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Characteristics of Rice Husk-Admixed Conplast SP 430 Concrete

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ABSTRACT

Experimental work was mounted using 5.7 mL of the Conplast SP430 admixture and rice husk ash (RHA) at replacement levels of 0 to 50% at 10% intervals by wt. % of cement. It is on the performance of Conplast SP 430 admixture and its effects on concrete and concrete with rice husk ash. Concrete specimens were cast and cured for 3 to 90 days and subjected to slump and mechanical characteristics tests. Data generated from the experiments were analyzed and sensitivity analysis of the concrete mix was determined using the Minitab 18 Statistical Package. The results showed that CP with concrete improves the workability of the concrete and reduces water absorption. The reverse was the case when RHA was used with the admixture which may be an issue of compatibility. The statistical characteristics restrict good and within the specified limits.

Keywords: Rice husk ash; Admixture; Mechanical characteristics; Statistical analysis

1. Introduction

The construction concrete industry is one of the largest sources of greenhouse gas (GHG) emissions with a magnitude of 50% of the world's emissions [1]. Portland cement (PC) is one of the most important concrete parameters that contribute significantly to GHG [2]. Its manufacture contributes to global CO_2 emissions approximately 7% of the total emissions. The calcination of CaO in the production of cement contributes approximately 50% of the GHG emissions.

Today, a great number of agricultural wastes are used as cement replacement materials (CRMs) or supplementary cement materials (SCMs) and it is one such strategy that has resulted in a large decrease

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in the use of traditional Portland cement while also removing the hazards associated with the disposal of waste materials from diverse industries [3]. Recent sustainable research in concrete shows that the most effective strategy to lower the carbon footprint in the building sector is to substitute acceptable alternative cementitious materials for PC clinker [4]. Rice husk, a byproduct from rice processing has been used for concrete production based on the high percentage of the silicate content which is very high. The use of the material is by calcination of the husk to a temperature range of 400-600 °C. This produces ash of acceptable quality for concrete production [5].

Experimental data collected from these agricultural byproducts are subjected to variable factors ranging from an environment where they are grown to the prevailing climate. These are some of the reasons for data variabilities. RHA has been identified as a porous material with a large specific surface, and angular structure which can significantly affect the water demand [6,7]. Superplasticizers (SP) are widely used in concrete to limit water demand while improving the workability and maintaining or improving the strength of the concrete [7].

Conplast SP 430 admixture is used as the SP in this work. This use of Conplast SP 430 with RHA for concrete has not received wide publicity in the literature. The characteristics of the SP are shown in **Tables 1-3**. This superplasticizer conforms to ASTM-C-494-92 [8], chloride-free which is based on the selected sulfonated naphthalene polymers. It is a brown solution that disperses in water and is suitable for use with all types of Portland cement and cement replacement materials such as rice husk ash [9].

The performance of the product identified in **Table 2** is in conformity with the set of declared performance. This declaration of performance is issued in accordance with Regulation (EU) No 305/2011, under the sole responsibility of the manufacturer [9].

The thrust of this work, therefore, is an evaluation performance of CP as an admixture material and its possible effects on concrete and RHA-concrete. The acceptability of the experimental data on workability, water absorption, density, and the compressive strengths of RHA and RHA-CP concrete samples were confirmed using established statistical methods in Minitab 18 Software. These statistical measures include mean ($\bar{x}$), standard deviation (s), coefficient of determination (r^2), coefficient of variation (CoV), and performance index (ρ).

Table 1. Typical properties of Conplast SP 430.

Parameter	**Description**
Appearance	Brown liquid
Specific gravity	1.18 @ 25 °C
Chloride content	Nil to BS 5075/BS: EN934
Air entrainment	Less than 2% additional air is entrained at normal dosages

Table 2. Essential characteristics of Conplast SP 430.

Essential characteristics	Performance	Test method
Chloride ion content	≤ 0.1% by mass	EN934-2:2009
Alkali content	≤ 7.2 by mass	EN934-2:2009
Corrosion behavior	Contains only compounds according to EN 931-1-2008	EN934-2:2009
Water reduction	Test mix 12% with control	EN934-2:2009
Increase in consistence	Increase in slump ≥ 120 mm from initial (30 10 mm) Increase in flow ≥ 160 mm from initial (350 ± 20 mm)	EN934-2:2009
Retention of consistence	In 30 min after the addition, that mix value	EN934-2:2009
Compressive strength-equal consistence	At 1 day, test mix ≥ 140% of control mix. At 28 days, test mix ≥ 115% of control mix.	EN934-2:2009
Compressive strength-equal W/C ratio	At 28 days, test mix ≥ 90% of control mix. Test mix ≤ 2	EN934-2:2009
Dangerous substance	NPD (No Performance Declared)	
Durability	NPD (No Performance Declared)	

Table 3. Uses and advantages of Conplast SP 430 [9].

