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EFFECT OF CARBIDE WASTE ON THE PROPERTIES OF RICE HUSK ASH CONCRETE.

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ABSTRACT.

The impact of carbide waste,CW on the strength of concrete made with cement partially replaced with Rice Husk Ash,RHA for use in rigid pavement was investigated. Oxide composition analysis of CW and RHA confirm their status as non pozzolanic material rich in CaO component and pozzolanic materials, respectively. Setting times, slump, compressive and indirect tensile strength tests were conducted on fresh and hardened concrete. Twenty-eight (28) and Fifty-six (56) days peak compressive strength and indirect tensile strength values of 35.00 N/mm^2, 39.53 N/mm^2 and 1.69 N/mm^2 respectively was obtained when 10% CW was mixed with 10% RHA plus 80% cement. Values comparable to 28 and 56days peak compressive strength and indirect tensile strength values of 37.11 N/mm,^{2} 40.00N/mm^2 and 1.71 N/mm^2 respectively obtained with the use of only cement as binder. The use of CW and RHA in concrete will ensure economy in concrete production and a better way of disposing these wastes.

KEY WORDS: Carbide Waste, Rice Husk Ash, Cement, Concrete and Rigid Pavement.

INTRODUCTION

The search for suitable material that can partially replace cement has been on for quite some time, the use of rice husk ash (RHA) to replace cement was reported by Oyetola and Abdullahi (2006, Al-khalaf et al. (1984), Zhang and Malhotra (1996), Ou et al, (2007) and Mbachu and Kolawole (1998).Dashan and Kamang (1999) reported the use of Acha Husk ash to partially replace cement in concrete production. Alabadan et al. (2005) reported the use of Bambara groundnut shell ash in the partial replacement of cement for concrete production. Elinwa and Awari (2001) reported the use of Groundnut husk ash to partially replace cement in concrete production. Aribisala and Bamisaye (2006) reported the use of Bone powder ash in concrete production. In all the cases reported above, it is only the use of BPA that resulted in strength increase above the control (use of only cement), decline in strength was reported with the use of the remaining agro waste materials.

Rice Husk Ash, RHA is obtained from the combustion of rice husk, a by product from rice milling operation, the husk accounts for 20-24% of the rough rice produced. According to Al-Khalaf et al (1984), decrease in compressive strength was observed with increase in RHA content in the production of concrete. Zhang and Malhotra (1996) reported high compressive strength with RHA content in concrete production, such increase was attributed to reduced porosity, reduced $Ca(OH)_2$ and reduced width of the interfacial zone between the paste and aggregate. Oyetola and Abdullahi (2006) observed and reported reduction in compressive strength of blocks made with RHA incorporated into cement used as binder. OU et al (2007) reported increase in compressive strength up to 30% with the replacement of cement with 10% RHA, in addition to reduction in water permeability by 60%.

Carbide waste is a by-product obtained from the production of acetylene gas (C_2H_2). It consists mainly of ($Ca(OH)_2$) lime, caustic solid substances, and white when pure. The reaction between calcium carbide and water presented as Equation (1) yields acetylene gas used in oxyacetylene welding and $Ca(OH)_2$ as a residue.

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2 \qquad (1)$$

The production of CaC_2 is as presented in

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Equations (2) and (3), the process begins with the burning of limestone ($CaCO_3$) to yield lime (CaO) and carbon IV Oxide (CO_2) as depicted in Equation (2)

$$CaCO_3 \xrightarrow{\quad\quad} CaO+CO_2 \qquad (2)$$

CaO obtained from Equation (2) is made to react with coal (C) to yield calcium carbide (CaC_2) and carbon monoxide (CO) as presented in Equation (3).

$$CaO + 3C \xrightarrow{\quad\quad} CaC_2+CO \qquad (3)$$

According to Cincotto and de Carvalho (2009) calcium oxide obtained as waste from acetylene production can be used for civil construction materials, with a caution on reactivity loss, associated with storage of waste, hence the recommendation of usage immediately after the production of the waste. Krammart and Tangtersirikul (2003) reported the use of Carbide waste, CW in concrete work, with increase in initial and final setting times and decrease in compressive strength of mortars produced with cement partially replaced with CW.

Obam and Tyagher (2005) reported promising result with the use of 45% slake lime mixed with 55% RHA in the production of concrete. According to Jaturapitakkul and Roongregung (2003) 28 days and 180 days compressive strength values of 15.6 Mpa and 19.1 Mpa, respectively were obtained for mortar using rice husk ash to calcium carbide residue ratio of 50: 50 by weight.

