO_4$

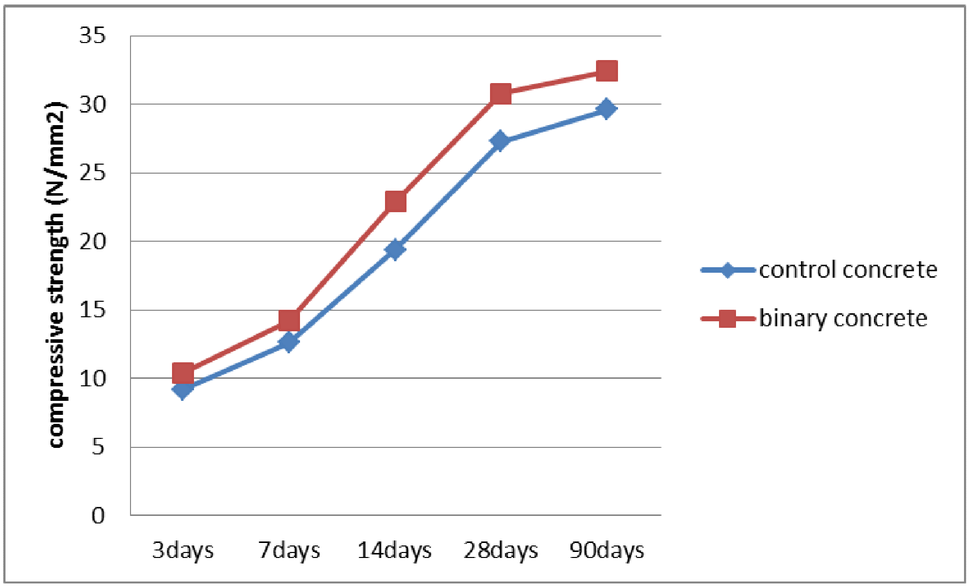

Figure 4: Average compressive strength of concrete samples cured in 1% $MgSO_4$

Figure 4 present the result of compressive strength of concrete samples cured in 1% $MgSO_4$ at 3, 7, 14, 28 and 90 days curing period.

As it can be noted from the result, the sulfate solution has a slight effect on compressive strength of the concrete samples when the result of compressive strength of the concrete samples cured in 1% $MgSO_4$ was compared with the result of compressive strength of the concrete samples cured in water. For instance, the binary concrete attained an average compressive strength of 33.6 N/mm^2 at 28 days when cured in water and 32.4 N/mm^2 when cured in 1% $MgSO_4$.

4.4 Tensile strength

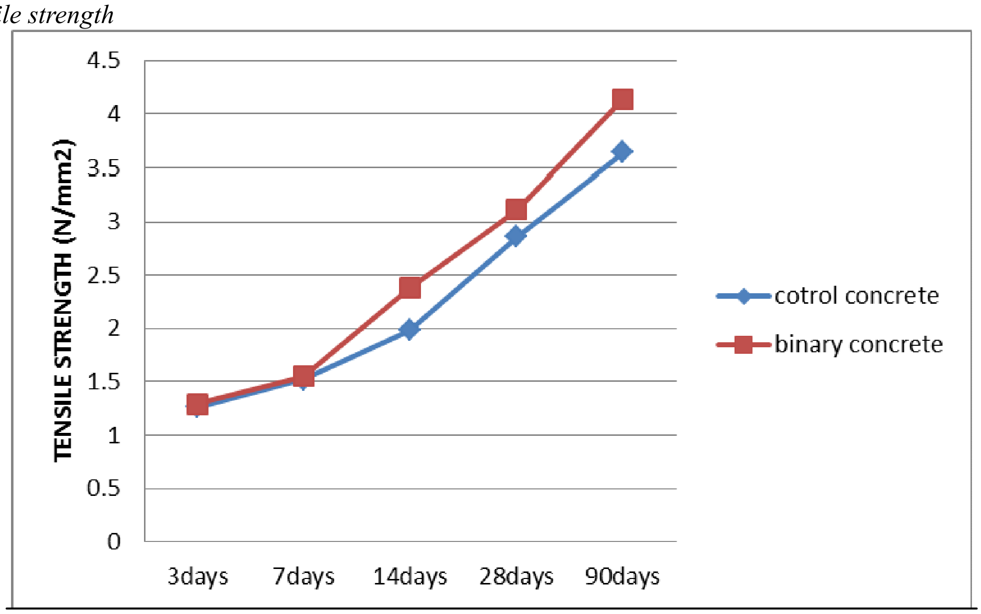

Figure 5: Average tensile strength for control and binary concrete

Figure 5 present the tensile strength of the control and binary concrete specimens. The binary concrete attained a tensile strength of 3.11 N/mm^2 at 28 days and the control concrete attained a tensile strength of 2.86 N/mm^2. It can be seen that, the binary concrete has higher tensile strength than the control concrete by 12.5% at 28 days. The tensile strength of the binary concrete was higher than that of control concrete throughout the curing period of 90 days.