Uses

i. To provide excellent acceleration of strength gain at early ages and major increases in strength at all ages by significantly reducing water demand in a concrete mix.
ii. Particularly suitable for precast concrete and other high early strength requirements.
iii. To significantly improve the workability of site mixed and precast concrete without increasing water demand.
iv. To provide improved durability by increasing ultimate strengths and reducing concrete permeability.

Advantages

i. Major increases in strength at early ages without increased cement contents are of particular benefit in precast concrete, allowing earlier stripping times.
ii. Makes possible major reductions in water: cement ratio which allows the production of high-strength concrete without excessive cement contents.
iii. Use in the production of flowing concrete permits easier construction with quicker placing and compaction and reduced labour costs without increasing water content.
iv. Increased workability levels are maintained for longer than with ordinary sulphonated melamine admixtures.
v. Improved cohesion and particle dispersion minimises segregation and bleeding and improve pumpability.
vi. Chloride free, safe for use in prestressed and reinforced concrete

2. Materials and methods

2.1 Materials

The materials used are Ashaka Portland cement, rice husk ash, and Conplast SP 430 as the plasticizer. The cement conforms to BS EN 197 Part 1 [10] and was procured at the local market in Bauchi, Nigeria. The rice husk ash used to produce the ash was collected as a waste threshed out and separated from the rice grains. Therefore, it was collected as waste and calcined in the kiln of the industrial department of the university, at a temperature range of 400 °C to 600 °C, ground using a pestle and a mortar, and sieved using a sieve size of 150 μm. The physical and chemical properties were carried out in accordance with ASTM C 618-12 [11]. The cement chemical properties were tested at Ashaka Cement Company in Ashaka, Gombe State. The physical and chemical properties of the 'Ashaka' OPC and RHA are shown in **Table 4**.

Table 4. Physical and chemical properties of Ashaka Portland cement and rice husk ash.

Parameter	Cement	Rice husk ash
Physical properties		
Specific gravity	3.12	1.934
Fineness (%)	330 (kg/m^2)	20.2 (%)
Bulk density (kg/m^3) [ref]	830-1650	
Consistency (%)	29	
Initial setting time (min)	65	
Final setting time (min)	275	
Soundness (mm)	2.5	
LOI (%)	-	7.0
Chemical properties		
SiO_2	19.68	73.97
Al_2O_3	6.44	7.03
Fe_2O_3	3.32	1.19
CaO	60.92	0.96
MgO	0.97	2.45
SO_3	2.28	3.14
K_2O	0.85	2.78
Na_2O	0.12	0.90
TiO_2	0.30	Nil
P_2O_5	0.20	6.18
Mn_2O_3	0.20	1.40

2.2 Experiment

A mix proportion of 1:1.5:3, with a cement content of 370 kgm^{-3}, fine and coarse aggregates of 573 kgm^{-3}, and 1272 kgm^{-3}, respectively, and a water-cement ratio of 0.5. Using the Absolute Volume Method (ACI), it is a mix designed to have a minimum compressive strength of 25 Nmm^{-2} (M-25). Six (6) different mixes labeled MR-00, MR-10, MR-20, MR-30 MR-40, MR-50, and an improvement mix containing a 5.7 mL [12] dosage of Conplast SP 430 were used. They are designated as MR-00-CP to MR-50-CP and were cast. The concrete mix labeled MR-00/MR-00-CP is the control mix containing 0% of RHA/RHA-CP, while the other mixes labeled MR-10/MR-10-CP to MR-50/MR-CP-50, are RHA/RHA-CP, at 10%, 20%, 30%, 40%, and 50% replacement by wt. % of the ordinary Portland cement. A total of 180 concrete specimens (90 from each mix) were cast and cured for 3 to 90 days in a curing tank under laboratory conditions according to BS EN 12390 Part-2 [13]. Three samples were cast for each replacement level and tested for failure at the end of the curing regime. The above mix compositions were used for the following experiments to determine the mechanical characteristics of the RHA-concrete. They are the slump, density, water absorption, and cube compressive strength.