In Nigeria, rice husk is produced in most northern and central states, were rice is grown, some of the states are Niger, Kaduna, Kano, Benue, Nasarawa, Kogi, Kwara etc. (Oyetola and Abdullahi, 2006). CW is normally dumped at different locations, especially mechanic villages and industries where oxy- acetylene gas welding is carried out. Such sites and locations are common features in most urban centres and some rural areas. Advantages to be derived from the use of RHA and CW in concrete work include, promotion of a better waste management at a little cost as RHA normally constitute environmental load as it is left or burnt in the open, while CW is normally disposed via land fill or open dumping which have effect on surface and ground water, arising from the leaching of harmful compounds and alkali to ground and surface water. The use of both wastes will reduce the quantity of cement used in concrete; ensure a conservation of lime stone, and reduction in CO emission from cement factory arising from the manufacture of cement, which affects the ozone layer, a phenomenon that is responsible for global warming.

When cement is partially replaced with RHA and CW the reaction begins with the hydration of cement, according to O'Flahery (1974) hydration begins with a fast reaction between C_3A of cement and water on the first day, a reaction responsible for initial and final setting and strength on the first day. No lime is liberated or released during this reaction. The next reaction is between the C_3S component of cement and water, this reaction contributes more to the development of early strength, from the second day to the fourteenth day. The reaction involves the liberation/evolution of lime, and the formation of the microcrystalline hydrate $C_3S_2H_3$ with some lime separating out as crystalline $Ca(OH)_2$ the quantity of lime liberated during this reaction is twice the quantity liberated during the hydration of C_2S. The hydration of C_2S is the next reaction. It hydrates slowly and is responsible for strength development after seven days. The quantity of lime evolved is half that obtained during the hydration of C_3S.

Unlike cement, pozzolanic material contains little CaO and high alumina-silicate glass, which reacts with lime (calcium hydroxide) released by the hydration of C_3S and C_2S component of cement to form cementitious materials. Addition of CW which is rich in CaO to RHA-Cement combination is expected to produce additional lime for effective reaction between silica and lime liberated during the hydration of C_3S and C_2S.

The reaction between hydrated lime and the silica and alumina component of the RHA is normally slower than the hydration of cement and takes one to two weeks for results to manifest. Addition of CW with high CaO composition is expected to provide additional free CaO for reaction with silica from RHA as the CaO from CW goes into reaction simultaneously with the CaO component from cement during the hydration of C_3S and C_2S to liberate more hydrated lime Ca (OH), that reacts with the silica and alumina components of the RHA, this deduction is based on Cojbasic et al (2005) observation.

Previous studies focused on the partial replacement of cement with RHA for use in low strength concrete, attention here is on its use in rigid pavement, which requires moderate to high strength. This study is aimed at verifying the effect of CW addition to cement – RHA mixture, in concrete production for use in rigid pavement. Addition of CW is expected to produce additional lime for reaction with silica from RHA, in cement-RHA combination.

MATERIALS AND METHODS

Materials

Carbide waste (CW) was collected from a welder located at the North Bank Mechanic village in Makurdi. It was dried in the open air, and grinded into fine particles, using pestle and mortar (in the absence of a ball mill and made to pass through the 300µm BS sieve.) Rice husk ash was obtained from a local rice milling factory at Makurdi, where indigenous milling technique was used. The husk was burnt in a furnace at a temperature of 500°C at the metallurgy laboratory of the University of Agriculture, Makurdi. In compliance with a temperature of 500°C suggested by Al-khalaf et al (1984) for burning of ash for good pozzolanic activity.

The burnt ash was grinded into fine particles, Using pestle and mortar (in the absence of ball mill) and made to pass through 300 micron BS sieve. Chemical analysis of CW, RHA and ordinary Portland cement was carried out in the laboratory of National Steel Council, Kaduna, using X-ray analyzer together with Atomic Absorption Spectrophotometer (AAS). Dangote brand of ordinary Portland cement produced at the cement factory located at Obajana in Kogi state of Nigeria, as obtained from the open market in Makurdi was used for the work. Washed gravel obtained from the aggregate market located at Wurukum area of Makurdi town was used. Naturally occurring clean river sand used was obtained from the bed of River Benue. Aggregate impact and crushing value of the coarse aggregate was carried out, in accordance with BS 812 (1990) part 110 and 112. Specific gravity, Particle size distribution of fine and coarse aggregate was carried out in accordance with BS 812(1985) part 103. Pure and clean tap water fit for drinking as found in the concrete laboratory of the University of Agriculture, Makurdi was used in concrete production.

