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Effect Of Partial Replacement of Fine Aggregate Using Rice Husk Ash in Concrete Mixture

Okafor Chinedum Vincent [1], Okolie Kevin Chuks [2], Okeke Arinze Uchenna [1]

[1]*Student, Department of Building, Nnamdi Azikiwe University, Awka, Nigeria.*

[2]*Professor, Department of Building, Nnamdi Azikiwe University, Awka, Nigeria.*

Corresponding Author: cv.okafor@unizik.edu.ng

Abstract: - This study was carried out to assess the Effect of partial replacement of fine aggregate using rice husk ash in concrete mixture**.** The study was performed by replacing percentages of fine aggregate with rice husk ash in order to produce a concrete of minimum compressive strength of $16.9N/mm^2$ for structural lightweight concrete. A total of 45 concrete cubes of 150 x 150 x 150(mm) was casted and cured. The percentage of rice husk ash were limited to 0%, 5%, 10%, 15%, and 25% by volume. The workability, slump and particle size analysis of the samples were monitored. The compressive strength, water absorption and comparative weight loss at the curing age of 7days, 14days and 28days were also conducted. The study found out that the compressive strength decreased with increase in the proportion of rice husk ash and the concrete workability decreased with the increase in the proportion of rice husk ash at a constant water-cement ratio. From the result of the experimental analysis carried out, the optimum partial replacement by volume of (80% sand and 20% RHA) gave the recommended compressive strength of $16.9N/mm^2$.

Key Words: - ***Rice Husk Ash, Sand, Compressive Strength, Weight, Water Absorption Test.***

I. Introduction

Lightweight concrete has been used for more than 2000years [1]. The notable lightweight structure includes the port of cosa, the pantheon dome and the coliseum [2]. Lightweight concrete is a special concrete which weighs lighter than conventional concrete. The dry density of a lightweight concrete is considerably low (300kg/m^3 to 1850kg/m^3) when compared to conventional concrete (2200kg/m^3 to 2600kg/m^3). Light weight concrete was first introduced by the Romans in the second century where the pantheon has been constructed using pumice [3]. From there on, the lightweight concrete has been widely spread across other countries. According to [4], the use of lightweight aggregate is by far the simplest and most commonly method of making a lightweight concrete.

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The aim of this research is to assess the Effect of partial replacement of fine aggregate using rice husk ash in concrete mixture. This aim was pursued with the following objectives:

- To determine the value of the compressive strength of the conventional concrete at 7-, 14- and 28-days curing period from the mix design adopted for the study.
- To determine the compressive strength of the lightweight concrete produced from the partial replacement of the fine aggregate by rice husk ash at 7, 14 and 28 days of curing respectively.
- To compare the weight of concrete produced using rice husk ash at different percentage replacement to that of normal concrete grade 20.
- To determine the percentage of water absorption rate of the lightweight concrete produced from the partial replacement of the fine aggregate by rice husk ash at 7,14- and 28-days curing period respectively.

II. Research Design

The various materials used in the experimental work are fine aggregate (sand and rice husk ash), coarse aggregate and water. The rice husk ash was burnt for approximately 60 hours under uncontrolled combustion process. The burning temperature was within 600-850c^0. The physical and chemical characteristics of the rice husk ash was determined from laboratory testing. On the backdrop of the literature, the percentage variation in fine aggregate replacing material was decided. Batching of the materials was done by volume. The percentage replacement of sand by rice husk ash was at 0%, 5%, 10%, 15%, 25% and 30% by volume in order to determine the optimal percentage replacement of sand that will produce a minimum compressive strength of concrete strength of $^{16.9N}/_{MM^2}$.

A total of 45 concrete cubes samples was casted (3 cube specimen for each curing period). The design concrete mix method (British Department of Environment Method) was adopted to determine the exact amount of material required to produce a 1m^3 of concrete. The compressive tests on the concrete cubes were carried out with the COMTEST Crushing machine at the IDC Construction Company Amansea, Awka, Nigeria at 7- and 28-days curing period. The compressive test was done in accordance with [5].

III. Particle Size Analysis

Table 1.0 and 1.1 shows the particle size distribution analysis carried out on the sand and rice husk ash respectively. In accordance with the guidelines specified by [6].

Table 1.0: Particle Size Distribution for Sand

PAN MASS=100.0g Initial Dry Sample mass+Pan=598.1g	Initial dry sample=498.1g Reference = BS 1377, Part 2,1990

Sieve size	Mass retained	% Weight retained	Cumulative % retained	%passing
6.3	**0**	**0**	**0**	**100**
2.36	**3.3**	**0.660**	**0.66**	**99.34**
1.12	**19.5**	**3.915**	**4.575**	**95.43**
0.8	**41.7**	**8.372**	**12.94**	**87.05**
0.425	**253.2**	**50.83**	**63.77**	**36.23**
0.390	**67.7**	**13.59**	**77.37**	**22.63**
0.150	**112.7**	**22.63**	**99.99**	**0**

Table 1.1: Particle Size Distribution for Rice husk ash

PAN MASS=100.0g Initial Dry Sample mass+Pan=412.5g	Initial dry sample=312.5g Reference = BS 1377, Part 2,1990

Sieve size	Mass retained	% Weight retained	Cumulative % retained	%passing
6.3	**0**	**0**	**0**	**100**
2.36	**0.3**	**0.096**	**0.96**	**99.0**
1.17	**8.2**	**2.62**	**3.58**	**96.4**
0.60	**20.3**	**6.49**	**10.1**	**89.9**
0.425	**122.0**	**39.0**	**49.1**	**50.8**
0.300	**40.2**	**12.8**	**61.9**	**38.0**
0.150	**66.1**	**21.2**	**83.1**	**16.8**
0.0075	**25.2**	**8.06**	**91.2**	**8.8**
Pan	**30.2**	**9.66**	**100**	**0**

Table 1.0 and Table 1.1 shows the presentation of the particle size distribution for sand and rice husk ash respectively.