The slump of RHA concrete

This property of the concrete was carried out in a fresh condition. The slump test determines how workable the concrete is. The standard slump cone for the slump test was used for the test by BS EN 12350: Part 2 [14] specifications on all batches of concrete produced. Three (3) tests were conducted for each batch, and the average of the results was taken. The results are shown in **Table 5**.

The density, water absorption, and cube compressive strength of RHA concrete

These tests were carried out in the hardened state of the concrete using cube molds of 100 mm. The density and water absorption were tested by BS EN 12390 Part 7 [15] and BS EN 1097-6 [16] respectively, while the compressive strength was tested in accordance with EN 12390-3 [17]. For the compressive strength a universal testing machine (Model CT-700) with a capacity of 100 tonnes, and a uniform rate of loading of 0.3 $kNmin^{-1}$ was used. **Table 6** shows the results of the slump, density, water absorption, and compressive strength of RHA concrete.

Table 5. Slump of RHA concrete.

Mix No	SP dosage (mL)	Slump (mm)
MR-00	-	15.88
MR-10	-	15.20
MR-20	-	11.50
MR-30	-	10.97
MR-40	-	10.34
MR-50	-	9.86
MR-00-CP	5.7	37.00
MR-10-CP	5.7	35.00
MR-20-CP	5.7	30.00
MR-30-CP	5.7	25.00
MR-40-CP	5.7	20.00
MR-50-CP	5.7	18.50

Table 6. Mechanical characteristics of RHA concrete.

Property	Mix No	SP dosage (mL)	Density (kgm^{-3})				
			3 days	7 days	28 days	60 days	90 days
Density (kgm^{-3})	MR-00	-	2610	2690	2660	2670	2550
	MR-10	-	2560	2610	2610	2630	2660
	MR-20	-	2580	2630	2570	2670	2620
	MR-30	-	2650	2490	2510	2580	2680
	MR-40	-	2320	2290	2360	2290	2240
	MR-50	-	2350	2310	2410	2460	2290
	MR-00-CP	5.7	2560	2620	2630	2650	2530
	MR-10-CP	5.7	2620	2680	2700	2610	2590
	MR-20-CP	5.7	2400	2420	2520	2540	2560
	MR-30-CP	5.7	2480	2570	2390	2520	2600
	MR-40-CP	5.7	2390	2370	2370	2500	2540
	MR-50-CP	5.7	2380	2360	2310	2340	2300

Table 6 continued

Property	Mix No	SP dosage (mL)	Density (kgm^{-3})				
			3 days	7 days	28 days	60 days	90 days
Water absorption (%)	MR-00	-	0.84	1.19	1.15	1.14	1.13
	MR-10	-	1.15	1.22	1.16	1.15	1.15
	MR-20	-	1.19	1.32	1.19	1.18	1.18
	MR-30	-	1.18	1.33	1.29	1.18	1.13
	MR-40	-	1.15	1.32	1.30	1.19	1.12
	MR-50	-	1.20	1.35	1.31	1.20	1.19
	MR-00-CP	5.7	0.77	0.86	0.77	0.77	0.76
	MR-10-CP	5.7	1.15	1.13	1.12	1.16	1.17
	MR-20-CP	5.7	1.18	1.28	1.19	1.21	1.19
	MR-30-CP	5.7	1.17	1.29	1.27	1.19	1.16
	MR-40-CP	5.7	1.18	1.19	1.20	1.12	1.06
	MR-50-CP	5.7	1.19	1.31	1.30	1.25	1.20
Compressive strength (Nmm^{-2})	MR-00	-	15.88	22.41	33.69	36.10	40.42
	MR-10	-	15.20	22.46	33.05	40.91	46.01
	MR-20	-	11.50	17.25	23.24	33.12	37.72
	MR-30	-	10.97	15.63	20.13	31.67	34.41
	MR-40	-	10.34	13.48	19.04	25.70	30.19
	MR-50	-	9.86	12.11	17.74	23.64	25.92
	MR-00-CP	5.7	15.58	22.35	33.59	39.60	43.67
	MR-10-CP	5.7	17.10	21.91	33.36	41.74	47.81
	MR-20-CP	5.7	12.99	16.68	30.51	37.53	40.52
	MR-30-CP	5.7	10.62	15.73	26.32	33.53	36.57
	MR-40-CP	5.7	10.35	13.45	20.31	28.33	32.92
	MR-50-CP	5.7	9.85	11.78	19.21	25.13	28.45

