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Original Article

Experimental Effect of Cassava Starch and Rice Husk Ash on Physical and Mechanical Properties of Concrete

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Abstract — *This study focused on assessing the suitability of using rice husk ash (RHA) to partially replace cement and cassava starch(CS) as a natural admixture in fresh and hardened concrete production. This was achieved by experimentally establishing the engineering properties of RHA and cassava starch (CS). CS and RHA were incorporated separately and jointly in different mixtures. The individual and combined effects of CS and RHA were monitored with respect to various properties of fresh and hardened concrete. 16 mixtures were designed in which CS ranged from 0, 1, 1.5 and 2% and RHA from 0, 10, 15, 20% in a mixing ratio of 1:1.87:3.62, with the cement-to-water ratio of 0.5. Specimens were cured for 7, 14, 28, 56 and 90 days. The results indicated that CS and RHA prolonged the setting time of cement; the optimum of 1% CS and 10% RHA gave good strength development.*

Keywords — *Cassava starch, Rice husk ash, Setting time, workability, Density, Compressive strength, Splitting tensile strength.*

I. INTRODUCTION

Concrete is one of the most commonly used building materials. Different ingredients, such as coarse aggregate, cement, water, and fine aggregate, combine to form it. Each element's individual properties have a considerable impact on concrete. Out of these elements, there are some additives or admixtures which are incorporated to either modify certain properties of the concrete or solve some environmental issues. A ternary mixture is simply a mixture of three components. Ternary cement is made by combining three-component cement made by combining ordinary Portland cement (OPC) with two supplementary cementing materials, for example, bamboo leaf ash and rice husk ash. The sustainability and affordability aspects of OPC concrete are better addressed with a ternary blend. The characteristics of OPC can be greatly influenced by combining it with other ingredients. In today's world, to achieve a variety of goals, different admixtures are incorporated into concrete to enhance the properties of fresh and hardened concrete. Several factors influence the concrete properties, including chemical configuration, molecule weight, and functional mixing groups [1]. There is a continuous change in the specification for high strength and durable concrete as long as new materials have been investigated. The focus of the study is on various admixtures that enhance the qualities of both fresh and hardened concrete. Oil-based and non-renewable compounds with pollution potential, such as formaldehyde, are the most common admixtures utilized in cementitious-based systems [2]. From the idea of eco-friendly concrete, bio-based admixture which can achieve as good as oil-based polymers admixture at the same time and being more affordable, the reason why starch is adopted. [3] noted that starch is one of the most abundant polymers in the world. Starch and its derivatives are known to have good viscosity modifying characteristics.

In Africa, around 5 million tons of rice husk are created annually. The husk of rice has been discovered to have a negative impact on the general appearance of the environment and has become a threat to the ecosystem. After the chemical analysis, the rice waste has been discovered to be an interesting pozzolana, replacing some of the cement as it met the requirements of [4] in terms of Physico-chemical characteristics, as with the case of the substitution of cement by glass powder in the PIONEER industry for the production of bricks, blocks and pavers, the decrease in cement demand, an increase in resource conservation and a decline in the high pollution linked to cement production.

Researchers chose to explore other environmentally friendly materials that may be utilized in concrete manufacturing because of the difficulty of waste disposal. As a result, the goal of this study is to utilize RHA waste material as cement partial substitution and CS as a natural additive in concrete, which has emerged as one of the most serious environmental challenges in developing countries.

II. MATERIALS AND METHODS

A. Materials

The materials utilized in this research were OPC 42.5 produced in Blue Triangle Factory, rice husk obtained from Mwea and burnt with a controlled temperature up to 650°C in a furnace to produce the required RHA, and CS which was obtained from the cassava root. The starch used in this study was extracted from cassava milk obtained from a sieving process, also used for processing cassava into Attieké, which is a staple food in Ivory Coast. The cassava root was bought in Muranga, peeled and washed. Fresh cassava was grated into a slurry then put in a sieve subjected to the pressure of the hand to expel water. The collected cassava-water extract from the sieving process was allowed to sediment for twenty-four hours, and the clear water was removed. After removing the water, the remaining substance stuck at the bottom was the starch. The starch was then sun-dried. The chemical composition and particle size distribution were determined.

All materials were collected from various areas in Kenya. The river sand was procured from Meru and the coarse aggregate from the Warren concrete factory. Figures 1 and 2 show the CS and RHA used in this research.

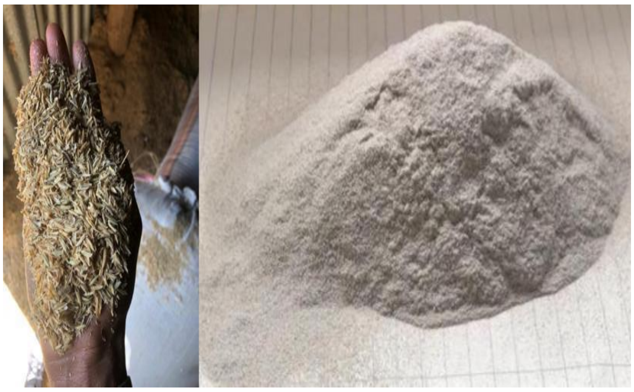

Fig. 1 Rice husk (left) and RHA (right)

Fig. 2 Cassava Starch and Cassava Starch Activation

B. Methods

In order to assess the suitability of coarse and fine aggregates used in concrete, the particle size distribution was performed according to BS EN 933-1:2012[5]. The chemical properties of cement were carried out using an XRF test conforming to [6].

