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Mechanical Properties of Self-Compacting Concrete Incorporating Rice Husk Ash as a Partial Replacement of Cement

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ABSTRACT: Cement is widely known to be most expensive constituents of concrete. Therefore, the rising cost of construction materials like cement in developing countries has necessitated research into the use of alternative materials for civil engineering and building constructions. The alternative construction materials like agro-wastes etc., are used to replace cement in concrete production. In this paper, Rice Husk Ash (RHA) was used as a partial replacement of cement in Self-Compacting Concrete (SCC) to determine the influence of the RHA on the compressive and flexural strengths of the tested specimens. The percentage replacements were 0%, 5%, 10%, 15% and 20% of the RHA in the corresponding concrete mixes. Concrete cubes and prisms were cast, cured and their mechanical properties (compressive and flexural strengths) were evaluated at 7, 14, 21 and 28 days. The results show that remarkable strengths values of compressive and flexural strengths were manifested, when compared with the control specimens. In conclusion, it was established that 5% cement replacement of the RHA was found to be a favourable value from among the percentage replacements considered. Moreover, the study demonstrated the use of agro-waste which enhanced the reduction of cement usage and will pave a sustainable way of innovative construction.
KEYWORDS: Self-Compacting Concrete; Rice Husk Ash; Compressive Strength; Flexural Strength; Slump Flow

I. INTRODUCTION

Nowadays the utilization of agro-waste as pozzalanas in cement-mortar or concrete is on the increase and has been reported by many research studies [1–3]. On the other hand, developing countries like Nigeria several efforts are made to utilized the application of waste materials in building and civil engineering constructions as a result of shortage of local construction materials [4-5].Apart from getting rid of these waste materials, their usage in construction projectsmay save the environment from contamination; and it may also pave a way to explore the idea of using local materials especially those regarded as waste for construction purposes [6]. Conventionally, rice husk has been considered a waste material and has generally been disposed of by dumping or sometimes burning. RHA has been successfully used as a pozzolana in commercial production in a number of countries [7].

RHA use in civil and building construction fields may be a viable solution to its disposal as waste on the environment. Mehta [8] in (1977), observed that ashes rich in silica (in crystalline or glassy state) could be obtained depending on the combustion conditions. He added that in the glassy silica case, highly pozzolanic ashes could be obtained, which would be suitable for partial substitution of Portland cement. Therefore, the use of RHA with cement improves workability and stability, decreases heat evolution, thermal cracking and plastic shrinkage etc. The process also increases strength development, impermeability and durability by strengthening transition zone, modifying the pore-structure, blocking the large voids in the hydrated cement paste through pozzolanic reaction [9]. RHA minimizes alkali-aggregate reaction, reduces expansion, refines pore structure and hinders diffusion of alkali ions to the surface of aggregate by micro porous structure. These properties are difficult to achieve by the use of Portland cement alone. Significant number of studies on the use of RHA as a construction material has been reported by [9-13], where the quantity of replacement varies from 0 to 20%.

On the other hand the use of conventional Normal Vibrated Concrete (NVC) in civil and building construction works may lead to an inadequate compaction and insufficient passage of the concrete to a desired position, as the flow is controlled by vibration [14]. Therefore, using innovative way of concreting with a flow able and cohesive concrete as SCC may eliminate the inability of the concrete passage to a required position as it compacts by its own self weight while its homogeneity is maintained been a self-compacting. Because of the above mentioned problem that is associated with NVC, it is therefore recommended that SCC could be used as a substitute of the conventional concrete. Thus, in the present study the possibility of using RHA as a partial replacement of cement in SCC is investigated in order to ascertain its feasibility.

II. EXPERIMENTAL PROGRAM

Materials

The materials used in the study were cement, fine aggregates, coarse aggregates, rice husk ash (RHA), water and superplasticizer (master glenium ACE 456). The RHA used is as shown in Figure 1.

Fig 1:(a) Rice husk before burning (b) Rice husk after burning (c) Rice husk ash

Preparation of rice husk to rice husk ash

The rice husk was obtained from Kura Local government area in Kano State. It was thoroughly washed with clean water to remove impurities and other solid debris. It was then air dried at a room for five (5) days. The dried specimens were burnt between 750^{o}C to 800^{o}C to collect the RHA. The collected specimen was allowed to cool and was sieved through a BS sieve size 75µm. Chemical content test on the RHA was conducted and compared with the results of other research studies conducted by [4,7,13,15] as presented in Table 1.