The mass of both sand and rice husk ash retained on each sieve size was obtained by subtracting the weight of the empty sieve from the mass of the sieve + the retained sand/Rice husk ash respectively, and the mass was recorded as weight retained on the data sheet. The sum of the retained mass was approximately equal to the limited mass of the soil sample. A loss of mass than two percent is termed unsatisfactory.

The percentage retained for both the sand and rice husk ash respectively was obtained by dividing the weight retained on each sieve by the original sample mass.

The percentage passing for both the sand and rice husk ash respectively was calculated by starting from 100% and subtracting the percentage retained on each sieve as a cumulative procedure.

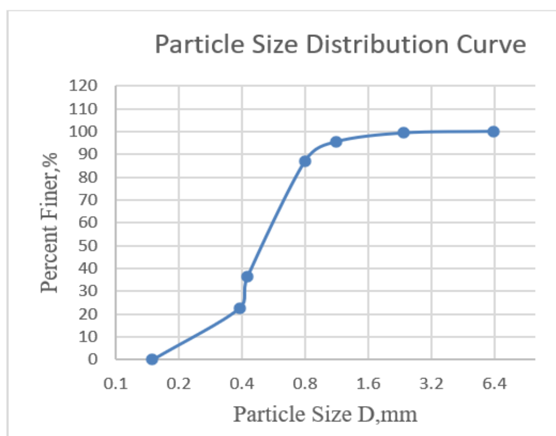

Figure 1.0: Particle Size Distribution Curve for Sand

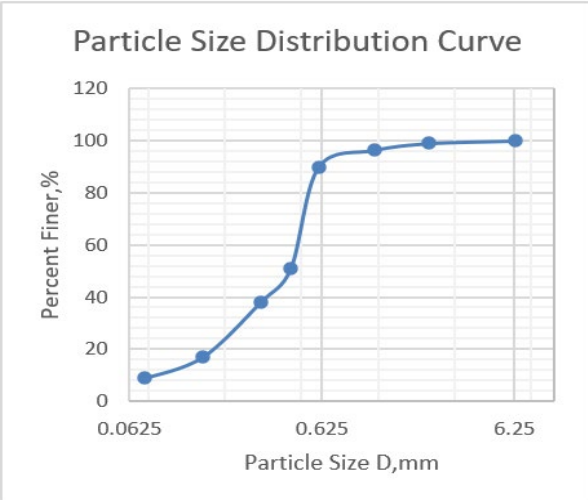

Figure 1.1: Particle Size Distribution Curve for RHA

Figure 1.0 and 1.1 shows the particle distribution curve for both the sand and the rice husk ash respectively. A flat S – Curve, such as the curve on figure 1.0 and 1.1 represents a sample which contains particles of different sizes in good proportion. Such a sample is called a well graded or uniformly graded sample. The uniformity of a soil is expressed quantitatively by a term known as uniformity coefficient, C_U, given by $C_U = \frac{D_{60}}{D_{10}}$.

Where D_{60} =particle size such that 60% of the sand or rice husk ash is finer than this size and

D_{10} = Particle size such that 10% of the sand or rice husk ash is finer than this size

Uniformity Coefficient for the sand $C_U = \frac{D_{60}}{D_{10}} = \frac{0.58}{0.22} = 2.63$

Uniformity Coefficient for the rice husk ash $C_U = \frac{D_{60}}{D_{10}} = \frac{0.5}{0.085} = 6.25$

The uniformity coefficient of sand (2.63) and Rice husk ash (6.25) are very good values. This indicates that the two specimens are graded (uniformly and well graded respectively) and are suitable for fine aggregate. The grading indicates that rice husk ash can replace sand as fine aggregate without adverse effects on the concrete due to the occurrence of voids or pore space in the hardened concrete.

IV. Design Of The Concrete Mix According To The British Department Of Environment Method

To design concrete mix within stipulations for proportioning.

Characteristic C.S= 16.9N/mm^2 with a 2.5% defective rate.

Portland cement Class = 42.5

Slump Required= 10-30mm

Max Aggregate Size = 20

Fine aggregate 70% passing through a 600μm sieve size.

Max Free water/cement ratio = 0.5

Max cement content = $270 {kg}/{m^2}$

Step 1:

Margin = K (Risk Factor) x S

Where K is the risk factor = 1.96(Risk factor is taken on the assumption that 1.98% of the results are allowed to fall below the specified characteristic strength).

S is the standard deviation = 7.5(Max value of Standard deviation)

Margin = K x S = 1.96 X 7.5= $14.70N/MM^2$.

$F_M = F_C + M =$
$16.9N/MM^2 + 14.70N/MM^2 = 31.60N/MM^2$

Where F_M is the Target mean strength and F_C is the characteristic compressive strength.

Step 2:

From (British Standard Method of Mix Design), Compressive strength after 28Days =$49N/MM^2$.

From (British Standard Method of Mix Design), Free water/cement ratio = 0.62

$0.62 > 0.5$

Therefore, we use 0.62.

From (British Standard Method of Mix Design), free water content = $190Kg/m^3$.

$\frac{watercontent}{cementcontent} = 0.62$

Step 3:

Cement content =$\frac{watercontent}{0.62} = \frac{190kg/m^2}{0.62} = 306kg/m^3$

Step 4:

From (British Standard Method of Mix Design), wet density of concrete mix = $2450kg/m^3$

Remember that wet density of concrete= density of water + density of cement + density of aggregate (fine and coarse aggregate).

