EXPERIMENTAL INVESTIGATION OF SESAME STRAW ASH BLENDED WITH RICE HUSK ASH ON FLEXURAL STRENGTH AND DURABILITY OF CONCRETE

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ABSTRACT

This study investigates the effect of sesame straw ash (SSA) blended with rice husk ash (RHA) as a substitute for cement on the flexural strength and durability of concrete. The investigation involves the replacement of cement with blended ashes of sesame straw and rice husk in an increment of 0, 10, 15, 20, 25, and 30 %. The flexural test was done on SSA-RHA concrete beams at 3, 7, 28, 56, and 90 days of curing in the water while the compressive strength of SSA-RHA-concrete exposed to 5 % Conc. of H_2SO_4 was performed after 28 days in water at 3, 7 and 28 days of curing in the solution of 5 % Conc. of H_2SO_4. The X-ray fluorescence (XRF) test was carried out on SSA and RHA. The result of the XRF test carried out on SSA and RHA shows that SSA had a CaO content of 45.42 % and RHA had the sum of Al_2O_3, SiO_2, and Fe_2O_3 of RHA as 84.22 %. The workability of SSA-RHA-concrete decreases as the percentage of SSA-RHA content increases. The flexural strength of SSA-RHA concrete decreases and increases as the percentage of SSA-RHA and curing period increase respectively. However, the retained compressive strength of SSA-RHA-concrete cured in H_2SO_4 solution decreases as the percentage addition of SSA-RHA and curing increase. On the other hand, the water absorption increases with an increase in the percentage of SSA-RHA content. The density of concrete decreased as the curing period in H_2SO_4 solution increased. However, most of the densities of SSA-RHA-concrete fall within the limits of 2200 kg/m^3 to 2600 kg/m^3. It was concluded that SSA and RHA blend can be used as supplementary cementitious materials in the production of concrete.

Keywords: Durability, Flexural Strength, Rice Husk Ash (RHA), Sesame Straw Ash (SSA), Sulphuric acid.
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INTRODUCTION

Concrete is the most commonly used composite material in the construction industry, with cement being the major constituent material, that contributes the most to strength development in concrete. The hardened cement paste responsible for strength development is formed when cement comes in contact with water, resulting in an improvement in the bond at the interface between the cement paste and aggregate [1]. Cement plays a significant role in the production of concrete and mortar and at the same time, the strength of concrete depends on its cohesion of its cement paste and its adhesion to aggregate particles. So, the cohesiveness and adhesiveness of cement show its importance in the production of concrete. However, the price of cement keeps increasing which contributes to the high cost of buildings. So, the need to produce concrete from agricultural waste cannot be over-emphasized, because of the high abundance of agricultural wastes such as sesame straw, rice husk and so on. Sesame Straw and rice husk are agricultural by-products (wastes) that are usually burnt, dumped, or left to decay naturally, and may cause inconvenient to both health and the environment when not properly disposed of, these may create large amounts of wastes that must be transported away and stored in landfills.

