Nigerian Journal of Engineering, Vol. 29, No. 1, April 2022, ISSN (print): 0794 – 4756, ISSN(online):2705-3954.

Nigerian Journal of Engineering,
Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria
journal homepage: www.njeabu.com.ng

Strength Properties Assessment of Sesame Straw Ash Blended with Rice Husk Ash as an Alternative for Cement in Concrete

T. A. Sulaiman*, S. P. Ejeh, A. Lawan, J. M. Kaura

Department of Civil Engineering, Ahmadu Bello University, Zaria – Nigeria.
*tasiuashirusulaiman@gmail.com

Research Article

Abstract

This paper aims at assessing the influence of using Sesame straw ash (SSA) blended with rice husk ash (RHA) as an alternative for cement in grade 20 concrete. Setting times, soundness and consistency tests were carried out on SSA-RHA-cement paste, while the slump (workability) test and strength tests were conducted on concrete. Influences of SS-RHA on concrete and cement paste were examined for the addition of 0, 5, 10, 15, 20 and 25 % by weight of cement, and 3, 7, 28, 56 and 90 days were considered for the curing period. The result shows that the addition of SSA-RHA decreases the workability (slump) of fresh concrete, but increases the consistency, soundness and setting times of SSA-RHA-cement paste. Moreover, the splitting tensile strength and compressive strength of SSA-RHA-concrete increase as the curing time increases and decrease as the quantity of SSA-RHA increases. It was established that at 28 days of curing, the concrete's strength made with 15 % SSA-RHA was beyond the design strength of 20 N/mm^2. In addition, the densities of SSA-RHA-concrete samples fall within the range of 2200 kg/m^3 to 2600 kg/m^3. Finally, it was concluded that the maximum quantity of SSA-RHA to be used should not be more than 15 % for the production of concrete

Keywords
Cement; compressive strength; Rice husk Ash; Sesame straw ash (SSA); workability.

Article History
Received: – January, 2022
Reviewed: – March, 2022
Accepted: – April, 2022
Published: – April, 2022

1. Introduction

The use of different ashes sourced from agricultural wastes as a potential alternative for cement in concrete or mortar production has drawn the attention of different researchers due to its likely to cut down or do away with the usage of cement in concrete and mortar production (Ogork and Uche, 2014). The use of supplementary cementing materials (SCM) in the production of concrete is very essential where there is a demand to modify the characteristics of concrete. The selection to assess the use of Sesame straw ash (SSA) and rice husk ash (RHA) as supplementary cementing materials in the production of concrete with the view of enhancing the farmers' economic standard by employing the waste materials as a less expensive alternative to that of normal admixtures, with a view of reducing the cost of buildings and other civil engineering construction and a way of dealing the environmental pollution made by the assemblage of uncontrollable waste. However, there are few available studies or no literature on the use of Sesame straw ash (SSA) in concrete, but related literature on the use of agricultural waste ashes is reported. In a study conducted by Sulaiman *et al.*, (2020) addition of sesame straw ash (SSA) decreased the flow (workability) 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. A study conducted by Orame *et al.*, (2020) claimed that Sesame plant Mucilage (SPM) 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, concrete 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 and split tensile strength and their values obtained are higher than that of the control specimen at all curing periods. A study carried out on the effect of adding Sesame stalks fibre (SSF) to the concrete mixture by Elmardi *et al.*, (2021) claimed that the strengths of SSF-concrete decreased as the percentage of sesame stalks fibre (SSF) increases, however, the addition of (SSF) increases the concrete resistance against crack growth. It has been a fact that rice husk ash (RHA) is classified as reactive pozzolana with high SiO_2 content and it is suitable as a supplementary cementitious material (Olamide and Oyawale, 2012). Sulaiman *et al*., (2020) stated that incorporating GSA-SDA decreases the workability of concrete but increases the setting times and soundness of GSA-SDA-cement paste. Moreover, the 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 a portion of GSA-SDA increases. They concluded that the maximum percentage of GSA-SDA to be used should not be more than 10%. Jaya *et al*., (2011) claimed that the addition of RHA as a substitute for cement has enhanced the concrete's strength. According to Abubakar (2018) the optimum amount of RHA content to be used as a replacement for cement was around 10 % to 20 % with a longer curing period, and beyond 20 % RHA there is an abrupt decrease in mechanical properties of concrete. Studies carried out by Kartin (2010) revealed that incorporating RHA as a substitute material for cement has drastically improved the durability of concrete. Abalaka and Okoli (2013) reported that the workability of concrete mix having 5 % RHA content was better than the benchmark mix at the different water-cement ratios of 0.55 and 0.50. The addition of rice husk ash (RHA) beyond 7 % declined the workability but is still good for the production of concrete (Adinna *et al.*, 2019). Malhotra and Mehta (2004) stated that the addition of rice husk ash (RHA) increases the concrete's strength, and improved its properties. According to a study carried out by Ogork *et al.,* (2015), GHA was characterized as a low reactive pozzolana, and white rice husk ash RHA was classified as reactive pozzolana with the sum of iron oxide (Fe_2O_3), aluminium oxide (Al_2O_3), silicon oxide (SiO_2) as 26.06 % and 80.33 % respectively. Aboshio *et al.,* (2009) stated that the slump of RHA-concrete stepped up as the quantity of RHA steps up for both grades of concrete produced, however, the strength of concretes raised when 5 % RHA and 10 % RHA was added and better advance in the strength of concrete was observed at 5 % RHA. They recommended that 5 % RHA can be used as an admixture in concrete. Ogork *et al.,* (2015) disclosed that the slump and characteristics strength of concrete stepped down as the quantity of GHA-RHA content added increased, and also concluded that 15 % GHA-RHA was considered to be an optimum for use in concrete. Rambabu *et al.,* (2015) claimed that 6 % RHA exhibits a better strength, though, an increase in the concentration of H_2SO_4 solution decreased the strength of concrete at 28 days, 60 days and 90 days. Zahemen *et al.,* (2019) highlighted the strength of RHA-CCW concrete zoomed due to the increase in RHA-CCW, they concluded that 5 % RHA-CCW gave a better functioning.