$2450kg/m^3 = 190kg/m^3 + 306kg/m^3 + D_{Agg}$

$D_{Agg} = (2450 - 190 - 306)\ kg/m^3 = 1954kg/m^3$

Step 5:
From (British Standard Method of Mix Design), proportion of fine aggregate = 30% which means that out of $1954kg/_{m^3}$,
Fine aggregate constitutes $\frac{30}{100} x\ 1954 = 586kg/_{m^3}$.
Course Aggregate = $1954kg/_{m^3} - 586kg/_{m^3} = 1368kg/_{m^3}$

Step 6:
Final Mix Proportions

Table 1.3: Final Mix Proportion

QUANTITIES	CEMENT (kg)	WATER (kg)	FA	CA 10mm	20 mm
Per m^3	306	190	586	456	912
0.00375 m^3	1.148	0.713	2.197	1.71	3.42

Source: Mix calculation per volume of concrete

Trial mix [(0.1 x 0.1 x 0.1) x 3] + [25% Contingency of trial mix volume]
0.003 + 0.00075 = 0.00375m^3.
If the maximum aggregate size is 20mm, the ratio = 1:2
If the maximum aggregate size is 40mm, the ratio = 1:1.5:3
Since our maximum aggregate size is 20mm, therefore, $\frac{1}{3} x\ 1368 = 456kg/_{m^3}$(10mm aggregate).

$\frac{2}{3} x\ 1368 = 912kg/_{m^3}$(20mm Aggregate).

V. Results And Discussion

The data collected during the experiment was analyzed using One-Way Analysis of Variance (ANOVA), the description was used to show the mean of the observations and the mean plot showed a clearer view of the difference in mean across various percentage replacement of sand using Rice Husk Ash.

5.1 Objective 1

To determine the compressive strength of the lightweight concrete produced from the partial replacement of the fine aggregate by rice husk ash at 7, 14 and 28 days of curing respectively.

5.1.1 Compressive Strength After 7 Days

Table 1.3: Descriptive Statistics of Compressive Strength of Concretes after 7 Days

Percentage Replacement	N	Mean (N/mm^2)	Std. Deviation	Minimum (N/mm^2)	Maximum (N/mm^2)
100% sand, 0% RHA	3	19.69	0.575	19.12	20.27
85% sand, 15% RHA	3	16.02	0.092	15.92	16.09
90% sand, 10% RHA	3	16.85	0.762	15.97	17.29
95% sand, 5% RHA	3	17.36	0.259	17.06	17.51
80% sand, 20% RHA	3	8.700	0.793	7.80	9.30
75% sand, 25% RHA	3	8.000	0.264	7.80	8.30
Total	18	86.63	2.748	83.67	88.76

Table 1.3 showed that after 7 days, concretes produced without RHA replacement (100% sand) developed a mean compressive strength of 19.69N/mm^2, with its minimum and maximum value at 19.12N/mm^2 and 20.27N/mm^2 respectively. It also shows that at 85% sand and 15% RHA, the mean compressive strength reduced to a value of 16.03N/mm^2 and its minimum and maximum values were 15.92 N/mm^2 and 16.09N/mm^2respectively. At 90% sand and 10% RHA, the value of the mean compressive strength further reduced to 16.85mpa with its minimum and maximum values at 15.97N/mm^2 and 17.29N/mm^2 respectively. The table also shows that at 95% sand and 5% RHA, the value of the mean compressive strength of the concrete produced was 17.36N/mm^2 with its minimum and maximum values at 17.06N/mm^2 and 17.51N/mm^2 respectively. At 80% sand and 20% RHA, the mean compressive strength of the concrete produced was 8.70N/mm^2 and its minimum and maximum values were 7.80N/mm^2 and 9.30N/mm^2 respectively. Lastly at 75% sand and 25% RHA, the value of the mean compressive strength of the concrete produced was 8.00N/mm^2 and its minimum and maximum values were 7.80N/mm^2 and 8.30N/mm^2 respectively.

Table 1.4: ANOVA Test for compressive strength after 7 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	356.717	5	71.343	253.656	.000
Within Groups	3.375	12	.281		
Total	360.092	17			

From table 1.4, the ANOVA test shows that there is a significant difference between the mean compressive strength of the different levels of partial replacement of RHA with F= 253.656, significant value = 0.000 at $\alpha = 0.05$.
The means plot of the data is shown below:

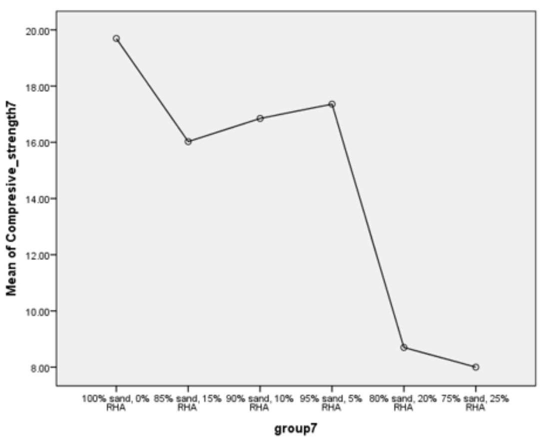

Fig. 1.2: Means plot of the compressive strength of the different levels of partial replacement of RHA after 7 days

The means plot shows that 100% sand has greater mean, followed by (95% sand 5% RHA), then (75% sand 25% RHA) has the least mean.

5.1.2 Compressive Strength After 14 Days

Table 1.5 shows that after 14 days, the concretes produced at 100% sand had a mean compressive strength value of $21.39N/mm^2$, with a minimum value of $19.29N/mm^2$ and maximum value of $22.68N/mm^2$. Also, it shows that at 85% sand and 15% RHA, the mean compressive strength value after 14 days curing period was $16.94N/mm^2$ with its minimum and maximum values at $16.12N/mm^2$ and $17.96N/mm^2$ respectively.