The mix design was done in agreement with [7]. The control mix used only Ordinary Portland cement (OPC), while the other mixes used binary (RHA, OPC), ternary (RHA, CS, OPC), and ternary (RHA, CS, OPC) mixtures, as shown in Table 1, with RHA percentages ranging from 0% to 20% cement substitution and CS added by cement weight varying from 0% to 2%. The maximum proportion of CS was 2%, which is in conformity with section 5.2.6 of [8]. A total of 16 concrete mixtures with a constant of W/C 0.5 were created.

In each mixture, 15 cubes of 100 mm × 100 mm × 100 mm were molded for compressive strength testing, 15 cylinders of size 100 mm × 200 mm were molded for splitting tensile strength testing. The concrete was cast and cured for 7, 14, 28, 56 and 90 days in line with [9].

In accordance with [10], the Vicat apparatus was utilized to find the mix's standard consistency initial and final setting times. The workability (slump) test was examined according to stipulated procedures in [11]. The density was determined using [12]. The compressive strength was calculated according to [13]. Concrete cylinders were used to measure split tensile strength in accordance with [14].

Table 1. Mix Proportions of Concrete (Kg/m3)

Mix	OPC	CS	RHA	C.A	F.A	Water
Control	340	-	-	1247	642	170
1CS	340	3.4	-	1247	642	170
1.5CS	340	5.1	-	1247	642	170
2CS	340	6.8	-	1247	642	170
10RHA	306	-	34	1247	642	170
15RHA	289	-	51	1247	642	170
20RHA	272	-	68	1247	642	170
1CS10RHA	306	3.4	34	1247	642	170
1CS15RHA	289	3.4	51	1247	642	170
1CS20RHA	272	3.4	68	1247	642	170
1.5CS10RHA	306	5.1	34	1247	642	170
1.5CS15RHA	289	5.1	51	1247	642	170
1.5CS20RHA	272	5.1	68	1247	642	170
2CS10RHA	306	6.8	34	1247	642	170
2CS15RHA	289	6.8	51	1247	642	170
2CS20RHA	272	6.8	68	1247	642	170

III. RESULTS AND DISCUSSION

A. Material characterization

coarse aggregate (CA), Fine aggregate (FA), rice husk ash (RHA), cassava starch, and ordinary Portland cement (OPC) were categorized with regard to properties listed in Table 2. Also, the FA and CA grading are revealed in figures 3 and 4.

Table 2. Physical and Mechanical Properties of Materials

Property	**FA**	**CA**	**Specification (ASTM C33 limits)**
Specific gravity (SSD)	2.42	2.69	2.4-2.9
Unit weight	1480	1420	1200-1750 kg/m3
Water absorption	3.2%	3.39%	<4%
Voids in aggregate	42%	44.3%	30-45%
Silt content	4.92	-	<5%
Moisture content	1.2%	1%	0-4%
Aggregate crushing value	-	22.3%	-
Aggregate impact value	-	16.5%	-
Fineness modulus	2.35	2.89	2.3-3.1

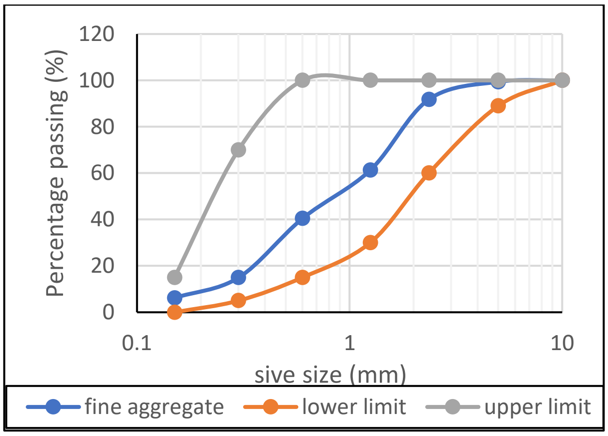

Fig. 3 Particle size distribution of fine aggregate

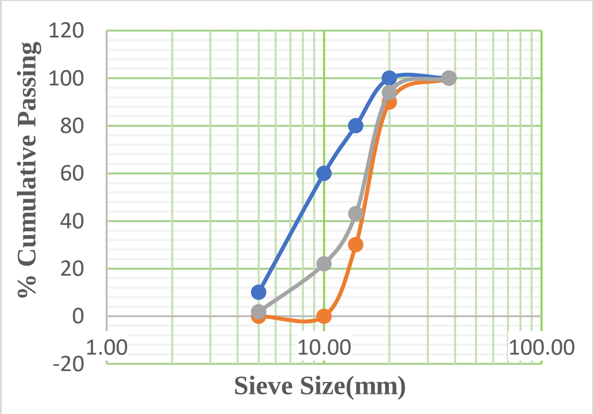

Fig. 4 Particle Size Distribution of Coarse Aggregate

Figure 3 shows the FA grading. The envelope revealed that the FA grading is within the reasonable range as stated in [5]. The size distribution of FA is between 0.16 and 5 mm. A correct grading of aggregate results in a well-closed-packing of combining aggregate in concrete. The fineness modulus was identified as 2.35, which fall within the ASTMC C33 [15] span of 2.3-3.1. This has an impact on concrete's workability. Table 2 lists the other properties of FA, which can be used to ensure that it is suitable for utilization in normal-weight concrete. Figure 4 depicts the grading of CA, revealing that 94 per cent of CA was discovered between the aperture sizes of 5 mm and 25 mm. This indicates that most of the aggregates pass through the 25 mm sieve. According to BS812-103.1 [16], the curve envelop comprised the lower limit and upper limit curves. Table 2 lists the coarse aggregate's other characteristics.