The pollution arising from such waste is a cause of concern for many developing nations such as Nigeria. Researchers have continued to intensify efforts at sourcing local materials that could be used as partial replacements for Ordinary Portland Cement (OPC) in building and civil engineering works. Supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete such that blended cement is now used in many parts of the world [2, 3]. Dwivedia *et al.*, [4] reported that the cementing quality is enhanced if good pozzolanic material is blended in a suitable quantity with OPC. The utilization of local waste by-products as a building material has attracted great attention for environmental sustainability and has become a fundamental part of sustainable construction [5]. However, there are few available studies on the use of Sesame straw ash (SSA) in concrete, but related literature on the use of agricultural waste ashes are reported. In a study conducted by Sulaiman *et al.*, [6] the addition of sesame straw ash (SSA) decreased the flow and compressive strength of mortar but increased the soundness, setting times, and consistency of SSA-cement paste. However, the compressive strength of SSA-mortar increased as the curing period increased. According to a study carried out on the effect of adding Sesame stalks fibre (SSF) to the concrete mixture by Elmardi *et al.*, [7] claimed that the compressive strength and flexural strength of SSF-concrete decreased as the percentage of sesame stalks fibre (SSF) increased. Additionally, the addition of (SSF) increases the concrete resistance against crack growth. Orame *et al.*, [8] carried out a study on the suitability of Sesame Plant Mucilage (Sesamum Indicum) as an admixture in concrete. They reported that Sesame Mucilage has a combined SiO_2, Al_2O_3, and Fe_2O_3 composition of 25.58%. However, the results of their findings showed that at 28 days of curing, concretes made with different percentages of Sesame mucilage have higher compressive strength than the control mix with 33.2 N/mm^2, 31.3 N/mm^2, and 30.8 N/mm^2 for 1.0%, 1.5%, and 2.0% Sesame mucilage content respectively. They concluded that the addition of sesame mucilage content increased flexural strength and tensile strength and their values are higher than that of the control mix at all curing ages. Aliyu *et al.*, [9] reported that the resistance of the concrete to acid increases as the percentage addition of Quarry dust increases, while the weight of concrete decreases with an increase in the exposure period. Akeke *et al.*, [10] carried out a study on flexural properties and tensile strength characteristics of RHA-concrete to determine the moduli of rupture and cracking respectively, the values of flexural strength obtained at 28 days were 3, 2.5, and 2.4 N/mm^2, while the tensile strength values are 1.94, 1.17, and 0.91 N/mm^2 at replacement percentages of 10%, 20%, and 25%. Tsado *et al.*, [11] found that the highest compressive strength obtained for replacement samples of RHA was in 10% RHA at 30.58 N/mm^2, while 26.51 N/mm^2, and 17.68 N/mm^2 were obtained for 20% and 30% replacement of RHA for OPC respectively. Ofuyatan *et al.*, [12] worked on the assessment of the strength properties of cassava peel ash-concrete, their findings showed that the compressive strength, durability, and resistance to sulphuric acid have been improved considerably at 10 % replacement. They concluded that concrete with cassava peel ash can be used for light construction works where durability is a major concern. Ogork *et al.*, [13] determines the effect of groundnut hush ash (GHA) blended with rice husk ash (RHA) in concrete and mortar, and the results indicated that the workability, compressive strength, splitting tensile strength, and flexural strength of concrete decreases with increase in GHA-RHA content, and also concluded that 15% would be considered as the optimum for structural concrete.

According to Sulaiman *et al*. [14] incorporating GSA-SDA decreases the workability of concrete but increases the setting times and soundness GSA-SDA-cement paste. Moreover, the compressive strength of concrete was enhanced as the curing age increased, it also increases up to 10% at 28 days of curing and then decreases when percentage of GSA-SDA increases. They concluded that the maximum percentage of GSA-SDA to be used should not be more than 10%. Ettu, *et al*., [15] Carried out a study on the compressive strength of ternary blended cement concrete containing cassava waste ash (CWA) and coconut husk ash (CHA), and the results showed that a very high concrete strength could be obtained with OPC-CWA-CHA ternary blended cement when high control measures are applied at longer days of hydration. Dabai *et al*., [16] reported that the silica content of the RHA was found to be 68.12%, which indicated higher silica content than in cement. The value is closer to the required value of 70 % minimum for pozzolanas (ASTM, 1978), which is a very good value for workability. According to Rambabu and Rao [17] the use of natural pozzolanic material as a replacement for ordinary cement partially in concrete has been found to improve the confrontation of concrete to sulfate attack. According to Gunduz and Kalkan, [18] the use of RHA significantly improves the cement mortar strength at the 20 % replacement level at the age of 90 days. An experimental study carried out by Kueaket and Tonnayopas [5] revealed that the compressive strength, water absorption, porosity, and durability characteristics of POBC mortar incorporating RHA and CB were improved by long-term curing.

This study aims at investigating the influence of sesame straw ash (SSA) blended with rice husk ash (RHA) on the flexural strength and durability of concrete.

MATERIALS AND METHODS

Materials

The Portland limestone cement (PLC) used was Dangote BlocMaster, grade: 42.5R. The fine aggregate and coarse aggregate used were sourced from Zaria Local Government Area, Kaduna State, Nigeria. Sesame straw ash (SSA) used was obtained by burning the sesame straw (SS) sourced from Jigawa State, Nigeria. It has a moisture content of 1.95 %, and a specific gravity of 2.69. The water used was potable, sourced from the Department of Civil Engineering laboratory of ABU, Zaria, Kaduna State, Nigeria.

Methods

Sieve analysis of fine and coarse aggregate

The sieve analysis tests were carried out according to [19] to know the particle size distribution of the fine and coarse aggregate.

Mix proportions for SSA-RHA-Concrete

The Design of Experiment (DOE) method was used to calculate the concrete mix proportions for grade 20 concrete. The mix proportions used are presented in Table 1.

Table 1: Mix proportion for SSA-RHA-Concrete.