Table 1.5: Descriptive Statistics of Compressive Strength of Concretes after 14 Days

Percentage Replacement	N	Mean (N/mm^2)	Std. Deviation	Minimum (N/mm^2)	Maximum (N/mm^2)
100% sand, 0% RHA	3	21.39	1.838	19.29	22.68
85% sand, 15% RHA	3	16.94	0.934	16.12	17.96
90% sand, 10% RHA	3	17.50	0.450	17.05	17.95
95% sand, 5% RHA	3	19.27	1.371	17.75	20.41
80% sand, 20% RHA	3	13.56	0.208	13.40	13.80
75% sand, 25% RHA	3	11.56	0.802	10.80	12.40
Total	18	166.9	5.604	94.41	105.2

At 90% sand and 10% RHA, the mean compressive strength of the concrete increased to a value of $17.50N/mm^2$ with its minimum and maximum values at $17.05N/mm^2$ and $17.95N/mm^2$ respectively. At 95% sand and 5% RHA, the mean compressive strength further increased to $19.27N/mm^2$ with its minimum and maximum values at $17.75N/mm^2$ and $20.41N/mm^2$ respectively. At 80% sand and 20% RHA, the mean compressive strength reduced to a value of $13.57N/mm^2$ with its minimum and maximum values at $13.40N/mm^2$ and $13.80N/mm^2$ respectively. Lastly at 75% sand and 25% RHA, the value of the mean compressive strength of the concrete produced was $11.57N/mm^2$ and its minimum and maximum values were $10.80N/mm^2$ and $12.40N/mm^2$ respectively.

Table 1.6: ANOVA Test for compressive strength after 14 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	196.65	5	39.331	33.60	.020
Within Groups	14.046	12	1.170		
Total	210.70	17			

From table 1.6, the ANOVA test shows that there is a significant difference between the mean compressive strength of the different levels of partial replacement of RHA with F= 33.603, significant value = 0.020 at α = 0.05.
The means plot of the data is shown below:

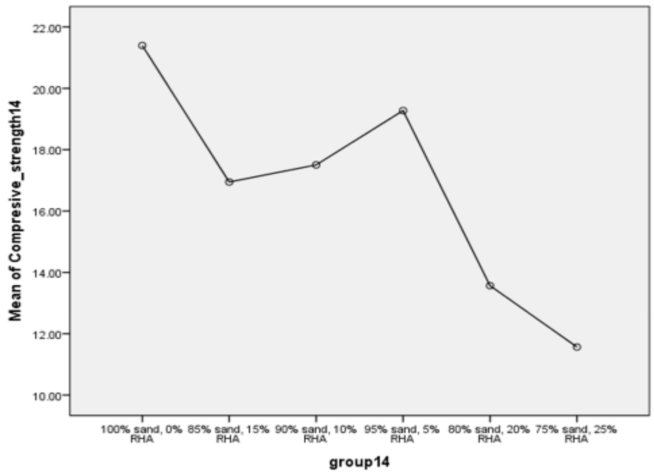

Fig. 1.3: Means plot of the compressive strength of the different levels of partial replacement of RHA after 14 days

The means plot shows that 100% sand has greater mean, followed by (95% sand and 5% RHA), meanwhile (75% sand and 25% RHA) has the least mean.

5.1.3 Compressive Strength After 28 Days

Table 1.7: Descriptive Statistics of Compressive Strength of Concretes after 28 Days

Percentage Replacement	N	Mean (N/mm^2)	Std. Deviation	Minimum (N/mm^2)	Maximum (N/mm^2)
100% sand, 0% RHA	3	24.77	0.87573	24.14	25.77
85% sand, 15% RHA	3	19.29	0.51287	18.74	19.75
90% sand, 10% RHA	3	19.74	0.13748	19.62	19.89
95% sand, 5% RHA	3	20.64	0.19655	20.42	20.79
80% sand, 20% RHA	3	16.93	0.35119	16.60	17.30
75% sand, 25% RHA	3	13.70	0.50000	13.20	14.20
Total	18	115.1	2.57382	112.72	117.7

Table 1.7 shows that after 28 days, concretes produced at 100% sand had a mean compressive strength value of $24.77N/mm^2$ with minimum value of $24.14N/mm^2$ and maximum value of $25.77N/mm^2$. Table 1.7 also shows that at 85% sand and 15% RHA, the value of the mean compressive strength of the concrete produced was $19.29N/mm^2$ with its minimum and maximum values at $18.74N/mm^2$ and $19.75N/mm^2$ respectively. At 90% sand and 10% RHA, the value of the mean compressive strength was 19.74 and its minimum and maximum values were $19.62N/mm^2$ and $19.89N/mm^2$ respectively. At 95% sand and 5% RHA, the mean compressive strength was $20.64N/mm^2$ with its minimum and maximum values at $20.42N/mm^2$ and $20.79N/mm^2$ respectively. At 80% sand and 20% RHA, the value of the mean compressive strength was 16.933 and its minimum and maximum values were $16.60N/mm^2$ and $17.30N/mm^2$ respectively. Lastly at 75% sand and 25% RHA, the value of the mean compressive strength was $13.70N/mm^2$ and its minimum and maximum values were $13.20N/mm^2$ and $14.20N/mm^2$ respectively.