The main aim of this research is to determine the effect of sesame straw ash (SSA) blended with rice husk ash (RHA) as an alternative for cement on thestrength properties of concrete.

2. Materials and Methods

2.1 Materials

The Portland limestone cement (PLC) used was Dangote BlocMaster, grade: 42.5R, having a moisture content of 1.81 % and a specific gravity of 3.16. The cement oxide composition is exhibited in Table 2. The fine aggregate used was sourced from Zaria Local Government Area, Kaduna State, Nigeria, with a silt content of 2 %, specific gravity as 2.68, bulk density of 1737 kg/m^3. The coarse aggregate used has a specific gravity of 2.68 and bulk density of 1425 kg/m^3. Sesame straw ash (SSA) used was obtained from an uncontrolled burning of sesame straw (SS), ground after cooling, and sieved through a 75 µm sieve. The sesame straw (SS) was sourced from Jigawa State, Nigeria. It has a moisture content of 1.95 %, a specific gravity of 2.69, and LOI of 0.3 %. The rice husk ash (RHA) used was obtained by burning the rice husk (RH) obtained from Kura local government, Kano. It was sieved through 75 µm sieve, and has a moisture content of 2.32 %, a specific gravity of 2.75, and LOI of 2.89 %. The water used was potable, sourced from the Department of Civil Engineering Lab of ABU, Zaria, Kaduna State, Nigeria.

2.2 Methods

2.2.1 Sieve Analysis of Fine and Coarse Aggregate

The sieve analysis tests were carried out according to BS 812-103.1 (1985) to know the particle size distribution of fine and coarse aggregate.

2.2.2 Oxide Composition of Cement, SSA and RHA

The oxide composition test was carried out in accordance with BS EN 196-2:1995 using X-Ray Fluorescence (XRF).

2.2.3 Consistency, Setting Times, Soundness of Test of SSA-RHA-Cement Paste

The consistency, setting times, and soundness tests conducted on SSA-RHA-cement paste in accordance with BS EN 196-3 (1995).

2.2.4 Mix Proportions for SSA-RHA-Concrete

The design of the Experimental (DOE) method was used to calculate the concrete mix proportions for grade 20 concrete. The mix proportions used are highlighted 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 Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)	W/C
T0	320	0	0	723	1231	176	0.55
T10	304	0	32	723	1231	176	0.55
T15	288	16	32	723	1231	176	0.55
T20	272	32	32	723	1231	176	0.55
T25	256	48	32	723	1231	176	0.55
T30	240	64	32	723	1231	176	0.55

2.2.5 Slump of Fresh SSA-RHA-Concrete

The slump test was carried out on fresh concrete in accordance with BS 1881:102 (1983)

2.2.6 Compressive Strength of SSA-RHA-Concrete

The strength test on SSA-RHA-concrete was conducted in accordance with BS 1881-116: (1983). Concrete cubes were cast and a total of 3 cubes were considered for an average for each curing age (3, 7, 28, 56 and 90 days) using the Avery-Denison Universal testing machine.