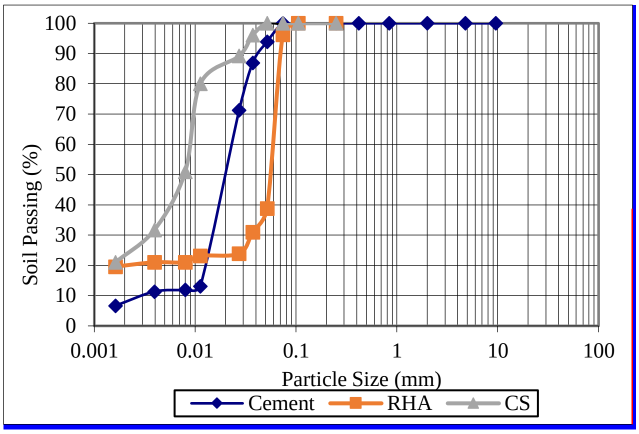

Fig. 5 Particle size distribution for cement, RHA and CS

Regarding the comparison between grading for cement, RHA and CS, Figure 5 was used to show the similarities between the three materials for the study. The dense particle size of cement was within 13 to 70% of the grading range for particle size ranging from 13 to 18.2 µm, respectively. For RHA, the particle size distributions were within 22 to 92% of the grading range for particle size ranging from 26 to 61 µm, respectively, which is coarser than the cement. Most of the particle size distribution of CS were within 20 to 90% of the grading range for particle size ranging from 9 to 12.3 µm, which is finer than the cement and RHA. The implication is that the smaller the particle is, the faster strength development occurs due to the filling effect [17].

Table 3 shows that RHA has a chemical composition of SiO2 + Al2O3 + Fe2O of 96.95%, which is higher than the requirement in [4] of 70% for a pozzolana.

Table 3. Chemical properties of RHA and OPC

Chemical composition	**Content (%)**	
	RHA	**OPC**
Silica (SiO_2)	96.85	12.99
Aluminium oxide (Al_2O_3)	-	3.69
Calcium oxide (CaO)	1.47	75.22
Potassium oxide (K_2O)	-	0.44
Iron oxide (Fe_2O_3)	0.10	2.74
Sulfur (SO_2)	-	3.09
Titanium oxide (TiO_2)	0.02	0.23
Phosphorus oxide (K_2O)	0.64	1.25
Loss on ignition	5.99	3.4

In the objective of characterizing the microstructure of Supplementary Cementitious Materials(SCM) used as substitutes, scanning electron microscope (SEM) the test was conducted on the raw particles of rice husk ash (RHA) and cassava starch (CS). At the micro-scale level, the different materials were tested to find out shape and size. That information helps understand the interaction between particles and the behaviour of SCM during its development. Figures 6 and 7 display the SEM of RHA and CS used in this study. The shape longitudinal was seen on the SEM of RHA with some micro-pores at the surface, which justifies the porous nature of RHA. This is likely to decrease concrete workability by absorbing the water required for the mix. Concerning CS, the particles were found to have a round or spherical shape and present a better regularity than the RHA. This increases the availability of CS for adsorption onto the surfaces of cement grains. Because of the particle size, shape, and specific surface area, the gel formed from CS will easily envelop the surfaces of cement grains. Slump is reduced in CS because of the adsorption of more starch upon cement grains surfaces. This increases viscosity and is consistent with the study's findings [18].

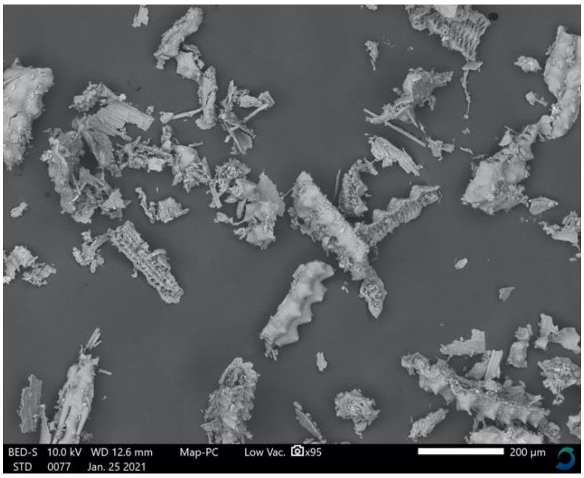

Fig. 6 RHA at 200*magnification

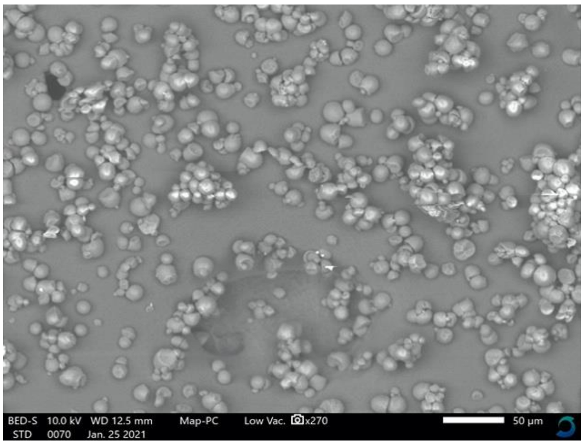

Fig. 7 CS at 50* Magnification

Table 4. Display CS chemical composition

Table 4. Chemical Composition of Cassava Starch

Property	Value
Moisture content (%)	9.86
Ash content (%)	1.1675
Fat content (%)	0.555
Protein content (%)	0
Carbohydrates (%)	88.4175

The material was found to be predominantly carbohydrate up to 88%. [19]-[20] reported values of 87% and 88% carbohydrates, respectively, which agrees with the chemical properties of cassava starch in Table 4. [21] also reported that cassava powder has a higher carbohydrate concentration of about 85%. This confirms the starchy constitution of the material utilized in this study.

