Compressive Strength Analysis of Ternary Blended Concrete Partially Replaced with Rice Husk Ash (RHA) and Wood Ash (WA)

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Abstract- The environmental pollution resulting from the production process of cement has contributed to the climate change being experienced worldwide. The need to reduce the rate of depletion of the ozone layer and also to produce durable and sustainable concrete has led to this study. Thirty six (36) concrete cubes of 150 mm x 150 mm x 150 mm were produced with OPC /RHA / WA blended concrete at percentage OPC replacement with pozzolans of 5%, 10% and 15%, Twelve (12) concrete cubes were cast as control. Cubes from the concrete mixes were cured for 7, 14 and 28 days and were crushed to determine their compressive strengths. Experimental work was carried out on Ordinary Portland Cement (OPC), Rice Husk Ash (RHA) and Wood Ash (WA) concrete to determine their essential properties in fresh and hardened state, they are all within the limits specified by relevant standards. It was observed that at 10% replacement the maximum compressive strength of 18.36N/mm2 was obtained for the ternary blended concrete of OPC /RHA /WA at 28 days, representing 35.46% increase in strength over the 100% OPC concrete, indicating the optimal value of compressive strength attained. This indicate that RHA and WA combination is an excellent pozzolans that can be utilize for both binary and ternary blended concrete production.

Indexed Terms- Pozzolans, Ternary, Ozone layer, Pollution, Rice husk ash, Wood ash, Greenhouse gases, Cementious.

I. INTRODUCTION

Concrete is a composite construction material composed primarily of aggregate, cement and water. Concrete has been considered the first widely used construction material throughout the world. Over the years it has been used in vast quantity for the construction of buildings, bridges, roads, dams and many other civil infrastructures. According to Glavind and Munch-Petersen (2002), its worldwide annual consumption in 2002 was about 5 billion m^3. Moreover, it has been predicted that its demand would double every decade (Mehta, 2001). Hence its performance and effects on the environment are of great importance.

Compared to other constituents, cement performs a vital role for the production of concrete. However, the production process of cement causes some negative effect to the natural environment, in addition to the high cost of cement due to continuous increase in the demand. The process of making cement is among the third largest CO_2 producers in the world. According to Malhotra, (2002), during this process, for every ton of cement produced, more than half of all CO_2 emissions are released into the air. These greenhouse gases (CO_2 and SO_2) contribute to the depletion of the ozone layer which leads to global warming. This dramatic increase in CO_2 emissions from cement production has been stated by Muga *et al.,* (2005). Undeniably, cement production depends on many other factors, more often than not, the production of cement is an extremely energy intensive production process because the energy and the consumption of other natural resources per ton are estimated to be approximately 4GJ and 1.6 ton (Muga *et al.,2005)*. Given the relationships between life cycle characteristics and CO_2 use, the emission of CO_2 can be assessed for environmentally friendly concrete production (Park *et al.,* 2012). To combat the aforementioned problem, cement can be partially replaced by supplementary cementitious materials, such as industrial by-product (fly ash, silica fume and slag) and agricultural wastes (rice husk ash, coconut husk ash, palm oil fuel ash and ash from timber). Most of these supplementary cementing materials are by-products; thus, their inclusion not only serves as an invaluable means to preserve environmental resources but also enhances concrete construction properties including its sustainability (Aitcin, 1998; Mehta and Monteiro, 2006).

Supplementary cementitious materials are added to concrete as part of the total cementitious system. They may be used in addition to or as a partial replacement of Portland cement or blended cement in concrete, depending on the properties of the materials and the desired effect on concrete. Supplementary cementitious materials include fly ash (is a byproduct of the combustion of pulverized coal in electric power generating plants), silica fume (reduction of high-purity quartz with coal in an electric arc furnace), timber ash (TA), rice husk ash (RHA), coconut husk ash (CHA), ground granulated blast- furnace slag and metakaolin (calcined clay). They are added to cement either through intergrinding with cement clinker, or by blending with cement after grinding, or can be added during concrete batching to supplement the cement. According to Arum et al., (2013), in developing countries of the world, the current research interest in the use of SCMs for mortar and concrete production appear to favour Pozzolans from biogenic wastes at the expense of industrial by-products. Due to difference in chemistry, supplementary cementitious materials (SCMS) affect the performance of cement in concrete to suit different applications. The use of SCMs allows the cement industry to maintain the performance expected of cement while reducing the amount of clinker required in cement. As a result, this reduced the emissions of greenhouse gases, a key measure in the cement industry of environment performance.