Mix	Cement (kg/m^3)	SSA (kg/m^3)	RHA (kg/m^3)	Fine (kg/m^3)	Coarse (kg/m^3)	Water (kg/m^3)
T0	320	0	0	723	1231	176
T10	304	0	32	723	1231	176
T15	288	16	32	723	1231	176
T20	272	32	32	723	1231	176
T25	256	48	32	723	1231	176
T30	240	64	32	723	1231	176

Slump test of fresh concrete
The workability test was performed on fresh concrete in accordance with [20].

Flexural strength test of SSA-RHA-Concrete
The flexural strength test on SSA-RHA-concrete beams was conducted according to [21]. Beams were cast and three specimens were tested for a mean for each curing span (3, 7, 28, 56, and 90) using the Avery-Denison universal testing machine.

Water absorption test of SSA-RHA-Concrete
This water absorption test was performed on SSA-RHA-concrete samples accordance with [22]. A total of eighteen (18) specimens were cast and cured for 28 days, then after 28 days of curing, three specimens were tested and the average result was reported.

Compressive strength of SSA-RHA-Concrete
The compressive strength test on SSA-RHA-concrete was conducted according to [23]. A total of fifty-four (54) concrete cubes were cast, cured in 5% concentration of sulphuric acid (H_2SO_4) solution after 28 days of water curing and three (3) specimens were tested for a mean for each curing period (3, 7, and 28 days).

RESULTS AND DISCUSSIONS

Oxide composition of cement, SSA and RHA
The results of the XRF test performed on cement, SSA, and RHA are displayed in Table 2. The oxide composition of SSA indicates that the total of aluminium oxide (Al_2O_3), silicon oxide (SiO_2), and iron oxide (Fe_2O_3) is 28.92%, which is less than the lower limit of 50 % specified by ASTM C 618 for pozzolana. The CaO content of 45.42% in SSA shows that it possesses some cementing properties. While the add up of aluminium oxide (Al_2O_3), silicon oxide (SiO_2), and iron oxide (Fe_2O_3) of RHA are found to be 84.22 higher than 70% as specified by ASTM C 618 for natural pozzolana and characterized as high reactive pozzolana.

Table 2: Oxide Composition of Cement, SSA, and RHA

Oxide	Cement	SSA (%)	RHA (%)
Na_2O	0.18	1.08	0.50
MgO	1.05	3.55	0.37
Al_2O_3	2.83	1.82	2.17
SiO_2	21.4	20.83	80.60
SO_3	1.42	2.52	0.63
P_2O_5	-	6.96	4.89
Cl	-	1.01	-
BaO	0.01	-	0.12
K_2O	0.62	8.02	2.80
CaO	68.02	45.42	2.90
TiO_2	0.17	1.01	0.57
Cr_2O_3	-	1.47	-
Mn_2O_3	0.03	0.15	1.32
Fe_2O_3	2.77	6.27	1.45
ZnO	0.39	0.37	0.40
V_2O_5	0.02	-	-
SrO	-	0.49	-
LOI	-	0.30	2.89

Sieve analysis of fine and coarse aggregate
The results of particle size distributions of fine aggregate and coarse aggregate are shown in Figure 1. It was observed that the fine aggregate used belongs to zone 1 accordance with [19] for grading limits for fine aggregate. The fine aggregate has a silt content of 2 which is less than the maximum of 6.0 and specific gravity of 2.72. While the coarse aggregate used has a bulk density of 1425 kg/m^3 and specific gravity of 2.68. It was noticed that the coarse aggregate was well-graded. This indicates that the fine aggregate (sand) and coarse aggregate can be used in the production of concrete.

Slump of SSA-RHA-Concrete
The results of slump test carried out on a fresh concrete made with various percentages of SSA-RHA content were shown in Figure 2. The result indicated that the workability of concrete decreased as the percentage of SSA-RHA increased. It was observed that the concrete becomes sticky with increase in the SSA-RHA content and hence, more water is needed for improved workability. The increase in the mix water requirement was a result of the increase in the silica content with SSA-RHA. The decrease in a slump maybe because of the high surface area of SSA-RHA for a constant water-binder ratio [14]**.** Similar behaviour was also reported by Sulaiman & Aliyu [24].

Flexural strength of SSA-RHA-Concrete
The results of flexural strength of concrete produced with different percentages of SSA-RHA content were shown in Figure 3. It was observed that the flexural strength of concrete produced with different percentages of SSA-RHA content decreased as the percentage addition of SSA-RHA content increased, moreover, it increased as the curing age increased.