[22] CS is a carbohydrate polymer made up of two molecules: linear amylose and branched amylopectin. “Amylose functions as a thickening, water binder, emulsion stabilizer, and gelling agent, whereas amylopectin, which makes up a larger percentage of the starch” [23]. Amylose and amylopectin contribute to the delaying effect of starch granules by lowering the reactivity of C3A when added in concrete, reducing the development of undesirable hydration products like ettringite.

B. Initial and final setting time

The setting times of CS and RHA mortar are displayed in Figure 8.

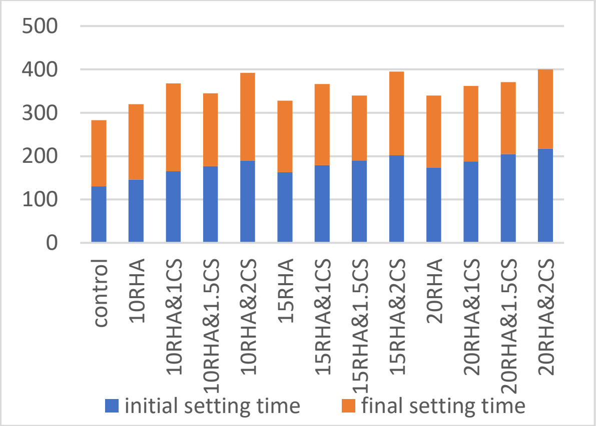

Fig. 8 Initial and Final Setting Times of CS and RHA Concrete

In the literature, there is a general agreement on the retardation of the initial setting (IS) and final setting (FS) times of the mortar containing CS. The RHA displayed behaviour that was distinct from that of CS. Regarding the influence of RHA content on concrete setting time, there was no universal agreement in the literature. Some researchers [24], [25] stated that RHA has a retarding effect while others reported its accelerating effect [26], [27] on the setting times [3], [5], [6]-[8].

When the concrete with binary blended of OPC RHA was evaluated, it was found that the RHA increased the delay in the setting time with an increasing amount of RHA in this study. As shown in Figure 8.

For ternary binders containing OPC, RHA and CS, the IS and FS setting times are shown in Figure 8. There is a clear trend that the binary use of RHA and CS with OPC significantly prolonged the IS and FS times compared with the control value. The lower cement content might be one of the reasons for the retardation in setting time. It can also be observed that the set times for a ternary binder increased as the percentage replacement of OPC with RHA increased. [28] attributed the delay to a combination of lower cement content and the effective admixture dosage per weight of cement. Furthermore, starch polymer adsorption to Tri-calcium aluminate (C3A), which governs the set properties of cement paste may cause retardation [29], [30] [10]-[12]. Of all the mixtures, 20%RHA and 2% CS showed the higher retardation in IS and FS times.

C. Physical properties of concrete

a) Workability (Slump)

The workability of the slump test is shown in Figures 9 and 10, respectively, for CS concrete and RHA concrete.

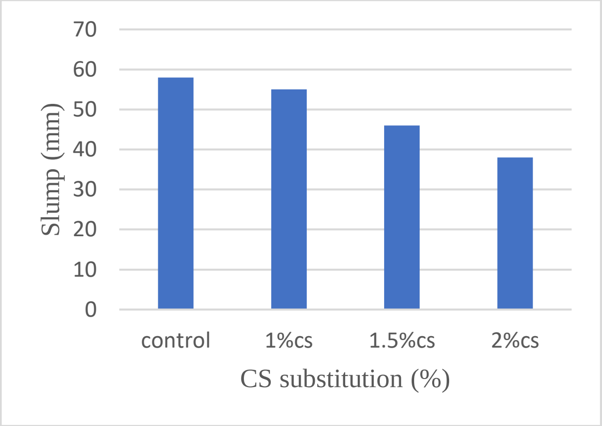

Fig. 9 Workability of CS Concrete

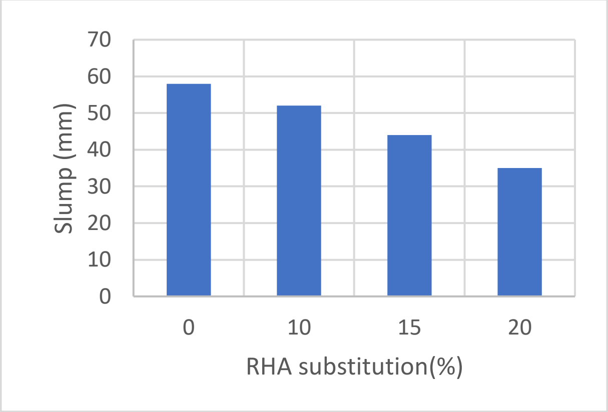

Fig. 10 Workability of RHA Concrete

From Figure 9, there was still a decrease in a slump with augmentation in CS percentage. The workability progressively decreased from 58mm for the control concrete to 38mm for 2% addition of CS. This might be linked to the thickening power of CS resulting from the viscosity modifying properties of starch. The spherical shape of CS, according to Figure 6, grants the starch gel to easily envelop the surface of cement grains and resulting in a growth of the mix viscosity [31],[2].

From Figure 10, RHA presence in the mix increases the number of fines in concrete which increase the mix water demand. The high demand of water in RHA concrete could be due to the porous structure of RHA, as seen previously in the SEM analysis of RHA.