3. Statistical characteristics of RHA concrete

The data on the experiments using the cube compressive strengths were subjected to a sensitivity analysis test using the Minitab 18 Software. The purpose of this is to assess the integrity of the RHA concrete data collected. This was observed using two variables of measurements, the *Curing Age,* and the *Mix.* Data analysis is quantitative and refers to sets of processes by which numerical data are analyzed. Often, it involves the use of statistical modeling such as standard deviation, mean, etc., and the presentation of correlation tests between two or more variables of significance, ultimately arriving at a conclusion. **Table 7** refers to the situation when the concrete age was considered as the variable, and **Table 8** to the situation when the Mix is considered as the variable.

3.1 Correlation and P-value

Correlation factors are used to measure the strength of the linear relationship between two variables, and a correlation coefficient greater than zero indicates a positive relationship while a value less than zero signifies a negative relationship. The correlation coefficient is given as:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad [Correlation]$$

where r = correlation factor.

Tables 9 and 10 are cases for the two variables (age and mix) in consideration.

Table 7. Statistical characteristics of RHA/RHA-CP (curing).

Variable Age	Additions	Mean	SE mean	StDev	Variance	CoefVar	Range	95% CI	
								Lower	Upper
3 d	RHA only	12.29	1.06	2.59	6.69	21.04	6.02	10.40	14.18
7 d		17.22	1.80	4.41	19.40	25.58	10.35	14.01	20.44
28 d		24.48	2.91	7.12	50.75	29.10	15.95	19.28	29.69
60 d		31.86	2.63	6.43	41.40	20.20	17.27	27.16	36.56
90 d		35.78	2.95	7.22	52.06	20.17	20.09	30.51	41.05
3 d	RHA + 5.7 mL Conplast	12.75	1.23	3.02	9.14	23.71	7.25	10.54	14.96
7 d		16.98	1.77	4.34	18.86	25.57	10.57	13.81	20.16
28 d		27.22	2.59	6.35	40.36	23.34	14.38	22.58	31.86
60 d		34.31	2.67	6.55	42.84	19.08	16.61	29.53	39.09
90 d		38.32	2.90	7.12	50.63	18.57	19.36	33.13	45.52

Table 8. Statistical characteristics of RHA/RHA-CP (mix).

Variable Mix	Additions	Mean	SE mean	StDev	Variance	CoefVar	Range	95% CI	
								Lower	Upper
M-0	RHA	29.70	4.56	10.20	103.98	34.33	24.54	21.71	37.69
M-10		31.53	5.70	12.74	162.22	40.40	30.81	21.54	41.51
M-20		24.57	4.86	10.87	118.05	44.23	26.22	16.05	33.08
M-30		22.56	4.54	10.14	102.92	44.96	23.44	14.61	30.52
M-40		19.75	3.69	8.26	68.19	41.81	19.85	13.28	26.22
M-50		17.85	3.13	6.99	48.86	39.15	16.06	10.37	23.33
M-0-CP	RHA + 5.7 mL Conplast	30.96	5.26	11.77	138.45	38.01	28.09	21.73	40.18
M-10-CP		32.38	5.79	12.94	167.44	39.96	30.71	22.24	42.53
M-20-CP		27.65	5.51	12.32	151.67	44.55	27.53	17.99	37.30
M-30-CP		24.55	5.00	11.18	125.02	45.54	25.95	15.79	33.32
M-40-CP		21.07	4.28	9.57	91.67	45.44	22.57	13.57	28.58
M-50-CP		18.88	3.62	8.10	65.68	42.92	18.60	12.53	25.24

3.2 Covariance

Covariance and correlation are very helpful in understanding the relationship between two continuous variables. Covariance tells whether both variables vary in the same direction (positive covariance) or in the opposite direction (negative covariance). Covariance between two variables x and y can be calculated as follows:

Tables 11 and 12 are results of the two variables, age and mix.

Table 9. Correlation and P-values of RHA concrete (curing).