Table 1.8: ANOVA Test for compressive strength after 28 days

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	206.38	5	41.277	169.5	.000
Within Groups	2.922	12	0.243		
Total	209.305	17			

From table 1.8, the ANOVA test shows that there is a significant difference between the mean compressive strength of the different levels of partial replacement of RHA with F= 169.538, significant value = 0.000 at α = 0.05.
The means plot of the data is shown below:

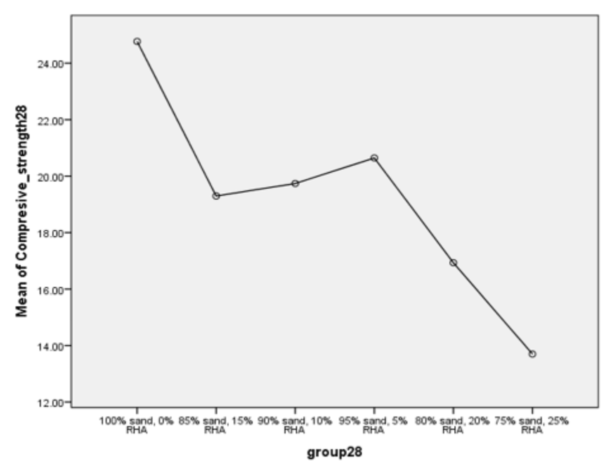

Fig. 1.4: Means plot of the compressive strength of the different levels of partial replacement of RHA after 28 days

The means plot shows that 100% sand has greater mean compressive strength, followed by (95% sand 5% RHA), whereas (75% sand 25% RHA) has the least mean compressive strength.

Nevertheless, we can clearly find out that at the partial replacement of sand by 20% RHA, we got a mean observation of $16.97N/mm^2$ compressive strength which is approximately $17N/mm^2$.

Therefore, the optimum partial replacement quantity by volume of 80% sand and RHA 20%, gave us a concrete of $16.9N/mm^2$ compressive strength as recommended for this research work.

5.2 Objective 2

To determine the percentage of water absorption rate of the lightweight concrete produced from the partial replacement of the fine aggregate by rice husk ash at 7-, 14- and 28-days curing period respectively.

5.2.1 Water Absorption After 7 Days

Table 2.1: Descriptive Statistics water absorption of RHA Concrete after 7 days

Percentage Replacement	N	Mean	Std. Deviation	Minimum	Maximum
100% sand, 0% RHA	3	0.853	0.015	0.84	0.87
85% sand, 15% RHA	3	0.900	0.020	0.88	0.92
90% sand, 10% RHA	3	0.853	0.015	0.84	0.87
95% sand, 5% RHA	3	0.846	0.015	0.83	0.86
80% sand, 20% RHA	3	0.933	0.015	0.92	0.95
75% sand, 25% RHA	3	0.966	0.005	0.96	0.97
Total	18	5.353	0.086	5.27	5.44

Table 2.1 shows that concretes produced at 100% sand had a mean water absorption rate of 0.853 that is 85%, its minimum value was 0.84 and maximum value was 0.87. At 95% sand and 5% RHA, the mean water absorption rate increased to 0.8467, and its minimum and maximum values were 0.83 and 0.86 respectively. Table 2.1 also shows that at 90% sand and 10% RHA, the mean water absorption rate further increased to 0.8467(85%), with its minimum and maximum values at 0.84 and 0.87 respectively. At 85% sand and 15% RHA, the mean water absorption rate was 0.90, its minimum and maximum values were 0.88 and 0.92 respectively. At 80% sand and 20% RHA, the mean water absorption rate was 0.9333, that is 93%, and its minimum and maximum values were 0.92 and 0.95 respectively. Lastly at 75% sand and 25% RHA, the mean water absorption rate was 0.9667, that is 96%, and its minimum and maximum values were 0.96 and 0.97 respectively.

Table 2.2: ANOVA Test for Water Absorption after 7 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.037	5	.007	32.644	0.000
Within Groups	0.003	12	.000		
Total	0.040	17			

From table 2.2, the ANOVA test shows that there is a significant difference between the means of water absorption at the different levels of partial replacement of RHA with F= 32.644, significant value = 0.000 at α = 0.05.

The Means plot will be used to show the mean distribution

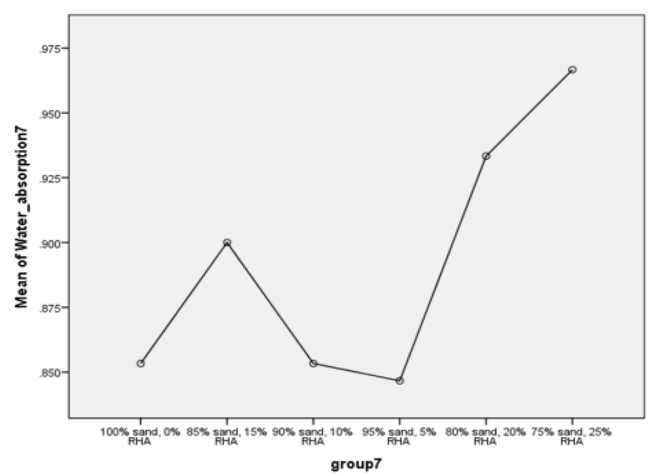

Fig. 1.5: means plot of water absorption of different levels of partial replacement of RHA after 7 days

From the means plot, we can clearly see that when the sand composition was at 100%, (90% sand and 10% RHA), (95% sand and 5% RHA), all had close mean water absorption rate. Meanwhile (75% sand and 25% RHA) had the highest percentage water absorption rate, followed by (80% sand and 20% RHA) before (85% sand and 15% RHA).

5.2.2. Water Absorption After 14 Days

Table 2.3: Descriptive Statistics water absorption of RHA Concrete after 14 days

Percentage Replacement	N	Mean	Std. Deviation	Minimum	Maximum
100% sand, 0% RHA	3	0.606	0.02082	0.59	0.63
85% sand, 15% RHA	3	0.706	0.02082	0.69	0.73
90% sand, 10% RHA	3	0.620	0.03000	0.59	0.65
95% sand, 5% RHA	3	0.600	0.01000	0.59	0.61
80% sand, 20% RHA	3	0.760	0.01000	0.75	0.77
75% sand, 25% RHA	3	0.803	0.01528	0.79	0.82
Total	18	4.096	0.09692	4	4.21

Table 2.3 shows that concretes produced at 100% sand had a mean water absorption rate of 0.6067 that is 61%, its minimum value was 0.59 and maximum value was 0.63. Also it shows that at 85% sand and 15% RHA, the mean water absorption rate was 0.7067 that is 71%, its minimum and maximum values were 0.69 and 0.73 respectively. At 90% sand and 10% RHA, the mean water absorption rate was 0.62, that is 62%, and its minimum and maximum values were 0.59 and 0.65 respectively. At 95% sand and 5% RHA, the mean water absorption rate was 0.60, that is 60%, and its minimum and maximum values were 0.59 and 0.61 respectively. At 80% sand and 20% RHA, the mean water absorption rate was 0.7600, that is 76%, and its minimum and maximum values were 0.75 and 0.77 respectively. Lastly at 75% sand and 25% RHA, the mean water absorption rate was 0.79, that is 79%, and its minimum and maximum values were 0.79 and 0.82 respectively.