2.2.7 Splitting Tensile Strength of SSA-RHA-Concrete

The tensile strength test on SSA-RHA-concrete prisms was conducted according to BS 1881-117: (1983). Concrete cylinders were cast and three (3) samples opted for a mean for each curing age (3, 7, 28, 56 and 90 days) using the Avery-Denison Universal testing machine.

3. Results and Discussions

3.1 Oxide Composition of Cement, SSA and RHA

The results of the XRF test performed on cement, SSA and RHA are displayed in Table 2.

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	21.43	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	-	0.3	2.89

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 adding up aluminium oxide (Al_2O_3), silicon oxide (SiO_2) and iron oxide (Fe_2O_3) of RHA are found to be 84.22 % more than 70 % as specified by ASTM C 618 for pozzolana and characterized as high reactive pozzolana.

3.2 Sieve Analysis of Fine and Coarse Aggregate

The results of particle size distributions of fine aggregate and coarse aggregate are presented in Figure 1. It was observed that the fine aggregate used belongs to zone 1 accordance with BS 882 (1992) 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 proves that the fine aggregate (sand) and coarse aggregate can be used in the production of concrete.

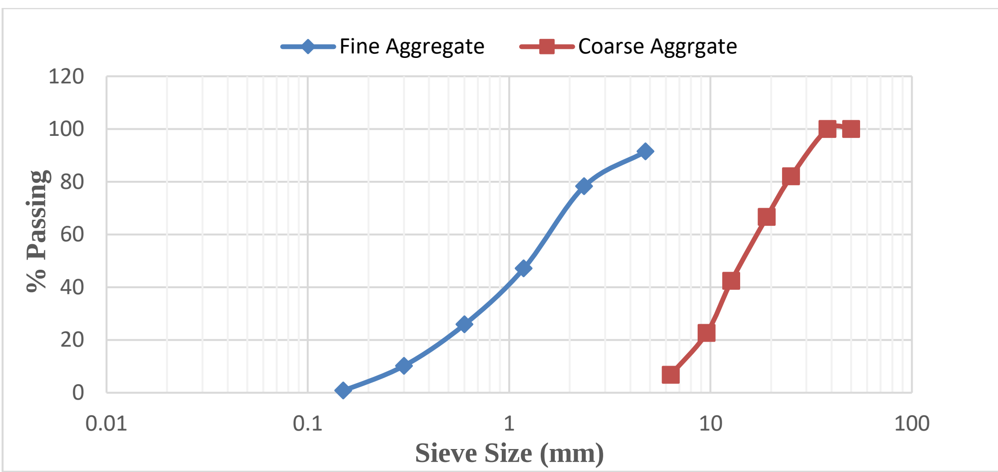

Figure 1: Particle Size Distribution of Fine Aggregate and Coarse Aggregate

3.3 Consistency of SSA-RHA-Cement Paste

The result of the consistency test carried out on SSA-RHA-cement paste is demonstrated in Figure 2. It was observed that as the amount of SSA-RHA increased the consistency increased. This trend shows that SSA-RHA-cement paste required more water to get the desired consistency as the additional amount of SSA-RHA content was added. The increment in water requirement may be because of the more porosity of SSA-RHA when compared to cement, the findings are consistent with the work of (Elinwa and Ejeh 2004; Wazumtu and Ogork 2015). This might also be owing to a lower specific gravity of SSA and RHA compared to Cement (PLC).