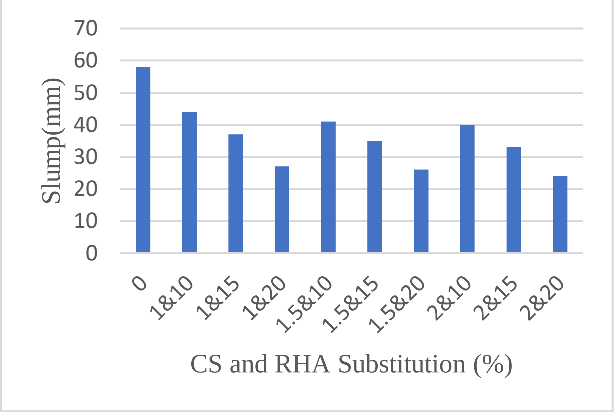

Fig. 11 Workability of RHA and CS Concrete

From Figure 11, the slump of RHA & CS concrete decreased in all mixes compared to the control. The lowest slump registered falls within the range of the mix design (10-30mm). The decrease in workability of RHA & CS concrete must be due to the porous nature of RHA, and as a consequence, more water is required for adequate workability. Also, the particle size was fine, hence the increasing quantity of fines in the matrix [32]. It can also be linked to the viscosity modifying effect of CS in the concrete.

D. Mechanical properties of concrete

a) Density of RHA and CS concrete

The density of concrete containing CS and the one containing RHA are shown in Figures and respectively.

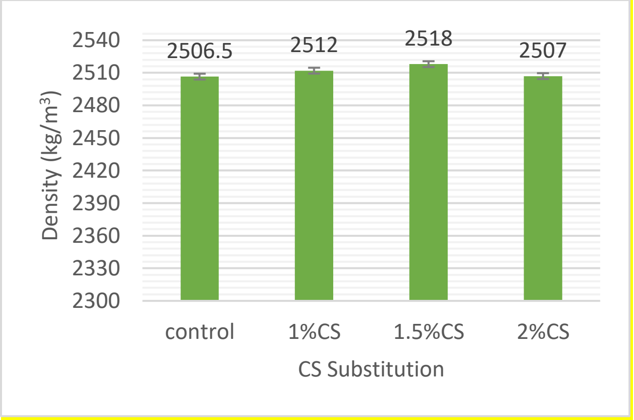

Fig. 12 Density of CS concrete

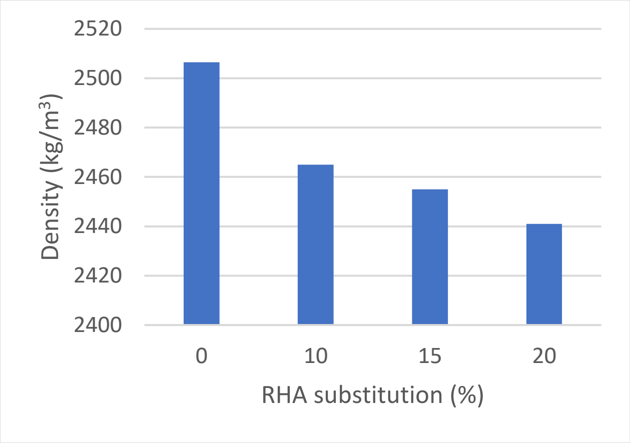

Fig. 13 Density of RHA Concrete

The figure 12 also shows the density of concrete made with CS. It can be observed that the density increases gradually and reaches a maximum at 1.5 % CS and then drops. The reduction can be due to the reducing workability of the concrete, which influences and give better compaction. Figure 13 shows the density of OPC concrete and RHA concrete at 28 curing days reduced with an increased percentage of RHA. The decrease in density can be attributed to RHA's lower specific gravity, resulting in a direct decrease in matrix density with an increase in RHA concentration. The density was found to be in the interval of 2000-2600kg/m3 for normal concrete as required in [12]. Furthermore, all the RHA concrete and CS concrete falls within this interval.

From Figure 14, it can be observed that the density decrease progressively in all mixes from 1CS&10RHA to 2CS&20RHA from 2474 kg/m^3 to 2359 kg/m$^{3.}$ This might be due to RHA lower specific gravity, thereby straightly decreasing the density of the matrix with the increasing percentage of RHA workability of RHA and CS concrete which could have led to poor compaction, creating some void in the concrete. The density was in the interval of 2000-2600kg/m^3.