Concrete Mixture proportions:

Mixed design was carried out for concrete of grade 35 using the procedure for the design of normal concrete mixes [DOE, 1988]. The constituent materials were batched by weight, except the replacement of cement with RHA and CW that was done by volume, because of variation in the specific gravity of the materials. The mix produced with only cement as binder served as the control mix. Summary of the mix design is as presented in Table 1.

Table 1. Summary of Mix Design

Material	Quantities (Kg) per m^3
Cement	450
Sand	548
Gravel	1277
Water	224

Three sets of cubes were cast and tested at 7, 14, 28 and 56 days using different mix proportions. 240 concrete cubes of 150 mm x 150 mm x 150 mm were cast and used to determine the compressive strength at each level of replacement, while 3 cylindrical specimens, each having a diameter of 150mm and length of 300mm were used to determine the indirect tensile strength. Materials were mixed at ambient temperature using a rotating pan type mixer (with a capacity of 0.05cubic metre). The quantity of the concrete prepared for each batch was at least 10 % in excess of the required amount. Mixing of the constituent materials was undertaken for six and a half minutes. Immediately after completion of the mixing process, the fresh concrete was sampled for slump test.

The slump was measured in accordance with BS 1881 (1983) part 102. Cylinder and cube specimens were prepared from the fresh concrete, after the slump test, in accordance with BS 1881(1983) part 108 and 110. The fresh concrete was placed in a cast iron cylinder mould with a diameter of 150mm and height of 300mm, and cube moulds of 150 mm x150 mm x150 mm in two layers. Each concrete layer was compacted by Roding in the manner specified by BS 1881(1983) part 108 and 110, after which the moulds with their contents were vibrated on an ELE vibrating table for 5 minutes, before storage for 24 hours to allow the concrete to set before demoulding and curing. The compressive strength of the concrete cubes were determined at ages of 7, 14, 28 and 56 days respectively, in accordance with BS 1881(1983) part 116.

Indirect tensile strength was determined using the cylindrical specimens after curing for 28days in accordance with BS 1881(1983) part 117. The cylindrical specimens were placed in a longitudinal mode in accordance with BS 1881(1983) part 117 to determine the maximum load sustained by the cylindrical specimen before failure. Indirect tensile strength was calculated using Equation (4) given as

$$\sigma_{ct}=\frac{2F}{\pi X l X d} \quad (4)$$

Where σ_{ct} = Indirect tensile strength, d = Diameter of cylinder in mm
l = Length of cylinder in mm, F = Maximum load applied to the cylinder in Newton.
In all tests for hardened concretes, triplicate specimens were used. The concrete specimens were cured by complete immersion in water, with the aid of a curing tank. The curing temperature was maintained at 30 ± 2°C.

RESULTS AND DISCUSSIONS

Particle size distribution curves of, fine and coarse aggregate used in concrete production is as shown in Figure 1. Makurdi river sand with a specific gravity and fineness modulus of 2.60 and 3.16, respectively belong to zone C of fine aggregate based on Neville and Brooks (1999).

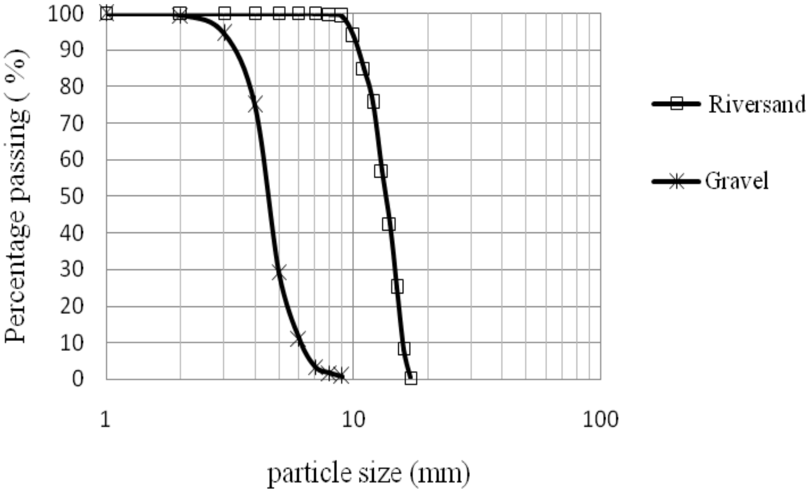

Figure.1 Particle size Distribution of River sand and Gravel.