Table 2.4: ANOVA Test for Water Absorption after 14 days

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.113	5	.023	61.615	.000
Within Groups	.004	12	.000		
Total	.117	17			

From table 2.4, the ANOVA test shows that there is a significant difference between the means of water absorption at the different levels of partial replacement of RHA with F= 61.615, significant value = 0.000 at α = 0.05.

The Means plot will be used to show the mean distribution

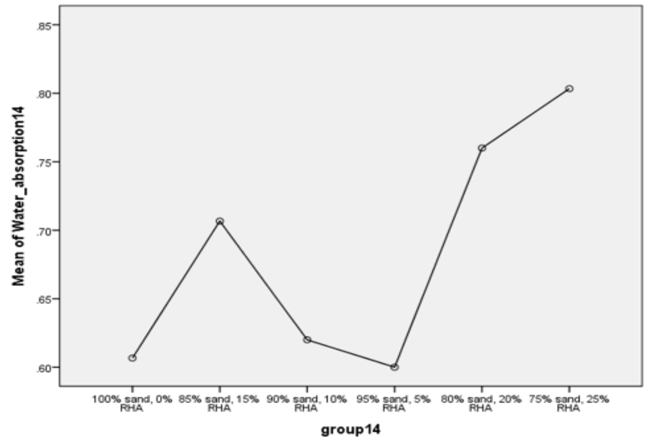

Fig. 1.6: means plot of water absorption of different levels of partial replacement of RHA after 14 days

From the means plot, we can clearly see that when the sand composition is at 100%, (90% sand and 10% RHA), (95% sand and 5% RHA), also had close mean water absorption rate. Meanwhile (75% sand and 25% RHA) had the highest percentage water absorption rate while (95%sand and 5% RHA) had the least water absorption rate after 14 days.

5.2.3. Water Absorption After 28 Days

Table 2.5: Descriptive Statistics water absorption of RHA Concrete after 28 days

Percentage Replacement	N	Mean	Std. Deviation	Minimum	Maximum
100% sand, 0% RHA	3	0.5400	0.03464	0.50	0.56
85% sand, 15% RHA	3	0.6267	0.04041	0.59	0.67
90% sand, 10% RHA	3	0.5867	0.01528	0.57	0.60
95% sand, 5% RHA	3	0.5567	0.01528	0.54	0.57
80% sand, 20% RHA	3	0.7000	0.01000	0.69	0.71
75% sand, 25% RHA	3	0.7667	0.01528	0.75	0.78
Total	18	3.7768	0.13089	3.64	3.89

Table 2.5 above shows that after 28 days curing period, concretes produced at 100% sand has a mean water absorption rate of 0.54 that is 54%, its minimum value was 0.50 and maximum value was 0.56. Also it shows that at 85% sand and 15% RHA, the mean water absorption rate was 0.6267 that is 63%, and its minimum and maximum values were 0.59 and 0.67 respectively. At 90% sand and 10% RHA, the mean water absorption rate was 0.5867, that is 59%, and its minimum and maximum values were 0.54 and 0.57 respectively. At 95% sand and 5% RHA, the mean water absorption was 0.5567, that is 56%, and its minimum and maximum values were 0.54 and 0.57 respectively. At 80% sand and 20% RHA, the mean water absorption rate was 0.700, that is 70%, and its minimum and maximum values were 0.69 and 0.71 respectively. Lastly at 75% sand and 25% RHA, the mean water absorption was 0.7667, that is 77%, and its minimum and maximum values were 0.75 and 0.78 respectively.

Table 2.6: ANOVA Test for Water Absorption after 28 days

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.117	5	0.023	38.585	0.007
Within Groups	0.007	12	0.001		
Total	0.124	17			

From table 2.6, the ANOVA test shows that there is a significant difference between the means of water absorption at the different levels of partial replacement of RHA with F= 38.585, significant value = 0.007 at α = 0.05.

The Means plot will be used to show the mean distribution

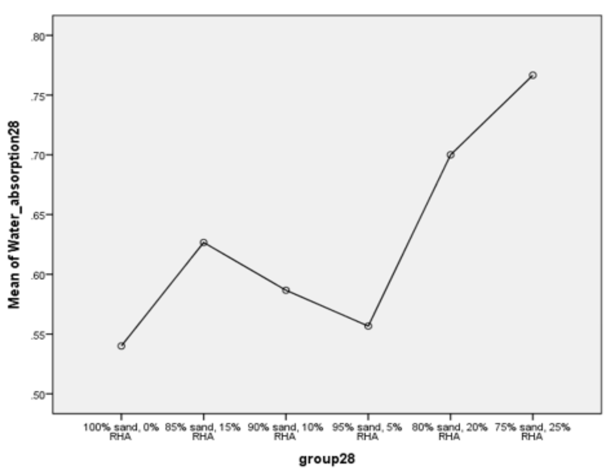

Fig. 1.7. means plot of water absorption of different levels of partial replacement of RHA after 28 days

From the means plot, we can clearly see that after the 28 days concrete curing period, the mean absorption rate for the $16.9N/mm^2$ (80% sand and 20% RHA) concrete was higher than that of the $20N/mm^2$ (100%) concrete. The least water absorption rate when the sand composition was at 100%, followed by (95% sand and 5% RHA), meanwhile (75% sand and 25% RHA) had the highest percentage water absorption rate.