Age	Addition	3 d	7 d	28 d	60 d
7 d	RHA only	0.98 (0.001)			
28 d		1.00 (0.000)	0.98 (0.000)		
60 d		0.88 (0.022)	0.95 (0.004)	0.89 (0.016)	
90 d		0.87 (0.023)	0.95 (0.003)	0.90 (0.015)	0.99 (0.000)
7 d	RHA + 5.7 mL Conplast	0.96 (0.003)			
28 d		0.91 (0.012)	0.95 (0.004)		
60 d		0.92 (0.010)	0.94 (0.005)	0.99 (0.000)	
90 d		0.95 (0.004)	0.95 (0.003)	0.96 (0.002)	0.99 (0.000)

Table 10. Correlation and P-value of RHA concrete (mix).

Mix	Additions	M-0	M-10	M-20	M-30	M-40
M-10	RHA only	0.99 (0.002)				
M-20		0.96(0.010)	0.99 (0.001)			
M-30		0.93 (0.020)	0.98 (0.004)	1.00 (0.000)		
M-40		0.96 (0.010)	0.99 (0.001)	1.00 (0.000)	0.99 (0.001)	
M-50		0.97 (0.008)	0.99 (0.001)	1.00 (0.000)	0.99 (0.001)	1.00 (0.000)
M-10	RHA + 5.7 mL Conplast	0.99 (0.002)				
M-20		0.96 (0.010)	0.99 (0.001)			
M-30		0.93 (0.020)	0.98 (0.004)	1.00 (0.000)		
M-40		0.96 (0.010)	0.99 (0.001)	1.00 (0.000)	0.99 (0.001)	
M-50		0.97 (0.008)	0.99 (0.001)	1.00 (0.000)	0.99 (0.001)	1.00 (0.000)

Table 11. Covariance of RHA concrete (curing).

Age	Additions	3 d	7 d	28 d	60 d	90 d
3 d	RHA only	6.69				
7 d		11.13	19.40			
28 d		18.34	30.87459	50.75		
60 d		14.56	26.96203	40.96	41.40	
90 d		16.31	30.24291	46.17	46.09	52.06
3 d	RHA + 5.7 mL Conplast	9.14				
7 d		12.56	18.86			
28 d		17.45	26.13	40.36		
60 d		18.14	26.78	41.09	42.84	
90 d		20.45	29.49	43.51	46.03	50.63

Table 12. Covariance of RHA concrete (mix).

Mix	Additions	M-0	M-10	M-20	M-30	M-40	M-50
M-0	RHA only	103.98					
M-10		128.28	162.22				
M-20		106.09	137.10	118.05			
M-30		96.58	126.37	109.79	102.92		
M-40		80.73	104.11	89.50	83.04	68.19	
M-50		68.85	88.38	75.55	70.23	57.49	48.86
M-0-CP	RHA + 5.7 mL Conplast	138.45					
M-10-CP		151.18	167.44				
M-20-CP		144.10	158.18	151.67			
M-30-CP		131.30	144.11	137.36	125.02		
M-40-CP		110.46	123.41	115.70	105.71	91.67	
M-50-CP		94.13	104.70	99.03	90.04	77.36	65.68

4. Discussion

4.1 Workability of RHA concrete

The workability of concrete is the ease of placing concrete. This property of concrete is affected by some factors like water content, mix proportion, aggregate size, shape, grading, texture, and the use of admixture. The slumps of the rice hush ash concrete and that to which 5.7 mL Conplast SP 430 are shown in **Figure 1**. The performance of CP is evaluated in three (3) stages: a) control mix; b) addition of RHA, and c) addition of CP to RHA, respectively.

The purpose of the addition of CP to a concrete mix is to limit the water demand while improving workability. Thus, the addition of CP to concrete achieved a consistency of 37 mm, compared to the control mix. This is lower than the manufacturer's specification of ≥ 120 mm. This is approximately 69% lower than the specified. Additions of RHA to the mix achieved a consistency range of 15.2 mm to 9.9 mm, a reduction in workability of 4.3% to 37.9%. This behavior has been attributed to the texture and amorphous nature of the RHA [5]. The addition of CP to concrete-RHA mix recorded a consistency range of 30 mm to 18.5 mm. Superplasticizers (SPs) are generally negatively charged (anionic) polymers, which tend to adsorb the positively charged (cationic) surfaces and the products formed from the hydration process. RHA particles are porous, and the CP polymers may get trapped in the pores. This is presumed to hinder dispersion by steric repulsion, compromising the efficiency to enhance the workability [6]. This could be seen as a reduction of 18.9% to 50.0%, respectively.