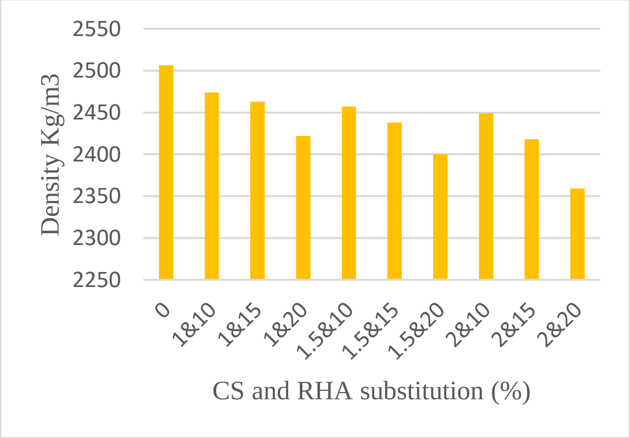

Fig. 14 Density of RHA and CS Concrete

b) Compressive strength of RHA and CS concrete

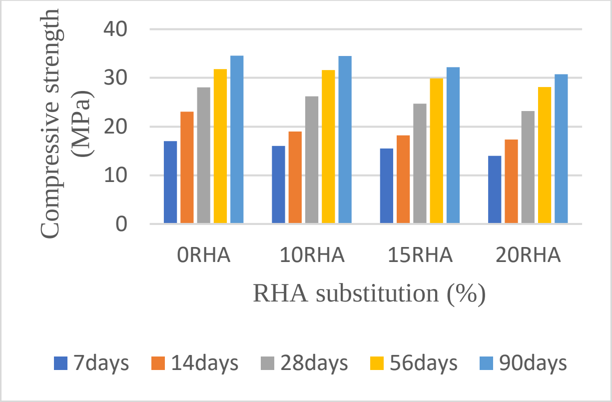

Fig. 15 Compressive Strength of RHA Concrete

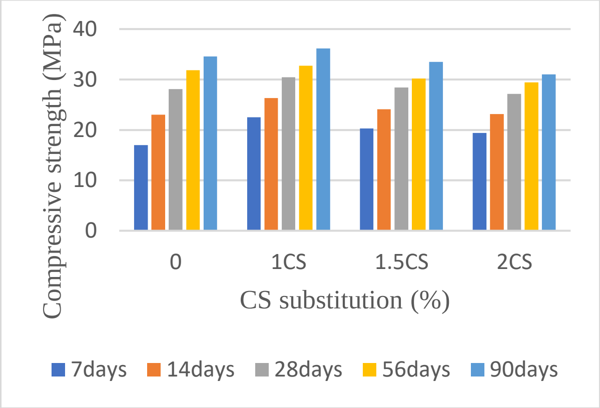

Fig. 16 Compressive Strength of CS Concrete

From the experimental study of the compressive strength RHA concrete, Figure 15 shows that the increase in the amount of substitution up to 20% reduces the early strength of RHA. Concrete strength at 7 and 14 days was determined to be lower than OPC strength. Such observation is in close agreement with the finding reported by [33],[34]. The significantly lower calcium oxide content of rice husk ash (1.47%) compared to cement (75.22 %) might account for the reduction in compressive strength of RHA concrete. However, from 28, 56 and 90 days, it can be observed some increase in the strength for all replacement comparatively to the early age. The substitution percentage of 10% registers the highest compressive strength, comparable to the control one. The later strength gaining might be the resultant of the later pozzolanic reaction of RHA in the concrete [35].

Figure 16 shows the compressive strength of CS concrete. This compressive strength increased over the control at all curing days. This can be linked to the moderating behaviour of starch to reducing bleeding and segregation in concrete because of viscous starch nature. Also, internal curing is improved due to the viscosity modifying properties of starch. According to [18], CS have a higher degree of polymerization, which gives the material increased binding force [11]. This could explain why adding CS enhances compressive strength. These results compare positively with the findings of [36], [37], [31], [9], [1]-[2].

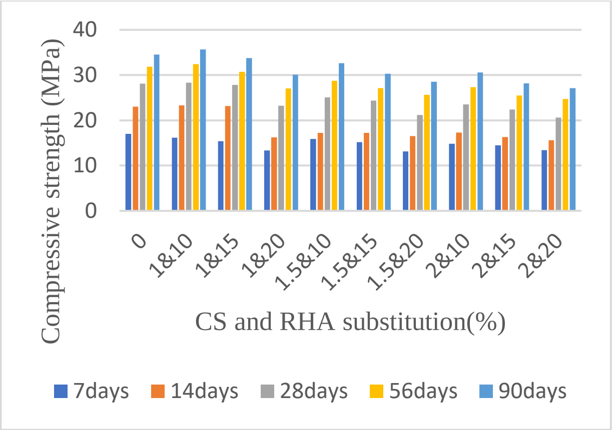

Fig. 17 Compressive strength of CS and RHA concrete

The compressive strength of concrete blended with RHA and CS at curing ages of 7, 14, 28, 56, and 90 days is displayed in Figure 17. It was seen that there was a drop in concrete strength at 7 days of curing for all percentage replacement of RHA and CS compared to the control mix at 17.01MPa. Nonetheless, the 1CS10RHA and 1CS15RHA mixes showed greater strengths after 14 days of curing, reaching 23.3 and 23.13 MPa, respectively. The compressive strength of the other mixes, on the other hand, was found to be slightly lower.

At 28, 56 and 90 days, the maximum strength was recorded at 1CS&10RHA replacement compared to the control, while the other dosage showed a slight increase but still inferior to the control. The increase in force could be attributed to RHA being a pozzolanic material that takes time to react, adding to that the viscosity power of CS, which helps avoid segregation and bleeding in concrete and maintain the matrix well-packed together. Thus, the optimum is at 1CS&10RHA replacement. Any further increase beyond 1CS&10RHA substitution would cause strength reduction.