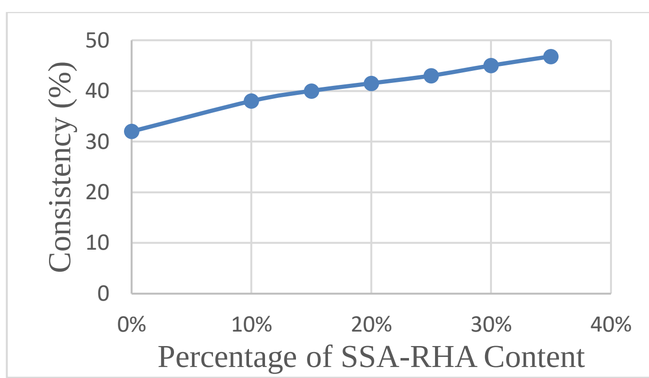

Figure 2: Relationship between Consistency and percentage of SSA-RHA Content

3.4 Setting Times of SSA-RHA-Cement Paste

The relationship between the initial setting time and the final setting time of SSA-RHA-cement paste is presented in Figure 3. It was observed that the initial setting time and final setting time increased as the percentage of SSA-RHA content increased. It was noticed that the initial setting time and final setting time at all replacement levels were more 45 minutes and less 375 minutes as stated by BS EN 196-3 (1995) respectively. Thus, the increment might be because of the presence of potassium oxide that impedes the complete combination of lime and causes setting negative influence on the setting, consistent with Wazamtu and Ogork (2004). The decrease in the setting time might be ascribed to the increase in the amount of C3S in the paste (Abubakar, 2018).

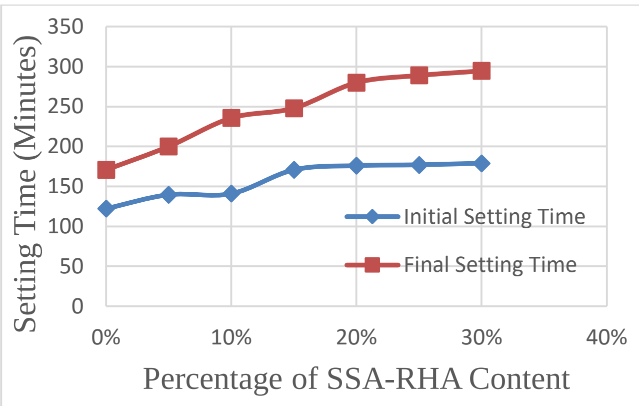

Figure 3: Relationship between Setting Times and percentage of SSA-RHA Content

3.5 Soundness of SSA-RHA-Cement Paste

The result of the soundness test carried out on SSA-RHA-cement paste was demonstrated in Figure 4. It was noticed that the soundness of SSA-RHA-cement pastes increased as the portion of SSA-RHA content increased. However, all the values found at each level of replacement (i.e. from 0.1 mm to 3.4 mm) were within the acceptable limits as highlighted by BS EN 196-3 (1995), which justified that cement is good if the value of its soundness spans from 0 - 10 mm and not sound beyond 10 mm. The same pattern was observed by (Sulaiman and Aliyu, 2020).

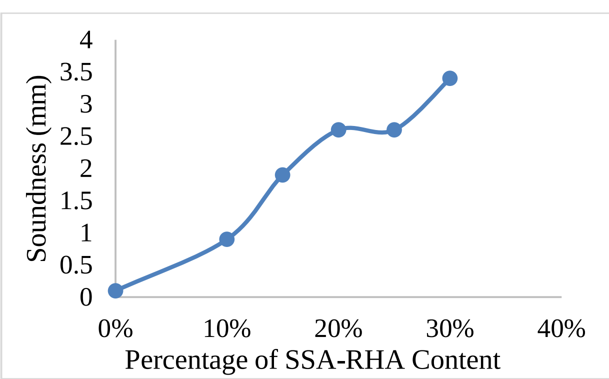

Figure 4: Relationship between Soundness and percentage of SSA-RHA Content

3.6 Slump of SSA-RHA-Concrete

Figure 5 shows the slump of fresh SSA-RHA-concrete in 0, 10, 15, 20, 25 and 30 % of SSA-RHA. The result indicated that the workability of concrete decreased as the percentage of SSA-RHA content increased. It observed that the concrete became sticky as the percentage of SSA-RHA content increased meaning that the concrete needs more water to be more workable. The high requirement of water as a result of an increase in SSA-RHA was due to the increment of silica content in the mixture. The highest value of slump was observed to be 23 mm at 0 % of SSA content while the lowest was 1 mm at 30 % SSA content. The decrease in a slump maybe because of the high surface area of SSA-RHA for constant water-binder ratio (Wazumtu and Ogork, 2015**).** Similar behaviours were also reported by Sulaiman and Aliyu (2020).