The maximum size of gravel used as coarse aggregate as obtained from sieve analysis result was 37.5mm. The specific gravity of the gravel was 2.65, with aggregate impact and crushing values of 15% and 33%, respectively. These values are within the range of aggregate impact and crushing values of (9 – 35%) specified for crushed granite as recorded by O'Flaherty (1974), hence its suitability for use in concrete for rigid pavement. The cement content obtained from the mix design is in agreement with FHA (2000).

Chemical Analysis of RHA/OPC/CW

Oxide composition analysis of RHA, OPC and CW shown in Table 2 confirmed the status of RHA as a pozzolanic material with low calcium oxide composition, while CW is a non pozzolanic material with high calcium oxide content, the CaO component of RHA and CW are 1.36 % and 64%, respectively with Silicon dioxide (SiO_2) compositions values of 67.30 and 2.69%, respectively. Based on their oxide composition analysis, the use of CW and RHA to replace cement could help compensate for deficiencies in SiO_2 and CaO associated with the singular use of either CW or RHA to replace cement in concrete production. The specific gravities of cement, CW and RHA were determined to be 3.15, 1.90 and 2.07, respectively.

Table 2: Chemical Composition of Rice Husk Ash (RHA), Carbide Waste (CW) and Ordinary Portland Cement (OPC)

Elemental Oxide	Percentage Composition		
	RHA	OPC	CW
Fe_2O_3	0.95	2.50	0.17
MgO	1.81	1.94	0.80
SiO_2	67.30	20.40	2.69
Al_2O_3	4.90	5.75	1.78
CaO	1.36	64	61.41
SO_3	2.8	2.75	0.36
LOI	17.78	1.2	32.51

Setting Times

Addition of CW to RHA-cement mixture resulted in a decline in setting times at 10% CW, after which increase in setting times was observed with further addition of CW (see Table 3). Increase in setting times with CW and RHA can be attributed to low heat liberated during the hydration of cement-RHA – CW mixture which is responsible for slow rate of moisture evaporation and stiffening of the paste, as compared to high heat liberation during the hydration of cement which aids evaporation of moisture and stiffening of cement paste. The low heat liberation can be attributed to reactivity loss associated with the use of CW arising from storage and decrease in heat liberated by cement as it is partially replaced with CW and RHA.

Table 3: Setting Times Test Result.

Carbide Waste Content (%)	0	10	20	30	40
0 % Rice Husk Ash					
Initial setting Time(min)	100	106	119	132	156
Final setting Times (min)	134	140	180	200	250
10 % Rice Husk Ash					
Initial setting Time(min)	115	110	125	235	266
Final setting Times (min)	230	205	265	297	367
20 % Rice Husk Ash					
Initial setting Time(min)	150	130	150	247	270
Final setting Times (min)	280	270	300	368	400
30 % Rice Husk Ash					
Initial setting Time(min)	155	140	170	190	275
Final setting Times (min)	330	307	353	378	415

Slump Test

Slump test result presented in Table 4 indicated that slump values are within the range of 32-50 mm specified for concrete design for use in rigid pavement, specified by (FHA,2000). The implication is that, the addition of CW to RHA-cement combination can be used to produce concrete for use in rigid pavement within the required slump value. Water/cement ratio increased with the addition of CW to RHA-cement combination, this may be due to more water required for effective hydration of the combination of CW-RHA and cement arising from CW addition.

Table 4: Actual Water/Binder Ratio and Slump Values.

Carbide Waste Content (%)	0	10	20	30	40
0 % Rice Husk Ash					
Slump (mm)	40	40	40	45	40
Water cement Ratio	0.37	0.37	0.41	0.45	0.43
10 % Rice Husk Ash					
Slump (mm)	40	39	30	30	40
Water cement Ratio	0.37	0.36	0.41	0.48	0.52
20 % Rice Husk Ash					
Slump (mm)	33	40	40	40	45
Water cement Ratio	0.43	0.47	0.52	0.53	0.65
30 % Rice Husk Ash					
Slump (mm)	32	39	45	40	45
Water cement Ratio	0.52	0.56	0.73	0.73	0.74

Compressive Strength

Compressive strength test result (see Table 5) showed that the partial replacement of cement with either RHA or CW resulted in a decrease in compressive strength. Addition of CW to cement partially replaced with RHA resulted in peak 28 and 56 days compressive strength values of 35.00N/mm^{2}and 39.53N/mm,^{2} respectively, at a combination of 10% CW, 10% RHA and 80% cement. These values are adequate for concrete intended for use in rigid pavement construction and not too different from 28 days and 56 days compressive strength values of 37.11N/mm^2 and 40.00N/mm^2 obtained with the use of only cement as binder. Decrease in compressive strength was observed with further addition of CW to RHA - cement mixtures, such decrease can be attributed to the less reactive nature of lime contributed by CW, when compared with lime liberated during the hydration of cement, in addition to reactivity loss associated with the use of CW, arising from storage/delay in usage of CW immediately after the generation of the waste.