II. MATERIALS AND METHODS

- Rice Husk Ash

The rice husk was obtained from a rice mill in Ekpoma, Edo state and was processed through burning in the open air. The rice husk was burnt until it totally turns ash and the fine particles were further sieved through a sieve of 45µm aperture size. The particles passing through the sieve were then used as pozzolan to replaced varying percentages of OPC.

- Wood Ash (WA)

Saw dust from Sawmill was collected within Ekpoma, Edo State. The Wood Ash (WA) was obtained from open field burning. The material was dried and carefully homogenized. An adequate wood ash particle size was obtained. The fine particles were further sieved through a sieve of 45µm aperture size. The particles passing through the sieve were then used as pozzolan to replaced varying percentages of OPC.

- Ordinary Portland cement

Elephant brand of Portland cement was used. It was purchased in bags of 50kg from a cement store along BIU road, Benin City, Edo state. It was properly stacked and it was ensured that the cement satisfied the British Standard Specification BS12 (1978). The Elephant cement was not affected by weather which includes dampness due to atmospheric moisture.

- Aggregates

The fine aggregate used for this research was river sand which was collected from a river bank in Benin City, Edo State. The river sand was sieved in-situ through 4.75mm sieve to remove stubs, sticks and other forms of impurities that could cause concrete properties to be compromised. The coarse aggregate used was granite. This was purchased from a dump site along BIU road, Benin City, Edo state. It was notably angular and well-shaped with little fine stone dust inclusion. This material was basalt and had some nature of igneous rock in its formation. The nominal size was less than 20mm in diameter.

- Potable Water

Water was fetched from a tap around the Concrete/ Structural Engineering Laboratory in Benson Idahosa University, Benin City, for the production of concrete. The water was clean and free from silt, organic matter and harmful impurities such as oil, alkaline and acid.

- Compressive Strength Test

This test was carried out in accordance to BS 1881: part 116 (1983) and the procedure is as follow:

i. Batching
ii. Mixing

iii. Casting
iv. Curing
v. Crushing

- Batching

Batching was done by weight of the constituent materials according to BS 1881: part 125 (1983). The different percentage of the combination of rice husk ash and wood ash were 5%, 10% and 15% each. The water/ binder ratio used was 0.55. The concrete ratio was 1:2:4 that is, one part of cement or cement mixture to two parts of river sand to four parts of granite.

- Mixing

Shovel was used for mixing by hand. The constituents were mixed thoroughly until uniform mixture was achieved in order to have a good consistency before being poured into the steel cube. Mixing was done in accordance to BS 1881: part 125 (1983).

- Preparation of Cubes

The cubes were of internal size 150mm x 150mm x 150mm and were made of steel. The cubes were put in the right shape by using binding wires. They were then greased with lubricating oil so as to ease the removal of the concrete cubes after hardening.

- Casting

Fresh concrete was placed in the cube in three layers with the use of scoop. Each layer was compacted at interval using a tamping rod with 25 blows. The top surface of the concrete was leveled off with a trowel. The surface of cube were smoothened evenly with the trowel, the date of casting, the type of SCM used and the experiment number were written on each of the cubes after 15 minutes of setting to allow for easy identification. Casting was done in accordance to BS 1881: part 108 (1983).

- Curing

Curing was done according to BS 1881: part 3 (1970), after 24 hours of hardening, concrete cubes were gently removed from the steel cubes and properly placed in the curing tank filled with water in order to maintain their moisture contents, thereby allowing them to attain their full strength. The cubes were removed after 7, 14 and 28 days for crushing test.