Table 1: Chemical content test in (%)

Oxides parameters	Present study	Other studies			
		[4]	[7]	[13]	[15]
S_iO_2	76.51	68.10	75.00	86.90	94.26
C_aO	0.26	1.01	3.30	0.3 – 2.2	0.28
Al_2O_3	1.05	1.06	1.29	0.20	1.07
Fe_2O_3	0.75	0.78	0.78	0.10	0.76
M_gO	0.28	1.31	0.22	0.2 – 0.6	0.59
K_2O	-	21.23	1.5	2.15 – 2.3	-
SO_3	-	0.14	-	-	0.28
Na_2O	-	-	0.40	0.1 – 0.8	-
MnO	-	-	0.20	-	-
P_2O_5	-	-	0.59	-	-
LOI	-	18.25	2.15	3.15 – 4.4	-

LOI = Loss of ignition

Mix proportioning

This is the process of selecting suitable ingredients of concrete and determining their relative amount with the objective of producing a concrete of a required workability, strength and durability as economically as possible. The principle for the selection and proportioning of the SCC constituents was based on the guidelines laid byEuropean guidelines for self-compacting concrete [16]. The summary of mix proportions of different mixes is as shown in Table 2. In summary, sixty (60) concrete cubes of 150 mm x 150 mm x 150 mm and forty (40) concrete prisms of 100 mm x 100 mm x 500 mm were prepared for compressive and flexural strengths test. The concrete used was designed for a targeted strength of 20 N/mm^2 at 28 days of curing.

Table 2: Summary of concrete mix proportions

Constituent Materials	RHA 0%	RHA 5%	RHA 10%	RHA 15%	RHA 20%
Cement (Kg/m^3)	376.30	358.50	337.80	320.00	302.20
RHA (Kg/m^3)	0.00	17.80	38.50	56.30	74.10
Fine Aggregate (Kg/m^3)	874.10	874.10	874.10	874.10	874.10
Coarse Aggregate (Kg/m^3)	1312.60	1312.60	1312.60	1312.60	1312.60
Water (Kg/m^3)	207.40	207.40	207.40	207.40	207.40
Water/cement ratio	0.55	0.55	0.55	0.55	0.55
Superplasticizer Dosage (Ltr/m^3)	7.41	7.41	7.41	7.41	7.41

Test procedure

Concrete mixes were examined for slump flow test in accordance with provisions in [16-18]. The slump flow considered in this study is slump flow class 1 (i.e., SF1) which is ranged between 550 mm to 650 mm. Compressive strength values were evaluated using cube sizes of 150 mm as earlier mentioned based on the recommendations of BS EN 12390-3 [19]. The flexural strength test was conducted in accordance with BS EN 12390-5 [20], using a concrete prisms of size 100 mm x 100 mm x 500 mm as also earlier mentioned.

III. RESULTS AND DISCUSSIONS

Fresh properties of the SCC

The concrete mixes are identified as batch 1, 2 etc., as B1, B2 respectively. The slump flow test was conducted on the fresh concrete mixes containing zero RHA (control specimens) and those with the percentage addition (test samples). The result of the slump flow and T_{500} test is presented in Table 3.

Table 3: Slump flow and T_{500} results

Mix	RHA % Replacement	Average Slump Flow (mm)	Average T_{500} (s)
B1 (control)	0	595	1.00
B2 (test samples)	5	585	1.05
B3 (test samples)	10	575	1.10
B4 (test samples)	15	565	1.30
B5 (test samples)	20	560	2.00

Standard range is between 550 mm to 650 mm for SF1 and $T_{500} \leq 2$s according EG (2005)

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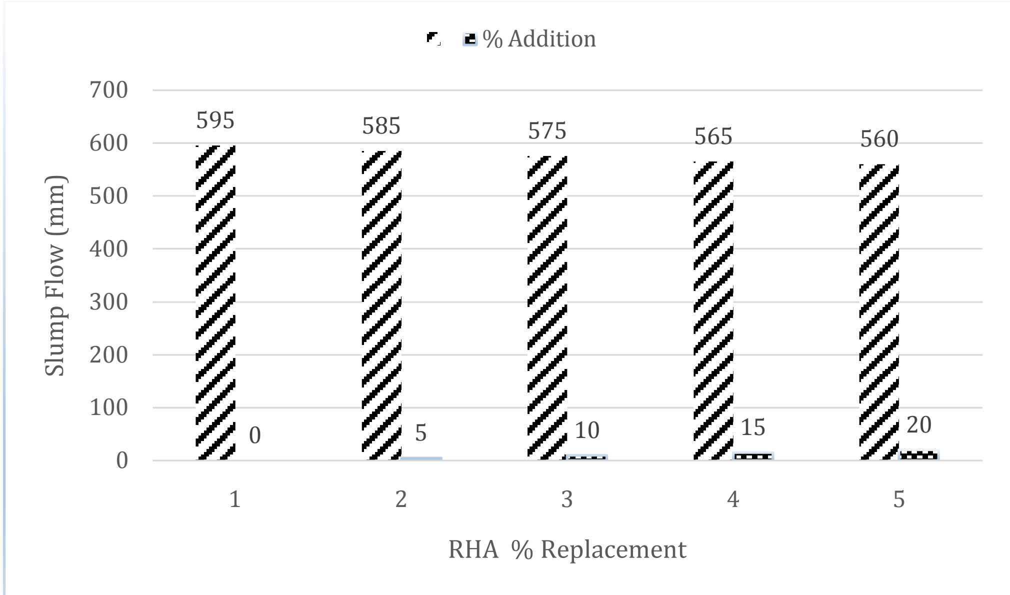