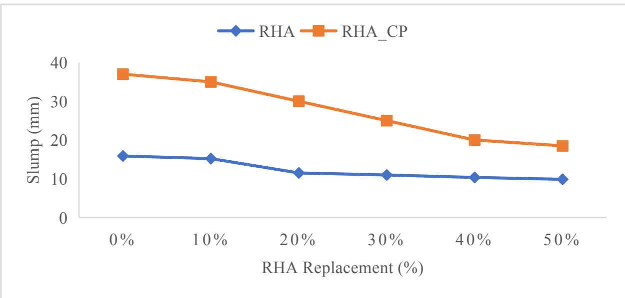


Figure 1. Slump of RHA/RHA-CP concrete.

4.2 Water absorption of RHA concrete

The water absorption of RHA concrete is a function of the characteristics of the constituent materials of the concrete. The levels to which the addition of CP admixture has transformed the concrete mix (Control) are evaluated from the results given in **Table 5**. This shows the addition of CP to concrete has a decreasing effect on water absorption. This ranges from 8.3% to 33% as the age of concrete increases. Therefore, it can be concluded that the addition of CP reduces the water absorption and densifies the concrete. This is in line with the assertions of the manufacturers (≥ 12%) [9]. On average 26.8% can be assumed to be achieved when CP is used in concrete.

The effect of adding RHA to a concrete mix from the experimental data shows the reverse. The water absorption increased rather than decrease. The same findings have been acknowledged by previous research and have been attributed to the texture and amorphous nature of RHA [5]. Not only that RHA is a porous material that has a very large specific surface area, but also has an angular structure [7,8], as shown in **Figure 2**. However, this increase reduces as curing progresses, but increases as the percentage replacement of cement by wt. % of RHA continues. It is equally noticed with interest the high-water absorption recorded for the early age of 3 days. This occurs from 10% to 50% replacements. To be able to have a realistic evaluation of how RHA did affect the water absorption, the total average is calculated, and this is 12.8%. Therefore, the addition of RHA to concrete will increase the water absorption by approximately 12.8%.

The effect of adding CP to RHA concrete mixture was also evaluated. The results from **Table 6** show that this addition did not reduce the water absorption but rather increased the water absorption. This behavior may be a compatibility problem between the admixture CP-SP430 and the RHA. A total average of 52.9% is recorded as an increase. These total averages of 12.8% and 52.9% respectively, for RHA and RHA-CP, are based on comparing the performances of RHA and RHA-CP, with their control mixes respectively. The results are remarkable. Therefore, further investigations on the compatibility of RHA and CP are advocated. Evaluating the effect of CP on the mixes, RHA and RHA-CP minimal reduction of approximately 1.4% on the replacement levels is observed. This can be a further pointer to the fact that the use of CP as an admixture with RHA may not be compatible.

4.3 Density of RHA/RHA-CP concrete

The density of a material is an important property that is tied to the characteristics like the strength of the material. The evaluation of the density of RHA and RHA-CP shows that additions of RHA and RHA-CP to a concrete mix are beneficial up to 30%, for RHA and RHA-CP, respectively, giving rise to densities ≥ 2400 kgm^{-3} ((Nor/Concrete). These satisfy their appropriateness to be used for reinforced concrete. Replacements from 40% to 50% could be used appropriately for lightweight concrete since their densities are ≥ 2200 ≤ 2400 kgm^{-3} (L/Concrete). However, it is seen from **Table 13** that there are abnormalities at 60 days and 90 days at 40% replacement, which registered densities ≥ 2400 kgm^{-3}. One of the reasons for the high values of the densities registered is because of the pozzolanic actions of the RHA and the impact of the CP admixture.

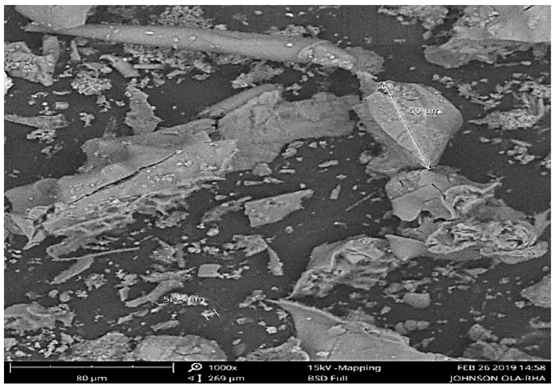


Figure 2. Scanning electron microscope (SEM) image of a RHA particle.