4.5 Abrasion resistance

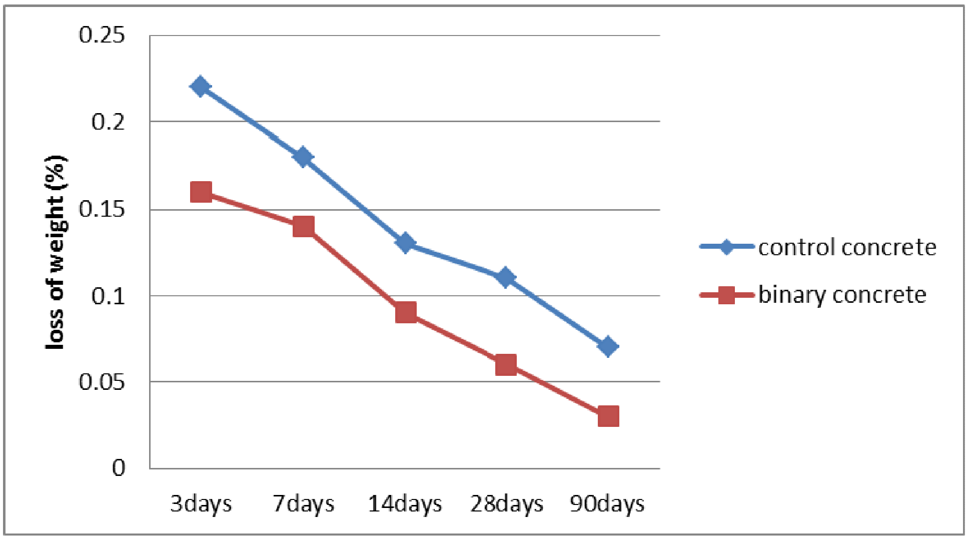

Figure 6: Abrasion resistance for control and binary concrete specimens

Figure 6 shows the abrasion resistance of control concrete and binary concrete samples determined at 3,7,28 and 90 days curing period. The loss in weight for binary concrete specimens was less than that of control concrete specimens. This means that, the binary concrete sample resist abrasion than the control concrete. At 28 days, after abrasion the binary concrete losses a weight of about 0.06 % and the control concrete losses a weight of about 0.11 %. At 90 days, after abrasion the binary concrete sample losses a weight of about 0.03% and the control sample losses a weight of about 0.07%.

From the result it can be observed that, the resistance to abrasion of all the concrete samples increases with increase in curing days and the binary concrete sample resist abrasion than the control concrete samples throughout the curing period.

4.6 water absorption

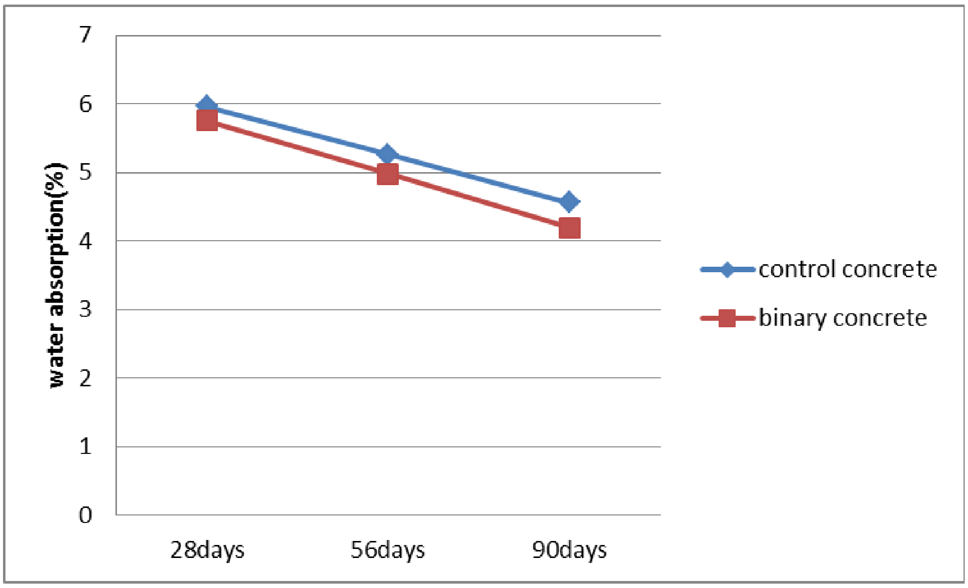

Figure 7: Water absorption for binary and control concrete specimens

Figure 7 present water absorption test result for control and binary concrete specimens. the binary concrete has lower water absorption than the control concrete having a water absorption of 5.76%, 4.98% and

4.2% at 28, 56 and 90 days while the control concrete has a water absorption of 5.96%, 5.26% and 4.56% at 28, 56 and 90 days respectively. From the result it can be clearly seen that, the binary concrete has less water absorption than the binary concrete. This implies that, it will have less susceptibility to permeability by liquids and off-course more strong and durable.

5. Conclusions

Based on the result of the research carried out the following conclusions were arrived at:

i. The effect of 1% $MgSO_4$ on the binary concrete is insignificant when the result of compressive strength of the concrete samples cured in water was compared with that of the concrete samples cured in 1% $MgSO_4$. Therefore it can be concluded that, the binary concrete can be used in a soil rich of magnesium sulfate.
ii. The binary concrete has higher resistance to abrasion than the control concrete by 33.33%.
iii. OPC replacement by RHA leads to the improvement of compressive strength by 14.6% and tensile strength by 12.5%. Therefore adding RHA in to the concrete leads to the improvement of compressive and tensile strength.
iv. Incorporating RHA in a concrete leads to the reduction of water absorption by 5.32% and this can improve the durability of a concrete.

6. Recommendations

i. The concrete can be used for structural and non-structural purpose because it is in conformity with BS 8110 (1985).
ii. In view of encouraging result further research should be carried out to assess the durability properties of binary concrete containing RHA as partial replacement of cement using different durability testing parameters.
iii. The Nigerian government/stake holders should establish Cement Companies that will be producing blended cement containing rice husk ash.
iv. Rice husk ash should be incorporated in the national building code as part of the materials to be used for building.

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