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An Empirical Investigation Of Relationship Between Water/Cement + RHA Ratio And The Compressive Strength Of RHA Concrete

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Abstract

The study has empirically examined the relationship between water/cement + RHA ratio and compressive strength of RHA Concrete. Using a 35% replacement of OPC with RHA, RHA concrete cubes were cast with varying water/cement + RHA ratios (0.60, 0.63, 0.68, 0.72, 0.81, 0.86, 0.90 and 0.99 respectively) and theircorresponding compressive strengths determined. Applying a statistical technique (Pearson Product moment correlation), it was established that a positive correlation (0.63) exist between the variables. The study further indicated that 39.46% of the total variations in compressive strength of RHA concrete for seven (7) days are due to the water/cement + RHA ratio. The rest variations (60.54%) need to be investigated.

1.Introduction

Rice husk, an agricultural waste, constitute about one-fifth of the 500 million metric tons of rice produced annually in the world (anon). Due to the growing environmental concern, and the need to conserve energy and resources, efforts have been made to burn the husks at controlled temperature and atmosphere and to utilize the ash so produced as a building material (anon).

Rice husk ash (RHA) is a very fine pozzolanic material and its particle size and specific surface depend upon the burning conditions under which it is produced. In general, the average particle size ranges from 5 – 10µm, and the specific surface area ranges from 20 – 50m^2/g (Zhang et al 1996). As outlined by Ella (1992), a series of studies carried out on some materials such as fly ash finely divided residue from combustion of grind coal), burnt clay powder (crushed waste from bricks), rice husk, ground nut shells for making particle boards and rice hull husk ash (RHA) obtained by burningrice hulls as partial substitutes for cement have shown their suitability in soil stabilization and concrete production. Mehta and Leo et al (1984) have shown that RHA is a suitable material for partial substitute for cement in making mortar and concrete. Also, Okereke and Obeng (1985) and Ralman (1986) found that RHA is a good material for soil stabilization for civil and building engineering works. Ojeyemi (1987) have shown that RHA is a suitable material for partial substitute for cement in making mortar. In each of these studies, RHA was produced using either the open–air burning or the closed–air burning method.Effect(s) of these methods on the properties ofRHA concrete were investigatedby Ella (1992).

However, the correlation, and its extent between the properties of RHA concrete is yetto be investigated.

1.1 Aim of the Study

The study aimed at the empirical investigation of the relationship and the extent between water/cement + RHA ratio and the compressive strength of RHA concrete. This was achieved by producing RHA concrete cubes with varying water/cement + RHA ratios (0.60, 0.63, 0.68, 0.72, 0.81, 0.86, 0.90 and 0.99) and their corresponding compressive strengths determined.Pearson Product correlation (statistical tool) was used to determine correlation and extent of correlation between the two variables – water/cement + RHA ratio and compressive strength of the RHA concrete.

1.2 Materials and Methods.

The study was carried out by means of laboratory tests and statistical technique (Pearson product moment correlation, r). The rice hulls for the study was obtained from a local rice mill in Birnin- kebbi (Old Town), Kebbi state, Nigeria, having an averagebulk density of 326kg/m^3. It was produced using the open – air burning method. This was achieved by burning the rice hulls in a metal container sealed at the bottom and opened at the top with an internal diameter of 500mm, 600mm high with a thickness of 3mm at the ultra- modern workshop, Metallurgy section, WaziriUmaru federal Polytechnic, B/kebbi, Kebbi state. The container was filled with the rice hulls and ignited. It continuedto burn until the hulls became ash. The maximum temperature recorded was 560^{o}c. At the end of the combustion, Ii was observed that the ash at the core of the container was completely white but varies from grey to black at the walls of the container. This makes the resulting ash whitish-grey and the Portion of the rice hulls close to the walls of the container partially burnt.