Fig 2: Variation of slump flow with different RHA replacement

It can be observed that the slump flow of the mixes dropped when the RHA was added to the corresponding mixes (see Fig. 2). The slump flow of the mix without the RHA was noted to be 595 mm. However, with the inclusion of the RHA by 5%, 10%, 15% and 20% the slump flow dropped to 585, 575, 565 and 560 mm correspondingly. The dropped in the slump flow was as a result of percentage addition of the RHA in the mixes. It is evident that mixes with RHA influences the flowing ability of the corresponding mixes which resulted in slower slump flow.

Compressive and flexural strengths

Table 4 presents the results of compressive and flexural strengths with and without the RHA replacement. The results show that inclusion of RHA reduces the compressive and flexural strengths of the concrete. However, remarkable increase in compressive and flexural strengths were manifested with a RHA addition of 5%. This is evident as it had a strength values both in compression and flexure close to the control specimens for all the curing days considered. This phenomenon is also illustrated in Figures 3 and 4. It is also evident that the compressive and flexural strengths were influenced by the addition of RHA. It can also be observed that a good correlation coefficient of R^2 = 0.98 for eqn. (1) below is obtained between flexural and compressive strength values, as shown in Figure (5).

$$y = 0.1326x - 0.7381 \quad \text{Eqn. (1)}$$

Table 4: Mechanical properties of the concrete mixes

Mix	% Addition	Average compressive strength (N/mm^2)				Average flexural strength (N/mm^2)			
		7-day	14-day	21-day	28-day	7-day	14-day	21-day	28-day
B1	0	15.10	18.02	21.20	26.95	1.51	1.80	2.15	2.80
B2	5	13.78	17.03	19.25	26.22	1.40	1.70	2.03	2.72
B3	10	12.59	14.63	17.20	20.89	1.26	1.50	1.72	2.09
B4	15	11.41	13.89	16.50	19.56	1.14	1.39	1.65	1.96
B5	20	10.96	12.00	15.25	16.63	1.20	1.20	1.53	1.36

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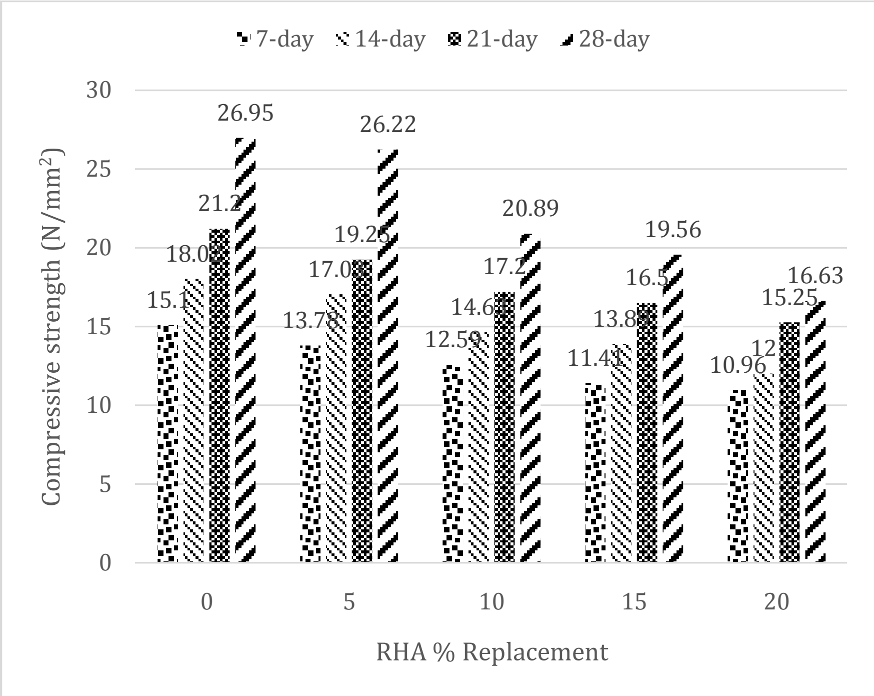