The increase in flexural strength of concrete as the curing age increased was as a result of the hydration of cement and pozzolanic reaction of SSA-RHA [25]. It may also be attributed to the reaction of SSA-RHA with calcium hydroxide [$Ca(OH)_2$] liberated during the hydration of cement as explained by Mujedu *et al.*, [26]. While the decrease in flexural strength maybe because of the addition of SSA-RHA content and the dilution effect of cement [25].

Compressive strength of SSA-RHA-Concrete after immersion in 5% H_2SO_4 solution

The results of the compressive strength of SSA-RHA-concrete cured in 5% H_2SO_4 solution were presented in Figure 4. It was observed that the retained compressive strength of SSA-RHA-concrete decreased with an increase in SSA-RHA content and the curing age in 5% concentration of H_2SO_4 solution. The highest and lowest compressive strengths recorded were at 0 % SSA-RHA content, 3 days of curing in H_2SO_4 solution, and 25% SSA-RHA content, 28 days of curing in H_2SO_4 as 21.73 N/mm^2 and 5.13 N/mm^2 respectively. It was observed that all the values of the compressive strength were lower than control at all replacement levels, except at 5 % replacement after 3 days in the solution. The reduction in the strength was attributed to strength reduction due to weight loss of the concrete. The weight loss was a result of acid attack on concrete. The loss of weight of concrete cubes in 5 % concentration of H_2SO_4 medium was due to ettringite formation. Acid attacks on $Ca(OH)_2$ and form $CaSO_4$ which is leached out of concrete [27].

Water Absorption of SSA-RHA-Concrete

Figure 5 shows the relationship between water absorption and the percentage addition of SSA-RHA. It shows that the more SSA-RHA content was added the more SSA-RHA-concrete absorbed water. The increase in water absorption may be a result of the addition of SSA-RHA content. And this behaviour shows that SSA-RHA can absorb or attract more water.

Density of retained SSA-RHA-Concrete cured in H_2SO_4 solution

Figure 6 shows the densities of concrete produced with different percentages of SSA-RHA as partial replacement of cement. It was observed that the density of concrete decreased as the curing period in H_2SO_4 solution increased. The decreased in the density of concrete may be as a result of acid attack, which causes the concrete degradation. However, most of the densities of SSA-RHA-concrete fall within the limits of 2200 kg/m^3 to 2600 kg/m^3.

CONCLUSIONS

Based on the results presented the following conclusions were drawn:

i. The workability of fresh SSA-RHA-concrete decreases as the percentage addition of SSA-RHA content increases.
ii. The flexural strength of concrete decreases and increases as the percentage of SSA-RHA content and curing period increase respectively.
iii. The retained compressive strength of SSA-RHA-concrete exposed to 5 % Conc. of H_2SO_4 solution decreases as the curing period and percentage addition of SSA-RHA content increase.
iv. It was concluded that SSA and RHA blend can be used as supplementary cementitious materials in the production of concrete.

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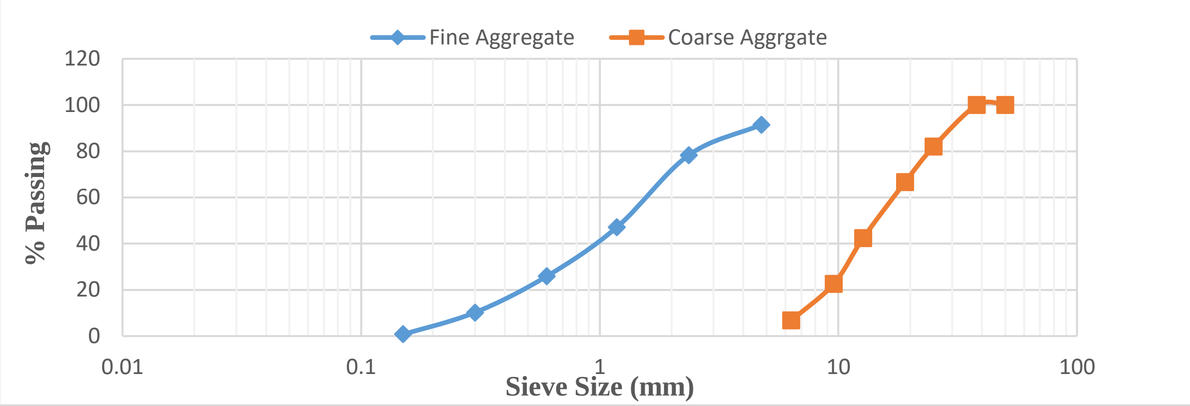