4.4 Compressive strength of RHA/RHA-CP concrete

Figures 3a and 3b are plots of the compressive strengths of RHA, and RHA-CP concrete obtained from **Table 6**. The characteristics depicted by the two mixes are similar. Both have their maximum compressive strengths at a maximum replacement of 10%. The addition of CP therefore seems not have visible effects on the maximum replacement level. It is also observed that the effectiveness of the addition of CP admixture starts after 28 days of curing. This is confirmed by the reductions recorded from 3 days to 28 days (1.9%, 0.3%, 0.3%).

Table 14 shows the classification chart useful as a tool for concrete works specifications. Three (3) classes of concrete grades are identified, and these are as follows:

a. Blinding concrete whose strength is < 15 kNm^{-2}. (blinding)

b. Lintel concrete > 15 $kNmm^{-2}$ < 20 kNm^{-2}. (lintel)

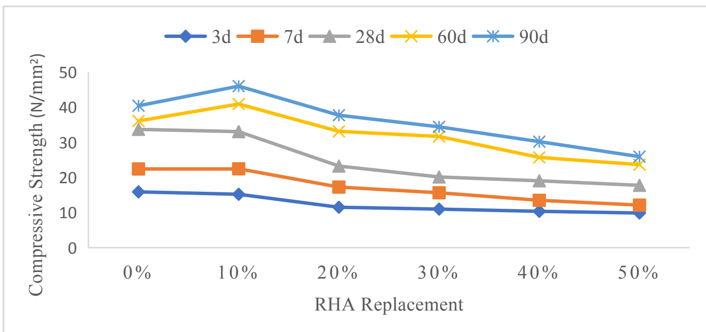
c. Reinforced concrete > 20 kNm^{-2}. (r/concrete)

4.5 Statistical characteristics

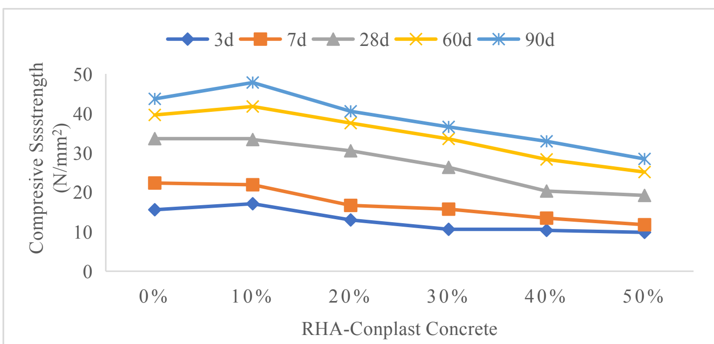
The mean represents the average value in a dataset and is important because it gives us an idea of where the centre value is in a dataset. It is also important because it carries a piece of information from *every* observation in a dataset. **Figures 4a and 4b** show the distribution of the means for RHA and RHA-CP mix, respectively. The effects show generally that both the RHA and the addition of Conplast to RHA gave a gradual increase in the mean as the age of the concrete increased. While, for **Figure 4a** the increase is pronounced from 28 days of curing and continues until 90 days however, minimally. For **Figure 4b**, the maximum mean is at 10% both for RHA and RHA-CP. Thus, it could be inferred that

Table 13. Density classification of RHA/RHA-CP.

Type	*Repl (%)*	*3 d*	*7 d*	*28 d*	*60 d*	*90 d*
RHA	10	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	20	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	30	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	40	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete
	50	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete
RHA-CP	10	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	20	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	30	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete	Nor/Concrete
	40	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete
	50	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete	LW/Concrete



(a)



(b)

Figure 3. Compressive strength of RHA/RHA-CP concrete.

both RHA and the use of Conplast are beneficial to the concrete mixture.

The characteristics of the data in **Table 7** have specifics. It shows that the values of the coefficient of variation (COV) are 21.04, 25.58, 29.10, and 20.20. These data reflect the size of the standard deviation to the mean and show consistency of performance. The consistent performance is further confirmed by the confidence limit (CI), which shows that the mean falls within the limits of CI.