Fig. 3: Variation of compressive strength with different RHA replacement

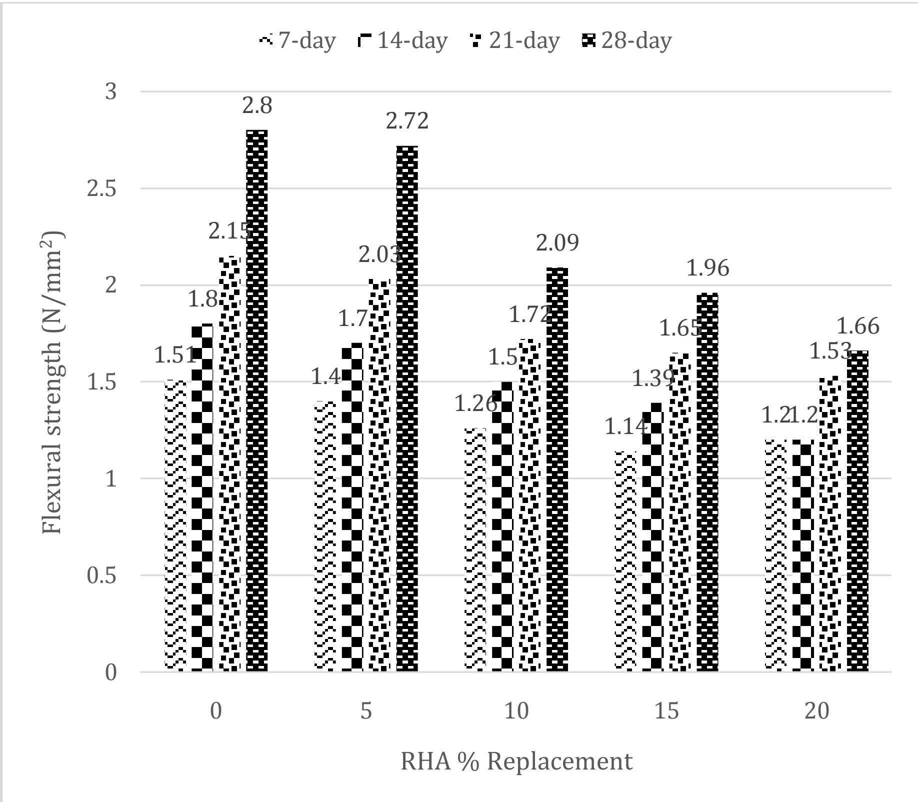

Fig. 4: Variation of flexural strength with different RHA replacement

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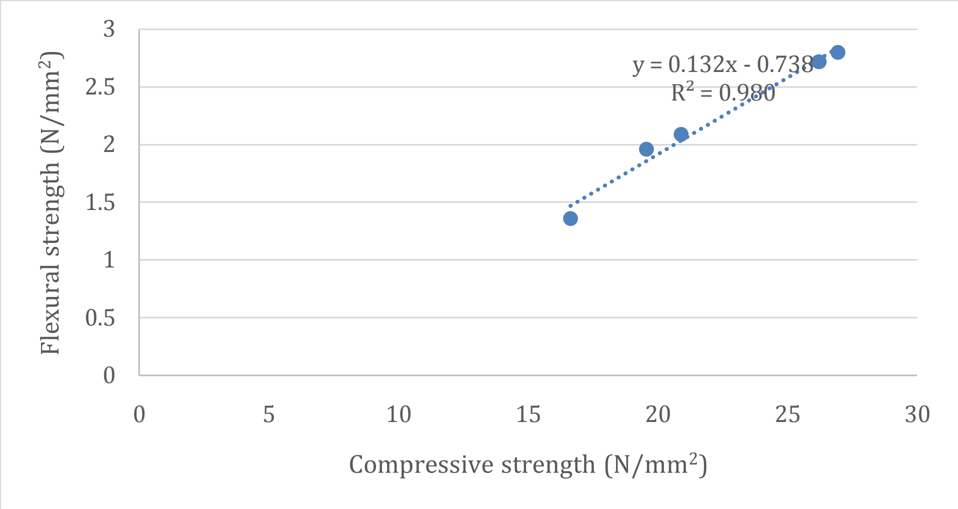

Fig. 5: Relationship between flexural and compressive strength values

IV. CONCLUSION

In the present study, the mechanical properties of self-compacting concrete incorporating RHA were explored. The usage of RHA in concrete helps to have a cleaner environment as well as the production of green concrete by reusing agricultural-waste. The following are concluded based on the investigations conducted.

I. By using RHA into the concrete mixes, the concrete became a little harsher, and its slump flow was seen to have decreased.
II. Compressive and flexural strengths were found to be influenced by the replacement of RHA.
III. However, favourable increased in compressive and flexural strengths were observed with 5% RHA replacement.
IV. It is therefore recommended that 5% of RHA can be employed to replace cement in civil and building constructions based on the study findings.

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