Figure 1: Particle size distribution of fine aggregate and coarse aggregate

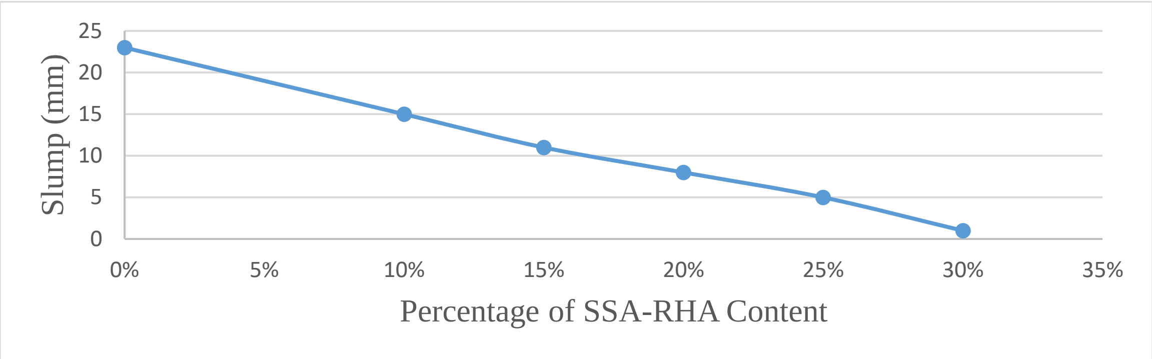

Figure 2: Slump values against SSA-RHA content

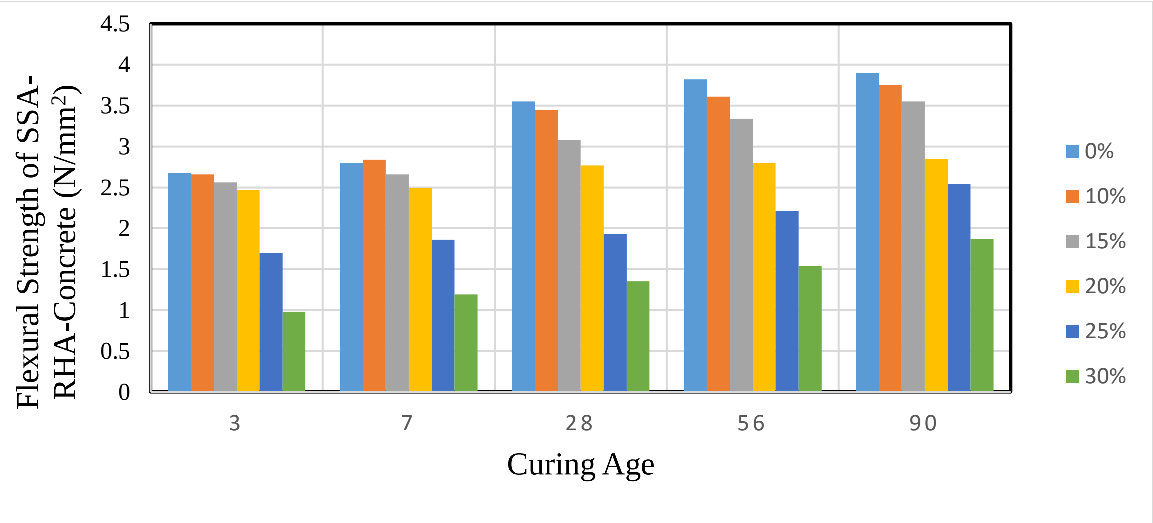

Figure 3: Flexural strength of SSA-RHA-Concrete against curing age

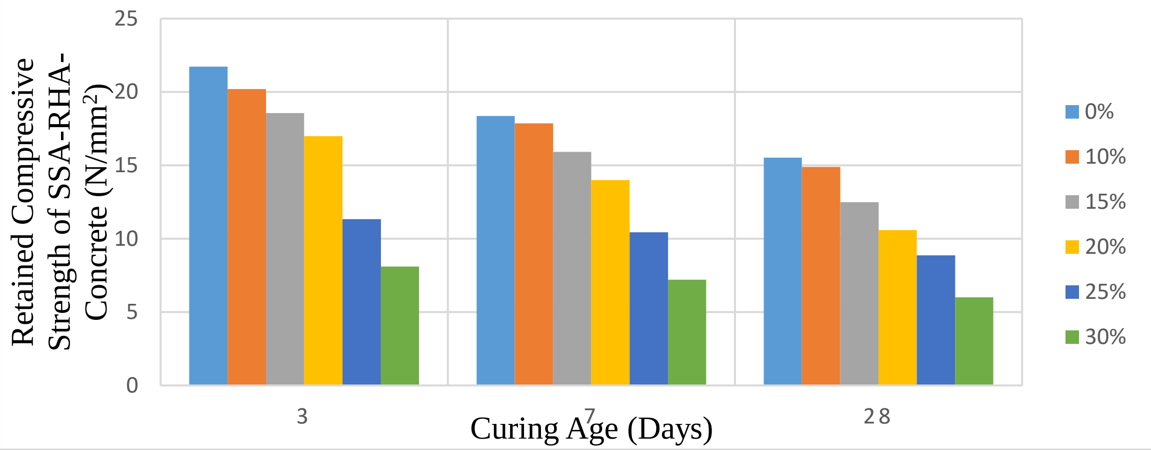