- Crushing

Concrete cubes at their specified days of curing were removed from the curing tank and allowed to dry for 24 hours because concrete tested on wet condition will not attain its actual strength. The concrete cubes were taken to the Structural Laboratory of the Civil Engineering Department of Benson Idahosa University, Benin city, for the crushing test. The procedure is as follows;

The cubes were weighed in a weighing balance. Each cube was placed in the crushing machine. The smoother surface was made to rest on the crushing plate. A digital crushing machine was used for crushing. The crushing load was expressed in Newton (N). Three concrete cubes were crushed for each percentage of ash replacement for the concrete.

The following formulae were adopted in calculating the compressive strength of concrete.

$$\text{Density } (Kg/m^3) = \frac{Weight\ of\ cube}{Volume\ of\ cube}$$

$$R_C = \frac{F_C}{A}$$

where

R_C = The compressive strength in Newton's per square millimeter (N/mm^2)

F_C = The maximum load at fracture in Newton's (N)

A = The area of the load bearing plates, in square millimeter (mm^2)

Similar test was carried out on all other cubes

III. RESULTS AND DISCUSSION

Compressive Strength Test

The result of the compressive strength test carried out on concrete of 7, 14 and 28 days curing are given in tables below.

CUBE NO.	CUBE WEIGHT (kg)	LOAD AT FAILURE (kN)	CUBE VOLUME (m^3)	CUBE STRENGTH (N/mm^2)	AVG. CUBE STRENGTH (N/mm^2)
7 DAYS					
1	7.86	223.36	0.003375	9.93	11.24
2	7.82	266.58	0.003375	11.85	
3	7.89	268.36	0.003375	11.93	
14 DAYS					
1	7.81	280.85	0.003375	12.48	11.83
2	8.22	262.64	0.003375	11.67	
3	7.98	254.83	0.003375	11.33	
28 DAYS					
1	8.05	283.30	0.003375	12.59	11.85
2	8.26	264.49	0.003375	11.76	
3	8.17	251.70	0.003375	11.19	

Table 1: Compressive Strength of Concrete With 100% Ordinary Portland Cement

CUBE NO.	CUBE WEIGHT (kg)	LOAD AT FAILURE (kN)	CUBE VOLUME (m^3)	CUBE STRENGTH (N/mm^2)	AVG. CUBE STRENGTH (N/mm^2)
7 DAYS					
1	8.34	273.05	0.003375	12.14	13.99
2	8.06	352.02	0.003375	15.65	
3	8.33	314.73	0.003375	14.18	
14 DAYS					
1	8.16	228.58	0.003375	10.16	11.71
2	8.17	262.15	0.003375	11.65	
3	8.35	299.55	0.003375	13.32	
28 DAYS					
1	8.07	288.97	0.003375	12.84	12.74
2	7.97	270.26	0.003375	12.01	
3	8.18	301.04	0.003375	13.38	

Table 2: Compressive Strength of Concrete with 95% Ordinary Portland Cement and 5% RHA & WA Replacement.

CUBE NO.	CUBE WEIGHT (kg)	LOAD AT FAILURE (kN)	CUBE VOLUME (m^3)	CUBE STRENGTH (N/mm^2)	AVG. CUBE STRENGTH (N/mm^2)
7 DAYS					
1	7.78	308.41	0.003375	13.71	13.29
2	7.92	289.19	0.003375	13.03	
3	7.86	295.20	0.003375	13.12	
14 DAYS					
1	7.92	358.87	0.003375	15.95	15.54

2	7.94	366.14	0.003375	16.27	
3	7.70	324.28	0.003375	14.41	
28 DAYS					
1	7.89	422.47	0.003375	18.78	18.36
2	7.99	339.25	0.003375	15.07	
3	7.96	477.86	0.003375	21.24	

Table 3: Compressive Strength of Concrete with 90% Ordinary Portland Cement and 10% RHA & WA Replacement