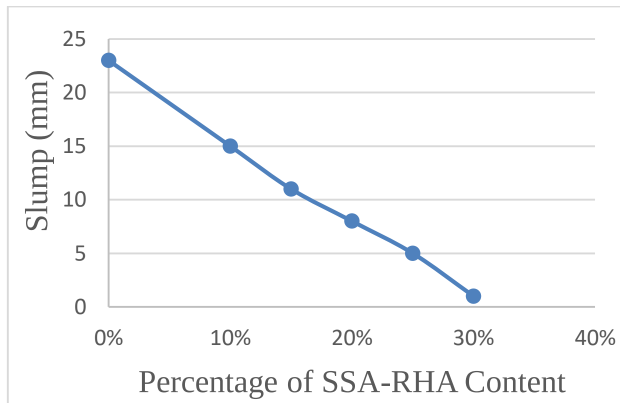

Figure 5: Slump against percentage of SSA-RHA Content

3.7 Compressive Strength of SSA-RHA-Concrete

The results of the compressive strength test conducted on SSA-RHA-concrete were presented in Figure 6. It was observed that the compressive strength of SSA-RHA-concrete decreased as the percentage of SSA-RHA increased. It increases as the curing age increases. Additionally, it was found at 28 days of curing, the compressive strength of concrete produced with 15 % SSA-RHA exceeded the design strength of 20 N/mm^2. However, the decrease in the compressive strength of concrete as the SSA-RHA content increased may be as a result of partial cement replacement with SSA-RHA that induced a decrease in the quantity of cement available for the hydration process (Prasanphan *et al.*, 2010). The formation of calcium silicate hydrate (C-S-H) gel due to the pozzolanic chemistry reaction of SSA-RHA is less strong than cement hydration. From one point of view, the increase in the compressive strength as the duration of curing increased is due to the hydration of cement and SSA-RHA (Wazumtu and Ogork, 2015). It may be because of the pozzolanic influence of silica oxide in the ashes that enhances the cementitious reaction (Zahemen *et al.*, 2019).

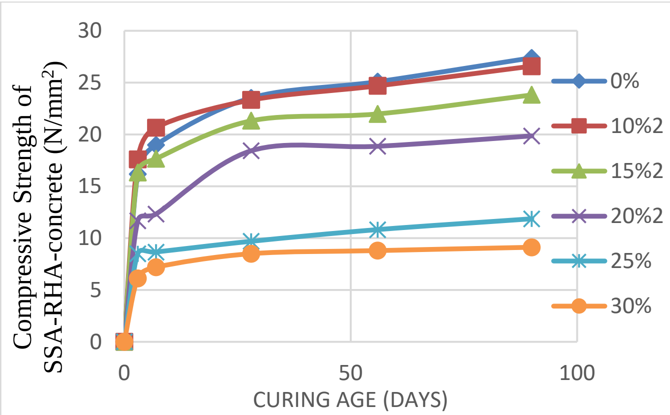

Figure 6: Compressive Strength against Curing Age

3.8 Splitting Tensile Strength of SSA-RHA-Concrete

The results of splitting tensile strength of concrete produced with various percentages of SSA-RHA were displayed in Figure 7. The splitting tensile strength of SSA-RHA-concrete decreased as the portion of SSA-RHA increased but increased as the curing age increased. The decrease in the splitting tensile strength of SSA-RHA-concrete most likely owing to the increase in pozzolanic chemical reaction of silica from SSA-RHA and liberated calcium hydroxide as a spin-off of cement hydration making excess calcium-silicate-hydrate where the binder efficiency increased, consistent with Ettu *et al.*, (2016). The increase in splitting tensile strength may be due to bonding consequences of the silica at the interface between aggregate and cement paste, however, the voids present at the interfacial zone was cut down because of the presence of silica. (Zahemen *et al.*, 2019).