5.3 Objective 3

To compare the weight of concrete produced using rice husk ash at different percentage replacement to that of normal concrete grade 20.

5.3.1. Weight Loss Of Concrete After 7 Days

Table 3.1: Mean weight loss of concrete produced using RHA after 7 Days

Percentage Replacement	N	Mean(kg)	Std. Deviation	Minimum (kg)	Maximum (kg)
100% sand, 0% RHA	3	0.0000	0.00000	0.00	0.00
85% sand, 15% RHA	3	3.2133	0.03215	3.19	3.25
90% sand, 10% RHA	3	2.6067	0.09713	2.50	2.69
95% sand, 5% RHA	3	2.0333	0.15275	1.90	2.20
80% sand, 20% RHA	3	4.0267	0.06429	3.98	4.10
75% sand, 25% RHA	3	4.7833	0.16073	4.60	4.90
Total	18	16.6633	0.50705	16.17	17.14

Table 3.1 shows that after 7 days concrete curing, the concrete produced at 100% sand had no weight loss. At 95% sand and 5% RHA, the mean weight loss was 2.0333kg with its minimum and maximum values at 1.90kg and 2.20kg respectively. At 90% sand and 10% RHA, the mean weight loss of the concrete cubes increased to 2.6067kg with its minimum and maximum values at 2.50kg and 2.69kg respectively. Also it shows that at 85% sand and 15% RHA, the mean weight loss of the concrete cubes increased further to a value of 3.2133kg with its minimum and maximum values at 3.19kg and 3.25kg respectively. At 80% sand and 20% RHA, the mean weight loss

of the concrete cubes was 4.0267kg and its minimum and maximum values were 3.98kg and 4.10kg respectively. Lastly at 75% sand and 25% RHA, the concrete cube mean weight loss was 4.7833kg with its minimum and maximum values at 4.60kg and 4.90kg respectively.

Table 3.2: ANOVA Test of mean weight loss of RHA concretes after 7 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	42.214	5	8.443	794.402	0.000
Within Groups	.128	12	.011		
Total	42.341	17			

From table 3.2, the ANOVA test shows that there is a significant difference between the mean weight loss of the different levels of partial replacement of RHA with F= 794.402, significant value = 0.00 at α = 0.05.

The means plot to clearly show the mean distribution of weight loss is shown below

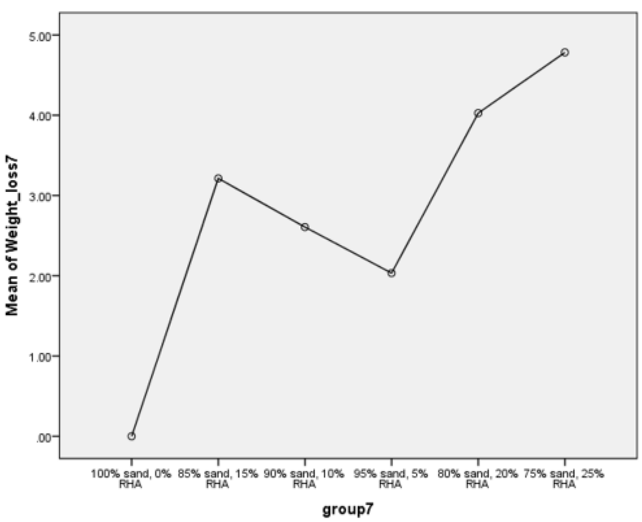

Fig 1.8: Means plot of weight loss across all levels of partial replacement of RHA after 7 days

Figure 1.8 shows that at 100% sand composition, no weight loss was recorded for the concrete cubes. And at (95% sand and 5% RHA) composition a mean weight of 2.03kg was lost, which was the least among all other levels of replacement. (75% sand and 25% RHA) has the highest weight loss.

5.3.2 Weight Loss of Concrete After 14 Days

Table 3.3: Mean weight loss of concrete produced using RHA after 14 Days

Percentage Replacement	N	Mean	Std. Deviation	Minimum	Maximum
100% sand, 0% RHA	3	0.0000	0.00000	0.00	0.00
85% sand, 15% RHA	3	3.2067	0.04041	3.17	3.25
90% sand, 10% RHA	3	2.5933	0.09292	2.49	2.67
95% sand, 5% RHA	3	2.0233	0.06807	1.97	2.10
80% sand, 20% RHA	3	4.0100	0.06083	3.97	4.08
75% sand, 25% RHA	3	4.7300	0.12490	4.59	4.83
Total	18	16.563	0.38713	16.19	16.93

Table 3.3 shows that after 14 days, concretes produced at 100% sand also had a mean weight loss of 0kg. It shows that at 85% sand and 15% RHA, the mean weight loss was 3.2067kg with its minimum and maximum values at 3.17kg and 3.25kg respectively. At 90% sand and 10% RHA, the mean weight loss was 2.5933kg and its minimum and maximum values were 2.49kg and 2.67kg respectively. Table 4.15 also shows that at 95% sand and 5% RHA, the mean weight loss was 2.0233kg with its minimum and maximum values at 1.97kg and 2.10kg respectively. At 80% sand and 20% RHA, the mean weight loss was 4.010kg and its minimum and maximum values were at 3.97kg and 4.08kg respectively. Lastly at 75% sand and 25% RHA, the mean weight loss was 4.730kg and its minimum and maximum values were 4.59kg and 4.83kg respectively.