The ash was sieved with a 300μm BS sieve and 35% of RHA was used as a partial replacement of OPC in a mix proportion of 1:2:4 with w/c + RHA ratios of 0.60, 0.63, 0.68, 0.72, 0.81, 0.86, 0.90 and 0.99. These ratios were chosen from the knowledge of the optimum w/c + RHA ratio of 0.72 used by Leo et al (1984) for a 35% RHA replacement of OPC in a mix proportion of 1:2:4. A total of thirty-two (32) sample cubes were cast, cured and crushed for compressive strength at the age of seven (7) days for the test; Sixteen (16) each for RHA and normal concrete (concrete with 100% OPC) with a w/c of 0.62. (Table 1.0). Workability of fresh RHA concrete, specific gravity, bulk density,fineness and compressive strength of RHA concrete were determined. The fineness was determined by wet sieving a sample of RHA for about 20mins with a 63μm sieve, then kept in an oven for 24hrs at 105^{o}c and weighed. The constituent materials used for both conventional concrete and RHA concrete are Sokoto cement assumed to conform with BS12 (1971), fine aggregate (river sand), crushed granite of 20mm, clean water suitable for drinking and for making concrete (BS 3148). The following hypotheses were then formulated and tested at a significant level of 0.05.

Ho:There is no statistically significant relationship between the water-cement + RHA (w/c + RHA) ratio and compressive strength of (RHA) rice hull ash concrete.

H_1:There is statistically significant relationship between the water-cement+ RHA (w/c + RHA) ratio and compressive strength of (RHA) rice hull ash concrete.A statistical technique (Pearson Product moment correlation)was used to determine the relationship between water/cement + RHA ratios and the compressive strengths of RHA concrete (Table 1.0).Decision Rule: reject Ho if calculated statistic (t_{cal}) is greater than critical statistic (t_{cri}) from student distribution table.

Table 1.0 - Water/cement ratios and compressive strengths at seven (7) days for RHA concrete.

Mix Batch	w/c+RHA ratio (x)	Comp. str. (Y)
Ai	0.60	3.65
Bi	0.63	3.74
Ci	0.68	4.22
Di	0.72	4.71
Ei	0.81	5.80
Fi	0.86	5.25
Gi	0.90	4.71
Hi	0.99	4.61
Aii	0.60	3.50
Bii	0.63	3.93
Cii	0.68	4.67
Dii	0.72	4.20
Eii	0.81	5.45
Fii	0.81	5.45
Gii	0.90	4.72
Hii	0.99	4.58

Table 2.0 – Computed values of the variables under study.

Mix batch	w/c (x)	Comp str. (y)	X^2	Y^2	XY
Ai	0.60	3.65	0.36	13.32	2.19
Bi	0.63	3.74	0.40	13.99	2.36
Ci	0.68	4.22	0.46	17.81	2.87
Di	0.72	4.71	0.52	22.18	3.39
Ei	0.81	5.80	0.66	33.64	4.70
Fi	0.86	5.25	0.74	27.56	4.52
Gi	0.90	4.71	0.81	22.09	4.24
Hi	0.99	4.61	0.98	21.25	4.56
Aii	0.60	3.50	0.36	12.25	2.10
Bii	0.63	3.93	0.40	15.45	2.48
Cii	0.68	4.67	0.46	21.81	3.18
Dii	0.72	4.20	0.52	17.64	3.02
Eii	0.81	5.45	0.66	29.70	4.41
Fii	0.86	5.45	0.74	29.70	4.69
Gii	0.90	4.72	0.81	22.28	4.29
Hii	0.99	4.58	0.98	20.98	4.53

∑	**∑x = 12.38**	**∑y = 73.19**	**$\sum x^2$ = 9.85**	**$\sum y^2$ = 341.65**	**∑xy = 57.48**

Apply formula:

$$r = \frac{\sum xy - \frac{(\sum x)(\sum y)}{n}}{\sqrt{(\sum x^2) - \frac{(\sum x)^2}{n}}\ \sqrt{(\sum y^2) - \frac{(\sum y)^2}{n}}}$$

$$= \frac{57.4821 - \frac{(12.38 \times 73.19)}{16}}{\sqrt{9.847 - \frac{12.38^2}{16}}\ \sqrt{341.6508 - \frac{73.19^2}{16}}}$$