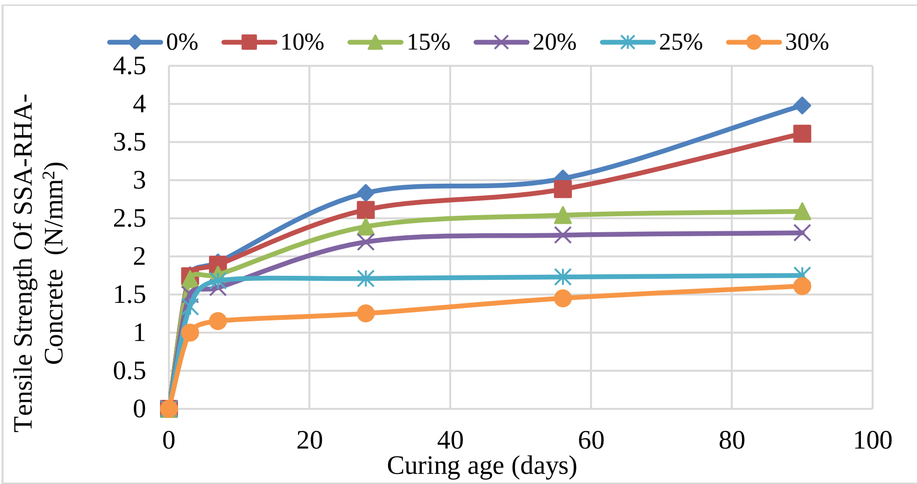

Figure 7: Relationship between Tensile Strength of SSA-RHA-Concrete and Curing Age

3.9 Density of SSA-RHA-concrete

The densities of SSA-RHA-concrete produced with various percentages of SSA-RHA as a cement substitute in concrete were presented in Figure 8. It shows that all the densities of SSA-RHA-concrete fall within the limits of 2200 kg/m^3 to 2600 kg/m^3.

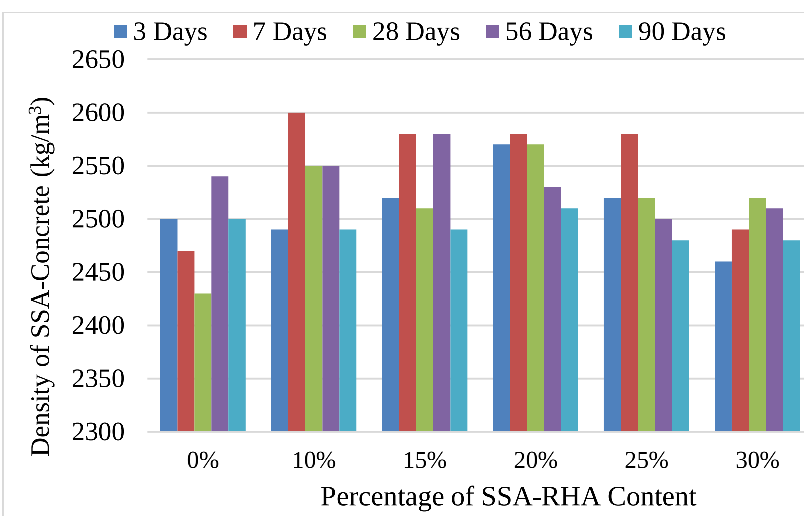

Figure 8: Relationship between Density of SSA-RHA-Concrete and portion of SSA-RHA.

4. Conclusion

Based on the results presented, the following decisions were outlined;

1. The consistency, soundness, initial setting and final setting time of SSA-RHA-cement paste increased with an increase in the percentage of SSA-RHA content. On the other hand, the workability (slump) of SSA-RHA-concrete significantly decreased as the percentage of SSA-RHA content increased.
2. The compressive strength and splitting tensile strength of concrete increase as the curing age increases and then decrease as the percentage of SSA-RHA content increases. However, at 28 days of curing, the strength of concrete made with 15 % SSA-RHA surpassed the design strength of 20 N/mm^2.
3. Up to the combination of 5 % SSA and 10 % RHA content should be used in concrete production.

References

Abalaka, A.E. and Okoli, O.G. (2013) 'Influence of water-binder ratio on normal strength concrete with rice husk ash" International Journal of Sciences, Vol. 2 pp. 28-36.

Aboshio, A., Ogork, E. N., and Balami, D. A. (2009). Rice Husk Ash as Admixture in Concrete. *Journal of Engineering and Technology* Vol.4, No. 2, pp: 95-101.

Abubakar, A. U. (2018). Progress on the Use of Rice Husk Ash (RHA) as a Construction Material in Nigeria. *Sustainable Structure and Materials,* Vol. 1, No .2, PP: 1-13.

Adinna, B. O., Nwaiwu, C. M. O., and Igwagu, C. J. (2019). Effect of Rice Husk Ash Admixture on the Strength and Workability of Concrete. *Nigerian Journal of Technology (NIJOTECH),* Vol. 38, No. 1, pp. 48 – 51.

BS 882, Part 2, (1992). Grading limits for fine aggregates, British Standard Institution, London.

BS EN 196, Part 3, (1995). Methods of testing cement: Determination of setting time and soundness. British Standard Institution, London.