CUBE NO.	CUBE WEIGHT (kg)	LOAD AT FAILURE (kN)	CUBE VOLUME (m^3)	CUBE STRENGTH (N/mm^2)	AVG. CUBE STRENGTH (N/mm^2)
7 DAYS					
1	7.93	262.23	0.003375	11.65	11.00
2	7.86	248.73	0.003375	11.05	
3	7.98	231.53	0.003375	10.29	
14 DAYS					
1	7.93	251.25	0.003375	11.17	9.98
2	7.95	226.87	0.003375	10.08	
3	7.82	195.58	0.003375	8.69	
28 DAYS					
1	7.93	216.33	0.003375	9.61	12.63
2	7.85	247.22	0.003375	10.99	
3	7.83	380.18	0.003375	17.28	

Table 4: Compressive Strength of Concrete with 85% Ordinary Portland Cement and 15% RHA & WA Replacement

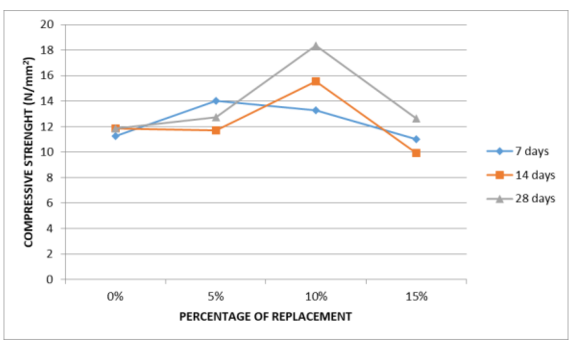

Figure 1: Comparison of compressive strength at different percentage replacement level with RHA and WA

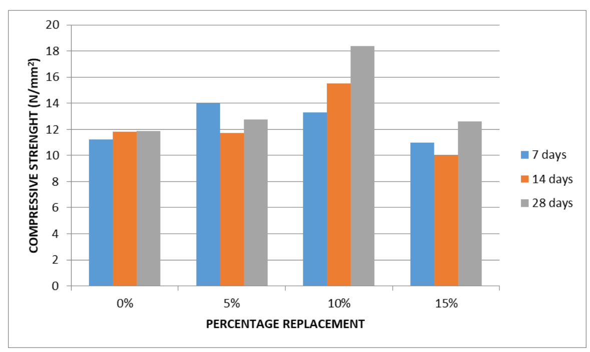

Figure 2: Chart indicating the optimum percentage replacement with OPC

- Discussion of Results

From the above Figure displaying the compressive strength development of specimens containing various amount of RHA and WA. The standard control cubes were discovered to have an average comprehensive strength of 11.24N/mm^2 on day 7, 11.83N/mm^2 on day 14, and 11.85N/mm^2 on day 28.

The compressive strength of concrete cubes that had 5 percent of RHA and WA were 13.99N/mm^2, 11.71N/mm^2, 12.74N/mm^2 in 7, 14, 28 days respectively.

The compressive strength of concrete cubes that had 10 percent of RHA and WA were 13.29N/mm^2 on day 7, 15.54N/mm^2 on day 14, 18.36N/mm^2 on day 28 and the compressive strength of concrete cubes that had 15 percent of RHA and WA were 11.00N/mm^2, 9.98N/mm^2, and 12.63N/mm^2 on 7, 14, and 28 days respectively.

The optimum compressive strengths were obtained at 10 percent replacement at 14 and 28 days.

CONCLUSION AND RECOMMENDATION

1. The Compressive strength of concrete at 10 percent replacement RHA and WA are higher than that of the OPC throughout the numbers days of curing, It gave the highest compressive strength of 15.54N/mm^2 and 18.36N/mm^2 at 14 and 28 days respectively.
2. The supplementary cementitious materials show an increase in compressive strength from 5 percent replacement of RHA and WA to 10 percent replacement before a decrease in the compressive strength of the concrete.
3. Proper utilization of supplementary cementitious materials will reduce environmental pollution by limiting the quantity of cement being produced as the production process causes environmental degradation.

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