Another factor worthy of mention is imbalances in lime supplied by both CW and hydration of cement available for reaction with Silica from RHA at other combinations outside the combination of 10% CW and 10% RHA plus 80 % cement.

Table 5: Compressive strength of concrete obtained with the replacement of cement with different combinations of CW and RHA content (%)

CW (%)	0	10	20	30	40
0%RHA					
7d	23.11	16.44	15.11	11.11	9.78
14d	29.33	24.78	22.22	15.11	13.78
28d	37.11	30.07	24.89	17.78	16.00
56d	40.00	36.33	29.78	22.22	17.78
10%RHA					
7d	16.89	21.53	17.22	14.22	6.67
14d	24.89	25.33	21.00	16.00	9.33
28d	34.66	35.00	27.33	19.33	11.33
56d	36.73	39.53	30.67	24.67	14.67
20%RHA					
7d	17.33	18.33	12.89	9.78	5.00
14d	24.89	22.00	18.44	12.78	8.11
28d	30.67	27.78	21.11	17.56	10.22
56d	32.67	31.67	26.00	21.11	13.11
30%RHA					
7d	13.33	9.44	7.33	4.56	3.56
14d	18.67	14.02	10.33	7.78	5.78
28d	21.89	19.11	13.11	11.89	7.89
56d	26.00	21.24	16.78	13.56	11.78

Indirect Tensile Strength.

Indirect tensile strength of RHA-cement combination decrease with CW content after the attainment of peak values with the addition of 10% CW. Maximum indirect tensile strength value of 1.69N/mm^{2}was attained when 10% CW was mixed with 10% RHA and 80% cement. This value is close to the value of 1.71N/mm^2 obtained with the use of only cement as binder, reasons advanced for decrease in compressive strength is also responsible for the trend observed with indirect tensile strength. The relationship between indirect tensile strength of concrete made, with cement partially replaced with CW and RHA content is as shown in Figure 2.

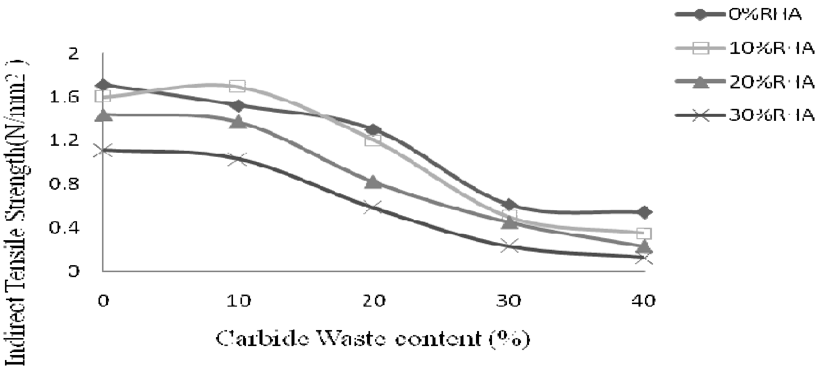

Figure 2 Relationship between CW, RHA and Indirect Tensile Strength.

CONCLUSIONS

Oxide composition analysis of CW shows that CW is a non pozzolanic material with high CaO content, and low SiO_2 content, while RHA is a pozzolanic material rich in SiO_2 component. Setting times of RHA-cement combination increased with CW content in paste made with cement partially replaced with RHA. Compressive strength and indirect tensile strength results shows that CW has effect on the strength of concrete made with RHA-cement combination. Compressive strength test result of concrete made with RHA-cement exhibited great improvement with the addition of 10% CW after which a decline in compressive strength was observed, similar trend was also observed with indirect tensile strength of cement-RHA-CW combination. Hence the recommendation of a combination of 10%RHA and 10% CW for use in concrete production for use in rigid pavement construction, because peak compressive strength at this replacement level is comparable with result obtained with the use of only cement as binder.

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