Figure 4: Retained compressive strength against curing (exposure) age

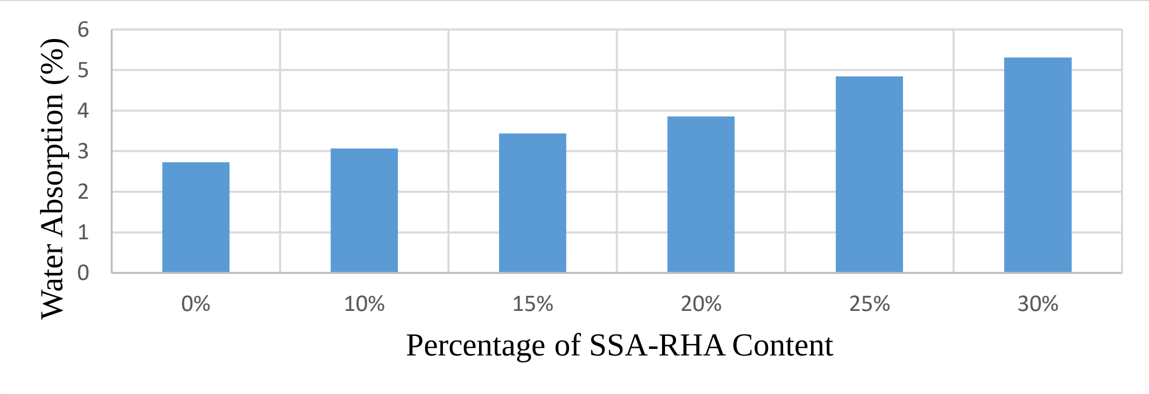

Figure 5: Water absorption of against percentage of SSA-RHA content

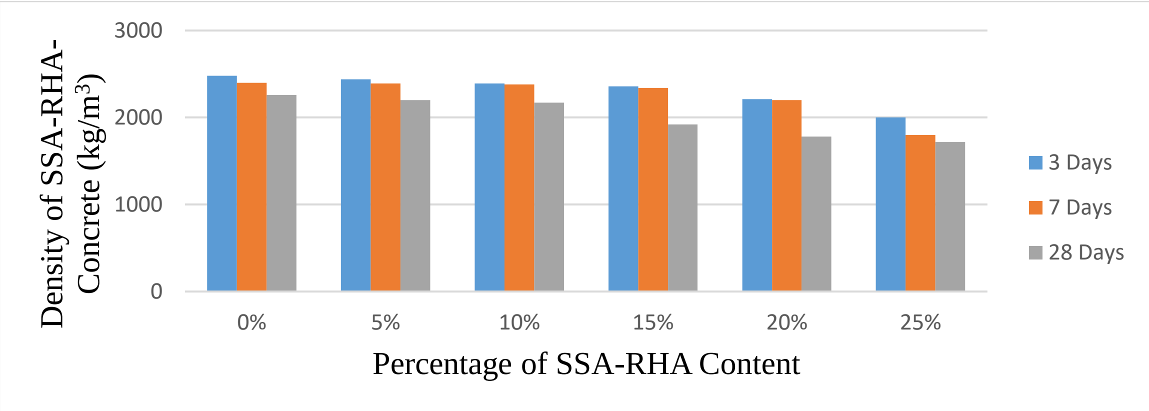

Figure 6: Density of SSA-RHA-Concrete against percentage of SSA-RHA content