BS EN 12350, Part 2, (2009). Slump Test, British Standard Institution, London.

BS EN 12390, Part 3, (2009). Method for Determination of Compressive strength of Concrete Cubes, British Standard Institution, London.

Elinwa, A. U and Ejeh, S. P. (2004). Effects of the Incorporation of Sawdust Waste Incineration Fly Ash in Cement Pastes and Mortars. *Journal of Asian Architecture & Building Engineering.* Vol. 3 (1), 1-7

Elmardi, M. A., Kbbashe, A. I., Alkhair, O. A., Abdelmagid, T. I. (2021). The Effect of Adding Sesame Stalks Fibers to Concrete Mixture. *International Research Journal of Modernization in Engineering Technology and Science,* Vol. 3, No. 3, pp 1402 – 1409.

Jaya, R. P., Abu Bakar, B. H, Johari, M. A. M, Ibrahim, M. H. W (2011). Strength and permeability properties of concrete containing rice husk ash with different grinding time. *Central European Journal of Engineering,* Vol. 1, No. (1), pp: 103-112.

Kartini, K (2010). Rice Husk Ash in Concrete. University Publication Centre (UPENA), Shah Alam, Malaysia. ISBN 978-967-363-025-7.

Ogork, E. N, Uche, O. A, and Elinwa, A. U. (2015). Characterization of groundnut Shell Ash (GSA) admixed with Rice Husk Ash (RHA) in cement paste and concrete. Advanced Materials Research, Vol. 11 No.19, pp 662-671. DOI:10.4028.

Ogork, E. N. and Ayuba, S. (2014). Influence of Sawdust Ash (SDA) as Admixture in Cement Paste and Concrete. *International Journal of Innovative Science, Engineering and Technology*, Vol. 1 No. 10. pp: 736-743. www.ijiset.com.

Olamide, O and Oyawale, F. A. (2012). Characterization of rice husk via Atomic absorption Spectro Photometer for optimal silica production. *International Journal of Science and Technology.* Vol. 2, No. 4, pp. 210-213.

Orame, A. P., Abdulazeez, A. S. and Kolawole, M. A. (2020). An explorative study on the suitability of Sesame Plant Mucilage (Sesamum Indicum) as Admixture in Concrete. *International Journal of Engineering Applied Science and Technology*, Vol. 4, No. 11, pp: 574-581.

Prasanphan, S; Sanguanpak, S; Wansom, S. and Panyathanmaporn, T. (2010): Effect of ash content and curing time on compressive strength of cement paste with rice husk ash. *Suranaee Journal of Science and Technology,* Vol. 17, No. 3, pp. 1-10

Rambabu, P. V. and Rao, G. V. R. (2018). M60 Grade Rice Husk Ash Concrete in Sulfate Milieu. *International Journal of Civil Engineering and Technology (IJCIET)***,** Vol. 9, No. 6, pp: 99 – 108.

Sulaiman, T. A. and Aliyu, I. (2020). Combined Effect of Rice Husk Ash and Cement Kiln Dust as Cement Replacement Materials in Concrete. *FUDMA Journal of Sciences (FJS),* Vol. 4 No. 1, pp 446 – 452.

Sulaiman, T. A., Mohammed, A., Aliyu, I., Ja'e, I. A., Wada, S. A. (2020). Assessment of Sesame Straw Ash as Partial Replacement of Cement in Mortar. *Proceedings of the Materials Science and Technology Society of Nigeria (MSN), OAU, Ile-Ife*, Nigeria. Vol. 1, pp: 40-45.

Sulaiman, T. A., Aliyu, I., Yau, Y., Bello, I. (2020). Assessment of Groundnut Shell Ash and Sawdust Ash as Partial Replacement of Cement in Concrete. *FUTA Journal of Eng. & Eng. Tech.,* Vol. 14(2), pp: 117-125.

Wazumtu, M and Ogork, E. N. (2015). Assessment of Groundnut Shell Ash (GSA) as Admixture in Cement Paste and Concrete. *International Journal of Innovative Science, Engineering & Technology,* Vol. 2, No. 2, pp: 77-86. www.ijiset.com

Zahemen, T. L., Alao, J. and John, W. (2019). Performance of Rice Husk Ash - Calcium Carbide Waste in Concrete. *Advanced Materials Research*, Vol. 11, No. 55, pp: 41-53.