c) Splitting tensile strength of RHA and CS concrete

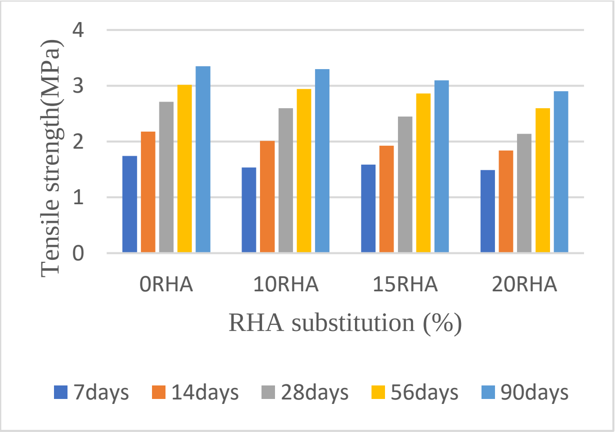

Fig. 18 Tensile Strength of RHA Concrete

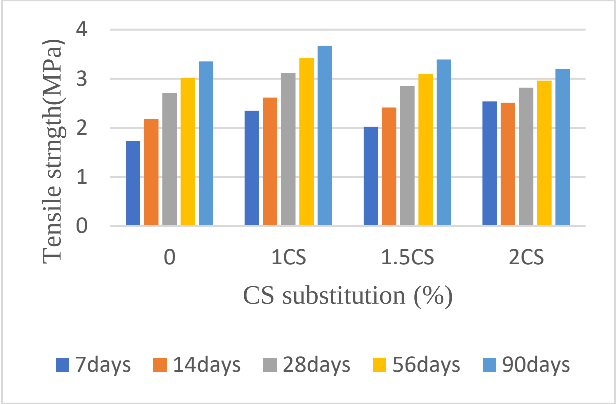

Fig. 19 Tensile Strength of CS Concrete

Figures 18 and 19 show the splitting tensile strength of RHA concrete and CS concrete, respectively. The findings illustrate a pattern equivalent to the compressive strength results. From figure 18, it can be observed that at 7 and 14 days, the splitting tensile strength of RHA concrete decreased with a percentage increase. This can be due to decreased bonding behaviour of RHA in constituent materials in concrete compared to cement. The splitting tensile of RHA concrete increased compared to the control at 28, 56, and 90 days, with maximum strength at 10% RHA. This could be due to the pozzolanic influence of RHA, it being a long-term process. From figure 19, the splitting tensile strength of CS concrete registers better performance at all ages with 1%CS compared to the control. Any other increment of CS reduces the splitting tensile strength. The increment in tensile strength can be due to the faculty of starch to control bleeding, thereby decreasing the formation of micro-crack at the paste-aggregate interphase as suggested by the [38].

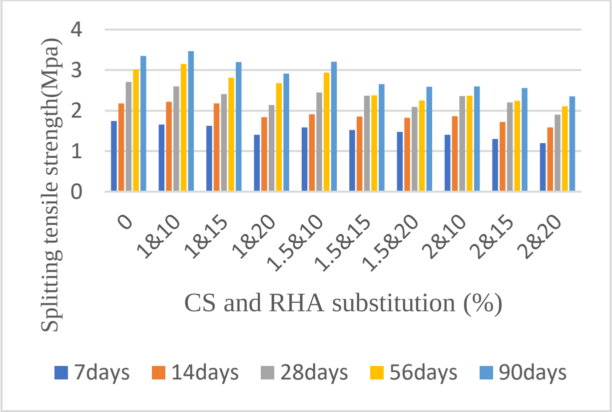

Fig. 20 Tensile Strength of RHA and CS Concrete

The effect of CS and RHA concrete on splitting tensile strength at 7, 14, 28, 56 and 90 days are shown in figure 20. It was found that the splitting tensile strength follows the same trend as the compressive strength. Based on the results, it has been observed that the percentage increase of the splitting tensile strength is 2.3% and 1.1%, respectively, for 1CS10RHA and 1CS15RHA at the age of 14 days compared to the control. This improvement during the early age witnessed the strength development during early age because starch is known to have a high degree of polymerization [18].

At 28, 56 and 90 days of curing, it can be depicted that the mix 1CS10RHA registers the highest splitting tensile strength. While the increased percentage of CS and RHA show a decrease in the tensile strength. This may be due to the pozzolanic influence of RHA is a long term process, thereby taking time to get the necessary strength. The CS effect on the ternary mix might have contributed to filling micropores in the matrix due to the viscosity modifying effect avoiding bleeding and segregation, thereby increasing the mix's binding forces [18].

IV. CONCLUSION

The following conclusion was made based on the finding of this research:

Concrete workability decrease with an increase in RHA and CS percentage. Furthermore, the setting time is prolonged when the substitution of RHA and CS increases. The concrete made with the blend of RHA and CS improved the compressive and splitting tensile strength in the short and long term compared to the RHA and the control concrete with an optimum of 1CS10RHA.

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REFERENCES

[1] J. Liu, H. Zhou, and P. Ouyang, Effect of straw mixing amount on mechanical properties of admixture-adding hollow block, J. Wuhan Univ. Technol. Mater. Sci. Ed., 28(3) (2013) 508–513, doi: 10.1007/s11595-013-0722-5.

[2] Q. Wen et al., Study on activated carbon derived from sewage sludge for adsorption of gaseous formaldehyde, Bioresour. Technol., 102(2) (2011) 942–947, doi: 10.1016/j.biortech.2010.09.042.

[3] L. Crépy, V. Miri, N. Joly, P. Martin, and J. M. Lefebvre, Effect of side-chain length on the structure and thermomechanical properties of fully substituted cellulose fatty esters, Carbohydr. Polym., 83(4) (2011) 1812–1820, doi: 10.1016/j.carbpol.2010.10.045.

[4] ASTM C618, Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. USA: ASTM International, (2005).

[5] BS EN 933-1, the Particle size distribution of aggregate. London, UK: British Standards Institution, (2012).

[6] BS EN 196-2, chemical properties of cement. London, UK, (2013).

[7] BS 8500-2, The mix design. London, UK, (2012).

[8] BS EN 206, admixture proportion. London, UK, (2013).

[9] BS EN 12390:2, Casting curing of concrete. London, UK, (2009).

[10] BS EN 196-3, setting time and soundness of cement. London, UK, (2016).

[11] BS EN 12350-2, Consistency of fresh concrete by slump test. London, UK, (2009).

[12] BS EN 12390-7, determining the density of hardened concrete. London, UK, (2019).

[13] BS EN 12390:3, determining compressive strength. London, UK, (2009).

[14] BS EN 12390-6, determining tensile strength. London, UK, (2009).