Table 15 further shows the characteristics of the RHA/RHA-CP concrete based on the correlation and covariance analysis and their implications. As highlighted previously **Correlation** tells us both the strength and the direction of this relationship, while **Covariance** indicates the extent to which two random variables increase or decrease in tandem with each other. These principles of analysis are applied to the two variables of consideration the Curing and the Mix, respectively. The results of the analysis shown in **Table 15** confirm the acceptability of using CP with RHA. The correlation and correlation factors are high. Equally the covariances along the row (Age, days) and down the column (Replacement %) exhibit notable characteristics, confirming the maximum performance at 10% replacement [5].

Table 14. Strength classification chart of RHA/RHA-CP.

Type	*Repl (%)*	*3 d*	*7 d*	*28 d*	*60 d*	*90 d*
	10	blinding	r/concrete	r/concrete	r/concrete	r/concrete
	20	lintel	blinding	r/concrete	r/concrete	r/concrete
RHA	30	lintel	blinding	r/concrete	r/concrete	r/concrete
	40	lintel	lintel	blinding	r/concrete	r/concrete
	50	lintel	lintel	blinding	r/concrete	r/concrete
	10	blinding	r/concrete	r/concrete	r/concrete	r/concrete
	20	lintel	blinding	r/concrete	r/concrete	r/concrete
RHA_CP	30	lintel	blinding	r/concrete	r/concrete	r/concrete
	40	lintel	lintel	r/concrete	r/concrete	r/concrete
	50	lintel	lintel	r/concrete	r/concrete	r/concrete

Table 15. Correlation and P-value, covariance of RHA/RHA-CP.

Variable	**Type**	**Correlation**		**Covariance**	
		r^2	(ρ)	Row	Column
Curing	RHA	$0.88 \le r < 1.0$	$0.023 \le \rho \le 0.005$	Increase	Decrease
	RHA-CP	$0.91 \le r < 1.00$	$0.012 \le \rho < 0.005$	Increase	Increase
Mix	RHA	$0.93 \le r < 1.0$	$0.020 \le \rho < 0.005$	Max-10% > 10% Decrease	Max-10% > 10% Decrease
	RHA-CP	$0.93 \le r < 1.0$	$0.020 \le \rho < 0.005$	Max-10% > 10% Decrease	Max-10% > 10% Decrease

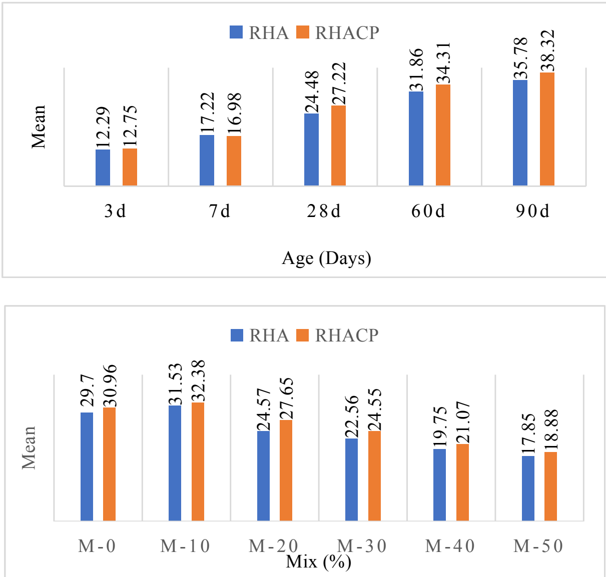


Figure 4. Mean values of RHA/RHA-CP.

5. Conclusions

This work presents an evaluation test on CP admixture and its effects on concrete and concrete-RHA mixes. The conclusions are as follows:

The addition of CP admixture to concrete (Control) improved the workability marginally and reduced water absorption. While the addition of RHA to concrete reduced the workability because of its texture which absorbs water and increased the water absorption. The texture of RHA and the non-compatibility of CP with RHA are probable factors that caused the water absorption to increase when RHA and CP are used together.

The densities and the compressive strengths of RHA and RHA-CP concrete are high and good for reinforced concrete. The maximum strength of 25 kNm^{-3} is achieved at 10% replacement.

The statistical characteristics of the results on the test samples of the concrete-RHA and concrete-RHA-CP mixes show that the use of RHA and CP admixture for concrete production produces reliable concrete. The means of the test results and other characteristics are within the derived limits. The correlations (r^2) and correlation factors (ρ) show good interactions between the concrete parameters. The covariances confirm that hydration proceeded as curing continues confirming the maximum replacement to be at 10%.

Conflict of Interest

There is no conflict of interest.

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