Table 3.4: ANOVA Test of mean weight loss of RHA concretes after 14 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	41.493	5	8.299	1455.891	0.000
Within Groups	.068	12	0.006		
Total	41.561	17			

From table 3.4, the ANOVA test shows that there is a significant difference between the mean weight loss of the different levels of partial replacement of RHA with F= 1455.891, significant value = 0.000 at α = 0.05.

The means plot to clearly show the mean distribution of weight loss is shown below

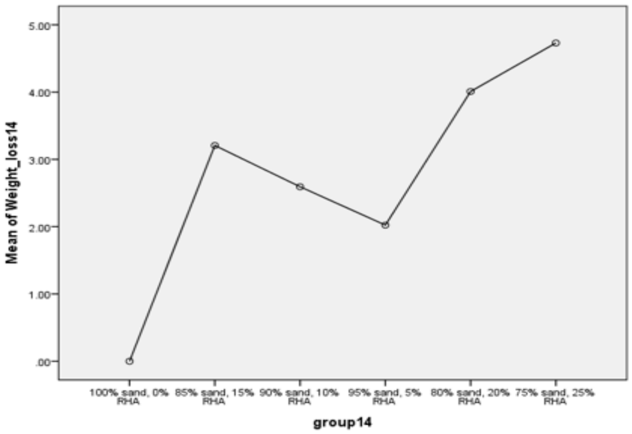

Fig 1.9: Means plot of weight loss across all levels of partial replacement of RHA after 14 days

Figure 1.9 shows that at 100% sand composition, no weight was lost. At 95% sand and 5% RHA composition a mean weight of 2.02kg was lost, which was the least among all other levels of replacement, (75% sand and 25% RHA) had the highest weight loss.

5.3.2. Weight Loss Of Concrete After 28 Days

Table 3.5: Mean weight loss of concrete produced using RHA after 28 Days

Percentage Replacement	N	Mean(kg)	Std. Deviation	Minimum (kg)	Maximum (kg)
100% sand, 0% RHA	3	0.0000	0.0000	0.00	0.00
85% sand, 15% RHA	3	3.0367	0.04726	3.00	3.09
90% sand, 10% RHA	3	2.5433	0.11015	2.47	2.67
95% sand, 5% RHA	3	1.9733	0.07506	1.90	2.05
80% sand, 20% RHA	3	3.9900	0.03464	3.95	4.01
75% sand, 25% RHA	3	4.6733	0.15308	4.50	4.79
Total	18	16.2166	0.42019	15.82	16.61

Table 3.5 shows that after 28 days curing period, concretes produced at 100% sand showed no significant weight loss. Also, at 95% sand and 5% RHA, the mean weight loss observed in the concrete cube was 1.9733kg with its minimum and maximum values at 1.90kg and 2.05kg respectively. At 90% sand and 10% RHA, the mean weight loss was 2.5433kg with its minimum and maximum values are 2.47kg and 2.67kg respectively. It also shows that at 85% sand and 15% RHA, the mean weight of the concrete cubes was further increased to 3.0367kg with its minimum and maximum values at 3.00kg and 3.09kg respectively. At 80% sand and 20% RHA, the mean weight loss was 3.990kg with its minimum and maximum values at 3.95kg and 4.01kg respectively. Lastly at 75% sand and 25% RHA, the mean weight loss was 4.6733kg with its minimum and maximum values at 4.50kg and 4.79kg respectively.

Table 3.6: ANOVA Test of mean weight loss of RHA concretes after 28 days

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	40.542	5	8.108	1090.004	0.000
Within Groups	0.089	12	0.007		
Total	40.631	17			

From table 3.6, the ANOVA test shows that after the 28 days curing period, there was a significant difference between the mean weight loss of the different levels of partial replacement of RHA with F= 1090.004, significant value = 0.000 at α = 0.05. The means plot to clearly show the mean distribution of weight loss is shown below

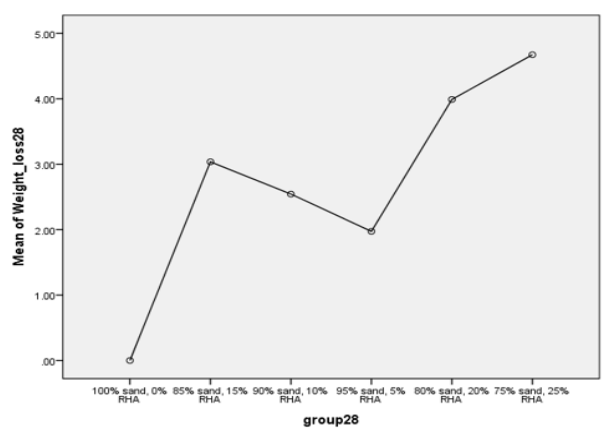

Fig 1.10: Means plot of weight loss across all levels of partial replacement of RHA after 28 days

Figure 1.10 shows that at $20N/mm^2$ (100%) sand composition, no weight loss was recorded. (At 95% sand and 5% RHA) composition a mean weight of 1.9733kg was lost, which according to figure 4.9 was the least among all other levels of RHA replacement. (75% sand and 25% RHA) recorded the highest weight loss.

The concrete compressive strength of $16.9N/mm^2$ approximately $17N/mm^2$ (80% sand and 20% RHA) which was recommended for this research recorded a mean comparative weight loss of 3.99kg.

VI. Conclusion

From the findings, the following conclusions were summarized as follows:

The optimum partial replacement by volume of (80% sand and 20%RHA) gave the recommended compressive strength of $16.9^{N}/_{MM^2}$. According to BS8110-2:1985, the minimum compressive strength recommended for reinforced lightweight concrete is $20^{N}/_{MM^2}$ however since lintels are members of minor structural importance, $16.9^{N}/_{MM^2}$ was adopted.

Also, from the result of the water absorption test performed on the concrete cube samples, it was discovered that as the percentage replacement of sand with rice husk ash increases, the rate of water absorption of the concrete also increases.

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