[15] ASTMC C33, Particle-size distribution. USA: ASTM International, (2003).

[16] BS 812-103.1, the particle size distribution of coarse aggregate. London, UK, (1985).

[17] A. Kumar et al., The filler effect: The influence of filler content and type on the hydration rate of tricalcium silicate, J. Am. Ceram. Soc., 100(7) (2017) 3316–3328, doi: 10.1111/jace.14859.

[18] J. J. M. Swinkels, Composition and Properties of Commercial Native Starches, Starch - Stärke, 37(1) (1985) 1–5, doi: 10.1002/star.19850370102.

[19] G. Road and A. Centre, Quality Characteristics, Root Yield and Nutrient Composition of S Ix Cassava (Manihot esculenta Crantz) Varieties, (18) (2013) 1–13.

[20] M. Leonel, T. S. de Freitas, and M. M. Mischan, Physical characteristics of extruded cassava starch, Sci. Agric., 66(4) (2009) 486–493, doi: 10.1590/s0103-90162009000400009.

[21] S. A. Oyeyinka, A. A. Adeloye, S. A. Smith, B. O. Adesina, and F. F. Akinwande, Physicochemical properties of flour and starch from two cassava varieties, Agrosearch, 19(1) (2019) 28, doi: 10.4314/agrosh.v19i1.3.

[22] C. E. Chinma, C. C. Ariahu, and J. O. Abu, Chemical composition, functional and pasting properties of cassava starch and soy protein concentrate blends, J. Food Sci. Technol., 50(6) (2013) 1179–1185, doi: 10.1007/s13197-011-0451-8.

[23] M. Schirmer, A. Höchstötter, M. Jekle, E. Arendt, and T. Becker, Physicochemical and morphological characterization of different starches with variable amylose/amylopectin ratio, Food Hydrocoll., 32(1) (2013) 52–63, doi: 10.1016/j.foodhyd.2012.11.032.

[24] K. Ganesan, K. Rajagopal, and K. Thangavel, Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete, Constr. Build. Mater., 22(8) (2008) 1675–1683 doi: 10.1016/j.conbuildmat.2007.06.011.

[25] N. K. Krishna, S. Sandeep, and K. M. Mini, Study on concrete with partial replacement of cement by rice husk ash, IOP Conf. Ser. Mater. Sci. Eng., 149(1) (2016), doi: 10.1088/1757-899X/149/1/012109.

[26] M. a. Givi, A. N., Abdul Rashid, S., Abdul Aziz, F. N. & Mohd Salleh, Contribution of Rice Husk Ash to the Properties of Mortar and Concrete : A Review, J. Am. Sci., 6(3) (2010) 157–165.

[27] A. El-Dakroury and M. S. Gasser, Rice husk ash (RHA) as cement admixture for immobilization of liquid radioactive waste at different temperatures, J. Nucl. Mater., 381(3) (2008) 271–277, doi: 10.1016/j.jnucmat.2008.08.026.

[28] J. J. Brooks, M. A. Megat Johari, and M. Mazloom, Effect of admixtures on the setting times of high-strength concrete, Cem. Concr. Compos., 22(4) (2000) 293–301, doi: 10.1016/S0958-9465(00)00025-1.

[29] A. Popova, G. Geoffroy, M. F. Renou-Gonnord, P. Faucon, and E. Gartner, Interactions between polymeric dispersants and calcium silicate hydrates, J. Am. Ceram. Soc., 83(10) (2000) 2556–2560, doi: 10.1111/j.1151-2916.2000.tb01590.x.

[30] K. H. Tsao, FIMP dark matter freeze-in gauge mediation and hidden sector, J. Phys. G Nucl. Part. Phys., 45(7) (2018) 830–842, doi: 10.1088/1361-6471/aac3b9.

[31] A. A. Akindahunsi and W. Schmidt, Effect of cassava starch on shrinkage characteristics of concrete†, African J. Sci. Technol. Innov. Dev., 11(4) (2019) 441–447, doi: 10.1080/20421338.2017.1380580.

[32] O. Zaid, J. Ahmad, M. S. Siddique, and F. Aslam, Effect of Incorporation of Rice Husk Ash Instead of Cement on the Performance of Steel Fibers Reinforced Concrete, Front. Mater., 8 (2021) 1–14, doi: 10.3389/fmats.2021.665625.

[33] C. Marthong, Effect of Rice Husk Ash (RHA) as Partial Replacement of Cement on Concrete Properties, Int. J. Eng. Res. Technol., 1(6) (2012) 1–3.

[34] K. Kartini, M. . Nurul Nazierah, M. . Zaidahtulakmal, and G. Siti Aisyah, Effects of Silica in Rice Husk Ash (RHA) in producing High Strength Concrete, Int. J. Eng. Technol., 2(12) (2012) 1951–1956.

[35] P. Chindaprasirt and S. Rukzon, Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar, Constr. Build. Mater., 22(8) (2008) 1601–1606, doi: 10.1016/j.conbuildmat.2007.06.010.

[36] D. Oluwabusayo ONI, J. Mwero, and C. Kabubo, Experimental Investigation of the Physical and Mechanical Properties of Cassava Starch Modified Concrete, Open Constr. Build. Technol. J., 13(1) (2020) 331–343, doi: 10.2174/1874836801913010331.

[37] A. A. Akindahunsi and H. C. Uzoegbo, Strength and Durability Properties of Concrete with Starch Admixture, Int. J. Concr. Struct. Mater., 9(3) (2015) 323–335, doi: 10.1007/s40069-015-0103-x.

[38] M. S. Shetty, Concrete Technology: Theory and Practice, 055 (2005).