$= \frac{0.8513}{1.3552} = 0.6282$. Substitute r = 0.6282 in the teststatistic: $t = r\sqrt{n-2} / \sqrt{1-r^2} = 0.6282\sqrt{16-2}/\sqrt{1-0.6282^2} = 2.3505/0.6054 = 3.883$; $t_{cal} = 3.883$

From tables, for df = 16 -1 = 15; $t_{cri} = 2.131$ @ 0.05 confidence level.

Decision: Since t_{cal} (3.883 >t_{cri} (2.131), Ho is rejected.

Coefficient of determination (r^2)

The strength of correlation between the two variables is indicated by the coefficient of correlation ® which is 0.6282 = 0.6282 x 100 = 62.82% while the coefficient of determination (r^2) which determines the extent of correlation between variables is 0.6282^2 = 0.3946 x 100 = 39.46%. This shows that there is a positive correlation between w/c + RHA ratios and the compressive strength of RHA concrete for seven (7) days and that 39.46% of the total variations in compressive strengths of RHA concrete is due to the water/cement + RHA ratios. The remaining 60.54% of the total variations in compressive strengths of RHA concrete could be attributed to other factors like age of RHA concrete, curing conditions, type and quality of cement, degree of compaction and others.

2.0 Experimental Results and discussion

The specific gravity (Gs) for RHA determined is 2.16. This is in agreement with that obtained by Ella (1992) which is 2.12 and 2.13 for both types of RHA concrete and Zhang et al (1996) who obtained a value of 2.06. The value obtained from this study is less than the standard value for cement (3.15). This is not unconnected with varying chemical composition for cement and RHA. Moreover, specific gravity depends on constituent mineral elements and volume of voids (Dashan and Kamang, 1999).

The average bulk density for RHA obtained from this study is 326.39kg/m^3. Ella (1992) had an average of 299.51kg/m^3 for RHA produced by open – air burning and 352.35kg/m^3 for close- air burning method. This places the material in the range of bulk densities of lightweight aggregates. Bulk densities of lightweight aggregates vary from 300 – 1299kg/m^3 (BS: 882).

The RHA produced from this study has a fineness of 69%. Using a 63μm sieve, Ella (1992) had 69.5% for RHA produced through open – burning method and 2.55 for that obtained through closed – air burning. Zhang et al (1996) with a 45μm sieve had 99% fineness for RHA produced.The value obtained for this study is in close agreement with that of Ella (1992) since the same sieve was used.

From the empirical investigation (application of the Pearson Product moment correlation on the data in table 1.0 and 2.0), the test statistic (t_{cal}) is greater than (t_{cri}), that is, 3.883 is greater than 2.131 leading to the rejection of the null hypothesis (Ho), that there is no statistically significant relationship between water/cement + RHA ratio and compressive strength of (RHA) rice hull ash concrete and acceptance of (H_1) the alternate hypothesis at a significant level of 0.05. The result of r = 62.82% shows a positive correlation between the variables under study and that of 39.46% variations in the compressive strength of RHA concrete were due to the water/cement + RHA ratios. The remaining 60.54% of variations could be attributed to other factors not investigated.

3. Conclusions

The RHA used for this study has an average specific gravity of 2.16, average loose bulk density of 326.32kg/m^3, a fineness of 69% and an average density of 2004kg/m^3. There is a positive correlation (r= 62.825) between water/cement + RHA ratios and compressive strength of RHA concrete for seven (7) days. Also, **39.46%** of the total variations in compressive strength of RHA concrete for seven (7) days is due to the water/cement + RHA ratio. The remaining **60.54%** of the total variations in compressive strengths of RHA concrete could be attributed to other factors like age of RHA concrete, curing conditions, type and quality of cement, degree of compaction and should be investigated.

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